FRESH WATER ALGAE IN THE VICINITY OF MONTREAL

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Fresh-water Algae Occurring in the Vicinity of Montreal.

By

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The object of these studies has been to secure some data in regard to the Algal Flora of Montreal Island. In order to obtain this, collections of material were made during the autumn of 1911 from as many pools, ponds and streams as possible. and a number of aquaria containing the Algae were maintained in the Botanical Laboratory during the winter. Records were kept of the progress of the different aquaria, the forms which had been collected were studied and classified, and a number of experiments were made with nutrient media.

The results of these investigations are given in the following pages, where an attempt had been made to give as full notes as possible on the habitats, associations and relative abundance of the forms described. The importance of such ecological data has been strongly emphasized by Fritsch (1) in his work on the Algal Flora of the Tropics. The relation of certain results to the work of Benecke (2), Danforth (3), Copeland (4), and Fritsch and Rich (5) has been considered. Some observations of the Rhizoid formation of Spirogyra are given. A systematic list of the various species of fresh-water Algae collected completes the account. The determination of the species in the systematic list has been based on standard taxonomic works and has been corroborated by Professor Derick under whom the work has been done. I have been greatly aided in these studies by the advice and criticism of Professor Derick, who suggested the problem, and my thanks are also due to Mr. Ardley of the Museum staff, who gave me very valuable assistance in collecting material, and to Miss Ethelwyn Harris, who has assisted me in reading various German works.

As far as Algal literature is concerned, Canada appears to be terra incognita. No references occur even in the latest works to the distribution of any of the forms in Canada, and Mr. Collins in the preface to his work "The Green Algae of North America" (6) openly laments that apparently no data is to be had on the subject. With the exception of a list of forms recorded by Mr. A. B. Klugh from the Bruce Peninsula, in the Ottawa Naturalist (7) for September, 1911, I believe this is the first attempt at a systematic study of any Canadian fresh-water algae.

Occurrence and Distribution of Fresh-water Algae.

No moist situation is without some type of alga. While quiet lakes, pools and ponds form the most congenial situation for the larger forms, algae are also to be found in great abundance in water falls, and all sorts of swift running streams, and, indeed, there is no tree trunk, wet rock, water trough, damp wall or decaying fence-post but forms the habitat of some member of the group.

In quiet pools the large filamentous forms frequently occur, attached as epiphytes to rocks or to other aquatic plants, and stream up towards the surface in great felt-like masses. Some forms are found floating on the surface of ponds and lakes as a conspicuous slimy green mass; while others occur, especially on rocks over which water is constantly dripping, as a thin gelatinous film exhibiting a variety of color. These are usually forms belonging to the Cyanophyceae or blue-green algae and are some of the most beautiful and interesting of all the species.

Some algae have acquired a symbiotic relationship with other plants and even with animals. As examples are a species of Anabaena which lives symbiotically with the Hepatic Blasia, and a Nostoc which is similarly connected with Anthoceros. Both of these forms occur on the Island of Montreal. Then, there are several species of Chlorella which are associated symbiotically with Hydra viridis. Some algae have even adopted a parasitic mode of life, and Trichophilus (Weber) mentioned by West, is said to be found, on the hairs of Bradypus, the three-toed sloth.

Many of the most beautiful Algae are very small and occur in a gelatinous film on the leaves and stems of submerged plants. Other minute forms together with an abundance of Peridinieae and Copepoda occur in the surface waters of lakes and rivers, and constitute a great part of the fresh-water plankton which forms the food of most of the smaller aquatic animals, which, in turn, serve as the food of the lake and river fishes.

Algae exist under very diverse conditions of temperature. Many forms survive freezing. Filaments of Spirogyra and Vaucheria, which I have melted out of the ice, appear to suffer in no way from the low temperature. Species of the Cyanophyceae and Bacillariaceae are found in the Arctic regions and on mountain tops, where similar conditions exist, forming the principal parts of a snow flora and passing their entire existence on snow or ice, while other members of the same groups flourish in the waters of hot springs, where the temperature reaches 85°C.

The comparative richness of any district in Fresh-water Algae depends largely on its physical and geological features. West, in his "British Fresh-water Algae" (8), states that a mountainous region may be expected to show more forms than a flat district, which will contain the larger filamentous algae, and an abundance of unicellular forms. On the other hand, a mountainous region will show forms belonging chiefly to the Cyanophyceae and Conjugatae, especially numerous species of Mougeotia and Desmids. Moreover, he says, "If the mountains consist of the older Palaeozoic rocks or the Pre-Cambrian rocks, there is a surprising numerical increase not merely of species but also of individuals, and in comparison a mountainous region of carboniferous limestone or other formations is distinctly poor." Accordingly, it will be of interest to notice briefly the chief physical features of the Island of Montreal where the material for this study has been collected.

The Island of Montreal contains about two hundred and six square miles and is a rough isosceles triangle in shape. The long side is bounded by the Lake of the Two Mountains and the Rivière des Prairies, and the other two sides by Lake St. Louis and the St. Lawrence River, respectively.

The island itself is a part of a great palaeozoic plain, which extends up the Laurentian Plateau on the north, and from the Notre Dame Mountains in Quebec to Lake Huron, and southward into the United States. The plain is flat, and the average elevation in the vicinity of Montreal is about a hundred feet above the sea level. The whole area is drift covered and forms excellent farming lands. On the Island the continuity of the plain is broken by Mount Royal, an igneous mass rising behind the city and occupying an area of about one and a half miles. This is the most westerly of a line of old volcanoes and laccolites, known as the Monteregian Hills. About the base of Mount Royal the strata of the lower Silurian are represented by the Trenton Group, which covers the greater part of the island,- with Calciferous limestone at the western extremity, Chazy at Point Claire and at Cartierville, and Utica Shale along the river front at Verdun and Bout de l'Ile.

The upper part of the Palaeozoic and the whole of the Mesozoic and Tertiary are unrepresented, but the Pleistocene has left its record in a drift of Leda clay and Saxicava sand and in a series of terraces between Mount Royal and the harbor, marking the gradual retreat of the Pleistocene Sea.

Collection and Preservation.

Throughout the month of October I collected material for study and classification from a variety of situations and from as widely separated parts of the island as possible. The following localities from which material was obtained are shown on the accompanying map.

(1) The shore of the St. Lawrence at Verdun.

(2) The quarries at Amherst Park.

(3) The ponds and streams on Mount Royal.

(4) The Back River and brooklets emptying into it at Sault au Recollet.

(5) The shores of the St. Lawrence and Rivière des Prairies at Bout de l'Ile.

(1) Verdun.

Here, just opposite Nun's Island, the river is very shallow near the shore and abounds with small islands among which it runs slowly, forming a low, swampy tract of land. Reeds, rushes and sand-bar willows (Salix longifolia, Mühl) line the water edge, and a great variety of water weeds, such as Nympheae, Utricularia, Elodea and Myriophyllum, grow partly submerged in the shallow water. Entangled with these and also floating freely in the water, I found a great number of species of Zygnema and Spirogyra, also a very little Oscillatoria, some Nostoc, Pediastrum and quantities of Desmids. Some Diatoms were secured attached to filaments of Cladophora, which was found in abundance growing fastened to stones. A pool inside the old river dyke contained an enormous amount of Lemna; and, in March, Chaetophora was found growing in a thin film on the sides of the aquaria in which some of this had been placed. Leaves of Nymphaea and tufts of Elodea canadensis and other water weeds were collected and washed, to secure forms attached to them. My notes for this locality show that it was visited on the 30th of September and that the water was quite warm and abounded in animal life. I noted that, though there were many species, there were comparatively few individuals, that Ulothrix occurred in tufts composed entirely of Ulothrix filaments while Spirogyra and Zygnema were always associated with each other. No Spirogyra and only one Zygnema was found in a fruiting condition.

(2) Amherst Park.

This is a section of land at the north east of the mountain, which is now beginning to be built up. There is a thin layer of sandy soil over the surface of the Trenton limestone, which is well developed here. This has been, and is still being, extensively quarried. Many abandoned workings exist, and these have nearly all become filled with water, forming ponds of some size and great depth. The limestone is cut at intervals by dykes from the fourth period of Mount Royal's activity, and these, not having the commercial value of the limestone, have been left intact and serve to divide some of the quarries into ponds.

In two of the largest quarries <u>Anabaena inequalis</u> was found covering the whole surface like a thin creamy yellow film. Associated with this was a very little Oscillatoria. Very little water weed was to be seen in any of these artificial ponds, save here and there a few tufts of Elodea, probably because the sides were too steep and sheer to afford any convenient place for it to take root. It was noticeable that each quarry had a dominant form, though this might be the same in several. One form was always more abundant than the others associated with it. The shallower pools contained the filamentous forms, some presenting a very beautiful appearance because of the long graceful strands of filaments which streamed up from the bottom. These pools were supplied with water both by drainage from the surrounding plain and from tiny springs.

This was by far the richest region discovered both in the number of species and also in the quantity of individuals. Some twenty odd of these large and small ponds were visited in several excursions and a great deal of material was collected. I noticed that the ponds which contained the most refuse - for these abandoned quarries are evidently largely used as dumping grounds for rubbish - i.e. those which contained the most nitrogenous material, were very much the richest in algae. One pool in particular , which contained a great quantity of garbage, tin cans, old boots, etc., was evidently an ideal location for the Scenedesmaceae. All the weeds in the pool and all the weeds and grass which hung into it were coated with a thick gelatinous film composed of Desmids and Protococceaceae.

As far as the sources of the flora of these quarry holes are concerned, there is little possibility of the dissemination of spores by water currents, as the various excavations are unconnected, and there is but one small stream in the whole region. On the other hand, dissemination may occasionally take place by currents of air bearing spores for short distances. Probably the chief means of transportation are insects, birds and other animals. Frogs, in going from one pond to another, would readily convey spores or even filaments of algae attached to their bodies, and it has been observed by Mr. C. H. Thompson (10) in a study of the "Dissemination of Lemna", that Belostoma americana, commonly found flying about electric globes on the street, carries Lemna attached to its body. This insect stays in the water all day and flies about at night. What is true of Lemna may also occur in the case of algae which grow in the same habitats.

(3) Mount Royal.

The ponds and streams on the Mountain were by no means such favourable situations for Algae as the abandoned quarries at Amherst Park. But the fact that the summer of 1911 had been very long and very hot was no doubt partly the cause of this apparent scarcity, for most of the small streams were dried up and the ponds were low. A large artificial pond in the Roman Catholic cemetery was found to contain a very large quantity of Microspora entangled with the Myriophyllum which grew there. A small streamlet of water which flowed down a steep bank into this pond was filled with Ulothrix, which again was almost a pure mass.

On the brick flags of the floor of the conservatory, I noticed a thin blackish green scum which proved to be a mixture of Calothrix, Tolypothrix, Scenedesmus and Lyngbya. The metal horse-trough on the drive contained Ulothrix, some filaments of Spirogyra and Zygnema, and a good many Palmellaceae.

(4) Back River.

The Rivière des Prairies, which is also known as Back River, is very shallow in some places, especially at Sault au Recollet. Here, along the edge of the water, Elodea was very plentiful. Entangled with this was a great deal of Hydrodiction, Spirogyra and Zygnema. Later on, in the winter, Mougeotia developed in the aquaria in which these collections were placed. Cladophora also occurred here, showing its preference for running water. A small brook emptying into the river contained an enormous amount of Spirogyra, Vaucheria, Oedogonium and Zygnema growing together hanging from stones on the bottom. The Spirogyra was very luxuriant and dark green in color.

(5) Bout de l'Ile.

This is the extreme eastern end of the island, where the Rivière des Prairies and the St. Lawrence join. Both rivers are very deep here and flow swiftly, consequently Algal growth is scanty. Along the edge of the Rivière des Prairies, Stigeoclonium was abundant on the Leda clay, which appears to be a very favourable medium for it. All along the edge of the St. Lawrence , great mats of Vaucheria and Microspora were found which had evidently been brought down by the current and lodged there; these were caught in tufts of Elodea. Nearly all were covered by a thin layer of ice, for by this time it was the end of October. The Elodea appeared to have been killed by the low temperature, but the algae were unhurt. Quantities of Spirogyra and Oedogonium were found in a swamp near the street-car tracks. Cladophora, as usual, occurred along the river edges. It is interesting to note the preference which this alga shows for well aerated water and also the close connection between the occurrence of Elodea and filamentous forms.

While the majority of algae can be cultivated, or at least kept alive in fresh water under suitable conditions of light and temperature, some forms disintegrate and disappear within a short time after being brought into the laboratory. In order to secure such forms as might otherwise have disappeared before they could be identified, I preserved a sample of the freshly gathered contents of each aquarium. For this purpose I used a two per cent solution of potassium acetate containing just enough copper (in the form of Copper Acetate) to make it faintly blue. This solution, which is much more satisfactory than formalin as a preservative for algae, gave the most excellent results with nearly every form. Vaucheria was slightly plasmolysed by it, for some reason. This may be avoided by a method suggested by Mr. J. H.

Nieuland in the Botanical Gazette (11). The plant should be killed rapidly with three or four per cent formalin, which must be quickly and completely removed by repeated washing in water, after which it should be put into glycerine to which a little thymol has been added. Thus it will retain its color perfectly.

Anabaena was also very difficult to preserve in this solution, the filaments rapidly becoming disorganized and breaking down. This is probably due to the copper being too strong. As Dr. Moore (12) has shown in his experiments with copper as an algicide and disinfectant of water supplies, one part of copper to ten million parts of water is sufficient to destroy Anabaena in ponds and in reservoirs, while Oscillatoria requires one part of copper in every five million parts of water, and forms like Eudorina and Pandorina require one part of copper in every one hundred thousand parts of water.

The chief advantage of the potassium-copper-acetate solution, which serves at once as a killing, fixing and preserving solution, is the way in which it preserves the delicate shades of the green algae. Material preserved in this way may be mounted satisfactorily in glycerine jelly. I found the solution remarkably successful for Desmids and the various species of Spirogyra.

As well as securing forms for later identification, the sample from each aquarium served as a valuable check or control in studying the persistence or disappearance of various forms: the normal habit, periodicity, and the appearance and development of others, the spores of which had been gathered.

Algae under artificial environment.

On the field trips, a number of small collecting bottles were carried and each sample of algae secured from pool, pond or wet bank was placed by itself in one. If several samples were taken from the same large pond, they were all put into separate bottles. On being brought into the laboratory, the contents of each was placed in a separate aquarium which was then filled up with water. Stones and tufts of water weed with algae attached were collected and treated in the same way. By the end of October some sixty-five aquaria, ranging in size from one to ten liters, were set up, the majority being about three liters capacity. In every case the water used was the ordinary tap-water. The reports of various botanists who have cultivated algae in water and in nutrient solutions show that the results of tap-water cultures have been distinctly variable. The variation naturally depends largely on the chemical qualities of the water. The good results from cultures in Montreal water were marked. It was learned from the City Analyst (13) that the filtration plant in connection with the Montreal Water-works regularly placed a definite quantity of calcium chloride in the water supply as a disinfectant. Less than one part of the bleach to a million parts of water are being used, and while this amount destroys the deleterious bacteria, it was proved to have no ill effects upon higher organisms.

The following analysis obtained from the Chemical Department of McGill University, in addition, shows that the water contains the nutrient salts necessary for normal growth.

Total solids	11.13	Parts per 100,000
Temporary hardness	7.39	
Permanent hardness	none	
Organic and volatile matter	1.92	
Free NH_3	0.0026	
Albuminoid NH_3	0.0154	
Nitrogen as nitrate	0.65	
" " nitrite	none	
Oxygen as used in KNO_4 test	0.45	
Chlorine	0.6	
Silica	0.24	
Lime	2.5	
Magnesia	3.2	
Iron oxide and alumina	0.76	

In the Botanical Laboratories where these experiments with algae under artificial conditions were conducted, the windows facing the north were used during the early part of the winter for the aquaria. Towards spring, when experiments were made with nutritive solutions, parallel cultures were placed in both north and south-facing windows, but no difference in effect could be observed. Toward the latter part of March, when the sunlight was much stronger than it had been during the winter, it was observed that in such aquaria as had a coating of Oscillatoria, Stigeoclonium, Chaetophora or Ulothrix about the sides, growth was much more successful than in those where the filaments were exposed to the direct sunlight.

The beneficial effect of a comparatively low temperature was also apparent. The most favourable range was from 5° to 15° C. Under this temperature Spirogyra, Vaucheria and Cladophora lived most successfully, whereas they appeared less healthy and were shorter-lived according as the temperature of the culture was raised above 20°C. Mougeotia, Ulothrix, Stigeoclonium and the Desmids appear to require a slightly higher temperature than other forms, for it was noticed that they usually appeared in aquaria where the temperature had been raised. Oscillatoria also showed in a marked degree the effect of a higher temperature, the blue green tufts of this form always appearing in a culture within a day or two after the temperature had been allowed to rise to 25° or 30° C.

In the case of the filamentous forms like Cladophora and Vaucheria, the lower temperature probably proved favourable to growth because of the increased amount of oxygen and carbon dioxide, which would be dissolved in the water at the lower temperature. The same consideration would also apply to the Spirogyras, though as a rule they can grow in a less aerated water than Vaucheria and Cladophora, probably because they possess thinner cell walls and numerous chloroplasts which permit an easy diffusion of gases. (1)

The Mougeotia, Ulothrix and Stigeoclonium, on the other hand, were probably collected in the form of spores, and an increase of temperature in the cultures in which they happened to be, probably induced germination. The same applies to the Oscillatoria and the Desmids.

It was found impossible to keep Anabaena alive in the

Laboratory for more than a week or two after collection. Generally, after a few days, the filaments had begun to disintegrate.

Zygnema was also difficult to keep alive. Though in some of the aquaria it continued to live for a couple of months, it had disappeared from the majority after about a month. Both of these forms began to appear in some of the aquaria in March, noticeably those which contained a number of other types.

No Mougeotia was observed in the material first collected. But in December, when the temperature of many of the aquaria was allowed to rise considerably, it appeared in great quantities in a large number. Ulothrix began to appear early in February in many of the aquaria where it had not been previously observed. Cladophora glomerata, which was growing attached to a stone, lived in a uniformly healthy condition all winter. So did Microspora crasior, which appeared to be especially hardy and flourished under every condition of light and temperature.

One aquarium contained a lump of clay on which a quantity of Stigeoclonium was growing. This began to die down in December and by the beginning of January there was none to be found. The lump of clay was then placed in a two per cent Knop's solution. This solution is composed of:

Potassium Nitrate	1 g.
Magnesium Sulphide	1 g.
Calcium Nitrate	3 g.
Potassium Phosphate	1 g.

Dissolved in a liter of distilled water, this may be considered a six per cent solution. In four weeks it was covered with a most luxuriant growth of Stigeoclonium. Cladophora also responded promptly to the nutritive effects of Knop's solution, but little or no effect would be observed when Spirogyra was treated with it.

Some twenty of the aquaria contained Spirogyra, generally associated with several other genera, but usually forming the bulk of the material in each. When collected, Zygnema and Oedogonium were usually associated with Spirogyra, but they soon died out. The Spirogyra continued to live for three or four months in a comparatively healthy condition, but after this it showed signs of degeneration, the filaments became etiolated, the cytoplasm broke up into bodies resembling cysts. But these were very small and never secreted a wall and this stage was immediately followed by the disintegration of the whole filament.

It was remarkable that in the large amount of Spirogyra collected during October none was found in a fruiting condition, nor were any spores observed. This material was watched carefully through the winter in the hope that conjugation might take place later on. By placing filaments in various culture media, attempts were made to induce conjugation by artificial means,but none of these gave the slightest success. Distilled water proved distinctly toxic, causing plasmolysis and death. Two per cent Knop's solution showed no marked effect, nor was the action of a four per cent solution any more noticeable.

A five per cent and a one per cent solution of NH_4NO_3 were tried, but appeared only to accelerate the death of the filaments, while in a culture of Desmids the five per cent solution caused luxuriant growth.

In the majority of the cultures which contained nothing but Spirogyra, it had died by the end of March. On the other hand, in aquaria where there were a large number of forms associated, growth at this time was becoming more and more luxuriant. Quantities of Oedogonium, Chaetophora and Stigeoclonium, some Anabaena and a little Spirogyra began to appear towards the end of this month. Vaucheria resisted comparatively well the disadvantages of growth under artificial conditions, and was found throughout the winter in various stages of development. Desmids and members of the Protococcaceae occurred in all the aquaria, the varieties of Scenedesmus being especially plentiful. A number of Diatoms were found either floating in chains or attached to filaments of Cladophora and Vaucheria. They were especially plentiful at a low temperature.

An aquarium containing a number of Cyanophyceae collected from the floor of the Conservatory at Mount Royal Cemetery, showed an interesting development. When the film was scraped off the damp tiles, it presented the appearance of a blackish green scum. This was found to be composed of Calothrix, Tolypothrix, Oscillatoria, Lyngbya, Desmids and various other unicellular forms. During the winter the aquarium containing them was not kept under the same conditions of light and warmth as had obtained in the conservatory. Although it was maintained at a higher temperature than the others, a marked difference in the color and relative numbers of the algal constituents had taken place. The contents of the culture were now a much lighter green, and while formerly the majority of the individuals had been blue green, now the green unicellular forms predominated and many of the blue-greens had entirely disappeared. This is an excellent instance on a small scale of the dominance of the Cyanophyceae under tropical conditions (such as obtained in the conservatory) and the greater adaptation of the Green Algae to conditions of less light and lower temperature which Dr. Fritsch has pointed out in his study of the Tropical Algae (1).

A good deal of animal life existed in the aquaria throughout the winter. In October, several small cray-fish were noticed and removed, as well as innumerable tiny snails, which were feeding upon the unicellular algae. Vorticella waa found in practically every culture, especially in connection with Vaucheria and Ulothrix. Paramoecia were also frequently noticed, often containing unicellular forms of algae which they had engulfed. Amoebae were not so plentiful and no Hydra were observed in any of the cultures, although a special search was made for them. Daphnia, Cypris and Cyclops were quite plentiful in aquaria which contained a quantity of water weed. It was interesting to observe that apparently Oscillatoria was not used by any of these forms as a food, and that in several small aquaria where it appeared in large quantities the animal life disappeared shortly after the unicellular green algae had been exhausted. This may be due to the toxic qualities of the Oscillatoria which are suggested by the disagreeable gas that it gives off.

Periodicity in Spirogyra.

A brief consideration of the theories advanced by several botanists who have studied the question of periodicity in the occurrence and sexual reproduction of Spirogyra may serve to summarize and explain some of the results which have been noted in the foregoing pages.

Benecke (2) has advanced the theory that conjugation in Spirogyra is due to the failure of ammonium salts which he supposes to be removed from the water by angiosperms which increase in size and abundance as the season advances. He placed Spirogyra communis in various media, in bright light, with temperatures from $12^{\circ} - 20^{\circ}$ C., and found that in nitrogen-free solutions conjugation took place at once or in a short time. If parallel cultures were run, in which NH4 or NO3 had been added in appropriate amounts (.05%) to any of the above media or substituted for one of the constituent salts, no conjugation took place, but generally good vegetative growth ensued.

Danforth (3) repeated these experiments, using other species. Of the five species investigated, three failed entirely to give the same results as had been obtained in Benecke's work, the fourth failed in every case but one, and the remaining species, S. Grevilleana, seemed to agree more closely with S. communis, but even here the agreement was not complete. Apparently, Benecke did not find any specific stimulus which would induce conjugation unless the absence of ammonium salts be taken as such. Danforth also found that some species of Spirogyra did not respond by vegetative growth as did others when NH4NO3 was added to the media. Spirogyra Setiformis was killed when placed in cultures of tap water and distilled water containing NH_4NO_3, even when a trace of this salt was added to a nutrient culture of five months' standing. His experiments seem to show clearly that in many cases at least the absence of ammonium salts is not enough to bring about conjugation. These results show considerable similarity to those which were given by my cultures, both in the deleterious effect of NH_4NO_3 on S.+Setiformis and the failure of all artificial methods to induce conjugation.

Copeland's work consisted in a study of Spirogyra both under natural and artificial environment. In the laboratory, he found that very satisfactory cultures could be made with tap-water, and Knop's solution as low as .04 per cent gave favourable results. But no particular advantage was observed from the use of food solutions. It was noticed that it was a decided advantage to the aquaria if they were shaded with dark paper when first started. The good effect was especially noticeable in the south-east windows, where the light was strongest.

Oedogonium and Chara proved beneficial to Spirogyra, Oedogonium being invariably present and often the predominating form in the aquaria where Spirogyra lived for several months or a year. Oak leaves and charcoal also appeared to be beneficial factors.

In regard to the possibility of satisfactory cultures in tap-water, the advantage of a certain amount of shade and the beneficial effects of an association with other forms, especially Oedogonium, my results agree fully with those of Copeland. In field-work, he collected thirteen species of Spirogyra, of which twelve fruited abundantly. Ten of these passed their period of maximum abundance in May, one in August and one in October. One reliable example of a second fruiting was S. dubia, which fruited in May and again in July. The period of maximum abundance was proved in every case to correspond with the period of maximum conjugation. After conjugation, the fruiting filaments and the vegetative forms disappeared at the same time. One species was observed during several years, but never found in a fruiting condition.

Copeland concludes, from notes taken in the field and supplemented by work in the laboratory, that conjugation results not so much from external as internal conditions. He, therefore, concludes that Spirogyra has definite periods of growth and activity.

Fritsch and Rich, in their "Preliminary Observations on Spirogyra", base their theories on observation of Spirogyra under natural environment.

Of the species examined, some appeared to be purely vernal or else to exhibit both a vernal and autumnal phase with an intervening period of scarcity or complete disappearance. The factors for the disappearance of Spirogyra after the vernal phase are enumerated as follows:

(a) The increase in the intensity and duration of the light.

(b) The increase in the temperature of the water and the consequent diminution of the amount of dissolved gases in the water.

(c) The gradual concentration of the salts dissolved in the water owing to the heat and lack of rain-fall in a normal summer.

(d) (?) The increase in the amount of higher vegetation present.

The autumnal appearance of certain species of Spirogyra may be due, they think, to the influence of certain combinations of external factors causing a small number of zygospores to germinate. In the absence of these conditions there may be no autumnal phase. Abnormal meteorological conditions may bring about abnormal absence or occurrence of Spirogyra. Reproduction takes place ordinarily in the vernal phase. They consider it to be the result of certain periodically recurring combinations of factors which vary for different species. The nature of the stimulus causing vernal reproduction is, therefore, an intensification of those conditions which are liable to change in spring. Such intensification taking place at other times in the year would lead, at such periods, to exceptional cases of reproduction.

In a study of this nature, it is out of the question to attempt to confirm either the theory of Copeland that conjugation results from internal rather than from external conditions, or that of Fritsch that conjugation results from a periodically recurring combination of external factors. However, such evidence as my notes from field and laboratory work present, the appearance of numerous species of Spirogyra in October, and the entire absence of any fruiting material at that time, as well as the failure to obtain any conjugation in the laboratory during the winter, incline me to believe that while certain combinations (i.e. factors of light, temperature and density of water), as Fritsch suggests, probably induce the second appearance of Spirogyra in the fall, conjugation results from certain periodically recurring internal conditions.

Rhizoid Formations of Spirogyra.

An interesting development was observed in an aquarium containing Spirogyra fluviatilis collected from one of the quarry holes in Amherst Park. This vessel contained a large amount of the alga and, in examining some of the filaments in January, it was observed that at the end of many there was an abnormal growth. The end cell seemed to have lost most of its chlorophyll, the characteristic spiral chromatophore was broken up,and the cell had branched into two or more narrow root-like prolongations. Further search revealed filaments in all stages of this development, from an almost imperceptible beginning of the forking to long colorless processes which were always found in contact with other filaments or with masses of slime. An examination of a large number of specimens showed that only the end cell was thus affected, though the cell next to it might lose some of its chlorophyll. These root-like processes were continuous with the end cell, they appeared to have a slightly laminated cell-wall, and usually showed a sort of mucilaginous excretion with which bacteria were frequently associated.

An examination of material preserved from the same aquarium in October showed that a few of the filaments had possessed these branches when collected, though in a less developed stage. Several other cultures of Spirogyra from different localities showed the same phenomenon but it appeared in every case to be the same species, while other species in the same aquaria showed no trace of the rhizoid-forming tendency.

From these observations, and after a number of experiments with various culture media which apparently did not affect the form in any definite way, I concluded that this tendency to form root-like projections must be a specific response to some physiological stimulus which occurs in nature as well as under artificial conditions. I have been unable to discover any mention of this phenomenon in any systematic work on Algae or any text-book of Physiology. In Goebel's "Organography of Plants" (14), I found a reference to Borge's "Über die Rhizoidenbildung" (15) stating that Borge had found that rhizoids could be produced in Spirogyra filaments by the action of certain culture media. A study of Borge's work confirmed my own observations and conclusions, and suggested to me a possible explanation.

In this very interesting article the author, after citing various instances where the phenomenon of rhizoid formation has been observed in members of the Chlorophyceae, which are ordinarily not supposed to possess these organs, describes a large number of experiments which he made in order to study the cause of this occurrence. He found that, when grown in a number of culture media, such as cane-sugar, asparagin, agar-agar and glycerine solutions, Spirogyra fluviatilis could be induced to form rhizoids, while in pure water cultures it did not. This species, as well as two others, which were unnamed for lack of fruiting material but which greatly resembled it, were found in different places growing fastened to stones in the water. Experiments were made next with S. inflata (Vauch). S.orthospira (Naeg.) and two unnamed species, all of which were found free-swimming in nature. None of these were apparently grown in the culture media,but all were used in contact cultures. While neither the attached nor the free-swimming forms produced rhizoids where grown in ordinary water cultures, it was found that every one of the species could be induced to form these organs in a few days by growing them in contact with some object like a microscope slide or cover-glass, in a drop culture.

To complicate matters, however, it was found that several other species failed entirely to respond to the contact treatment. These were S. Weberi and S. varians and several unnamed forms,all of which were found free-swimming in nature. Although all of these were grown in contact cultures for over a month, none showed any sign of rhizoid formation.

Spirogyra fluviatilis appeared to be the most highly sensitive of all the forms examined, and readily formed strong rhizoids. Other forms produced rhizoids in varying degrees under contact culture, S. orthospira showing the least response to the treatment. It was on this account, as the author explains, that S. fluviatilis was used for the majority of the experiments with culture media, as it appeared to be the most likely to form rhizoids. In none of these cases could he discover the cause of this phenomenon. In the rest of the paper, he discusses this rhizoid-forming tendency in other genera, such as Mougeotia, Ulothrix and Vaucheria. But with these forms we are not concerned at present, although they do show similar differences to those observed in various species of Spirogyra.

A consideration of all the evidence, both in this work and that furnished by my own observations of the rhizoid-forming power of Spirogyra, leads me to conclude that, in the first place, this phenomenon is due to a certain specific sensitiveness rather than to the nature of the stimulus. That there must be a stimulus of some sort is evident, but it seems to be rather the sensitiveness of the organism than the nature of the stimulus which determines the degree of the response.

The stimulus, both in Borge's culture media and drop cultures, was very probably the same, a certain amount of irritation due to contact. In my cultures, the stimulus was due in the same way to irritation caused by contact with other forms in a crowded aquarium, and, as the form was highly sensitive, this was sufficient to produce marked rhizoid formation. In the second place, it may be suggested that this sensitiveness among certain species of algae, which expresses itself in a more or less strongly marked tendency to form rhizoids, may have some connection with the thigmatropism shown by some of the higher plants.

Algae occurring on the Island of Montreal.

Systematic List.

Class I. Chlorophyceae.

Order I. Conjugatae.

Family I. Desmidiaceae.

Closterium Jenneri, Ralfs.

Crescent shaped, small, slightly tapering, six to eight times longer than broad, ends obtusely rounded, vacuole large, containing many active granules, cell-wall colorless, smooth. Diam. about 14 micr.

Verdun, Bout de l'Ile, Amherst Park.

Cosmarium Botrytis, Menegh.

Cells nearly twice as long as broad, sinus narrow linear, semicells with nearly straight base inclining to reniform, sides converging from inferior rounded angles to truncate end. Cell-wall granular. Diam. 35-36 micr.

Verdun, Amherst Park.

Micrasterias americana, (Ehrenb.) Ralfs.

Semicells three lobed, lateral lobes broad margins, incised serrate, subdivisions narrow dentate at extremities. Diam. 100-115 microns. Length one third greater.

Verdun, Amherst Park.

Family 2. Zygnemaceae.

Zygnema Vaucherii (Ag.)

Cella 10-22 micr. 2 1/2 or 3 to 5 x as long as broad.

Zygospores subglobose or broadly elliptical.

Verdun.

*Zygnema insigne Kütz.

No fruiting material. Vegetative cells 26-30 micr. diam. length equal or up to 2 diam.

Verdun.

*Spirogyra fluviatilis, Hilse.

Filaments 36 micr. diam. cells 5-6 diam. long.

Chromatophores, slender, very pale green, making 1 1/2-2 1/2 twins in the cells. No fruiting material; found sterile attached to stones; formed rhizoids when cultivated in water in laboratory.

Amherst Park, Back River.

*Spirogyra setiformis, Kütz, of Collins, or

Spirogyra orbicularis of Cooke.

Cells 110-140 micr. diam. about as long as broad, 4 rather broad chromatophores, with many large pyrenoids, making 1/2 - 1 turn in the cell. No fruiting material

Mount Royal.

Family 3. Mesocarpaceae.

*Mougeotia nummuloides (Hass.)

No fruiting material, vegetative cells 16 micr. diam. 102 micr. long.

Verdun, Mount Royal, Back River, Amherst Park, etc.

*Several forms of Zygnema and Mougeotia and a great many of Spirogyra were collected, but as no fruiting material was obtained, save in the case of one Zygnema, it was found impossible to decide with certainty to which species they belonged. A few forms are given, the vegetative condition of which appeared to be sufficiently characteristic to admit of listing them as accurately determined species.

Order II. Volvocales.

Family I. Chlamydomonadaceae.

Chlamydomonas Sp ?

Verdun.

Family 2. Volvocaceae.

Pandorina morum (Müll)

Colony globose to ellipsoid, up to 220 micr. broad, 16 cells, rarely more or less, cells 9 - 15 micr. diam.

Amherst Park, Verdun, etc.

Eudorina elegans. Ehrenberg.

Colonies 50-200 micr. diam. usually 32 arranged in 3 parallel circles of 8 each with four at each pole, cells 12-24 micr. diam.

Amherst Park.

Family 3. Tetrasporaceae.

Tetraspora lubrica. (Roth.)

Frond at first attached, soon splitting and forming irregular expansions, often with many rounded openings up to 20 cm. long and wide. Very gelatinous, usually yellowish in color, cells 7-11 micr. diam. Generally in fours.

Mount Royal, Amherst Park, Verdun.

Order III. Protococcales.

Family 1. Protococcaceae.

Characium Sieboldii, A. Braun in Kützing.

Cells 15-25 x 4-9 micr. erect, lanceolate when young, when adult short and broad. Stipe short, without basal disk. On Vaucheria.

Bout de l'Ile.

Family 2. Scenedesmaceae.

Raphidium falcatum (Corda)

Cells bright yellowish green, slender, fusiform, ends acute. 1.5-3.5 micr. diam. 15-25 diam. long, usually 2-32 united in a bundle.

Also var. aciculare (A.Br.)

Very slender, 1.5-3 micr. diam., 15-20 diam. long, acicular, straight or slightly curved, usually solitary.

Very plentiful in every locality.

Scenedesmus bijuga. (Turp.)

Colonies of 4-8 cells oblong-ellipsoid, with rounded ends 7-18 x 4-7 micr. arranged in a single or double row.

Every locality.

Also var. alternans (Rein sch.)

Cells broader than in the type, in two rows alternately placed.

Every locality.

Scenedesmus obliquus. (Turp.)

Colonies of 4-8 cells, cells fusiform with acute ends, usually in a single series. 5-27 x 3-9 micr.

Every locality.

S. denticulatus, Lagerheim.

Colonies, 4-8 cells, in a nearly straight line. 4-5 micr. wide, to 15 micr. long, each end with two minute teeth.

Every locality.

S. Quadricauda. (Turp.)

Colonies of 2-8 cells, oblong-cylindric with rounded ends, 9-33 x 3-12 micr. arranged in a single series, end cells with long filiform projections.

Every locality.

Crucigenia rectangularis. (A. Br.)

Cells 4-6 x 5-7 micr. 4-8-16-32 in a colony 13-35 micr. square with rounded angles, always in groups of 4, cells oval or oblong, touching near the outer end.

Amherst Park, Back River.

Selenastrum minutum. (Näg.)

Cells crescent shaped, usually uniformly curved. 7-9 micr. from tip to tip, 2-3 micr. wide at middle, cells usually free.

Back River, Amherst Park.

Kirchneriella lunaris (Kirchner)

Cells crescent shaped with rounded ends. 3-5 micr. diam. at middle, 6-10 micr. long.

Mount Royal, Amherst Park.

Family 3. Hydrodictyaceae.

Hydrodictyon reticulatum. (L.)

Cells usually several diameters long, length up to 1 cm. 100-200 micr. wide; families 1 to 2 dm. long.

Back River, Verdun, Bout de l'Ile.

Pediastrum Boryanum (Turp.)

Cells 4-64. 10-20 micr. wide forming a continuous circular disk, disk-cells 4-6 angled, marginal cells bi-lobed, each lobe ending in a short obtuse projection.

Verdun, Mount Royal.

P. Constrictum. Hass.

Cells of periphery irregularly 2-lobed, sinus narrow, lobes unequal produced into an obtuse horn, central cells, polygonal. 16-32 cells.

Verdun, Amherst Park.

P. Ehrenbergii. Braun.

Coenobium orbicular, composed of 8-16 cells or quadrate of 4 cells wedge-shaped, cells of periphery cuneate,truncate at base, deeply bilobate, lobes obliquely truncate, central cells polygonal, yellow green.

Verdun.

Order IV. Ulotrichaceae.

Family 1. Ulotrichaceae.

Ulothrix variabilis, Kützing.

Filaments 5-6 micr. diam. cells cylindrical 1/2 - 1 1/2 diam. long wall, thin, delicate, pyrenoid, single, small.

Mount Royal, Bout de l'Ile.

U. aequalis, Kützing.

Filaments 13-16 micr. diam. cylindrical cells 1-2 diam.long.

Mount Royal, Verdun.

U. Tenerrima, Kützing.

Filaments 7-9 micr. diam., cells cylindrical 2/3-11/3 diam. long, chromatophore contracted to one side of cell, pyrenoid, single. In light green, silky masses.

Mount Royal, Amherst Park.

Microspora crassior (Hansg.)

Filaments long, dark green, nearly cylindrical. 28-33 micr. diam. cells 1-16 diam. long, with wall 2.5-3 micr., thick, chromatophore dense, covering whole cell wall.

Bout de l'Ile, Mount Royal.

Family 2. Oedogoniaceae.

Oedogonium sp?

Bout de l'Ile, Back River.

Family 3. Chaetophoraceae.

Chaetophora incrassata (Huds.) Hazen.

Thalli irregularly extended, branched, closely packed, main filaments elongate, secund branches, setiferous ramuli, cells of main filaments 8-16 micr. diam. 2-6 diam. long, ramuli 6-11 micr. diam. cells 1-2 diam. long.

Verdun.

Stigeoclonium tenue (Ag.) Kütz.

Tufts up to 1 cm. high, bright green, filaments slender, 7-10 micr. diam. below, 5-6 micr. in ramuli, cells cylindrical 1-3 diam. long, about equal in ramuli, main branches opposite, ramuli numerous, tapering to slender seta.

Bout de l'Ile.

S. aestivale (Hazen).

Light green, palmelloid base, branching alternate main filaments 7-9 micr. diam. cells 2-6 diam. long below, equal in ramuli, thin walled, somewhat swollen, ramuli near summit few.

Verdun.

Gleocystis gigas. (Kütz).

Cells globose, 9-12 micr. diam. solitary, membrane thick lamellate, contents green.

From floor of conservatory, Mount Royal.

Family 4. Coleochaetaceae.

Coleochaete sp?

Verdun.

Order V. Siphonocladialis.

Family 1. Cladophoraceae.

Cladophora glomerata (L) (Kütz.)

Fronds up to 30 cm. high, branches more and more frequent toward the top, filaments cylindrical, 75-100 micr. diam. below, 6-7 diam. long. 35-50 micr. in ramuli, 3-6 diam. long, ramuli not tapering, tips rounded. (An extremely variable species - Collins).

Verdun, Back River, Bout de l'Ile.

C. Kuetzingiana, Grunow in Rabenhorst.

Soft, loose, feathery tufts, up to 30 cm. high, filaments 45-85 micr. diam. below, ramuli 25-35 micr. diameter, cells cylindrical, slightly swollen ramuli, 6-10 diam. long below, 2-4 diam. long in ramuli, branching erect, opposite, or alternate below, ramuli with acute tips.

Bout de l'Ile, Back River.

Order VI. Siphonales.

Family 1. Vauchereriaceae.

Vaucheria sessilis. (Vauch.)

Filaments 50-85 micr. diam. oogonia usually two, sessile ovoid, 70-85 x 75-100 micr. more or less oblique. Short beak, antheridium between the oogonia on short pedicel, circinate, ripe oospore with triple membrane, filling the oogonum.

Back River, Amherst Park, Bout de l'Ile.

V. geminata (Vauch.) Var. racemosa .

Filaments 50-90 x 60-75 micr. or smaller, corymbosely arranged about antheridium. which is hooked.

Bout de l'Ile.

Class Diatomaceae.

Found with Vaucheria and Cladophora from all the localities.

Order Pennatae.

Family 1. Tabellariaceae.

Tabellaria flocculosa (Roth.) Kütz.

Family 2. Fragilatriaceae.

Fragillaria capucina.

Length of valves 30-60 micr.

Synedra ulva (Nitzsch)

Length of valves 150-250 micr.

Family 3. Naviculaceae.

Navicula sp?

Family 4. Gomphonemaceae.

Gomphonema geminatum.

On filaments of Mougeotia.

G. Constrictum.

On filaments of Mougeotia.

Class Cyanophyceae.

Order I. Hormogoncea.

Family 1. Scytonemaceae.

Tolypothrix trunciola (Rab.)

Diam. of filaments 11-14 micr.

Dull aeruginous, articulatious 1/3 as long as broad.

Heterocysts subsperical, singly at the base of the branches, making a velvety black fuscous surface.

Mount Royal.

Family 2. Nostocaceae.

Nostoc Sp ?

Verdun.

Anabaena oscillarioides. Bouj.

Forming bluish green stratum. Trichomes elongated joints sub-quadrate distinct, heterocysts barrel shaped. Cells 4-5 x 4-6 micr. Heterocysts 6-8 x 7-9 micr. Spores 7-8 x 8-12 microns.

Bout de l'Ile.

A. inequalis (Kütz).

Trichomes vary in thickness about 4 microns in diam.

Amherst Park.

Family 3. Oscillatoriaceae.

Lyngbya aestuarii Lieb.

(Oscillatoria insignis) Cooke.

Thickness of Trichomes 24 microns.

Bout de l'Ile.

Oscillatoria tenuis Ag.

Trichomes straight, active, motile, joints half as long as broad, apex obtuse, cell contents pale blue, forming dark blue green stratum. Filaments 3 microns diam.

Bout de l'Ile, Back River, Amherst Park.

O. leptotricha var. splendida, Kütz.

Trichomes 2 micr. diam. indistinctly articulate, joints twice as long as broad, minutely punctate at periphery, cell contents pale bluish green.

Verdun.

Family 4. Rivulariaceae.

Calothrix confervicola, Ag.

Tufts fasciculate, filaments dark bluish purple, attenuated, 18 microns in diam. heterocysts all basal, generally few in number.

Mount Royal.

Rivularia haematites (Ag.)

Heterocysta basal, extremities of filament piliferous, no spores. Globose thallus attached to stones in streams and to Myriophyllum.

Amherst Park.

rder II. Coccogoneae.

Family 1. Chamaesiphoniaceae.

Chamaesiphon incrustaus, Grun.

Diam. of cells 3.5 - 4.8 micr.

On filaments of vaucheria from Bout de l'Ile.

Chroococcus turgidus (Kütz).

Diam. cells 13-25 microns.

Mount Royal.

Merismopedia glauca. Ehring.

Diam. of cells 3.3 - 3.8 microns.

Mount Royal.

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Drawings of Spirogyra.

Showing stages in the development of Rhizoids.

(1) Preserved Material, collected Oct. 2nd.

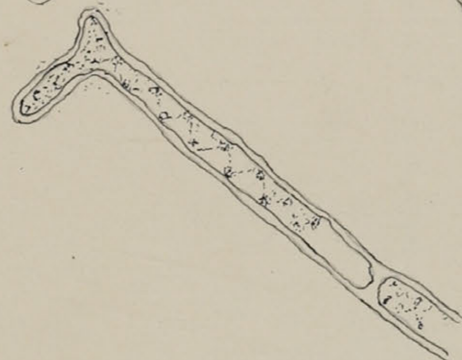
(2) " " " " "

(3) Material growing in tap-water Jan. 13.

(4) " " " " " " "

4

3



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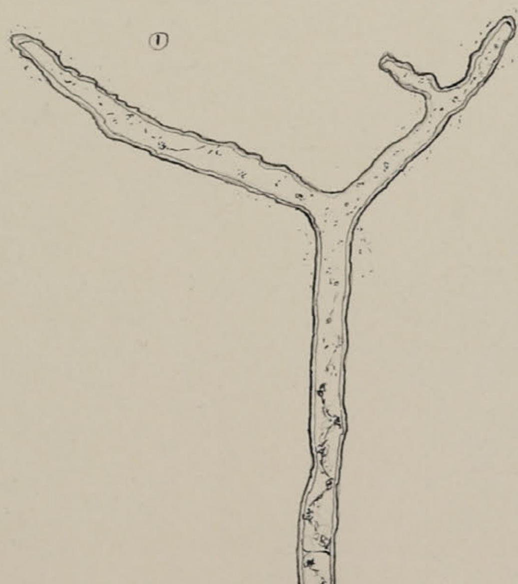

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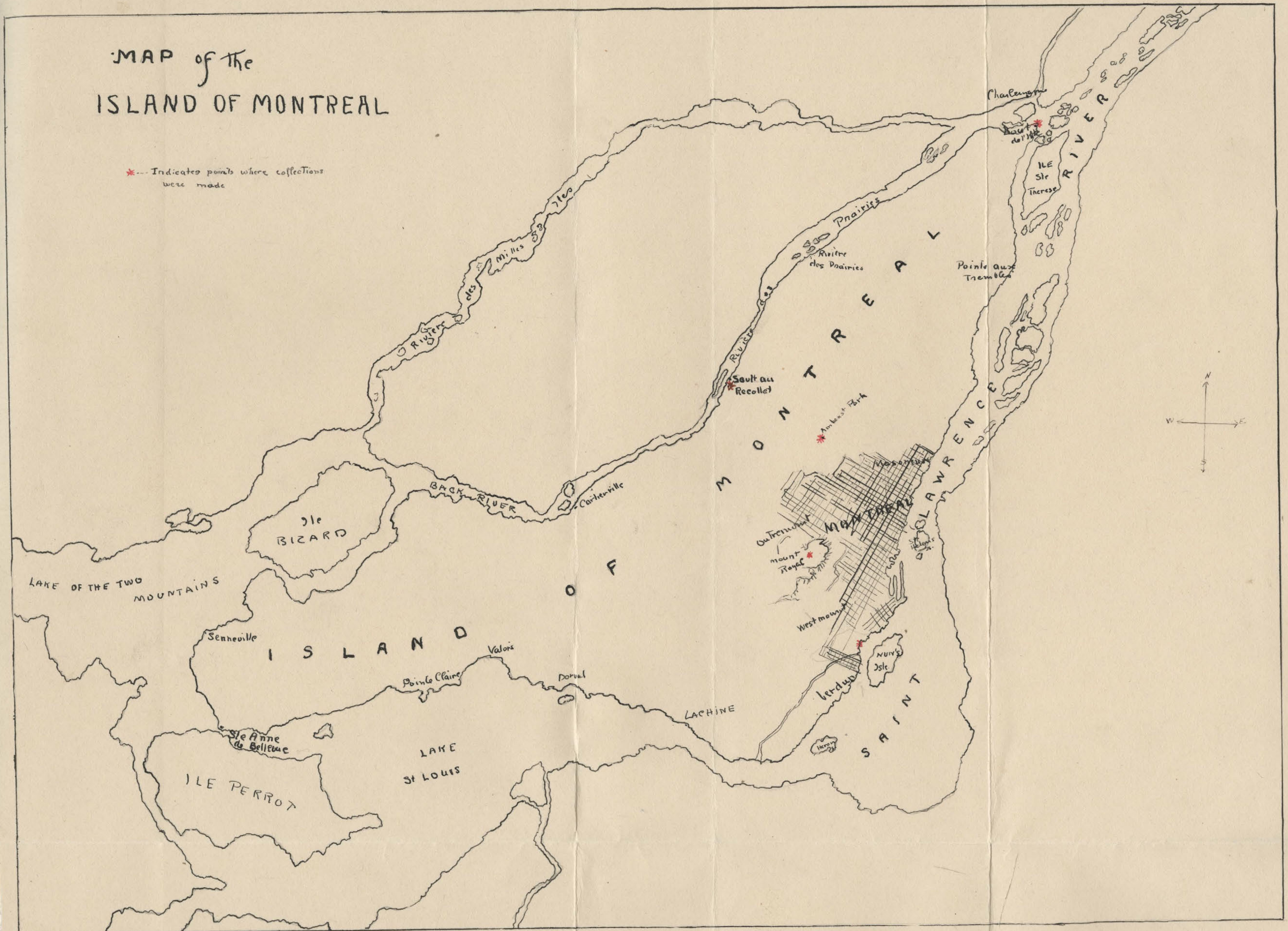
MAP of the
ISLAND OF MONTREAL
* --- Indicates points where collections were made
ISLAND OF MONTREAL
Rivière des Milles Iles
Rivière des Prairies
Rivière des Prairies
Back River
Sault au Recollet
Amherst Park
Cartierville
Ile Bizard
Lake of the Two Mountains
Senneville
Ste Anne de Bellevue
Ile Perrot
Lake St Louis
Pointe Claire
Valois
Dorval
Lachine
Verdun
Nun's Isle
Saint Lawrence River
Montreal
Outremont
Mount Royal
Westmount
Maisonneuve
Pointe aux Trembles
Ile Ste Therese
Bout de l'Ile
Charlemagne
N
W
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