

A Regular Fortnightly Exploration of the Plankton of the two Icelandic Lakes, Thingvallavatn and Myvatn. By C. H. Ostenfeld, Inspector of the Botanical Museum, Copenhagen, and Dr C. Wesenberg-Lund. *Communicated by* Sir JOHN MURRAY, K.C.B., F.R.S. (With Three Plates.)

(Read July 17, 1905.)

I. INTRODUCTION.

During the last five years the greater part of my time has been taken up by the study of the plankton in the fresh-water lakes of Denmark, and in the spring of 1904 the first part of an extensive paper upon this subject was published by me. In that paper I have compared the results arrived at by me with the results of plankton explorations in other countries, and have tried to collect together everything known at the present moment regarding the periodicity and geographical distribution of the European fresh-water plankton.

At the time I wrote my paper, extensive and regular plankton explorations were carried on no further north than in Denmark. On the other hand, plankton explorations had been commenced in Holstein and North Germany at an earlier period than mine. As the distance between these places, geographically speaking, is inconsiderable, it has been impossible for me to ascertain whether the differences and similarities between my observations and those arrived at further south were due only to the northerly situation or to other facts. This is especially the case with regard to the plankton of some of the northern lakes in Jutland.

Very little is known about the plankton in lakes in the northern parts of the temperate zone, as well as in arctic regions. Regular fortnightly explorations in lakes further north than the Danish ones are non-existent. The knowledge obtainable with regard to the fresh-water plankton of higher latitudes was restricted to an examination of some few samples of phyto- or zoo-plankton

respectively, which had been gathered during journeys with quite other objects in view.

Explorations on a very large scale were started years ago by Mr Huitfeldt Kaas in the Norwegian lakes; but to my knowledge only a minor part has as yet been published.

When comparing the results of my own explorations with those in foreign countries, I arrive at some general conclusions. These, I suppose, may be considered as facts of great probability. I have taken the liberty to give an account of some of the points which may be supposed to be of the greatest interest, in the following pages.

(Owing to the frequent use of the words "temperature" and "maximum development," I shall in the following abbreviate these to "tp." and "max." respectively.)

1. *Myxophyceæ*.—The bulk of these belong to the pond-like lakes with high summer tp. and rich in organic matter; most of them reach their max. only at a tp. of 20° C., and the only plankton *Myxophyceæ* which play a somewhat conspicuous part in the cold, clear alpine lakes are *Oscillatoria rubescens* (max. at tp. 5°–10° C.) and *Anabæna flos aquæ* (max. 16°–18° C.).

2. All the European fresh-water Diatoms seem mainly to attain their max. at a tp. below 15°–16° C. Only the max. of *Fragilaria crotonensis* is reached at a tp. of 13°–16° C. The greater part of the remainder reach their max. at a much lower tp. (7°–10° C.).

3. *Chlorophyceæ*.—Nearly all of these are pond forms and only very few belong to the pelagic region of the larger lakes. As such may be mentioned *Sphærocystis Schroeteri*, *Dictyosphaerium pulchellum* and a few species of *Oocystis*, *Botryococcus braunii*, *Raphidium braunii*, etc. Only very few of these species are of any importance in the pelagic regions, and the rest may all be regarded as tycholimnetic.

4. *Peridineæ*.—The only common plankton-organism within this group to be found in the European lakes is *Ceratium hirundinella*. It is a summer form, with max. occurring at the highest tp. of the water. Different species, especially of the genera *Peridinium* and *Glenodinium*, appear in the pelagic region, but they generally appear in small quantities and have been studied but little.

5. *Euflagellata*.—Of these the species of *Dinobryon* are the only real plankton organisms in the larger lakes. The remainder are all tycholimnetic, their home being in the smaller lakes or ponds.

6. *Rhizopoda*.—It seems that we have in the European lakes, and especially in the clearer and colder ones, a very peculiar but slightly studied fauna of *Rhizopoda*, consisting of but a few and very fragile species. Further investigations upon this point will presumably increase the number of species as well as give more detailed information regarding the periodicity and biology of these interesting animals.

7. *Infusoria*.—These are of hardly any importance in the pelagic region of the greater lakes, all having a surprisingly short and clearly defined max., which rarely extends beyond a longer period than one or one and a half months, and which generally occurs during spring. (*Dileptus trachelioides*, *Tintinnidium fluviatile*, *Staurophrya elegans*.) The only perennial Infusorium is *Codonella lacustris*.

8. *Rotifera*.—These may be referred to two groups. One of these contains cosmopolitan poly- or di-cyclic perennial species in larger lakes. They have two max. and two sexual periods, one in spring and another in autumn. The other, containing monocyclic periodical species, has its max. and sexual period in summer at the highest tp. of the water, and is of a more restricted distribution. The poly- or di-cyclic group generally attains its greatest max. in ponds, but may also reach a considerable max. in larger lakes. The max. reached by the monocyclic group is commonly rather small. All in all, the Rotifera in the pelagic region of the greater part of the larger lakes play but an inconspicuous part.

9. The association of plankton Crustacea in Danish lakes does not differ in any way from that of the lowland lakes of Central Europe. As shown by the explorations of Lilljeborg (1900), G. O. Sars (1861–1901), and by the considerations of Steuer (1901), it seemed probable, when I wrote my work, that a closer examination of the arctic regions would prove the existence of an association of plankton Crustacea, which differed from those inhabiting warmer countries. This association was, however, at that time but inconsiderably known.

10. During the last four years I have been occupied by the study

of the propagation of the plankton Cladocera in nine of our Danish lakes. These explorations will be published in the second part of my plankton work. I think they will bring out some new facts. Still, all in all, they are in accordance with Weismann's (1876-79) elaborate investigations of the Cladocera in Germany. On the other hand, it is shown by my own exploration of the Greenland Daphnids (1895) that the propagation in all probability is quite different in arctic lakes. I shall particularly point out, that the Cladocera of Greenland are always monocyclic, never poly- or acyclic, as is the case with many of the species to be found in temperate countries. If species which are polycyclic in southern countries become monocyclic in Greenland, then it is the sexual period occurring in autumn which thus is lost. The cycle is abbreviated as far as possible, if the parthenogenetic propagation is to be preserved at all. Lastly, I shall draw attention to my supposition that the number of eggs produced by the parthenogenetic females is smaller than in countries of a temperate climate. None of these assertions must be regarded as exact, because the material which I have had at my disposal was not collected with studies of this kind in view. The possibility of incorrectness is so much greater since Zschokke (1892), who has studied the life cycle in alpine lakes in Switzerland, arrived at quite different results. He maintains that the Cladocera of the alpine lakes are ordinarily polycyclic and not monocyclic, and that if Cladocera in lakes situated at a great elevation above the level of the sea are monocyclic, this is not owing to the loss of the autumnal sexual period, but to the merging of the two sexual periods into each other, the first of these having set in later and the second having commenced somewhat earlier than usual.

However that may be, one thing may be concluded from Weismann's, Zschokke's, and my own explorations,—the manner in which the life cycle of the Cladocera goes on is not the same all over the world, but depends on latitude and the height above the sea-level. According to my knowledge, this very interesting fact has not been established with so much certainty with regard to any other group of animals.

11. In 1900 I pointed out that in several very different plankton organisms the longitudinal axis is simultaneously lengthened

during summer and shortened during winter, and that the formation of all the various structures (spines, floating apparatus, etc.), considered necessary to enable the organisms to float, are most distinctly visible in summer forms and summer individuals. I also pointed out that the explanation must be looked for in the varying external conditions, which, so to speak, compel the organisms to vary regularly in accordance therewith. I ascribed these variations mainly to the annual changes in the specific gravity of the water, caused by the regular annual fluctuations in the tp. I started from the supposition that if the velocity of the falling motion of the plankton organisms be not the same at all seasons, the organisms must—in order to exist as such during the seasons when the velocity of the falling motion is invariably greatest—of necessity be capable of developing properties tending to reduce the velocity of the falling motion. Knowing that the spherical form in all bodies has the quickest falling velocity, and seeing that so many organisms with the increasing tp. and decreasing specific gravity of the water often obviously became lengthened in form, the thought struck me, that very probably the seasonal variations in the specific gravity of the water were the main factors in determining the seasonal variations in the shape of the organisms. It was subsequently pointed out by Ostwald (1902) that the lengthening of the longitudinal axis with increase of tp., and the shortening of the longitudinal axis with decrease of tp., cannot be attributed solely to the variations in the specific gravity of the water caused by the rising tp. in spring and falling tp. in autumn. He draws attention to the fact that the oscillations in the specific gravity of the water, with a tp. varying from 0° to 27° C., are too slight to account for these great seasonal variations in the form of the organisms. He agrees with me in taking it for granted that these seasonal variations in so many very different plankton organisms can only be due to variations in the external conditions. But he believes them to be due to the varying viscosity of the water, which, like the specific gravity, is dependent on the oscillations in the tp. of the water, while the variations in viscosity are far more perceptible than the variations in specific gravity. I think that Ostwald's modification of my views is quite correct.

While studying the seasonal variations in our own lakes, I was struck by the thought that if the variations are occasioned by outer conditions varying in accordance with the tp. variations of the water, we must expect the variations to be most conspicuous in those lakes which have the most pronounced annual variations in tp. It has now become evident that the seasonal variations are great and very conspicuous in a great many lakes of Denmark, South Sweden, and North Germany. If the theories held by Ostwald and myself prove to be correct, we might expect the seasonal variations to be inconspicuous or wholly absent in arctic or alpine lakes with their much slighter amplitude of the tp. scale.

It will be easily understood, that the various results and suppositions arrived at through my explorations would be strongly corroborated if it were possible to compare them with those from more northern latitudes.

If the results mentioned above were correct, we should expect to find the following conditions with regard to the arctic and sub-arctic lakes.

The Myxophyceæ would most probably be almost wholly absent, perhaps with the exception of *Anabaena flos aquæ* and *Oscillatoria rubescens*. The main part of the phytoplankton will be the Diatoms, of which especially *Melosira*, *Asterionella*, and *Tabellaria* will be of importance; on the other hand, *Fragilaria crotonensis*, with its higher max. tp., probably will be absent. The Chlorophyceæ will play only a small part in the phytoplankton: *Sphaerocystis* and some others form an exception to the rule. The Volvocineæ will probably be very scarce; according to A. Cleve (1899), Lagerheim (1900), and Levander (1901), no Volvocineæ have been noted in lakes in the Lappmark, the Bear Isle, and the Murman coast, while Vanhöffen (1897), Bürgesen (1898), and Ostenfeld (1904), have found *Volvox* as well as *Eudorina* in small ponds in Greenland (c. 71° lat. north) and Iceland.

Of the Peridineæ, *Ceratium hirundinella*, the only species which commonly is of importance in the plankton, probably will not attain a conspicuous frequency in more northern lakes. Here it is very rare, only a few specimens having been found by Levander (1901) in the lake Enare, and by Ostenfeld (1904) in

a small lake in Iceland. On the other hand, the occurrence of *Ceratium*, as well as of *Volvox* and *Eudorina* in Greenland and Iceland, show how cautious we must be in drawing our conclusions. The tp. at which a species has its max. and occurs in large quantities in the lakes in the temperate regions and in the lowland, will not always be a necessary condition for the progress of the species towards the North. Consequently it is always rather hazardous to draw conclusions from its max. tp. in temperate regions as to the northern limits of its geographical distribution. Of the other genera of Peridineæ we probably will meet species of *Peridinium* and *Gymnodinium*; the *P. willei* seems, according to papers of Huitfeldt Kaas (1900), Levander (1901), Ostenfeld (1903, 1904), West (1903), and Lemmermann (1904 *a*), to be a species with northerly (and north-westerly) distribution, hitherto found in Norway, Finland, Iceland, and the Faeroes, Scotland and Sweden. Among the other Flagellata the genus *Dinobryon* will no doubt be common. We are aware of its occurrence in Greenland, Iceland, the Faeroes, the Lappmark and the Murman coast, as well as further south. It will, together with the Diatoms, be the prominent form in the phytoplankton of lakes in higher latitudes. One species has been found in samples from Iceland (Ostenfeld, 1904), two species predominate in Greenland (Vanhöffen), and one in Lule Lappmark (A. Cleve). The Rotifera will only be represented by the cosmopolitic perennial dicyclic group, the monocyclic periodical summer forms most probably being wholly absent. It appears that there is a difference between this plankton Crustacea and ours. The life cycle is, as mentioned above, much simpler, and the seasonal variations are inconspicuous.

As I wished to have my results and suppositions as exact as possible before writing the second part of my plankton paper, there was only one thing to be done: to contrive regular fortnightly plankton explorations in lakes from higher latitudes. I wished to effect such explorations in pronounced arctic lakes as well as in lakes with a low summer tp. (never more than 12° C.). I consequently endeavoured to procure regularly collected samples from Greenland as well as from Iceland. With regard to Greenland I was rather unfortunate. I tried in different ways to bring about explorations; in the time from November 1902 to February

1903, samples have been sent me from a small lake near Ivigut, but these samples contained only mud and bottom organisms and no plankton at all; consequently they did not suit my purpose.

With regard to the Icelandic plankton, I had the good luck to find the right man for an undertaking of this kind. It was the Icelandic naturalist, Mr B. Sæmundsson, assistant teacher at the classical school in Reykiavik, who in several ways has promoted our knowledge of the Icelandic fauna. Near the Thingvallavatn he found a young man, Mr Simon Pjetursson, whom he could recommend as being capable of undertaking my task. Furthermore, he interested the Dean of Skutustöðum, the Rev. Arni Jónsson, who resides near Myvatn, in the plankton explorations. Two men from his parsonage have procured the samples from this lake.

It had, of course, been my intention to have the collections made simultaneously from both of the lakes, but a sad accident prevented this. All the apparatus which first were sent to the Rev. A. Jónsson were, while on the way to Myvatn, according to a letter from him, destroyed by a great fire in the town of Husavik. New apparatus had therefore to be sent to Skutustöðum, but these did not reach their destination until some nine months later. The explorations in Thingvallavatn were at that time already commenced.

On the Thingvallavatn the samples have been collected from 14th July 1902 to 30th June 1903; on the Myvatn from 1st April 1903 to 2nd April 1904. Only qualitative nets have been used for the explorations, and nearly all the samples are surface samples; from Thingvallavatn I have some summer samples from deep water. The samples have been taken with two different nets, the one Müllergauze No. 20, and the other my Bosmina net (Griesgauze No. 60). Only Crustacea and some of the Rotifers could be gathered in this last net, but no phytoplankton. The gatherings from No. 20 were preserved in formaline, the gatherings from the Bosmina net in alcohol. The tp. of the air and that of the surface water were taken by a centigrade thermometer of a very ordinary construction. In winter, when one of the lakes was ice-bound, samples were taken through a hole in the ice.

It must be considered that the method used was only a very primitive one, but it must be remembered that all the samples

had to be taken by men who had not the slightest idea of science, who could not be controlled at all, and of whom I had no knowledge whatever. Any man may throw a net into the water, row about for some minutes, and put the contents in a bottle. But it is always a very difficult thing to base scientific results upon samples from deep water collected by men who are in possession of no scientific education, and therefore I have omitted to do so with regard to the present exploration. With regard to the tp., I have supposed that the simpler the instruments used the more correct would be the statements. It is proved by the plankton samples that all my requests have been carried out to the letter, and I wish to offer all, especially Mr Sœmundsson, my sincerest thanks for the readiness with which the explorations have been established.

As it was impossible to get samples from Greenland, it will be seen that I could not in this paper give as much as I had intended. A regular fortnightly exploration of an arctic lake will always be a desideratum, the lakes of Iceland having only the low summer tp. in common with those in arctic countries, but, on the other hand, never being frozen over for as long a time as the arctic lakes. Still, the results of my exertions are not quite fruitless, seeing that Thingvallavatn and Myvatn are at this moment the most northerly lakes in which a regular plankton exploration has been carried out. Further, I hope that most of the above-mentioned results and suppositions, already arrived at through explorations of the Danish lakes, have been greatly corroborated through this little exploration.

In 1904 Ekman's extremely interesting and very valuable paper appeared. It treated of the Crustacea fauna of North Swedish alpine countries, together with their arctic and sub-arctic life conditions. In this paper Ekman stated the existence of a Crustacean fauna common for the arctic region, the Scandinavian and the Central European alpine region; this region he calls the boreo sub-glacial region.

The Crustacea of the lowland lakes in Sweden and the Central European plains differ greatly from those of this region. With regard to the plankton Crustacea of the arctic lakes the most common features may be the following: the great Crustacean plankton of the arctic lakes is mainly composed of the following

species: *Holopedium gibberum*, *Bythotrephes longimanus*, both having individuals of an extremely great size; *Daphnia longispina* (= *hyalina*) in different varieties; *Bosmina obtusirostris*, *Cyclops strenuus*, and *C. scutifer*; the three species of *Diaptomus*, *D. laticeps*, *laciniatus*, and *denticornis*. The following species, which form the greatest part of the Crustacea plankton in the lowland lakes, *Diaptomus graciloides*, *Leptodora kindtii*, *Hyalodaphnia cucullata*, *Bosmina coregoni*, and *Diaphanosoma brachyurum*, are here almost entirely absent.

With regard to the propagation of the Cladocera, Ekman has confirmed the correctness of my two above-mentioned suppositions, and supposes that when Zschokke has arrived at a result differing from mine, the reason may be looked for in the fact that the lakes explored by him have not had sufficiently arctic conditions. The number of eggs which the parthenogenetic females produce is, according to Ekman, by no means smaller than in more southern countries, it being, on the contrary, often much larger.

Ekman states, with regard to the seasonal variations, that these are by no means as conspicuous as in more southern countries. Brehm (1902) has arrived at quite a similar result regarding the alpine lake Achen in Tyrol.

Though I believe that the facts mentioned by Ekman are quite correct, I still suppose that his explorations have not made mine superfluous. Mine have been carried out in another country and have been based on principles quite different from Ekman's, his being an examination of many localities once or only a few times, and all in a relatively short time of the year. I, on the contrary, have examined but two localities, but these examinations have been carried on regularly every fortnight all the year round. My explorations are, furthermore, carried on in a country which only in a very few places offers life conditions which may be called arctic. Still, it might be expected that the results of my explorations of the Crustacea would be very similar to those arrived at by Ekman.

As I wished a botanist to work out the phytoplankton, I asked my friend Mr Ostenfeld, Inspector of the Botanical Museum in Copenhagen, to do it. He had recently published a paper on the phytoplankton of an Icelandic lake. To my great satisfaction he

complied with my request. The section Phytoplankton (pp. 1106–1128) is therefore entirely his work. The common results have been prepared by both of us; the rest of the paper is worked out by me.

Our knowledge of the Icelandic fresh-water plankton is at this moment but slight. De Guerne and Richard (1892, p. 310) communicated the zoological results arrived at by examination of some samples gathered by M. Rabot in three different regions of Iceland. One is gathered in the northern part near Akureyri, one in the western part in the neighbourhood of Reykiavik, and one in the eastern part, Lagarfjot, near Eskifjord. The samples contained 29 species: 16 Cladocera, 8 Copepoda, 2 Ostracoda, 2 Rotifers, and 1 Protozoan. The greater part of these species are bottom or shore animals, and only a smaller part of them are plankton animals. In Thingvallavatn M. Rabot had gathered the following species: *Scapholeberis mucronata*, O.F.M.; *Bosmina arctica*, Lillj.; *Eurycerus lamellatus*, O.F.M.; *Acroperus leucocephalus*, Kock; *Alona affinis*, Leyd.; *Chydorus sphaericus*, Jurine.; *Polyphemus pediculus*, De Geer; *Diaptomus minutus*, Lillj.; *Cyclops strenuus*, Fischer; *Cyclops viridis*, Fischer.

In the samples from Lagarfjot, De Guerne and Richard have found *Holopedium gibberum*, Zaddach; *Diaptomus minutus*, Lillj.; and *D. glacialis*, Lillj.

The result of the exploration may be summed up thus: Iceland takes an intermediate position between the arctic and the temperate region.

The phytoplankton in a sample from a lake in south Iceland, 63° 28' lat. N. and 18° 55' long., has later on been described by Mr Ostenfeld (1904, p. 331). This paper will be mentioned in the botanical part. Besides this, several small papers by Hariot Bellocq and Børjesen deal with some fresh-water algæ, among which a few plankton species may occur.

As I wished, as far as possible, to test the tps. reported to me, I applied to the Meteorological Institute of Copenhagen, which also has meteorological stations in Iceland. Mr Willaume Jantzen, second director of the Institute, kindly informed me of the fact that there were no stations situated at the two lakes. But as there was one at Reykiavik, it thus became possible to test the tp. measured in Thingvallavatn. Another was situated at Störinupur,

the first mentioned being a coast station, the second a much colder inland station. With regard to Myvatn, there was a similar coast station at Akureyri, and a very cold inland station at Mödrudalur. The mean tp. of the months in which the plankton samples have been taken has, according to my request, been used for the calculation. I take the liberty to offer Mr Willaume Jantzen and the Institute my best thanks for their kind services in this respect

As it was very difficult for me to find the widely spread literature treating on Myvatn, I begged of the well-known Icelandic geologist, Prof. Thoroddsen, to give me his aid. He kindly provided me with a list of literature appertaining to this lake. The sketch of the physical and natural conditions of the lake is based upon this list, more especially on Prof. Thoroddsen's own valuable papers on this subject.

I beg to forward to Prof. Thoroddsen my very best thanks for the valuable assistance he has given me.

For the beautiful photo of Thingvalla lake, my best thanks are due to Mr C. V. Prytz, professor at the Royal Veterinary and Agricultural School in Copenhagen.

C. WESENBERG-LUND.

II. THINGVALLAVATN.

(a) GENERAL REMARKS.

With regard to the Thingvallavatn, Mr B. Sæmundsson, in the journal edited by the Royal Danish Geographical Society 1904, has published an account of a thorough bathymetrical exploration of the lake, accompanied by a map, and some remarks pertaining to the environments, tp., vegetation, and geology. From this paper I have obtained the following information.

The Thingvallavatn is situated in the south-western part of Iceland, at c. 64° north latitude. It is a combination of a lava and a glacial lake. The length of the lake is about 16 kiloms., the greatest breadth is 8 kiloms. The water covers an area of about 115 square kiloms., the greatest depth is about 110 m., the surface of the lake is 106 m. above sea-level, the mean depth is about

35 m. ; it is the deepest of all known Icelandic lakes. It has two small islands, Sandey and Nesjaly. The bottom is, from the shore to the 10 m. curve, stone chips or dark volcanic sand, often covered with mud ; in the deepest part of the lake we find the mud absolutely predominant. This mud is of a dark, grayish-blue colour and consists chiefly of organic matter, especially diatom frustules. It is highly probable that the greater part of the water arises from springs in the bottom.

According to Mr Sæmundsson the surface tp. was, in the period from 16th July to 2nd August, 10 to 12, 2° C. The vegetation of higher plants along the shore is very poor ; on the other hand there is a luxurious growth of Characeæ (*Nitella*) in depths of 13 to 30 m. The rocks just beyond lake-level are covered with the gelatinous green alga, *Tetraspora cylindrica*. Insect larvæ and *Limnæa* are common near the shore.

With regard to my own tp. explorations, I may refer the reader to the tp. curves and to the mean tp. for the months taken at the meteorological stations at Reykiavik and Störinupur.

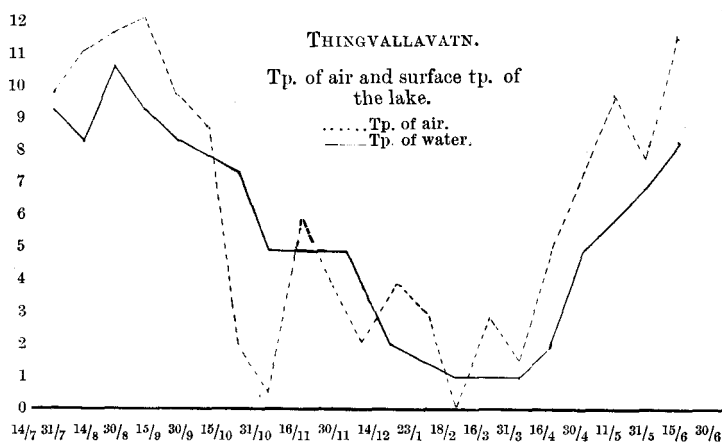
*Monthly Mean tps. of the Air at Reykiavik
and Störinupur.*

1902-1903.	Reykiavik.	Störinupur.
July,	11·1	...
August,	10·4	...
September,	9·2	...
October,	6·0	...
November,	3·5	...
December,	1·2	...
January,	-2·0	...
February,	-1·0	-1·9
March,	-1·6	-2·2
April,	0·5	-0·5
May,	5·5	4·5
June,	8·8	8·5

It will be seen that there, in spring, summer, and autumn, there is a fair conformity between the mean tp. of the month and the solitary observations taken of the atmosphere and of the surface water in the lake. On the other hand, it must be noted as a very remarkable instance, that during the entire winter no negative tp.

was reported me from the Thingvallavatn, even though the mean tp. of the air at the nearest coast station in the months January, February, and March was -1.6 to -2 , and at the inland station -1.9 to -0.5 . What may be the cause of this I do not know; probably the tp. of the winter months given me from Thingvallavatn have not been fully correct. All in all, we arrive through the observations made at the following facts:—

The highest tp. of the lake during the period of observations is 11° C., which was reached on 14th August 1902. Then the tp.



from 14th August to 31st October falls to 5° C. and keeps this tp. to 14th December, when the tp. further falls to 1° C. (16th March 1903), not rising until 16th April; already (30th June) it has reached $8\frac{1}{2}$ above zero. During the whole year the lake has not once been frozen over. Besides, it appears that the tp. of the lake is rather slow in following the variations in the tp. of the atmosphere; of course this must be ascribed to the considerable depth of the lake. As I wished to know whether or not it was a rare case that the lake had not been frozen, I asked Mr Sæmundsson to inform me as to this point, but as yet no reliable information has been obtained.

*(b) PHYTOPLANKTON. By C. H. OSTENFELD.**1. General Remarks.*

Last year Dr Wesenberg-Lund asked me to examine the plant-organisms in a series of samples from Thingvallavatn. I was very pleased at his request, as I just had published a little note on a plankton sample from an Icelandic lake, as well as some smaller papers on fresh-water phytoplankton from the Faeroes and from Norway. But the samples from Thingvallavatn were of special interest, because they were collected regularly every fortnight during a whole year, thus giving an idea of the seasonal changes in the plankton of a lake in Iceland. I therefore took up the work with pleasure. Very little is known concerning the phytoplankton of the northern countries; in the arctic region we have small contributions from Greenland (E. Vanhöffen, 1897) and Bear Isle (G. Lagerheim, 1900); to these we must add contributions from the Lule Lappmark (Miss A. Cleve, 1899) and from the Murman coast of Finland (K. M. Levander, 1901). There are further published some papers on the phytoplankton of Swedish lakes (O. Borge, 1900; Lemmermann, 1904 *a*), but very little from Norway (Holmboe, 1900; Ostensfeld, 1903). From the United Kingdom we have publications from Ireland and Scotland (W. and G. S. West, 1902, 1903; O. Borge, 1897), and small notes from the river Thames (F. E. Fritsch, 1902, 1905); an examination of phytoplankton from the Faeroes has also been published (F. Börgesen and Ostensfeld, 1902), as well as one of a single sample from a lake in South Iceland (Ostensfeld, 1904). All these publications have in common the drawback that they are based upon samples which have been collected only in the summer time and without any regularity. It is only in Denmark (Wesenberg-Lund), Germany (O. Zacharias, Lemmermann, etc.), Switzerland (C. Schroeter, R. Chodat, H. Bachmann, etc.) United States (Illinois, by C. S. Kofoed, etc.), and partly Hungary and Russia, that more regular investigations have taken place. The task undertaken by Dr Wesenberg-Lund—to obtain a series of samples from lakes in Iceland collected during an entire year—is therefore a very interesting one.

With regard to the physical conditions of the Thingvallavatn and the surrounding country, I may refer to the remarks above written by Dr Wesenberg-Lund; but I must be allowed to quote some few words from my little note concerning Icelandic fresh-water plankton (1904, p. 235): "I think we may say that the plankton is like that of the lowland lakes of northern Central Europe and Southern Scandinavia, but much poorer, especially by the want of the summer forms; this also is the case with the climate; it is the climate of northern Central Europe and Southern Scandinavia with regard to the autumn, winter, and spring, but the summer is skipped over." The insular climate causes the lakes, at least the lowland lakes in South Iceland, to be ice-covered during only a short period in winter or not at all, while the cold summer, with its abundance of cloudy and rainy days, is not warm enough to give the lake a high summer tp. These conditions will cause a plankton, in which the Diatoms predominate all the year round, and the Myxophyceæ are wanting or nearly so, as they reach their max. at higher tps.

Such is the result of the examinations of the samples from Thingvallavatn. In the accompanying table (pp 1154, 1155) I have arranged the phytoplankton according to the dates of collection, and furnished them with the ordinary signs denoting the quantity. We learn from this that the number of species is but small, and when restricted to the true limnetic species only, this is even diminished by half its number. The species belong to the Chlorophyceæ and Bacillariceæ, to which two Flagellates (*Mallomonas* and *Peridinium*) are to be added. *The Myxophyceæ are completely wanting*; but it must be noted that some of the samples contain specimens of bottom Myxophyceæ, viz., *Lyngbya* sp., *Anabæna variabilis*, Kütz., but only very sparsely, the few specimens occurring being mixed up in the plankton by wind and waves. Such accidentally occurring bottom forms are rather common in most of the samples; the climate is very windy, so it is but natural that the chance to meet with bottom forms in the plankton is great; especially are bottom Diatoms met with very frequently in the samples, viz. *Cymbella cistula*, *Ceratoneis arcus*, *Epithemia*, etc. Such forms which are specified in the table, viz., *Fragilaria construens*, *F. capucina*, *Synedra acus*, *S. ulna*,

Surirella biseriata, *Melosira varians*, and *M. arenaria*, may also be considered as bottom forms; they do not belong to the true plankton, but once broken off from their place in the bottom along the shores, they are capable of floating some time and perhaps of multiplying themselves while in a floating condition.

True plankton Diatoms are only the following: *Asterionella formosa*, *Fragilaria crotonensis*, *Cyclotella comta*, *Melosira italica* and *islandica*, and the two *Rhizosolenie*. Of these the two *Melosiræ* and *Asterionella* occur all the year round in the plankton, while the other may be found only during shorter or longer periods of the year; the *Rhizosolenie* have resting spores, and it is evident that they form their spores when past the flowering period; the spores sink to the bottom and there they rest until the next period. The same periodicity may occur with the *Fragilaria crotonensis* and the *Cyclotella*, but we have here no morphological sign to help us to decide when the period of flowering is ended.

Among the Chlorophyceæ the Desmids have no distinct period in which they disappear from the plankton; *Sphaerocystis* and *Oocystis*, on the contrary, act as the *Rhizosolenie*. Such periodicity is to be found also in the *Peridinium aciculiferum* and the *Mallomonas*, both having resting spores. Although it thus becomes evident that some of the plankton forms lack periodicity, inasmuch as they at no time of the year wholly disappear from the plankton, they still evidence periodicity in another way, viz., they attain at a given period their richest flowering or so-called max.; before this period they become more and more numerous, and afterwards steadily decrease in number until they reach a minimum from which they then again commence to increase in number. This periodicity is not much different from the periodicity mentioned first; if we suppose the minimum like zero, and if this minimum extends over some time, we have the first-mentioned periodicity; the difference is consequently but gradual, except in the cases where a formation of resting spores completes the max. The causes which produce a periodicity in each species are partly inner causes, partly causes based upon physical and chemical conditions of the surrounding matter. We do not

know anything about the inner causes, but we know a little with regard to the others. Based upon the numerous plankton investigations of the last twenty years, it may be affirmed that the tp., including the physical conditions depending upon tp. (viscosity, gravity), of the water, and its chemical composition, together with the light, are the effective factors in relation to the plankton organisms. The chemical composition of the water (contents of air and of salts) plays an important part with regard to the marine plankton, but in fresh water the tp. and the light are the most effective factors. It is not easy to decide which of these may be said to predominate—or, more correctly, in some cases the tp. is the critical factor, in other cases (probably more exceptionally so) the light predominates. Our table will give some examples of both cases. Preceding this, it must be mentioned that in July–September 1902 the main part of the plankton consisted of Crustaceans, which occur in such large quantities as to hide the phytoplankton completely. Consequently, the signs of quantity with regard to the plant organisms in the samples obtained during these months stand very low in the table. Apart from this, we learn that *Sphaerocystis* and *Oocystis* are dependent of the variations of the tp. as regards their frequency. They have their max. in October 1902 at a tp. of 5° – 7.5° , *Sphaerocystis* has a secondary max. in June 1903 at 7° – 8.5° ; it follows that we are right in stating that the two species here and in the year in question reach their max. at about 7° ; the lower tp. as well as the higher thus being unfavourable for their propagation. Nor does their growth depend upon the light, as the light in June is of much greater power than in October, and *Sphaerocystis* is of about the same great frequency at these two periods. It is also the tp. which regulates the growth of the two *Rhizosolenia* and the *Cyclotella*; they reach their max. in June 1903 at 7° – 8.5° .

The case is not so clear with regard to the three Diatoms, which are the most characteristic forms in the plankton, viz., *Asterionella*, *Melosira italica*, and *M. islandica*. We learn that *Asterionella* is rare in July–August, and from that we conclude that 9° – 11° is too high a tp.; but it grows very well in tps. varying from 1° – 8.5° , perhaps with a faint decrease in quantity

at 1° – 1.5° and at 8° – 8.5° ; if we must choose the most favourable tp., it must be 4° – 5° .* We do not find any tendency to relation to the light. *Asterionella* reaches one max. in the winter (November–February) and another in May–June. I think we may say that the growth of *Asterionella* in some degree depends upon the tp., but that the limits of the max. tp. are very wide, going from 1° to 8° .

The two *Melosiræ* act in a manner very similar to that of the *Asterionella*, although with some differences. They prefer a somewhat lower tp. than the *Asterionella*; their max. lies in March–May at a tp. of 1° – 5° , and they cannot endure a tp. of 7° – 8° as well as the *Asterionella*. They have no distinct relation to the light.

Finally, we take the *Peridinium aciculiferum*; it appears suddenly in great quantities in the sample of February at 1.5° and flowers in the next samples at about the same tp. (1° – 2°), but when the tp. rises it decreases in number; consequently it has its max. at 1° – 2° and is dependent on the tp.† Nevertheless we have no explanation of its sudden occurrence, and here, I think, we must take the light as the moving factor. The remaining forms have no distinct max. (*Staurostrum pelagicum* seems to follow *Sphaerocystis*). Some of them occur rather evenly throughout the entire year, but not in quantities; others, e.g., *Fragilaria construens*, show no regularity, and these last mentioned manifest thereby that they are only occasional guests in the plankton. If we summarise our remarks, they will be in accordance with my words quoted above. *Thingvallavatn* has a phytoplankton consisting mainly of a few species of Diatoms (*Asterionella* and *Melosiræ*), Myxophyceæ are wanting, Flagellates (in the widest sense) and Chlorophyceæ are without greater importance. The phytoplankton has not at all an alpine character, but is very like the plankton of the lakes in the Central European lowland during winter and early spring. It is very poor in species and one of its most remarkable features is the number of organisms one might

* Some authors (Marsson, B. Schröder) have suggested that the number of cells in the stellate colonies depends on the seasons, but this is not the case in Thingvallavatn, as I have found 4, 5, 6, or a still greater number of cells in each colony in all the samples.

† For its relation to the tp. in other countries see p. 1128.

expect to find, but which are wanting. Of these we may mention :—*Tabellaria fenestrata*, *Dinobryon* sp., *Scenedesmus*, *Pediastrum*, *Eudorina*, etc.,* besides all the Myxophyceæ.

2. Remarks on some Species.

CHLOROPHYCÆ.

The Desmids do not play any important part in the plankton, but there are some few species which occur in nearly all the samples, consequently all the year round. These are some species of *Staurastrum* and one *Cosmarium*; the long *Closteria*, which often have been found in plankton, do not seem to exist at all in the plankton of Thingvallavatn, nor do we find any species of the *Xantidia*. The max. of the Desmids occurs in October 1902, with a secondary max. in June 1903.

The species observed are rather interesting, as they come near or are identical with some of the many plankton Desmids mentioned and figured in the papers on phytoplankton from Ireland and Scotland by W. West and G. S. West (1902, 1903). As my identification of the species may be incorrect, I have drawn figures of them (see Pl. II. figs. 11-15).

Cosmarium phaseolus, Bréb.—The specimens observed were 32-38 μ long, 30-36 μ broad, ab. 18 μ thick, and the isthmus 12 μ . It is with some hesitation that I have referred them to this ubiquitous species; they greatly resemble Mr West's drawings of *C. abbreviatum*, Racib., var. on pl. xv. fig. 6 (1903); but the semi-cells of the latter are more flattened and more angular, and the dimensions are smaller.†

Staurastrum pelagicum, W. West and G. S. West, l.c. (1902) pl. ii. figs. 26-27, p. 46.—This very characteristic species, which has been described from Lough Neagh and Lough Beg in Ireland, occurs regularly in the samples from Thingvallavatn and is the most abundant Desmid in the plankton. As my drawing

* In a sample from the neighbourhood of Thingvallavatn, a *Dinobryon* occurs; and also all the other species enumerated as wanting have been found in other lakes in Iceland.

† O. Borge (1897) has given a drawing of a *C. phaseolus*, β . *achondrum* (Boldt)? from a lake in the island Mull (Scotland), but it is smaller than our form.

will show, the Icelandic form is quite like the Irish; the dimensions of the cell are also about the same (long. 40 μ , lat. cum spin. 67 μ , sine spin. 46). W. West and G. S. West have later (1903) described a *S. pseudopelagicum* only differing from *S. pelagicum* by its hollow processes and a somewhat different shape of the cells; but the Icelandic form is more like the true *S. pelagicum*. The two species have in common the two large spines at the apices of the processes, but in a specimen from Thingvallavatn I have observed three spines at one of the processes.

S. paradoxum, Meyen.—After *S. pelagicum* the most common plankton Desmid in Thingvallavatn is a form of the variable *S. paradoxum*. It is always quadrangular (I have not seen a single triangular specimen in the samples), and resembles somewhat the form figured by W. West and G. S. West (1903) pl. xviii. fig. 4, but is slenderer. Long. sine proc. ab. 40 μ , lat. sine proc. ab. 22–24 μ , lat. cum proc. ab. 100 μ . It differs much from the commonest plankton form of *S. paradoxum*, viz., var. *longipes*, Nordst.

S. brevispinum, Bréb.—The form which I have placed under this name on account of its resemblance to Ralfs' figure of it is also a constant form in the samples. My drawings show the shape of it. Long. ab. 50 μ , lat. sine spin. ab. 55 μ , lat. cum spin. ab. 65 μ , lat. isthmi ab. 12 μ .

S. Bieneanum, Rabenh., forma.—Although this species does not occur as constantly in the plankton of Thingvallavatn as the above-mentioned ones, it has been found in so many of the samples that I think it is a planktonic species. I am not convinced of the identification of this species. It is larger than the ordinary *S. Bieneanum*, being 60 μ long and 52 μ broad, but Mr Börgesen, who has seen my drawing, agrees with me in counting the Thingvallavatn form as a variety of *S. Bieneanum* nearest to the var. *ellipticum* of Wille (1879, pl. xiii. fig. 49); the semi-cells are alternating.

Besides these five species, several other Desmids have been observed in the samples; but as they occur without any regularity, and only in one or a few specimens, I have reckoned them as strangers to the plankton and therefore omitted them in the list;

they belong to the bottom flora and have been carried away accidentally by the rivulets or the waves.

Sphaerocystis schroeteri, Chodat.—This widely distributed plankton-alga is found in most of the samples; it seems to have its max. in the summer (June) and the autumn (October). Most of the specimens agree well with the figures, p. 64 and p. 115, in Chodat's paper (1902).

Oocystis crassa, Wittr.—Following *Sphaerocystis* in its periodicity a species of *Oocystis* occurs. It is very difficult to identify the species within this genus, in which the number of species has augmented greatly during the last few years, especially by descriptions of new forms by W. West and G. S. West and E. Lemmermann. The latter author has given a key to the plankton species of *Oocystis* (1904 a, pp. 106-108). G. S. West has recently (1904, p. 227) figured several species, and Chodat (1902, pp. 189-191) has enumerated the Switzerland species. These three authors do not quite agree in their views of the definition and limits of the species.

Lemmermann has created a new genus *Oocystella*, differing from *Oocystis* only by the existence of pyrenoids and the substellate chloroplasts, but West as well as Chodat admit the existence of pyrenoids in species of *Oocystis*; it seems therefore unnecessary to have this separate genus. The species from Thingvallavatn has one pyrenoid in each chloroplast; the chloroplasts are two or four in each cell, often tetrahedrally arranged; the cells are four (rarely two) in a globular mucilage; their shape is ellipsoid or ovate with subacute apices; length 22-26 μ , breadth 16-20 μ . In my note (1904, p. 235) on phytoplankton from a lake in South Iceland, I have drawn a figure of an *Oocystis* which is the same as the Thingvallavatn form;* the specimen drawn shows two chloroplasts in each cell, and the cells are not as subacute as in our form; the pyrenoids are not visible. Of the Thingvallavatn form I have drawn a specimen with pyrenoids in the four chloroplasts (Pl. I. fig. 8); this drawing comes near to G. S. West's figure (1904, p. 227, fig. 97 D) of *O. crassa*, Wittr., but these latter have eight chloroplasts. It is upon this figure that I base my determination of the form, as the description given by V. Wittrock (1880) is very short and with-

* I have named it *O. lacustris*, Chod. (?), which is evidently incorrect.

out any figure. Chodat has emended the diagnosis of the species (1902, p. 189), but he does not mention the pyrenoids, while these are present in West's drawing.

BACILLARIACEÆ.

Asterionella formosa, Hassall.—The *Asterionella*, which inhabits Thingvallavatn, is rather short and robust, thus representing the typical *A. formosa*.

Fragilaria.—With regard to the species of *Fragilaria*, my determinations may be insufficient; this genus is a very difficult one. No doubt the species are connected with each other without distinct limits. The easiest discernible form is *Fragilaria crotonensis*, (Edw.) Kitton, distinguished by the intervals between the cells; it is not common in Thingvallavatn, and occurs only in the summer and autumn. The commonest *Fragilaria* in the plankton is a small bottom form, *F. construens*, (Ehbg.) Grun., of which I have given a figure of a filament in my previously quoted paper (1904, p. 232, fig. 3). Very near to it, and mostly distinguished from it by the denser striæ, is *F. capucina*, Desmaz, which also often is present in the samples.

The last, again, goes over into the *F. virescens*. It seems to me as if the limit between *F. construens*, *F. binodis*, (Ehbg.) Grun., and *F. capucina* is not clear, and I fear that my identifications of these two species may have been arbitrary.

Synedra.—Besides *S. ulna*, (Nitzsch) Ehbg., another or several other species occur in the samples; they are smaller, narrower, and slenderer, but they vary much in length and breadth. Most of these individuals are 70–150 μ long and 2–4.5 μ broad; they agree well with the figures by Van Heurck (1880–1881, pl. xxxix. fig. 6) of *S. delicatissima*, W. Sm., v. *mesoleja*, Grun., but this form is very near to *S. radians*, W. Sm. (Van Heurck, l. c. pl. xxxix. fig. 11). I take all these species as forms of *S. acus*, Kütz., and name our form *S. acus*, f. *delicatissima*, (W. Sm.) Grun. The specimens have in most cases been found one by one, but occasionally 2, 4, 6 or a still greater number of individuals were arranged in a radiate manner, thus forming stellate colonies, probably an adaptation for the limnetic life (see Pl. II. figs. 16, 17).* Also

* Cp. the colony of *S. radians*, by W. Smith, 1853, pl. xi. fig. 89.

typical *S. acus* occur, but rarely, in the samples; the specimens observed measured 120-150 μ in length, and about 6 μ in breadth.

Cyclotella comta, (Ehbg.) Kütz.—In some of the samples a little *Cyclotella* has been found (Pl. I. figs. 9, 10). Its diameter is 7-17 μ ; it is very difficult to observe any heterogeneousness amongst the marginal radiating striæ, but perhaps some of them are more distinct than the others. Supposing this, and counting upon the fact that the frustules are not undulated, I take it as a small form of *C. comta*. The cells always occur separately. I have seen a single specimen of which one valve was of ordinary shape, the other semi-globular; this specimen is purely one daughter-cell of an auxospore, the semi-globular valve being the half part of the auxospore wall.

The *Melosiræ* play an important part in the plankton of Thingvallavatn. Several species have been found, but only two of these are true plankton forms and have a distinct max. in which they are the predominant forms. Two species occur more accidentally; of these *M. varians*, Ag., has been observed in most of the samples, but it was always rare and often the specimens were empty; thus we are right in taking it as a stranger, its home being at the shores.

Also *M. arenaria*, Moore, has only been found in a few specimens, and without doubt it acts just as the foregoing species; also of this species some of the specimens observed were dead.

With regard to the other species the matter is different. They are true plankton forms, which have been found in all the samples; they are not rare in July 1902, but since then their number decreases rapidly, so that they have become very rare in the late summer months, when the tp. is above 9.5°; in the autumn they begin to grow better, when the tp. sinks below 8°, but it is not before it has gone down to 5° that they really begin to develop. We now see that they are predominant in the winter, attaining their max. in March-April at a tp. of 1°-2°. The coarser of the two species begins to be numerous in November-February, and attains its max. in March-April; while the slenderer grows a little less intensely in the beginning and has its max. in April-May.

As it is very difficult to determine the *Melosira* species, I have

sent some samples and slides to Dr Otto Müller of Berlin, who has worked especially with this genus (1903, 1904). He has been so kind as to name the coarser species *M. islandica*, O. Müller, n. sp., and the narrower one "*M. italica*, Kütz., f. *tenuis* and f. *tenuissima*, with forms which pass into *M. crenulata*, Kütz." The *M. islandica* is most nearly allied to *M. granulata*, from which, according to his letter, it differs in the shape of the pores, in the absence of marginal teeth of the valves, and in the form of the so-called "mutation." Dr Müller will examine the species more thoroughly and publish the results later on in a separate paper. In a letter he tells me that the interesting facts of the different development of the pores in the two halves of a cell, or in the different cells of a chain, as well as in the different chains of a sample—a fact which he explains as *mutation* in the sense of H. de Vries—also occurs in the species from Thingvallavatn. He has given an interesting paper on this subject (1903), and he will now take also the two Icelandic forms into the examination. Dr Wesenberg-Lund and I are very happy to have obtained help from such an authority with regard to Diatoms as Dr Müller, and we desire to express to him, here, our best thanks for his kindness.

Dr Müller will probably treat the question of the auxospore formation from a more systematical point of view, but here I only intend to give a description of the development of this propagation method.

In *M. islandica* I have found numerous chains with *auxospores*, and thus I have been able to follow their formation rather well. The drawings in Pl. I. figs. 1–7 will show some of the successive stages. The formation begins in the same manner as the ordinary cell-division: a cell in the chain prolongs itself by moving the connecting parts apart from each other, the plasma becomes concentrated in the new-formed, thin-walled part of the cell, swells up and forms a sphere. At that time the cell bursts, because the cohesion between its two halves is diminished by the formation of the globular body; we therefore always find the auxospore at the end of a chain, and often the chains have an auxospore at each end. At first the auxospore has no siliceous wall; it increases until it reaches its legal dimension, then it produces a rather thick siliceous wall with a very low connecting part consisting of one

(later on of two) thickened rings placed parallel to the valve faces,* as shown in fig. 3. At the same time we generally notice that the cell of the chain next to the auxospore-forming cell is in bipartition; it has reached the prolongation stage. When the auxospore is fully developed, it almost immediately undergoes a division: between the half-globular valves a cylindrical part appears (fig. 4) and new flat valves are formed (figs. 5, 6). We now get a two-cellular chain, of which each cell has one globular and one flat valve. Contemporaneously with this process the above-mentioned next placed cell has finished its bipartition and has begun a new division. The auxospore chain continues its divisions in the ordinary manner (*cf.* Otto Müller, 1883); often many-celled chains (fig. 7) with the auxospore valves at the ends have been found. The thickness of these chains is about 2-3 times that of the ordinary ones. The auxospores are often cohering to the ordinary chains until the auxospores become two-cellular, but rarely later.

The auxospore formation must begin rather suddenly; in the sample of 14th December, no auxospores have been observed, while in that of 23rd January these are numerous observed and some of them already consist of two cells. In the sample of 18th February many-cellular auxospore chains occur, and such is also the case in the following samples. They do not become rare before May-June.

Also in *M. italica* I have found auxospores; but only rarely, and not at different stages; they occur in both samples from June 1903. They are rather like those of the foregoing species, as will be shown by my figures (Pl. II. figs. 6-8), but there are some differences. They are globular, and appear in the same manner in a prolonged ordinary cell, but while the cell in *M. islandica* soon bursts, it is not so in *M. italica*; on the other hand, the neighbour cells have often disappeared, the individual then only consisting of a much prolonged empty cell with a globular auxospore placed in the thin-walled part nearest to one of the valves. A further distinction from the above-mentioned species is the connecting ring, which is not always parallel to the valve faces, but often more or less oblique. As I have seen only the unicellular

* Holmboe (1900) has, p. 17, mentioned such auxospores in *M. granulata*, and given figures of them (figs. 2 and 3).

stage of the auxospores, I am unable to say anything of the further development; worthy of notice is the fact that they appear much later in the year than the auxospores of the other species.

A phenomenon in the plankton *Melosiræ*, which is rather interesting, is that *the chains are curved*, generally so much so that they form a spiral or corkscrew. In my note on phytoplankton from an Icelandic lake (1904, p. 233), I have mentioned the same phenomenon from a lake at Heidi in Myrdalur (South Iceland), and have given two drawings to illustrate it (figs. 4 and 5). The species which is so curved has been defined by me as *M. granulata*, f. *curvata*, Grun., but Dr O. Müller, who has seen the plankton sample, tells me that it is better to name it *M. italica*.

In Thingvallavatn the *M. italica* is straight or only a little curved, while the *M. islandica* is often curved in the same manner as the form from Heidi. My drawings of parts of auxospore-bearing chains will give an idea of the degree of curvature; the longer chains form often a corkscrew. There is no doubt that this curvature, as pointed out by me (1904, p. 233), must be regarded as an adaptation to the limnetic existence; it is evident that the power of floating must thus be augmented. It is curious that the curved *Melosiræ* are so seldom mentioned in the plankton literature, although the *Melosiræ* are very commonly found in the plankton of lakes in many different countries, and generally play a predominant part in the composition of the plankton where they occur. In a paper by E. Lemmermann (1904 b, p. 17) we find the following remarks concerning the evolution of new plankton forms: "As the first influential factor, I take, naturally, the movement of the water; it causes, e.g., the different curvatures of the *Melosira* forms. It is very rare to find quite straight chains in the plankton; generally the stronger of them are more or less semicircularly curved, the weaker ones often being spirally twisted" (cf. also E. Lemmermann, 1903, p. 92). If we add to this that R. Volk (1903, p. 133) in a table notes a curved *Melosira* as rarely occurring in a single sample, I have mentioned all which I have succeeded in finding on that question.*

* O. Müller (1895) has, according to information given me by Mr Lemmermann, mentioned the curved *Melosiræ*, but the paper has not been accessible to me.

From the remarks of Lemmermann, it seems as if the phenomenon is a very common one; but if we consult the numerous photographs by Wesenberg-Lund (1904), we always will find the *Melosiræ* straight. Dr Wesenberg-Lund also tells me that such is the case in the Danish lakes.

E. Lemmermann very likely is right in taking the movement of the water as the cause, but we have herein no explanation of the fact that the phenomenon is common in Iceland, but does not exist in Denmark. We want here the experiment, and it cannot be very difficult to make it, if one has plankton with *Melosiræ* at his disposal. Until that has been done, we must content ourselves by affirming the probability of the curvature being an adaptation for floating, but we are not able to explain anything of the cause which has produced it.

Rhizosolenia.—In many of the samples I have found the peculiar fresh-water *Rhizosolenias*, but only in the two samples from June 1903 did they become rather abundant. The identification of the species is not easy; at first I thought that all the specimens belonged to one species, which must be a form of *R. eriensis*, and that the individuals varied greatly in size and shape. But on a closer examination of many specimens, I became convinced of the existence of two species or races. I shall here give some figures representing the results of measurements of 14 specimens (in μ). It will be seen that the breadth of the cell

TABLE I.

Individuals. No.	Length of the Cell.	Length of the Cell without Setæ.	Length of the Setæ.	Breadth of the Cell.
1	174	134	20+20	8.5
2	104	68	20+16	7.5
3	110	74	18+18	10
4	184	136	24+24	10
5	132	98	18+16	8
6	160	122	20+18	8
7	180	136	20+24	11
8	120	84	20+16	4
9	120	90	16+14	5.5
10	160	120	22+20	7
11	148	110	20+18	4
12	112	76	20+16	4.5
13	100	70	16+14	4.5
14	134	94	20+20	5

varies greatly in the different individuals, the narrower ones measuring from 4 to 7 μ , the broader ones from 7.5 to 11 μ , but no relation seems to exist between the breadth of a cell and its length; there are broad and long, broad and short, narrow and long, and also narrow and short individuals; perhaps the broad individuals generally are a little longer than the narrow ones. Nor does any clear difference express itself between the broad and the narrow ones as regards the length of the setæ. But nevertheless do the broad individuals differ from the narrow ones in small morphological characters as well as in the breadth, which will be seen if we compare the drawings of some specimens (Pl. II. figs. 1-5). In the broad specimens an undulation of the cell contour near the basis of the setæ indicates the place of the seta of the neighbour cell, while in the narrow specimens the cell contour is not undulated, but has only a double outline, *i.e.*, the cell has a furrow, in which the seta of the neighbour cell fits in. Further, the narrow specimens are cylindric, the broad ones are applanated; a specimen, which was 11 μ broad at the one axis, measured only 4 μ at the other. Many of the narrow specimens are somewhat curved, while the broad ones always are straight. By all this I think we must conclude that the broad specimens belong to one race or species, the narrow ones to another.

In all the samples in which *Rhizosolenia* have been observed, some specimens have been measured with regard to the breadth of the cell. It was *a priori* possible that the two races were different forms of one season-dimorphic species; if so, we must have found samples in which only one of the forms occurred, other samples in which the one form was rare, the other common, etc.,* but this does not seem to be the case, as both races were present in about the same quantity in the samples in which a larger number of specimens has been met with, as will be seen from the following text-table II. In the first sample (14th July 1902) I did not succeed in finding the broad race, nor did I see more than three individuals of the narrow ones. In the samples from the early spring of 1903, very few specimens were seen, and the greater part of these were of the broad race; but as the number is so small, I dare not draw any conclusions based on observations of as few specimens as these.

* Cf. Schröter, C., and Vogler, P. (1901).

TABLE II.

Date of the Sample.	Narrow Race.		Broad Race.	
	Number.	Per cent.	Number.	Per cent.
1902, July 14	3	100	...	...
1903, Feb. 18	4	40	6	60
" March 31	2	20	8	80
" April 16	3	23	10	77
" " 30	15	60	10	40
" May 11	10	33	20	67
" " 31	10	50	10	50
" June 15	48	48	52	52
" " 30	20	51	19	49
Total	115	...	135	...

The measurements in Table I. have been taken from specimens lying in the preserving fluid, and after treatment with methyl-violet; the breadth of the cell varies then from 4 to 11 μ . In the same manner the 100 specimens in Table III. have been measured, but as the measurements of *Rhizosolenias* hitherto published by different authors generally have been made in dried specimens, I have also, for easier comparison, measured 100 specimens of the same sample (15th June 1903) in dried condition (Table IV.). The figures 4-16 represent the breadth of the cell in μ , and each point denotes a specimen; to the right the number of specimens have been summed up. In this way we get two curves, which tell us several things.

TABLE III.

*Breadth of the Cell (μ), 100
non-dried Specimens.*

4.	17
5.	16
6.	11
7.	6
8.	23
9.	11
10.	8
11.	6
12. ..	2

TABLE IV.

*Breadth of the Cell (μ), 100
dried Specimens.*

4. ...	3
5.	7
6.	10
7.	11
8.	17
9.	8
10.	7
11.	10
12.	15
13.	7
14. ...	3
15. .	1
16. .	1

Both curves have two climaxes, which become an important support for our opinion that there are two races. The comparison of the two tables shows further that the drying of specimens causes the climax of the narrow race to be transferred from $4\text{--}5\ \mu$ to $8\ \mu$, and that of the broad race from 8 to $12\ \mu$.* It is natural that the narrow race has changed a little less than the broad one, because the change occurring is that of a cylinder being flattened, and this effect must be greater in a large cylinder than in a smaller one. The effect of drying may also more directly be made out. Some of the broader specimens contain resting spores which are much more strongly silicified than the other part of the cell, and therefore they do not become flattened in any mentionable degree. In two specimens the figures were: breadth of the cells, $14\ \mu$ and $11\ \mu$, breadth of the corresponding spores respectively, $11\ \mu$ and $8\cdot5\ \mu$; the difference is then $3\text{--}2\cdot5\ \mu$; that is, $1\ \mu$ less than the comparison of the tables gives us, but it must be remembered that also the spore becomes a little flattened.

The result arrived at through all these reflections is, that the narrow race, which has its normal breadth at about $4\ \mu$, must be reckoned as about $8\ \mu$ broad, if we want to compare our figures with the measurements of other authors; regarding the broad race the figure is, instead of $8\ \mu$, about $12\ \mu$. To make these figures as exact as possible, I have measured specimens from all the samples in dried condition; the above Table II. gives the number of specimens measured in each sample, and in this table the distinction between the narrow and the broad race has been determined according to the above reflection and to the following Table V., in which the breadth of 250 specimens is represented.

* An ocularmicrometer, in which each space between two lines corresponds to $4\ \mu$, has been used for the measurements; this may explain the curious fact that Table III. is one-sided, then the specimens, which really are $3\ \mu$ broad, may easily be taken as $4\ \mu$ broad.

TABLE V.

Breadth of the Cell (μ), 250 dried Specimens.

4.	6
5.	16
6.	24
7.	26
8.	43
9.	13
10.	21
11.	23
12.	43
13.	18
14.	10
15.	5
16. ..	2

The shape of this curve is exactly like that of Table IV., the same two climaxes of 8 μ and of 12 μ exist here, also the same extremes of 4 μ and of 16 μ .

As mentioned above, the broad race bears *resting spores*, while I have not been able to discover any spore-bearing specimen of the narrow race. The spores occur only in the samples from June 1903. My drawings (Pl. II. figs. 2, 3) will give the shape of such a resting spore seen from the broad as well as from the narrow side; they have one convex and one concave valve, and are much more silicious than the other part of the cell; the whole plasmatic content of the cell is concentrated in the spore, in which the nucleus and the chromatophore substance is easily shown. The spore-bearing specimens vary in breadth from 9 to 16 μ (in dried condition), 11 to 13 μ being the ordinary figures.

If we wish to consult papers dealing with the fresh-water Rhizosolenias, we will find many notices scattered in different publications. The first-described species is *R. eriensis*, H. L. Smith, found in the large North-American lakes and later also registered from Europe (Italy, Switzerland, Germany, Finland, Sweden, and Scotland), but always only in a single or in few lakes in each country. To this species, of which two varieties have been proposed, I should refer the broad race from Thingvallavatn. Different drawings of this species exist. A drawing which comes near to the Thingvallavatn form has been published by O. Zacharias (1898, p. 716; 1899, p. 85). He gives some measurements which do not differ much from those of the Icelandic form, the most striking divergence being the length of the setæ. Also Bruno

Schröder (1898, p. 529) has measured a form of *R. eriensis*, which he found near Breslau; this form is shorter than ours.

K. M. Levander * (1904) has recently written a little paper on the Rhizosolenias of Finland; he has found *R. eriensis* in two lakes, and has had specimens from Lake Erie for comparison; his drawings of the Finland as well as of the Erie forms agree well with my drawings.

TABLE VI.

	Saxony.	Breslau.	Finland (Keitele).	Finland (Valijärvi).	Iceland (Thingvallavtn).	Canada.
Recorded by,	O. Zacharias	B. Schröder	Levander	Levander	Ostenfeld	Levander
Length of the setæ,	20-40	18.7-25.5	24	40	14-24	25-40
Length of the cell without setæ,	30-64	30-57.8	52	80	68-136	70
Breadth of the cell,	6-10	9.4-15.3	11	12	8-16	12-20

In Table VI. I have placed the different measurements together; it will be seen that the Icelandic form is somewhat longer than the others, but has shorter setæ.

The narrow race seems also to have been found by O. Zacharias, and his drawing and notes are published as quoted above. In 1898 he has named it *R. paludosa*, Zacharias, but in 1899, p. 87, he has taken it as a variety of *R. longiseta*, Zacharias, formerly described by him. From this species it differs by the much shorter setæ, the curved shape and the more distinct structure; the cells with setæ are 100 to 120 μ long, and 8 to 12 μ broad, while the setæ are about 40 μ . The typical *R. longiseta*, Zacharias, has a length of 160 μ (without setæ) and the setæ measure about 180 to 200 μ . By these figures it becomes evident that there is a great difference between the type and the variety, and if we take the narrow Icelandic form as belonging to the variety, the difference will be still greater. Although the above-mentioned measurements of the Icelandic form in some ways differ from Zacharias' figures of his *R. paludosa*, I have found it better to register my

* I have taken the figures of the Erie form in my Table VI. from the drawing on his plate i.

form under his name ; his drawing is very like mine, and the lengths and the breadths of the cells are about the same, but the Saxonian *R. paludosa* has longer setæ. Perhaps we should do better in making a new species, but at present I do not intend to do so. No doubt there are many races of fresh-water Rhizosolenias connected with each other, so that they form a series, of which the extremes are the broad *R. eriensis* with short setæ and the narrow *R. minima*, Levander, 1904, with very long setæ. There are two ways to go : either take all the races as one species or separate them ; whether the one or the other way is correct, is at present impossible to decide. The simultaneous occurrence of two forms in a sample may be used as an argument against as well as in favour of both contentions. We do not know anything of auxospores in the fresh-water Rhizosolenias, but if such things exist (which is not at all unlikely, as several of the marine Rhizosolenias have been found with auxospores) we therein perhaps may find the explanation of their peculiar occurrence in apparently distinct but nearly allied races.

It seems rather peculiar that both species in Thingvallavatn occur also in the winter samples, although they have their maxima in June. Nearly all the previous records of Rhizosolenias belong to the summer, only by Wesenberg-Lund (1904) we find records of *R. longiseta* from every month of the year (p. 68). This circumstance is probably partly due to the fact that most of the plankton investigations have been made in the summer, and partly on account of the very thin and small Rhizosolenias having been overlooked when they were not present in large quantities.

The fresh-water Rhizosolenias have a very wide distribution ; the most common form is *R. longiseta*, Zach. Of *R. eriensis* we have records from Canada (Lake Erie), Finland (two lakes), Germany (two lakes), Sweden (one lake), Scotland (two lakes), Switzerland (two lakes), and Italy. Worthy of notice is the very scattered occurrence. Concerning *R. paludosa*, Zach., the records are scarcer ; besides Germany, we have more or less reliable statements from Scotland (Loch Shin), Denmark (Sorö lake), and Finland (Väljjärvi). At last we must remember the most delicate form, *R. minima*, Levander, found in the bay of Wiborg (Finland), together with *Altheya* and other fresh-water forms.

FLAGELLATÆ.

Mallomonas.—In the two samples from June 1903 I have observed a few specimens of a small *Mallomonas*, but as I have seen only so few individuals, I have not succeeded in discerning distinctly the shape of the scales and cannot with certainty identify the species. I have drawn two figures (Pl. II. figs. 9–10), the one showing a specimen with resting spore, but without setæ; the other represents an ordinary cell with setæ only in the antapical (or apical?) part, perhaps also the resting part of the cell has been covered with setæ, now fallen off. As far as I have been able to notice, the scales are round, but they may also have been transversely ovate, the setæ are hardly visible, but I cannot tell whether they are smooth or denticulate. The dimensions (length 28μ , breadth 18μ) agree very well with those of *M. longiseta*, Lemm.,* of which no figure exists; it has denticulate setæ, which cover the entire cell, and ovate scales. Owing to these insufficient notices, I have preferred not to name the form specifically, hoping that future investigations may decide the question.

PERIDINIALES.

Peridinium.—The only † species of *Peridinium* which has been found in the samples is a rather interesting form; it occurs in the samples from 1903, and has its maximum in February–March, when it constitutes a great part of the phytoplankton. In the Plate I have given drawings of specimens at different stages. In February and March nearly all the individuals are cells without any wall, but embedded in a wide gelatinous envelope (see Pl. I. fig. 11). In the cell a large nucleus is shown partly covered by large refractive granules (see Pl. I. figs. 11–12). The vegetative multiplication occurs by ordinary cell-division, and different stages of the division are often seen, by which it is easily observed that the division takes place at a right angle to the longitudinal axis of the cell (Pl. I. fig. 13). In this stage of development it is impossible to identify the organism with any degree of exactness,

* See the key of the genus by E. Lemmermann (1904, pp. 117–118).

† In the sample from 30th June I found one single specimen of a little Peridinium which I was unable to define.

but it seems most natural to place it in the genus *Gymnodinium*. Together with these *Gymnodinium*-like cells a few specimens of a true *Peridinium* have been found, and these become more frequent in the samples from April, when the *Gymnodinium*-like cells decrease in number. From the similarity of the contents in the *Peridinium* (Pl. I. fig. 18) and of the naked cells, as well as from a few specimens of the *Peridinium* in which the cell-contents are breaking out (Pl. I. fig. 19), it will be evident that we have two stages of one and the same organism. The cell-wall is rather thin, and it is difficult to discern the plates, but after treatment with iodine-zinc-chloride the wall becomes reddish-violet and the sutures to a certain degree visible. The arrangement of the plates (Pl. II. fig. 18) of the apical limb is about the same as in *P. umbonatum*, Stein, but I have been unable to see the plates of the antapical one, so the placing of our organism in the genus *Peridinium* consequently is based on analogy. Around the antapical part of the longitudinal furrow three small spines occur; they are merely prominent membranous prolongations of the sutures (Pl. II. fig. 18); the middle one is the most prominent; it is linear when seen in a ventral view, but triangular when seen in more dorsal view. These three spines distinguish our species from the *P. umbonatum*, Stein, to which it is nearly allied. In the literature I have found a short description of a *Peridinium aciculiferum* named by E. Lemmermann (1900, p. 28), which agrees very well with our species, but as I did not dare to run the risk of identifying the two forms merely on the basis of but such a short description without any drawing, I asked Mr Lemmermann for a drawing or a sample containing his species. He has been so kind as to send me a drawing as well as a sample, for which I am much indebted to him, and after examination of the latter I do not hesitate to take my form as identical with his species, and consequently I name it *P. aciculiferum*, Lemm. Perhaps the spines in his form are a little longer, and more prominent. He writes that his species, which has been found in a lake in the neighbourhood of Berlin, has numerous, discoid, brown chromatophores; the above-mentioned refractive bodies are perhaps chromatophores, but it is impossible to decide on the question when having only preserved material at hand.

When the number of our species in May begins to decrease, a number of thick-walled cysts appear, one of which I have drawn on Pl. I, fig. 20; the cell-wall consists of cellulose, like the wall of the *Peridinium*; the cell-content contains starch and is rather condensed, but a nucleus of the ordinary Peridinium shape is clearly shown. I suppose that these cysts represent the resting stage of the Peridiniums. In June our species has become very rare, only some empty scales of the Peridinium stage and some cysts having been found. I presume that most of the cysts have dropped to the bottom. Then probably the life cycle of the species is as follows: in the summer and autumn the cysts rest in the bottom mud, then in January–February they rise in the plankton developed in the Gymnodinium stage and embedded in a large jelly; the cells divide repeatedly in February–March, and in April form the Peridinium stage with cell-walls consisting of plates. From this stage we must imagine the cysts developing in such a manner that the cell-contents of the Peridiniums go back from the inner side of the cell-wall, and then secrete the new, thick homogeneous cell-wall, thus forming the cysts which sink from the plankton to the bottom.

Length of the Peridinium, 35–40 μ ; breadth, ab. 30 μ . Lemmermann says (1900, p. 28) 32–42 μ broad and 41–51 μ long: thus his forms seems to be a little larger than the Thingvallavatn form.

In a later paper (1903, p. 109) he mentions our species as occurring in the months February to April, and quotes (pp. 86–90) the following tp. figures of the water, observed when the samples were taken, viz., 4·25°, 2·9°, 6·5°, 4·8°, 8·5° and 12·1°. These figures correspond rather well to the tps. of the Thingvallavatn, varying from 1° to 8·5° in February–June. We accordingly must take our species as a cold-water *Peridinium*.

(c) ZOOPLANKTON. BY C. WESENBERG-LUND.

HELIOZOA.

Acanthocystis aculeata, Hertwig and Lesser.

During the time from 31st March to 30th April I have found in the samples a small Heliozoan; it was always rare, being

most common on 16th and 30th April. As my knowledge of the Heliozoa is but slight, and as the animal was badly preserved, I sent it to Dr Penard, who kindly wrote me that, according to his opinion, it was an *Acanthocystis aculeata*, but a somewhat smaller specimen than those which he had examined in the Swiss lakes, for instance, in Lake Geneva.

INFUSORIA.

Frontonia, Ehrbg.

In the sample of 16th April I found a very peculiar body, which at first sight caused me a good deal of trouble; it was a brown sack generally *c.* 200 μ long and 50 μ broad; it was quite filled with long *Melosira* chains in numbers of 3-7, and the chains often stuck out either at the one end or the other; near the centre I always found a black body, and the surface of the creature was covered with fine granulations. I had never before in a plankton sample seen anything like this creature, and was hardly sure of having an animal before me. Dr Penard, who kindly also examined this body, told me that it must be an Infusorian, and Dr Roux, to whom he showed it, supposed it to be a *Frontonia*. I wish to offer both gentlemen my most cordial thanks for their kind determination of the animal.

It is the first time we have met with an Infusorian of this group as a plankton organism; as far as I remember, I have never seen such a one living so exclusively on another organism and, so to say, preying upon *Melosira* and solely upon this single organism.

ROTIFERA.

Polyarthra platyptera, Ehrbg.

P. platyptera is perennial, although it has not been found in a few of the early spring samples. The variety *euryptera* has not been found. *P. platyptera* has a great max. (14th July); at that time some individuals with male eggs have been proved; the dark-spined winter eggs are by no means rare, especially in the autumn and winter samples.

Synchaeta neglecta, Zach.

It is a well-known fact that the different species of the genus *Synchaeta* can hardly be distinguished by means of preserved material; when the water with the living animals is immediately poured out into glasses containing concentrated formaline, it sometimes happens that the animals do not pull in their wheel organ. In the samples I have found a few specimens with protruded wheel organ; on the basis of these samples I suppose that the species in the pelagic region of the lake is *S. neglecta* (Zach.). It is doubtless perennial, and its max. seems to occur at a low tp.

Ploesoma lenticulare, Herrick.

In the two samples of 15th and 30th September I have found a species of *Ploesoma*. The animal was rare; the lorica of the animal lacked the fluffy tissue characteristic of the two species *P. Hudsoni* (Imh.) and *P. molle* (Kellicott.) It differed from the easily recognisable *P. triacanthum* (Bergend.). Still, I am not sure whether I had the *P. lenticulare* (Herrick) or *P. truncatum* (Levander) to deal with, as all of the animals were greatly contracted. In all the samples from August to September I found the limnetic egg characterised by a great hyaline space between the very small yolk mass and the egg-shell.

Asplanchna priodonta, Gosse.

This species has occurred in very few samples at different times of the year. I believe it to be perennial, but it seems rare in the pelagic region of the lake.

Anuræa cochlearis, Gosse.

The species is found in all the samples and is therefore undoubtedly perennial; I have not observed any strongly marked max. The number of specimens is never great; perhaps a small max. may be pointed out for October and November. All the individuals belong to the well-marked hyaline, long-spined lake form.

Notholca longispina, Kell.

N. longispina of the Thingvalla lake differs slightly from most specimens of southern countries, the posterior spine is not straight or only slightly arched, but shows a very remarkable upward curve.

It is perennial, and seems to carry its eggs all the year round; strongly marked max. and min. have not been pointed out, but it seems to me that it has been most common in winter.

Notholca striata, O.F.M.

Only a very few specimens of *N. striata* have been found; just as with us, it appears in the winter months and disappears in early spring.

Conochilus unicornis, Rousselet.

The first individuals were found on 30th August, the last on 23rd January. I have not been able to find a single individual from January to August. In the samples the colonies have all been broken up and only single individuals were found.

Except *Ploesoma lenticulare*, all the Rotifers mentioned above belong to the common, widely spread stock of cosmopolitan plankton organisms which have been found in every locality where plankton explorations have been carried on. Their existence on the Kolgujev island has also been pointed out by Skorikow (1904, p. 209), and on the Murman coast by Levander (1901, p. 1.) It is strange that only so few of these species have been mentioned by Bergendal (1892) from Greenland, which has been better explored as regards its Rotifer fauna than any other arctic country. According to my opinion, this stock of cosmopolitan plankton Rotifers may also be found in Greenland. The reason why Prof. Bergendal has only met with such a few species in his explorations of the pelagic region of the greater lakes, is most likely because he could not make use of a plankton net, the plankton explorations in fresh water at that time (1890) being anything but methodically carried on.

Among the cosmopolitan stock of plankton Rotifers from greater lakes, I also reckon *Anuræa aculeata* and *Triarthra longiseta*, which have not been found in Thingvallavatn. This stock then consists of the following species: *Polyarthra platyptera*, *Synchaeta* sp., *Asplanchna priodonta*, *Anuræa cochlearis*, *Anuræa aculeata*, *Notholca longispina*, *Conochilus unicornis*, and *Triarthra longiseta*.

Skorikow (1904, p. 209) has pointed out that all the species from the lakes on Kolgújev have also been found in the alpine lakes of Switzerland. Skorikow's point of view in this regard is expressed as follows (p. 212): "Ein Übereinstimmen der arktischen und alpinen Fauna ist gewiss nichts Neues, aber eine so vollständige Identität wie in diesem Falle, meine ich, verdient einige Aufmerksamkeit; besonders ist dies hinsichtlich der Rotalien interessant weil man sie in schon übertriebenen Mass als untauglich für geographische Zwecke ansah."

According to my opinion, Skorikow takes a wrong view of the result of the exploration. Nowadays we have found in every thoroughly explored lake with a well-defined limnetic region the above-mentioned stock of Rotifers; it belongs by no means only to the arctic and alpine lakes, but quite as well to all lakes situated between the arctic and the central European highlands. So that when we may show "vollständige Identität" in the plankton Rotifers of the arctic and the alpine lakes, this is, geographically speaking, by no means noteworthy; on the other hand, and from a biological point of view, it becomes of interest that the association of Rotifers living under arctic conditions remains the same everywhere; in the shallower, and in summer much warmer, lowland lakes this association also exists, but is here mixed up with all the monocyclic summer Rotifers which, in order to exist, require a tp. of between 16° and 20° C.

It may be that the Rotifers at some future time may become instrumental in furthering geographical studies far beyond those we at present dream of. Still, I feel convinced that the way in which so many naturalists, from observations based upon a few samples collected in out-of-the-way places of the globe, often think fit to lay down laws for the distribution of the associations, or to subvert results that have been arrived at by others, is not much to the purpose.

CLADOCERA.

Daphnia longispina, O.F.M.

With regard to the *longispine* group of the genus *Daphnia*, I have in my plankton work (1904) followed Lilljeborg (1900), who refers all the *longispine* Daphnids to the two species *D. hyalina* (Leyd.) and *D. longispina* (O.F.M.). Still, I supposed these two species to be only one, of which the *hyaline* group, at any rate in our country, mainly consists of plankton organisms in the greater lakes, the *longispine* group belonging chiefly to the central parts of ponds and smaller lakes; for want of time I was prevented from studying the smaller lakes more closely, and did not venture at that stage of my explorations to refer all *longispine* Daphnids to one species only. Later on Sars (1903, p. 8) has united the two species, and Ekman (1904, p. 17) likewise. The form which occurs in the Thingvallavatn proves to belong to the *microcephala galeata* group (Ekman, p. 123).

In early spring we only find forms which undoubtedly are identic with the *microcephala* forms; Ekman also classifies these as spring forms. In Thingvallavatn the species never develop into the *galeata* forms, which often occur in Sweden as well as in our country. In the summer and fall the individuals may most probably be referred to the form *obtusifrons*, yet differing from this by a more *acute* rostrum and a greater bend in the ventral edge of the head.

On 14th July we only find young parthenogenetic mothers, some of them with 2 to 3 eggs (fig. 1); from 31st July males and females with ehippia (fig. 2) occur in all the samples till 15th September; the joint number of individuals is very small. On 15th September *D. longispina* is common; most of the animals are parthenogenetic females with few (2-3) eggs; ehippial females do not occur, but some males with faintly developed first pair of antennæ. On 30th September *D. longispina* is very common, and many of the females have ehippia again; besides, we find many quite young females without eggs of any kind (fig. 3); the males are now common. On 15th October *D. longispina* is remarkably rare; young females without ehippia and young males occur. From 31st October to 14th December *D. longispina*

is the main form in the plankton samples. On 31st October several females have ephippia, yet the greater part have none; the males appear in countless numbers and are now fully developed; even now we find no more young animals. On 16th November the

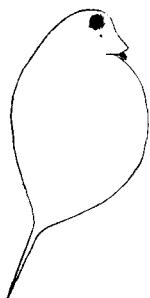


FIG. 1.—14th July,
young female,
two eggs.

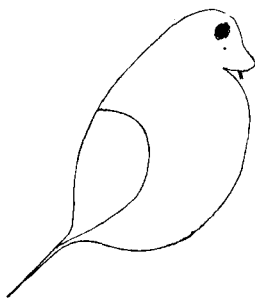


FIG. 2.—31st July,
female with
ephippium.

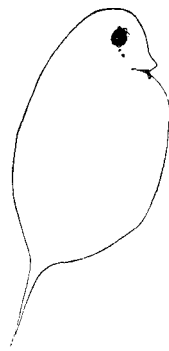


FIG. 3.—30th Sep-
tember, young
female.

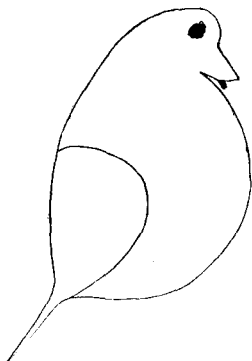


FIG. 4.—14th December,
big female with ephippium.

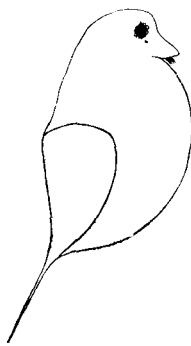


FIG. 5.—14th December,
small female with ephippium.

ephippia of most of the females are more or less conspicuous, but very few have eggs in them. On 30th November all the females have ephippia and in most of them are eggs; the number of males is decreasing. On 14th December only females with ephippia or barren females occur; males are wholly wanting. On 23rd January the number of *D. longispina* is but small and consists only of females. *D. longispina* is wanting in all the samples

from 23rd January till 31st May, when the first very slender young ones may be noticed; these occur also in the last samples, 15th and 30th June. In *D. longispina* of the Thingvallavatn we only find a very slight seasonal variation. The *microcephala* forms, which occur in May, and probably disappear in July-August, are very much alike throughout the period, but they differ somewhat from forms which occur during August-January and which, as stated above, may be considered as *obtusifrons* forms. The drawings will show the main differences, especially with regard to the shape of the head. I have not been able to point out any seasonal variations as to the *obtusifrons* form. Only in December it may be noted that the ephippial females occur in two sizes, the one is c. 2-3 mm., the other only 1.2 to 1.5 mm., the former has a short spine, the latter commonly a much longer one (figs. 4 and 5).

From the facts stated above, we may gather that the life cycle of *D. longispina* lasts at least from the end of May to February. Still, I think it very probable that some animals—the young ones of the last autumn's brood—here as in Danish lakes survive in deep water and propagate in spring. How large a percentage of the total number of *D. longispina* in the lake the stock of these females amounts to, and how many of these individuals are derived from ephippia, we are unable to decide.

With regard to the number of generations and broods, I have arrived at the following conclusions.

At the end of July and in August we find males and females with ephippia, but after the 15th September no ephippial females, but only young animals with 2 to 3 parthenogenetic eggs and a few not quite developed males, occur. As we again find on 30th September ephippial females and numerous males, I cannot see but that *D. longispina* in the Thingvallavatn may be regarded as dicyclical.

Moreover, when taking into consideration that during the time in which the first sexual period appears we first (July) find females with 2 to 3 eggs and later on males and females with ephippia, I conclude that the spring generation to begin with will propagate parthenogenetically, thus producing males and females, but in all probability only one or two broods; afterwards it will produce ephippia and then disappear (September).

The second generation will produce two parthenogenetic broods and then ephippia. The first of these broods will also, to begin with, propagate parthenogenetically (August–September), and later on sexually (October–December); the second one only sexually (November–December). The first of these broods lives from July to December, and is in December represented by large females with ephippia and short spines; the second brood, which lives from September–October to December, is in December represented by the small-sized, long-spined, ephippial females.

With regard to the above given details, there is especially one doubtful point. I have not been able to decide whether the first generation totally disappears in the latter part of August, or whether some of its members live on and assume the aspect of the *obtusifrons* generation; according to my knowledge of the cycle in the Danish lakes, I feel inclined to consider the first view as the correct one.

COPEPODA.

Diaptomus minutus, Lilljeb.

The *Diaptomus* species of the Thingvallavatn is the easily recognisable *D. minutus* (Lilljeborg). It is described by Lilljeborg from Greenland and Newfoundland; it is mentioned by Marsh (1893, p. 199) from Green lake, North America. In a subsequent paper (1897, p. 8) Marsh describes it as the commonest of all Diaptomidæ appearing in samples collected in the great American lakes.

Richard and De Guerne (1889, p. 632) states that it has been found in Greenland near Tasersuak. The species of the Thingvallavatn has already some time ago been determined as *D. minutus* by the same authors.

On 14th July *D. minutus* occurs in enormous numbers, but only as young ones. On 31st July I found many males with spermatophores within their bodies; the abdomen of the females is quite straight and the oviducts hardly noticeable; some females have 2 to 3 eggs. From 14th August till 15th September the sexual period is at its max. Males and females are nearly equal in number; the males all have spermatophores in their bodies, and the females often carry a cluster of 4 to 5. The egg-sacks never contain more than 4

eggs and later in the period only 2 to 3. The oviducts are very conspicuous, and present dark tubes containing unripe eggs. The abdomen of the females is strongly curved and often, owing to pressure of the egg-sack, bent upwards at a right angle with the cephalosome. Very often I have found females with remnants of an earlier egg-sack attached to the abdomen, at the same time having oviducts filled with unripe eggs. By this we learn that a female may produce more than one brood. From 30th September to 16th November the species gradually disappears. On 15th October the oviducts contain no more unripe eggs, and females with egg-sacks are rare. The *vasa efferentia* of the male have no spermatophores; a few males were found on 16th November but no females with eggs. The last individuals are observed on 23rd January, when the species totally disappears, new individuals again appearing in spring 1904.

As far as I have been able to make out, *D. minutus* has only one kind of egg, and I have never seen any egg beyond the gastrula stage. With regard to the colour, we find two kinds of eggs, one being red and uncleft, the other gray and cleft to the gastrula stage. First I supposed the shell of the former, which is of a yellow colour, to be a little thicker than the hyaline shell of the gray eggs, but later I found intermediate stages between these. Furthermore, as I have never found nauplii in the time from 14th July 1903 to 16th April 1904, I suppose that all of the eggs are resting eggs.

Ekman (1904, p. 103) arrives at the same result with regard to the eggs of *D. laciniatus*, *denticornis*, and *laliceps*.

Owing to the quality of the material it is impossible to give a correct conspectus of the life cycle of *D. minutus*; in this respect it is most unfortunate that the collections have not been carried on after 30th June 1903, when the nauplii had begun to appear.

I feel inclined to believe that the species has only one generation, which is hatched in April-May and dies out in January. This generation is derived from resting eggs which have hibernated in deep water either on the bottom or suspended in the water. My interpretation of the life cycle may perhaps be correct, inasmuch as Marsh, in 1897 as well as in 1903 (p. 22), after a most

thorough exploration, has given a rather similar sketch of the life cycle of *D. minutus* in Green lake and in Lake Winebago. According to Marsh, *D. minutus* occurs there from July to December; the great max. occurs about the 1st of August, but it also has another but smaller max. in October; the species is rare in winter and spring.

Cyclops strenuus, Fischer.

The Cyclops species of the pelagic region of the Thingvallavatn is *C. strenuus* (Fischer), and not *C. scutifer* (G. O. Sars), to which result Richard (1892, p. 310) already has arrived. The species appears in the *forma vernalis*, Lilljeb. (1901, p. 47), which, according to Ekman (1904, p. 30), also is characteristic for the North Swedish alpine region. As far as my experience goes, it has no conspicuous seasonal variations in the Thingvallavatn.

On 14th July the species is rare, and only a few young unripe animals are found; on 31st July the number of animals is enormous, but all are quite young. In all the following samples till 30th September, its occurrence is rare, after that the species again becomes common; ripe males and a few females with eggs appear; the number increases steadily until 23rd January, when the species attains the main form and occurs in enormous numbers. All the females carry eggs, and males may be noticed in all the samples, but become rare in January. Then *C. strenuus* disappears entirely, and is not seen again until 16th April. In all the following samples till 30th June we find the number of individuals increasing. In May we only observe nauplii or very young animals; they become very numerous in June.

From the above statements it is impossible to arrive at any conclusion as to the propagation of *C. strenuus* in the Thingvallavatn. The very small number of individuals at 14th July, the enormous quantities at 31st July, and the almost total disappearance from 31st July to 30th September, clearly show that the samples by no means verify the existing facts. We are only able to note that from 14th July to 30th September 1902, as well as from 16th April to 30th June 1903, no ripe males or females with eggs appear. During this period we only find nauplii or half-grown

broods; the sexual period does not begin till the last days of September, and continues till January.

The number of eggs in every egg-sack at 30th September is about 4, in October–November 6–7, but in December–January it diminishes again (2–3).

I suppose that further explorations will show that the limnetic region of the Thingvallavatn contains several other plankton Crustacea than those mentioned in this paper. It must be kept in mind that all the samples are surface samples, and I consider it most probable that different species, especially *Bythotrephes*, may be found in deeper waters. Richard and De Guerne mention, as stated above, different bottom and shore species, among which we also find *Bosmina arctica* (*B. obtusirostris*). This species may be considered a plankton as well as a shore organism. I only wish to emphasise that none of my numerous plankton samples ever contained a single *B. arctica*.

III. MYVATN. BY C. WESENBERG-LUND.

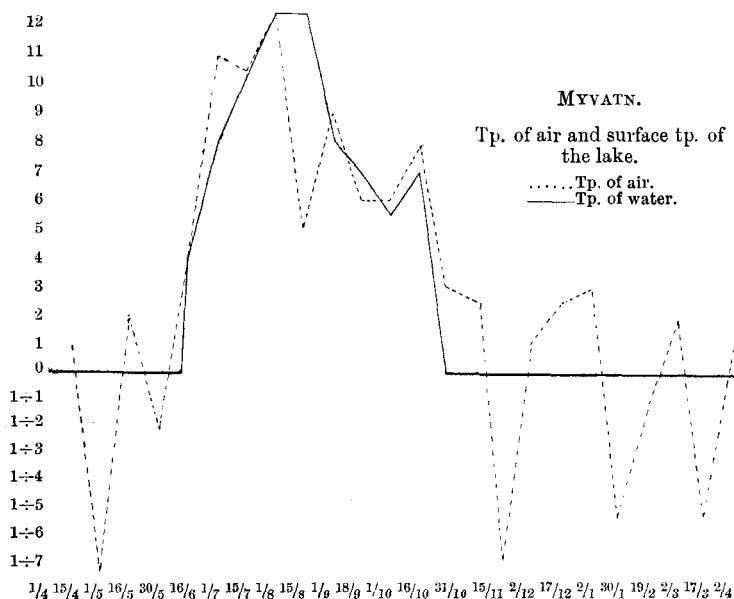
1. *General Remarks.*

Myvatn is situated in the northern part of Iceland, in latitude 65° 33' N., 292 m. above sea-level, and is nearly 27 square kiloms. in extent. The lake has been formed in down-sunken parts of enormous lava torrents. The bottom consists almost entirely of lava, and is nearly everywhere surrounded by widely extending lava grounds. Along the shores, and forming islets in the lake itself, the lava is congealed in very peculiar and fantastic columns. The lake is situated in a volcanic area, which even now-a-days may be considered extremely active. Upon the east side of the lake very many solfatares occur. According to Thoroddsen, the ground is here actually seething with hot vapours, and it is dangerous to walk upon it; little hillocks of sulphur are very common and alternate with pools of mud, which incessantly boil and bubble, while ejecting bluish-black clay mud.

The surrounding country, especially the northern and eastern part, is extremely void of water, as all the rain is absorbed by the porous volcanic soil. It seems as if the water, partly through

subterranean channels, is conducted to the lake, which is mainly nourished in this manner.

Especially the eastern side of the lake has very many bays, and in the lake itself we find many (c. 100) inlets, for instance, the wood-covered Sluttness and Geitey; many of the inlets are craters. The small Geitey, although measuring but 14 kiloms., has no less than 10 craters; the highest of these is 70 feet above the level of the



lake. Many of the craters are now filled with water, and present themselves as circular, quiet crater lakes.

The vegetation around the lake, upon the inlets and in the lake itself, is extremely rich. There exists a list of plants gathered near and in Myvatn by Grönlund (1890, p. 107), to which paper I refer. The islands are often covered with birch, sorb, and willows, the stems of the birch being 12–14 feet high, or with *Angelica* and other plants.

In the lake itself we find *Myriophyllum*, *Potamogeton*, *Hippuris*, etc., in great abundance. *Nostoc* is further, according to Sæmundsson and Thoroddsen, abundant, forming huge masses near the shores. Myvatn is an extremely shallow lake; the oars will

always reach the bottom in great parts of it, the greatest depth being only 2-3 m.

It must be emphasised that during the great volcanic eruption in 1729 the lava ran into the lake ; the greater part of this became exsiccated, and people thus laboured under the impression that the water burned like oil. Great quantities of the water were transformed into vapour, and all living organisms probably became extinct. The shape of the lake was altered, islands arose, and in other localities the water inundated the meadows and old islands disappeared.

At the present moment animal life is extremely rich. The fine mud, which covers the lava bottom, is filled by myriads of larvæ of gnats, especially *Chironomus* and other diptera ; at certain seasons the water teems with enormous quantities of the skins of the pupa and dense clouds of gnats arise. From these clouds the lake has derived its name, Myvatn signifying the lake of gnats. These gnats have never to my knowledge been scientifically studied.

Some of my samples contain nothing but skins of *Chironomus* pupæ, but undoubtedly stinging gnats (*Culex*, *Simulium*) may also be found in or near the lake.

All travellers have pointed out how difficult the sojourn is near or on the lake in hot summer days on account of the mosquitoes, which attack people as well as horses.

In shallower bays, especially in those in which the water is tepid owing to hot springs near the shore, a great many molluscs, especially *Limnea*, *Succinea*, and *Planorbis*, are found.

Myvatn is an extremely fine trout lake, the trout being present in enormous quantities. The same is also the case with Thingvallavatn. One of those peculiarities, which makes Myvatn an extremely interesting locality, is the innumerable masses of birds, especially ducks, which breed on its shores or along the inlets ; various travellers and naturalists have given extensive reports with regard to this bird life.

The *temperature* of Myvatn is quite different from that of Thingvallavatn ; still, it must be remembered that the observations made in the two lakes unfortunately do not date from the same year. The lake is icebound until 28th May, then the tp. in only 6 weeks reaches its max., 12½° C. (15th July). This tp. we also find

on 1st August, but as early as 15th August it has gone down to 8°. On 18th September it further falls to 6°, and then rises a little (on 1st October it is 7° C.); but then it falls rapidly, and on 24th October the lake is already icebound. It was frozen over the rest of the year, with the exception of a short period from 7th to 10th November, in which the lake was again open, but at the time when these observations were finished (2nd April) it was not once open. Hence we learn that the lake, in the year when the investigations were carried on, was only free from ice 152 days ($\frac{2}{3}$) of the year, being icebound 213 days ($\frac{3}{5}$). Further, we see that the water of the lake follows the variations in the tp. of the air extremely quickly, owing to which the lake is able to reach the relatively high tp. of 12° C. in a period of but 45 days.

Owing to the hot springs, the tp. in the bays of the lake may often rise to 15°–20° C. (Thoroddsen) at an air tp. of only 10° C.

*Monthly Mean tp. of the Air at
Akureyri and Mödrudalur.*

1903–1904.	Akureyri.	Mödrudalur.
March, . . .	–4.1	...
April, . . .	–0.8	–2.7
May, . . .	4.7	3.3
June, . . .	9.6	7.7
July, . . .	9.8	...
August, . . .	5.6	3.3
September, . . .	6.9	4.3
October, . . .	0.5	–1.1
November, . . .	–1.6	–6.3
December, . . .	–0.4	–3.6
January, . . .	–2.3	–6.3
February, . . .	–2.9	–6.9
March, . . .	–2.3	–6.6

2. *Plankton.*

It is the first time a regular plankton exploration has been established in a lake which is ice-covered for more than seven months, and it must, according to my opinion, be of great interest to receive some information concerning the plankton of such a lake.

Owing to the nature of the lake in question, the results of the

exploration must unfortunately—when taken as a paradigm to a sub-arctic lake—be used with great caution. This will best be understood when remembering that all animal life in the lake is, according to all accounts thereof, only 120 years old, and when keeping in mind the extremely volcanic area in which the lake is situated.

The most conspicuous fact with regard to the plankton of Myvatn is the non-existence of phytoplankton. Of the Myxophyceæ I have only noted some few individuals of the genus *Anabaena*, and this only in a single sample (15th July 1903) and at the highest tp. of the water. NOT A SINGLE PLANKTON DIATOM IS FOUND, nor any plankton Chlorophyceæ; the plankton of Myvatn is almost wholly zooplankton.

While the lake was ice-covered I ordered the samples taken from a hole in the ice. In these samples I have found the cosmopolitan perennial Rotifer fauna as mentioned above, as well as some bottom Crustacea shown in the plankton table. Of course the number of animals in these vertical samples, taken in a water column of only a few feet, is very small; yet the samples clearly show that in winter all life, even in as cold a lake as this, is by no means wholly wanting. Still, I presume that the plankton life in winter is greatly reduced, and that it only flourishes during a period of $4\frac{1}{2}$ months, for instance in 1904 from 28th May to 24th October.

The plankton consists almost solely of Rotifera and Crustacea. The Rotifer fauna is probably extremely rich. Among the plants contained in the samples I have found many bottom and shore Rotifers; in as shallow a lake as Myvatn, and one which is to such a degree covered with vegetation, no limit between a limnetic and a littoral region can be said to exist. Besides, we find in the samples the entire stock of cosmopolitan perennial Rotifers, but none of the periodical summer forms appear. I have only found well-marked max. and sexual period for *Conochilus* and for *Asplanchna priodonta*, both at the highest tp. of the water (15th July). Also with us these Rotifers reach their max. at tp. 12°, but as our lakes reach this tp. twice in the year, in May and in September–October, they are dicylic with us.

The Crustacea fauna I also suppose to be very rich. I found in the samples many bottom and shore animals, for instance, *Macrothrix*

hirsuticornis, *Alona* sp., *Acroperus leucocephalus*, *Chydorus sphaericus*, and several species of *Cyclops*. Of these bottom forms the sample of 18th September contains *C. sphaericus* in great numbers, as well as many *Macrothrix hirsuticornis*. Of the genus *Bosmina* only *B. obtusirostris* appears in May and June, but only a very few individuals of this species may be found. Of plankton Crustacea Myvatn has only one species, *Daphnia longispina*, which in its short lifetime fills the water with huge masses. I have tried to give its life-history in the following pages.

Most of the samples contain a lot of detritus, and the samples of 16th June and 1st July contain hardly anything but empty skins of pupæ of *Chironomus*, which colour the samples black. If this sample gives a true picture of the limnetic region of the lake, it must at that time have been teeming with pupa skins, and the great swarm must have been hatched by this time.

Owing to the absolute absence of all phytoplankton, the zooplankton is almost wholly reduced to depend upon detritus for its main sustenance. It is most interesting to see how the genus *Diaptomus*, which in a far greater degree than all other plankton Crustacea exist upon phytoplankton and more especially upon Diatoms, is wholly wanting, and that among the plankton Crustacea the main form of the plankton is also here a *Daphnia*, which is everywhere known to feed upon detritus. Without any attempt at generalising, I still suppose we may conclude that further investigations probably will prove the phytoplankton of the arctic lakes to play by no means the prominent part in the composition of the plankton as in lakes of the temperate zone.

3. *The life cycle of Daphnia longispina*, O.F.M.

D. longispina in Myvatn presents but a very slight seasonal variation. All the individuals from May to June belong to the typical *microcephala* form; later on the head becomes a little higher, and its ventral edge is curved slightly more inward; further, the rostrum is more prominent. All in all, the head is highest in those females which only propagate sexually, and lower in those which only propagate parthenogenetically.

On 30th May we only find a few quite young ones; on 16th June

we see the first parthenogenetic females containing 30-40 eggs (fig. 1); and on 1st July besides those a few young ones derived from ephippia or from parthenogenetic females. On 15th July we find many young small-sized animals, males and females (figs. 2 and 3), but only a few of the latter have eggs (2-3) and no ephippia; further, we find some females of larger size, all with eggs (often 12) (fig. 4). In all these samples the number of *D. longispina* has only been small; on 15th July we find for the first time the two sizes of females which now will be found in all the following samples. The small females are only c. 1.5 mm., the large c. 2.5 mm. in length.

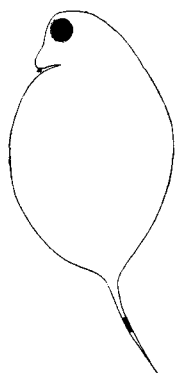


FIG. 1.—16th June, thirty-two eggs.

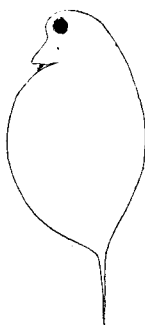


FIG. 2.—15th July, young female, small size.

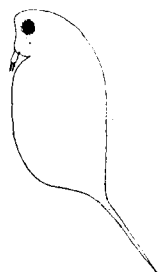


FIG. 3.—15th July, male.

On 1st and 15th August the number of animals is suddenly enormous; most of them are young animals, males and females (fig. 5), of which a few have ephippia (fig. 7). The large females from 15th July are now almost all barren; but on 15th August I have found a few with ephippia; a great many newly hatched young ones appear. On 1st September we find almost only animals of the smaller size, some of them with ephippia; males are rare. Of the large females I have only found but few and barren individuals. On 18th September a great many of the small-sized females (fig. 10) have ephippia (fig. 8), but these are only half-developed and without lodges; the males are rather common, and so are also the young ones. The large females are again very common and contain 8-10 eggs (fig. 9). On 1st October the smaller-sized ones commonly have fully-developed ephippia; still I noticed a few without these. A few

of these females contained 4–5 parthenogenetic eggs; young ones are still rather common, and so are the males and the big females containing 8–12 eggs. On 16th October almost all the small-sized

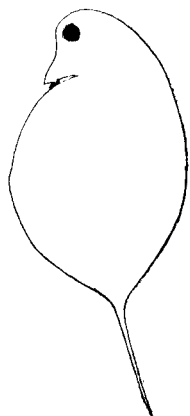


FIG. 4.—15th July,
big female, eight young ones.

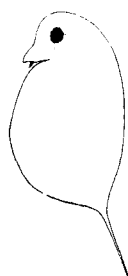


FIG. 5.—1st August,
young female.

females have ephippia, the males are rare and there is very little brood; the large females are still rather common and contain 7–9 eggs.

The above-mentioned facts may, I think, best be explained as

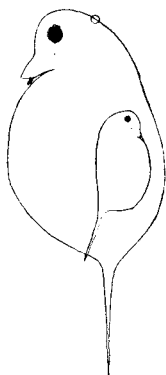


FIG. 6.—1st August,
big female with one young (♂).

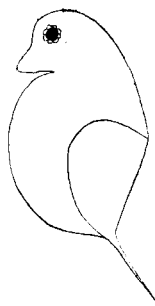


FIG. 7.—1st August,
small female with ephippium.

follows: As the number of animals to be found on 30th May, only two days after the ice has broken up, is extremely small and continues so the whole of June, I suppose that almost all the individuals of the lake have hibernated in ephippia. As the

sample of 16th October, only eight days before the lake is frozen over, contains numerous animals, many of these with parthenogenetic eggs or with young ones in the incubating part of the carapace, I cannot believe that the Daphnids should die immediately after the lake becomes frozen over, even though the sample of 31st October does not contain a single individual. Perhaps a few individuals will hibernate, but all in all I suppose that hibernating females here in Myvatn only play a very inconspicuous rôle in the whole life cycle of *D. longispina*. My opinion with regard to the cycles may be expressed as follows:



FIG. 8.—18th September, small female with ephippium.

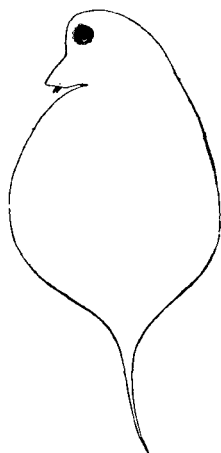


FIG. 9.—18th September, big female with twelve eggs.

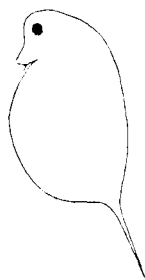


FIG. 10.—18th September, young female.

From 15th July to 16th October the females of *D. longispina* always appear in two different and well-marked sizes; the one is *c.* 1.5 mm., the other 2.5 mm.; between these two sizes I only have found (16th October) a few intermediate stages. The small females rarely have parthenogenetic eggs, and perhaps already, a fortnight after they have become full-grown, they carry ephippia; the size of the males agrees with that of these females. The large females propagate only parthenogenetically, only in one sample (15th August) we find a few with ephippia. I received the impression that almost all parthenogenetic propagation is restricted to those large females, and that the small females mainly are sexual ones, which in

case of fecundation will get resting eggs, but otherwise commonly will remain barren.

With regard to the derivation of these large females I think it most probable that they are derived immediately from the ephippia which in spring and during the few summer months will be hatched at quite different periods. If this holds good, the life cycle of the large females is as follows:

The individuals hatched in spring produce a very large brood (c. 40 eggs), and later on broods of some 6–12 eggs. How many broods they produce I don't know, but undoubtedly more than one. I have found females with big young ones in the incubatory part of the carapace, and with more than twenty dark eggs in the oviduct well separated from each other. How long the large females live is not known, but on 1st August I have found many with only one or two very large young ones (fig. 6) in the incubatory part, and these were always males. In the same sample were many barren females, and on 1st September almost all had disappeared; the few I saw were all barren. On the other hand, large females with many eggs become common again, as stated above, at 18th September as well as in the following samples.

As I have not myself made the collections, I will not draw the very obvious conclusion which the sample of 1st September might occasion, but shall restrict myself to the above-cited results, which may be arrived at through direct study of the sample. My opinion of the life cycle may shortly be expressed as follows:

During the time from May to November, the ephippia in different numbers will be hatched and the young ones—the first generation—very quickly grow out to large females, which commonly only propagate parthenogenetically, producing an unknown number of broods. The young ones—the second generation—derived from these females are males or sexual females, which pair and which ordinarily only produce resting eggs. *D. longispina* is in Myvatn monocyclic.

To the above I shall add the following remarks: In two of the Danish lakes, the lakes of Viborg and Hald, *D. longispina* appears in races very like the race of Myvatn. In the lake of Viborg we also find the above-mentioned great females characterised by their

enormous prolificness, and which I have never seen with ephippia. In the second part of my plankton work I shall further treat of the propagation of the species in these two lakes.

As far as I know, this is the first time that attempts have been made to determine the life cycle of a Daphnid in a special locality by means of regular fortnightly collections of plankton material. Of course I do not expect the above sketch of the life cycle of *D. longispina* in Thingvallavatn and Myvatn to be exact, especially as I have not myself gathered the samples. Further, it must be remembered that even if we suppose it to be reliable with regard to this particular year, the development of the organisms may in other years take a quite different course. Light, tp., and the settlement of ephippia, which depend on the direction and the force of wind at the moment of settlement, undoubtedly exercise their influence upon the course of the cycle. These pages must not be expected to present more than an outline sketch of my subject to the reader; further explorations must test its correctness.

When comparing the results of the investigations into the life-cycle of *D. longispina* in Thingvallavatn with that in Myvatn, we find these very different. In Thingvallavatn *D. longispina* may be regarded as dicyclic, in Myvatn it is monocyclic. As I have never had any living material, nor collected the samples myself, I do not wish the results to be regarded as conclusive. Besides, if this is the case, it becomes quite plain that *D. longispina* in Thingvallavatn, which in 1902-1903 seems never to have been frozen over, might be dicyclic and in Myvatn only monocyclic. I suppose that the last autumn brood hibernates in deep water and propagates in spring in Thingvallavatn as well as in our own lakes, and that the ephippia on the whole play but an inconspicuous part with regard to preserving the species in the lake. On the other hand, I should think that almost the whole stock of *D. longispina* in Myvatn is hatched from ephippia, and that the hibernating parthenogenetic females here only play a minor part in the whole life-cycle of the species. I venture to express this idea, because it agrees with the results of my explorations in Danish lakes, according to which the ephippial eggs of the plankton species of the genus *Daphnia* do not play a prominent part in regard to the life

cycle of the species, especially in the larger and deeper lakes; they only become of consequence in shallow and warm lakes or in ponds.

I think it very probable that the first of the two generations in Thingvallavatn belongs to the form *microcephala*, the second to the *obtusifrons*. The question arising with regard to the degree in which the different generations vary according to tp. is of the greatest moment with regard to the understanding of the seasonal variations, but it is also extremely difficult to deal with. I have studied this problem upon our own plankton organisms for quite a while, and a full account will be given of this in the second part of my plankton work. With regard to the question in the Icelandic lakes I have of course formed some opinions, but as these have not been tested by means of more thorough-going explorations in the Danish lakes, they are of no value, and will therefore not be mentioned here.

It will then be seen that the life cycle of *D. longispina* in Thingvallavatn is in accordance with the cycle which Zschokke (1892) has found in the Swiss alpine lakes, whereas that of *D. longispina* in Myvatn corresponds with what I have found in Greenland (1895) and Ekman (1904) in the sub-arctic alpine lakes in Sweden.

The exploration has further confirmed the supposition first set forth by me, and later on confirmed by Ekman, that otherwise polycyclical Cladocera nearer the poles will become monocyclic, the autumn sexual period being omitted, and that the parthenogenetic propagation here is of inferior significance when compared to the sexual one.

Ekman (1904, p. 94) maintains, contrary to my observations with regard to the Cladocera of Greenland, that the number of parthenogenetic eggs in an alpine or arctic country is by no means less than in a lowland country, but even greater. I daresay that Ekman, generally speaking, is quite right; still, I must emphasise the fact that the number of eggs which I have found in the Thingvallavatn samples has never exceeded 4 and has often numbered only 2 or 3. With regard to the number of eggs in Myvatn, I refer to the fact stated above: it is very high in spring, but by no means greater than may, for instance, occur in Danish lakes at the same time of the year. I suppose that, taken all in all, the number of eggs to be noted is about the same all the year round as in Danish lakes.

Ekman (1904, p. 88) states that in the first summer months he has occasionally found numerous males, which he supposes to have been derived from ehippial eggs. Not all of the females were outgrown, and none of them had eggs. He points out that the observations are of interest, because we would then here have the only known example, according to which males had been produced from ehippial eggs. Till more thorough explorations have been carried on, I think it safer to suppose that these males as a first brood have been derived from the females hatched from the ehippia.

IV. COMMON RESULTS.

Lastly, we shall shortly draw attention to the following results of the exploration. As compared with the Danish explorations, it will readily be seen how much these have been promoted and supported by this little investigation.

1. In Myvatn no phytoplankton has been found at all.

In Thingvallavatn we have not found any plankton Myxophyceæ; when we add hereto that none of the rather few samples from higher latitudes, which have as yet been studied, record Myxophyceæ, we may conclude that the Myxophyceæ do not play any conspicuous part in the plankton of more northerly situated lakes. When taking into consideration the explorations from Switzerland, Germany, and Denmark, we must suppose that the low tp. (below c. 12° C.) and the clear water, poor in organic matter, most probably form the greatest hindrances to the progress of the Myxophyceæ towards the poles. Further explorations may show whether the plankton *Oscillatoria* and *Lyngbya* are found further north than the other Myxophyceæ; then their max. may lie at a tp. which arctic or sub-arctic lakes, at least for a short time of the year, may also arrive at.

2. The Diatoms constitute the main part of the phytoplankton of northern lakes. In Thingvallavatn the *Melosira* and *Asterionella formosa* are the main forms; they have in temperate regions their max. at a tp. of 4°-10°, which is in accordance with their occurrence in Iceland.

On the other hand, *Fragilaria crotonensis*, whose max. lies at tp. 16°, occurs only in a few specimens and at the highest

tp., and consequently does not play any important part in the plankton. The occurrence of two *Rhizosoleniæ* in nearly all the months of the year, although only fairly common in June (tp. 7°–8.5°), is very interesting and indicates probably, as several other facts do, that Thingvallavatn by no means may be regarded as an arctic lake. It is only a northern lake in want of the higher summer tp.; it differs considerably from a true arctic lake in only being ice-covered for a short time, and even this does not occur every year. The same difference must also be remembered when comparing it to alpine lakes.

Corresponding hereto we do not find in Thingvallavatn the large quantities of *Cyclotella* which occur, e.g., in Switzerland.

If we compare our results concerning Diatoms with the few statements from arctic lakes, we find that in Greenland, at c. 71° lat. N. (Vanhöffen, 1897), in Bear Isle (Lagerheim, 1900), and in Lule Lappmark (A. Cleve, 1899), the plankton Diatoms do not play any prominent part in the plankton, the phytoplankton being very poor. The fact is worth noticing, that these statements are based on samples collected in very small lakes or, more correctly, in ponds (except those from Lule Lappmark).

We think that the large quantities of *Melosira* and *Asterionella* in Thingvallavatn show how nearly allied its plankton is to that of north-western Europe. Besides the above-mentioned forms, several other Diatoms occur regularly in the plankton of Thingvallavatn, viz., *Fragilaria construens*, *F. capucina*, *Synedra acus*, and *S. ulna*. These forms are not of as typical a limnetic character as the others; we presume that their home is the shores of the lake, from whence they are driven into the open lake by winds and waves. On account of the low tp. they are able to float for rather a long time. The papers by Lagerheim (1900) and Ostenfeld (1904) mention such tycholimnetic forms, which with higher tp. probably quickly would sink to the bottom.

3. As might be expected, the limnetic Chlorophyceæ are not abundant in Thingvallavatn; the main form is *Sphærocystis*, the same which predominates in alpine lakes and which is probably very common all over the Central European plain. In Thingvallavatn its max. occurs at 7° C.; with regard to its max. in other lakes we have no exact information. The rather common

occurrence of different Desmids in the limnetic region of Thingvallavatn is quite in accordance with the explorations of the lakes of the Faeroe islands, but particularly with those of Scotland. In the lakes of the most western part of the European Highlands, Scotland, Faeroes, Iceland (with regard to Norway nothing at all is known) there seems to exist a peculiar semi-limnetic flora of Desmids, which in the other parts of Europe is only represented by one or two species (*Staurostrum gracile*, *S. paradoxum*).

With regard to their occurrence in Scotland, Wesenberg-Lund (1905) has supposed that their very peculiar occurrence may be accounted for by the fact that these Desmids originally are derived from, and also nowadays are recruited from, the rich Desmid flora living in the almost always mist-wrapped moist moss carpets which cover the precipitous sides of the hills, where streamlets feed the rivers and from whence the Desmids, especially in spring, are carried out with the rapidly flowing waters into the limnetic region of the lakes (*cf.* p. 1158).

Probably this supposition will also hold good as to the occurrence of Desmids in the limnetic region of the lakes in the above-mentioned localities, although the hills around Thingvallavatn are not precipitous.

4. With regard to the Peridinians we particularly note the total absence of *Ceratium hirundinella*. In accordance with explorations in more southern countries, this was only what might be expected, the max. of *C. hirundinella* lying at a tp. which the Icelandic lakes rarely attain. Besides, we refer to the remarks about the Euflagellata.

5. The absence of *Dinobryon* is more striking. We are inclined to suppose the absence of this genus in the Thingvallavatn to be only accidental; probably *Dinobryon* is one of the main forms in arctic and northern lakes.

6. The total absence of *Tintinnidium* and *Codonella*, whose max. occurs at a relatively low tp., is rather remarkable.

7. The plankton Rotifers belong chiefly to the cosmopolitan perennial stock, whose members in more southern countries are poly- or di-cyclical, with max. at *c.* 12° C. in spring and in autumn.

According to observations from Myvatn, it seems as if the group in the more northern lakes is monocyclical, with the max.

July 1902-June 1903.—Plankton from Thingvallavatn, South Iceland.

Day,	14.	31.	14.	30.	15.	30.	16.	31.	16.	18.	16.	31.	16.	30.	11.	31.	15.	30.
Month,	VII.	VII.	VIII.	VIII.	IX.	IX.	X.	X.	XI.	XI.	III.	III.	III.	IV.	V.	V.	VI.	VI.
Temperature of the Air (°C.),	10°	11.5°	12°	12.3°	10°	9°	2°	0.5°	6°	4.5°	0°	3°	1.5°	5°	8.5°	10°	8°	12°
" " Water (°C.),	9.5°	9°	11°	9.5°	8.5°	8°	7.5°	5°	5°	5°	1°	1.5°	1°	2°	5°	5.7°	7°	8.5°
<i>Chlorophyceae.</i>																		
<i>Cosmarium phascolum</i> , Bréb.,	.	.	.	.	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	.	IT	IT	IT
<i>Staurastrum Biceanum</i> , Rabenh., var.,	.	.	.	.	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	.	IT	IT	IT
" <i>brevispinum</i> , Bréb.,	.	.	.	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
" <i>paradoxum</i> , Meyen,	.	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
" <i>delagicum</i> , West,	.	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
<i>Sphaerocystis Schroeteri</i> , Chodat,	.	.	.	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
<i>Oocystis crassa</i> , Wiltz.,	.	.	.	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
<i>Boryococcus Braunii</i> , Kütz.,	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
<i>Bacillariaceae.</i>																		
<i>Asterionella formosa</i> , Hassall.,	+	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
<i>Fragilaria capucina</i> , Desm.,	cc	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
" <i>construens</i> (Ehrbg.) Grun.,	cc	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
" <i>crotonensis</i> (Edw.) Kitton,	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
<i>Synedra acus</i> , Kütz.,	+	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
<i>Surirella ulna</i> (Nitzsch), Ehrbg.,	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
<i>Cyclotella biseriata</i> (Ehrbg.) Bréb.,	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
<i>Cyclotella comta</i> (Ehrbg.) Kütz.,	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
<i>Melosira varians</i> , Kütz.,	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
" <i>arenaria</i> , Moore,	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
" <i>italica</i> , Kütz.,	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
" <i>islandica</i> , O. Müller,	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
<i>Rhizosolenia eriensis</i> , L. Smith,	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT
" <i>paludosa</i> , O. Zach.,	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT	IT

occurring at midsummer time at the same tp. (12° C.) as in the southern ones.

8. Ekman (1904, p. 68) has, with regard to its Crustacea, adjoined Iceland as an appendix to the sub-region Greenland, which is a part of his boreo-glacial region. The reason for so doing he declares principally to be the common occurrence of *Diaptomus minutus*, hitherto not found outside of North America and Greenland.

Nothing in the present little exploration is in contradiction to Ekman's point of view. All plankton Crustacea hitherto found belong to the common boreo-subglacial society pointed out by Ekman. Owing to incomplete explorations of the island we have missed different species, especially *Bythotrephes*. Further explorations will undoubtedly also bring to light more species of *Diaptomus* and *Cyclops*. It must be hoped that the great collections from c. 60 localities made by Mr Sœmundsson may find their adapter. It must be noted that, in Iceland as well as in almost all other parts of the boreo-subglacial region, all the plankton Crustacea, which are characteristic for the limnetic region of the more southern lowland lakes (Ekman), are missing.

9. With regard to the life cycle of the Daphnids, I refer to p. 1149. The explorations have confirmed the fact that the otherwise polycyclical Cladocera will be monocyclical nearer the poles, the autumn sexual period being precluded; in more northern latitudes the parthenogenetic propagation is of inferior significance in comparison to the sexual one.

10. From Ekman's explorations in the Sarek, James Murray's and my own in Scotland, and the present report from Iceland, added to the numerous explorations in Central European lowland lakes, we may presume that the great seasonal variations of the plankton organisms are restricted to the lowland lakes with their high summer tp. They are wanting in all those lakes whose summer tp. never rises above 12° , the very tp. at which the variations begin in the lakes of the Central European plain.

As a general result of the exploration, we wish to draw attention to the following conclusions: We think it probable that the plankton of the arctic lakes, to a much greater degree than in more southern countries, mainly consists of zooplankton, and that

the phytoplankton, especially in {summer time, only plays an insignificant part in those lakes; hence the main nutriment of the zooplankton for a long time of the year mainly consists of detritus.

The phytoplankton of arctic and sub-arctic lakes consists in all probability mainly of algæ with yellowish or yellowish-brown chromatophores; algæ with green or blue-green chromatophores are almost entirely wanting. As exceptions from this common rule we only mention *Sphærocystis*, the semi-limnetic Desmids and a few rare Chlorophyceæ. It is a well-known fact that, in the arctic, antarctic, and cold temperate seas, the Phæophyceæ are the predominating algæ (see *e.g.*, Schimper, 1898, p. 832); also with regard to the marine phytoplankton, so the Diatoms with their yellow-brown chromatophores play the greatest part in the colder seas (see *e.g.*, Schütt, 1893, p. 26).

None of these facts can be explained by us. Further explorations may probably show whether the optima of assimilation for yellow-brown coloured chromatophores commonly lie at a lower tp. than those of the green or blue-green chromatophores.

We are quite aware that these assertions are as yet only problematic; still, we do not hesitate to set them forth here, thinking that they might be of use as working theories for further explorations carried on in higher latitudes than at this time has been possible.

Note received October 3, 1905 :—

After our paper had gone to press, I received from Professor W. West, F.L.S., and Professor G. S. West, M.A., F.L.S., their paper: A Further Contribution to the Fresh-water Plankton of the Scottish Lochs (*Trans. Roy. Soc. Edin.*, 1905, p. 477). As the said paper essentially touches on the same subjects as my paper: A Comparative Study of the Lakes of Scotland and Denmark (*Proceed. Roy. Soc. Edin.*, vol. xxv., 1905, p. 401), and the present paper, I take the liberty here shortly to mention some points in the same.

In the summary the authors write :—

1. "The quantity of plankton is relatively small at any time and scarce affects the colour of the water. It exhibits

little periodicity, the seasonal variations being slight. This absence of any marked variation in character is to be attributed to the relatively slight changes in the temperature of the surface waters at different seasons."

6. "The Desmids were doubtless originally derived from the pools and bays of the mountains, and only those species have flourished which found the conditions most suitable for their existence as pelagic organisms."
7. "There is no very obvious maximum development of Diatoms, and some of the larger species of the Naviculae and Surirelloideae have firmly established themselves."
8. "The proportion of Myxophyceae is relatively small, and species of Oscillatoria, Lyngbya, and other genera are somewhat scarce."

I am glad to see that in all these points we are of quite the same opinion. I take the liberty to point out that I in my paper, see especially pp. 423, 426, 427, 430-31, have expressed quite the same suppositions. This the authors seem quite to have overlooked. Also with regard to the derivation of the rich Desmid flora we are mainly in full accordance. Previously to the authors' statement, I had pointed out (p. 430), *that the plankton Desmids must have been originally derived from tarns and moors on the hill-tops*, and that the Scottish lakes (p. 431), *unlike most other larger lakes, present one of those great life-conditions which so many of the Desmids seem to require, viz., peaty water rich in humic acid* (*cf.* Summary, point 4, by Messrs West).

Besides, the authors add the very important fact that the Desmids *owe their existence* * (p. 515) to the Older Palaeozoan and Pre-Cambrian formation. On the other hand, when the authors (p. 512) maintain that I was of opinion that many of the Conjugates adopt a pelagic life as soon as they arrive in the lakes from the peat moors, and, contrary to me, set forth that the plankton Desmids have existed under these pelagic conditions for a very long time, the authors have totally misunderstood me. In p. 430 I have written that the Desmids were *originally* derived from the tarns and pools, and (p. 431) *that the home of the Desmids is the sides of the*

* An expression which I do not find very clear.

hills, and that some of those forms which, according to their primeval structure, were best adapted to plankton-life, are now in fact, under the new conditions, about to develop processes.

I have of course meant that the adaptation has been going on for immense spaces of time, and is going on to this day ; that many of the Desmids have existed under these pelagic conditions for a great length of time is a matter of course which I did not think necessary to point out especially, and which I never have denied. On the other hand, I suppose that the authors will hardly deny that the adaptation continually takes place up to this very day ; so that also on this point the suppositions of the authors are not at variance with mine. Besides, the very thorough study of the plankton Desmids by the English authors has greatly augmented our knowledge of the extremely interesting subject : the plankton Desmids of the Scottish and probably also the Icelandic lochs ; all in all, I cannot but see that they support the correctness of my suppositions set forth on p. 431. I am fully convinced that it is an exaggeration to say (Messrs West, p. 477) *that the lochs of the west and north-west of Scotland were probably richer as regards the phytoplankton than any lakes previously examined*, and it is not in accordance with facts that *the Danish plankton is relatively much poorer in Chlorophyceæ, especially Conjugates* (Messrs West, p. 514). Only with regard to the Desmids these two sentences are fully correct. The plankton in the lakes of the northern part of the Central European plain is much richer with regard to the number of species as well as to the masses in which the species appear. Especially with regard to Chlorophyceæ our plankton flora, the Desmids always excepted, is much richer than the Scottish lakes.

As my knowledge of the Scottish lakes of course could only be very furtive, I have in my paper only set forth the results of the explorations as mere suppositions. Several of those suppositions, viz., the relatively small quantity of plankton, the slight periodicity, the slight seasonal variations, the absence of well-marked maximum development of Diatoms, the scarceness of Myxophyceæ, especially *Oscillatoria*, *Lyngbya*, the English authors now regard as a "summary" of our knowledge of the phytoplankton. This may be so ; still, I feel inclined to pronounce that in my opinion the two authors have by no means grounded these suppositions

more substantially than I have been able to do. It is necessary to bear in mind that all the samples which the authors have used for their investigations only have been collected in July-September (Messrs West, p. 477). Without regular fortnightly or monthly explorations of the lakes, it is quite impossible to obtain a well-founded idea with regard to most of these points, and such regular explorations in the Scottish lakes are as yet only a desideratum; at all events, nothing has been published upon this point. In particular, it must be noted that the great maxima of Diatoms are always to be found in spring and in autumn, and that the maxima of *Oscillatoria* and *Lyngbya*, especially the latter, in our lakes are often extremely short and therefore only traceable by means of very thorough explorations.

C. W.-L.

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EXPLANATION OF PLATE I.

Figs. 1-7. *Melosira islandica*, O. Müller, n. sp. :—

1-5. Chains showing the successive stages of the auxospore formation.

6. Two-celled auxospore chain.

7. Eight-celled auxospore chain.

Fig. 8. *Oocystis crassa*, Wittr., forma.

Figs. 9-10. *Cyclotella comta*, Kütz.; a small and a large cell, valvar view.

Figs. 11-20. *Peridinium aciculiferum*, Lemmerm. :—

11. A cell in Gymnodinium stage with mucilaginous envelope.

12. Another Gymnodinium cell with large oil drops.

13. The formation of two daughter cells. Here and in fig. 12 the envelope has been omitted.

14-15. A specimen in two views.

16. Another specimen in dorsal view.

17. Side view.

18. Ventral view.

19. A specimen of which the contents are bursting.

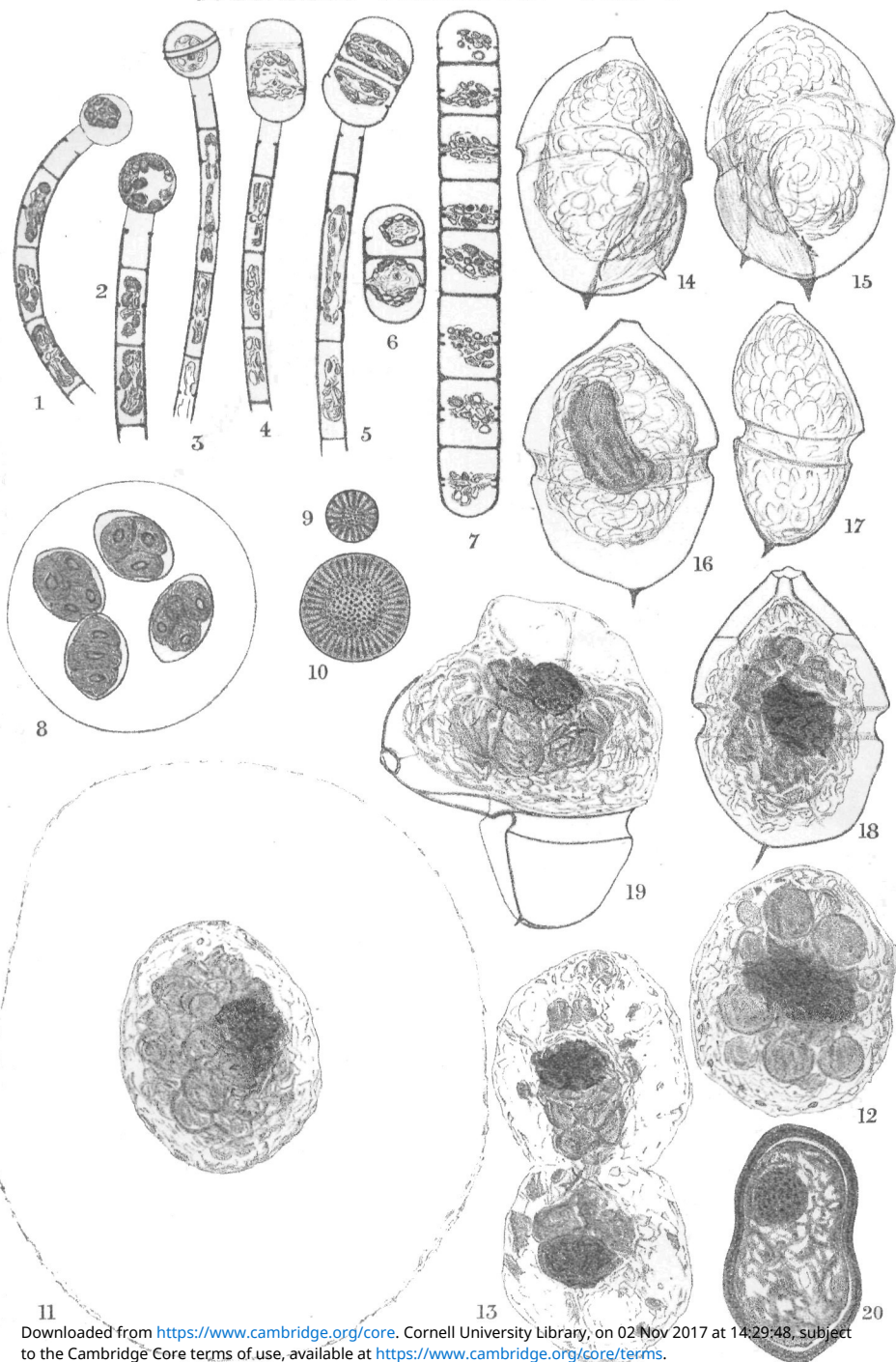
20. Resting cyst.

The microscope used is Zeiss's large microscope (Stand Ia), with compensating eye-pieces and apochromatic objectives. The figures are drawn with Abbé's camera (No. 44a). The magnifications are as follows :—

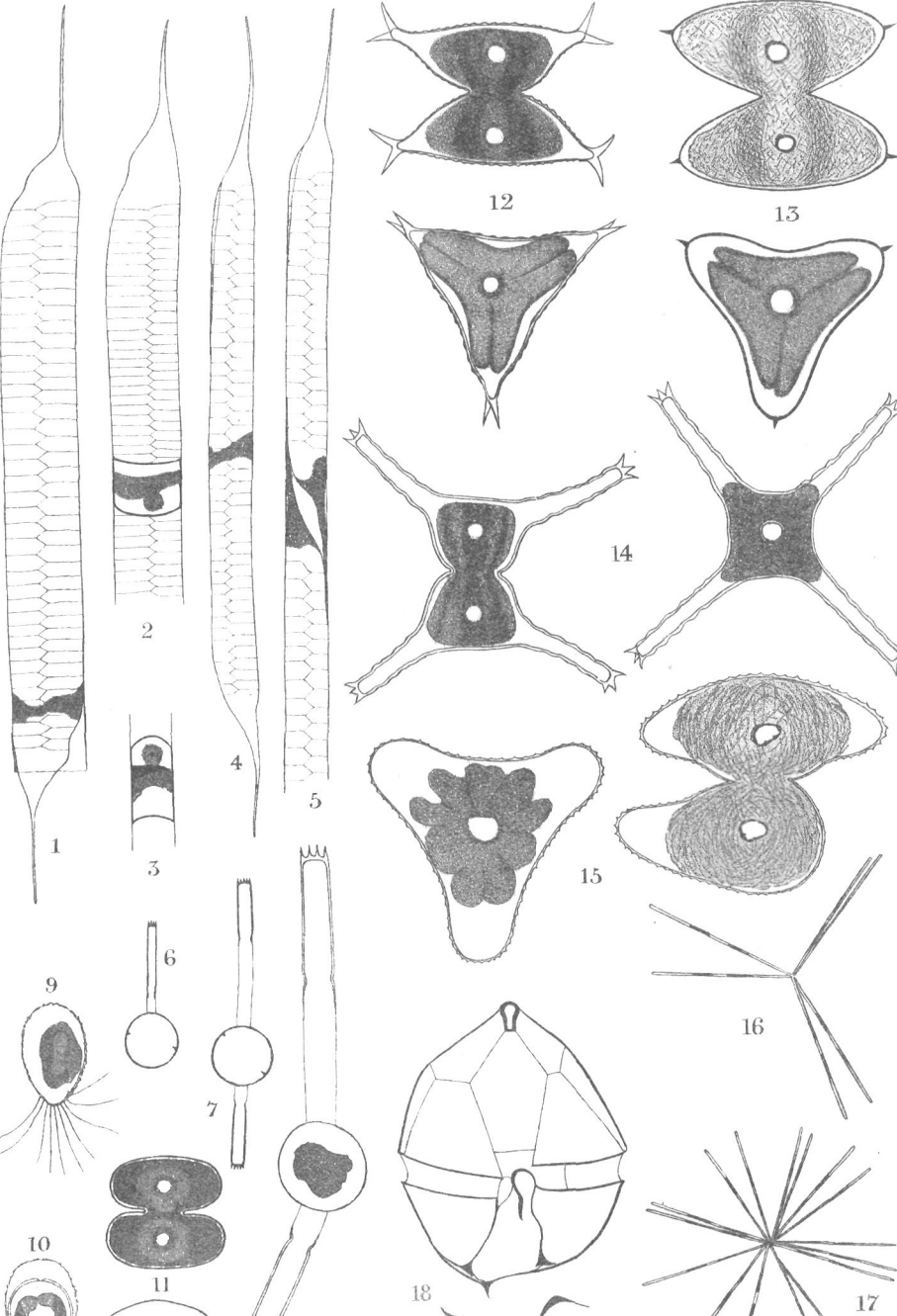
Figs. 1-7, 11-20, objective 1.25×2.5 mm. Comp. ocular, 8
(Water immersion.)

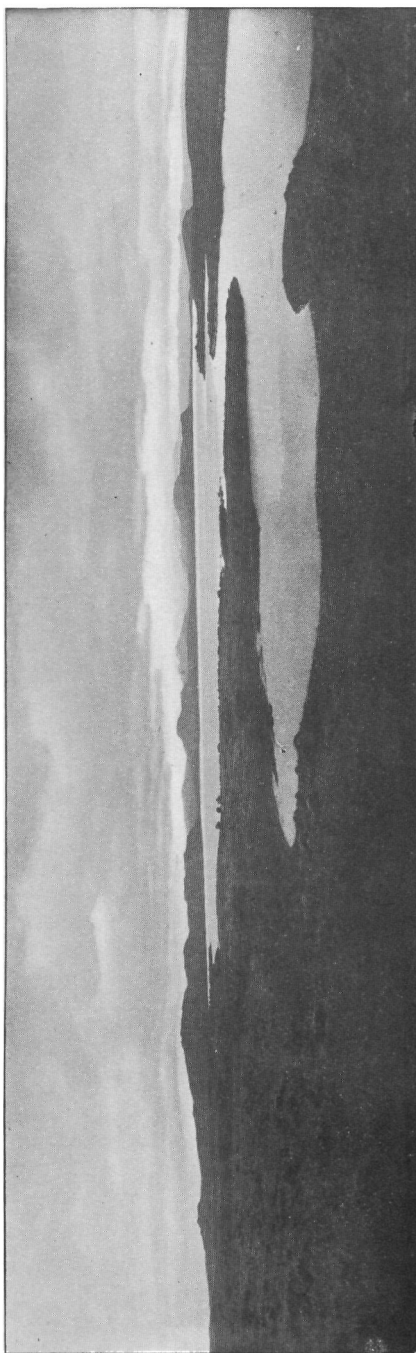
Fig. 8, objective 0.95×4.0 mm. Comp. ocular, . 8

Figs. 9-10, objective 1.40×2.0 mm. Comp. ocular, . 8
(Oil immersion.)

OSTENFELD AND WESENBERG — LUND:
ICELANDIC PLANKTON. Plate I.

OSTENFELD AND WESENBERG—LUND:
ICELANDIC PLANKTON. Plate II.





THINGVALLAVATN.

EXPLANATION OF PLATE II.

Figs. 1-3. *Rhizosolenia eriensis*, H. L. Smith:—

1. Large cell, with the plasma concentrated near the one end, where the rest from the last division is seen.
2. Part of a cell with resting spore.
3. Resting-spore of another cell, seen from the narrow side.

Figs. 4-5. *Rhizosolenia paludosa*, O. Zacharias:—

4. A whole cell.
5. Newly finished cell-division, the two daughter cells cohering.

Figs. 6-8. *Melosira italica*, Kütz.; parts of different chains with auxospores:

Figs. 9-10. *Mallomonas* sp.:—

9. Vegetative cell with setæ.
10. Spore-bearing cell without setæ.

Fig. 11. *Cosmarium phaseolus*, Bréb.; the same cell in front and in vertical view.

„ 12. *Staurastrum pelagicum*, West and G. S. W.; in front and in vertical view.

„ 13. *Staurastrum brevispinum*, Bréb.; in front and in vertical view.

„ 14. *Staurastrum paradoxum*, Meyen, forma; in front and in vertical view.

„ 15. *Staurastrum Bieneanum*, Rabenh., forma; in front and in vertical view.

Figs. 16-17. Stellate colonies of *Synedra acus*, Kütz., var. *delicatissima*, (W. Sm.) Grun.?

Fig. 18. *Peridinium aciculiferum*, Lemmerm.; cell in ventral view, showing the arrangement of the plates; underneath the three prominent ridges (forming the spines) seen from the antapex.

The magnifications are as follows:—

Figs. 1-5, 8, 18,	objective 1.25 × 2.5 mm.	Comp. ocular,	8
	(Water immersion.)		
„ 6, 7, 9-15,	objective 0.95 × 4.0 mm.	Comp. ocular,	8
„ 16, 17,	„ 0.65 × 8.0 mm.	„	8

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