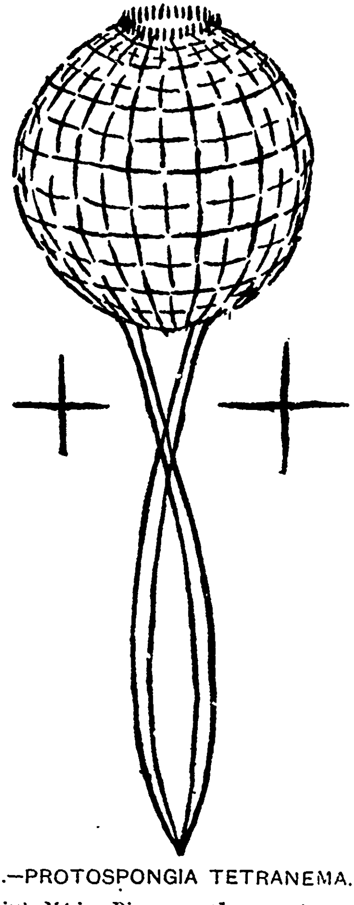

FIG. 1.—PROTOSPONGIA TETRANEMA. S.N.

Quebec group, Little Métis. Diagrammatic restoration, slightly enlarged.

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Preliminary Note on New Species of Sponges from the Quebec Group at Little Métis.

By Sir J. William Dawson, LL.D., F.R.S.

Little Métis Bay presents a good section of rocks of the Quebec Group, including sandstones, slates and conglomerates similar to those which characterise this series of beds along the south shore of the St. Lawrence. These beds have afforded a species of *Retiolites*, allied to or identical with *R. ensiformis* of Hall[1], worm-burrows of various forms, including a spiral form similar to *Arenicolites spiralis*, and radiating markings of the kind elsewhere known as *Astropolithon*. A small species of *Obolella* also occurs, resembling *O. Ida* of Billings. In the conglomerates are limestone boulders, holding fragments of Trilobites of the genus *Solenopleura* and other fossils; but these seem to be of Middle Cambrian age, or considerably older than the beds in which they occur.

There can be no doubt, from the stratigraphical position

[1] Identified by Prof. Lapworth.

of these beds, that they belong to the Quebec Group of Sir W. E. Logan. This is, however, now known to include, on the Lower St. Lawrence, beds ranging from the Calciferous to the Trenton, and the beds are so much plicated that it is often difficult to unravel their complexities of arrangement.[1] At Métis, the evidence of the pebbles in the conglomerates indicates that they are newer than the Middle Cambrian, and the few fossils found in the sandstones and shales would tend to place them at or near the base of the Lévis division, or approximately on the horizon of the Chazy, or equivalent to the English Arenig. Lapworth, in his paper on "Canadian Graptolites," suggests that the sandstones holding Retiolites are older than this; but hitherto we have not found at Métis the characteristic Graptolites of the older or Matane series, which occurs further east, and is probably of Calciferous or Tremadoc age.

In the past summer, Dr. Harrington, F.G.S., was so fortunate as to find a bed of black shale rich in remains of sponges, hitherto unknown in these rocks, and having made known the fact to the writer, we visited the place several times and made considerable collections of these interesting fossils, which are now in the Peter Redpath Museum.

The locality of this discovery is the beach at the foot of the cliff below the Wesleyan church, where a considerable thickness of black shales appears well exposed. The section at this place is as follows, in descending order:—

1. A thick bed of hard sandstone or quartzite and conglomerate, forming the cliff immediately in front of the church, and shewing in some of the beds radiating markings (*Astropolithon*).

2. Black and dark gray shales, with a few calcareous bands—thickness about 100 feet. The black shales of this band hold sponges and layers of sponge spicules, with fucoids (*Buthotrephis*, of a new species,) and valves of a small *Obolella*. All of these fossils are usually in a pyritised state.

[1] Logan, Geology of Canada, 1863; Selwyn, Report Geol. Survey, 1877-78; Ells, *Ibid*, 1880-82; Lapworth, Canadian Graptolites, Trans. R. S. C., 1886.

3. Flaggy sandstone and shale, about 20 feet.
4. Hard sandstone with quartz veins, 3 to 5 feet.
5. Hard gray shales and calcareous and dolomitic bands, with some layers sf sandstone—800 feet or more.
6. Apparently underlying these, and occupying a great extent of the shore, are black, gray and red shales and thick beds of gray sandstone, the latter appearing at Mt. Misery and Lighthouse Point, and holding the Graptolites above referred to. These beds must be of great thickness in the aggregate, but they are possibly repeated in part by faults and contortions.

The sponges contained in Band 2 above, are apparently confined to a small thickness of the shale, but in this are quite abundant. They are perfectly flattened, and their spicules are replaced by pyrite; but in some cases they retain the outline of their form, and have their root spicules attached. The spicules were, no doubt, originally siliceous, but they have shared the chemical change experienced by other fossils in this bed, whereby they have lost their siliceous matter and have had pyrite deposited in its place. In some cases, also, the pyritised spicules have been frosted with minute crystals of the same substance, greatly enlarging their size and giving them a mossy appearance. This pyritization of spicules, once probably silicious, is not uncommon in palæozoic rocks, and it arises from the soluble condition of the silica in sponges, and its association with organic matter, which, in some modern sponges, as in Hyalonema, enters into the composition of the spicule itself. These spicules, therefore, suffer the same change with the calcareous shells associated with them.

Many of the sponges in these beds have been entire when entombed. Others are decayed and partially broken up, and there are some surfaces covered with confused patches of loose spicules arising from the disintegration of many specimens.

Some remarks are perhaps necessary here respecting the appearance of sponges in different states of preservation. Of course the original textures of sponges are different, and those which have consolidated spicules or firm external cortex, are those most likely to retain their original forms. Even the looser kinds of sponges, however, may under certain circumstances preserve their rotundity of form, in which case they will usually show external markings, but not so well internal structure, unless when sliced. On the other hand, when completely flattened, which is usually the case in shaly beds, only an outline of the form remains, and sometimes not even this, while the forms and in part the arrangement of the spicules are usually apparent. Farther, the hollow and thin-walled species are more liable to be completely flattened, though in some cases, as in the Devonian Dictyospongiæ, they may retain their form. It was this property, and the membranous appearance of the outer coat, that for a long time sustained the belief that these were plants rather than sponges.

In the case of the sponges procured in the shales at Little Metis, perfect flattening has occurred, and in many cases the spicules have been separated, and appear as mere spicular patches or layers. In other instances, however, they remain approximately in their natural position, and even the general outline of the form can be observed. The collections include several species of sponges, Hexactinellid and Monactinellid; but, so far as observed, one of them is more abundant and better preserved than the others. The following may serve as a preliminary rough description of the species collected,—which will be more fully described and commented on by Dr. J. George Hinde, F.G.S., the author of the British Museum Catalogue of Fossil Sponges. See paper appended.

1. *Protospongia tetranema.* S. N. (Fig. 1)[1] The general form has been spheroidal, probably with an osculum or oscula at top. Root composed of four long spicules in two pairs, which diverge somewhat and then bend toward each

[1] This figure is a restoration, with two of the spicules enlarged. The defensive spicules and osculum are conjectural, being based merely on loose spicules and general form.

other and unite, forming a loop. General diameter, about 3 to 5 centimetres. Length of root-spicules, 6 to 7 centimetres, Wall of body apparently thin, composed of large cruciform spicules, stout at centre and tapering to sharp points, and arranged in square meshes, with smaller spicules of the same forms in the meshes. Length of largest spicules and size of meshes, 1 centimetre or less.

The structure of this sponge places it in Protospongia of Salter. It is true that the species of Protospongia are not known to have root spicules, but these must have been present in some form, and perhaps the bundle of spicules from the Menevian, described by Hicks as *P. flabella,*[1] may have been of this nature.

The root of this species is very peculiar in its arrangement. It seems to have been a cruciform spicule, of which the rays were bent upward and lengthened, forming a stalk for the sponge. This would give a firm attachment, and adapt itself to the gradual rise of the bottom to which the sponge was attached. The mechanical properties of such an arrangement of spicula are obviously well suited to effect their purpose.

Salter, in his original description of *Protospongia* from the Cambrian of Wales, compares it with *Acanthospongia* of Griffiths from the Silurian of Ireland, the original specimen of which he had seen ; but says it has six-radiate spicules. He also remarks that the spicules of Protospongia seem to be all on one plane.[2] *P. Major* of Hicks is a still older species from the Lower Cambrian or Longmynd Series, and seemingly of different structure and of much more open texture than that above described. Matthew has also noticed and figured fragments of Protospongia from the Lower Cambrian of St. John, New Brunswick. The present species, though somewhat later in age than the foregoing, has the merit of presenting a better state of preservation and better illustrating the general form, and more especially the root-spicules.

[1] Hicks' Jour. Geol. Soc., Vol. xxvii.

[2] Journal Geol. Soc., Vol. xx.

2. A second species shows numerous large and long root spicules similar to those included in the genus *Hyalostelia* of Hinde. Some of them shew crutch-shaped terminations at the distal ends. Such remains of the body of the sponge as have been found, appear to consist of small cruciform and simple spicules, not unlike the *debris* of a modern *Hyalonema.* This sponge was larger than the preceding. It may be provisionolly named *H. Metissica.*

3. A third shews what seem to be remains of a thin-walled hollow sponge, with vertical and tranverse spicules arranged somewhat in the manner of those of the genus *Cyathophycus* of Walcott.[1] Like that genus, it contains also small loose cruciform spicules. It seems to have been conical and pointed below, and without long roots. It may be named *C. Quebecensis.*

4. Small ovoid masses of stout biacerate spicules, diverging from the centre and sometimes in fan-shaped tufts, seem to indicate a species of the genus *Lasiocladia* of Hinde. The specimens shew indications of an external membrane, and they had somewhat strong root spicules, much larger than those of the body.

5. Oval masses of small simple spicules, imbedded in patches of pyrite and without any definite arrangement of root spicules, may either indicate the presence of a halichondroid sponge, or of patches of spicules imbedded in coprolitic matter. The former is, perhaps. more likely to be the correct explanation.

An interesting point in connection with these remains is the appeai ance of so many distinct types of silicious sponges in one locality and formation. This fact was not distinctly noticed till the specimens were carefully examined, and it invites to further search in the locality, in hope of discovering new forms or more perfect examples of those represented in the present collection only by fragments.

[1] See note appended.

In the shales containing the above species, the only other fossils observed were slender fucoids, a small Obolella and a minute Cystidean or Crinoid, as follows:—

Obolella Ida ? Billings.

I refer the specimens of Brachiopods found to this species, which belongs to the Lévis division of the Quebec Group. The valves are mostly pyritized, but sometimes flattened and then represented by a mere carbonaceous film. Mr. Whiteaves, to whom I have shewn these shells, agrees with me on their probable reference to one of Mr. Billings' smaller species from the Quebec Group.

Cystites ?

A small-jointed stem one centimetre in length, with an elongated, flattened, oval mass at one end, in which, however, no distinct plates can be discovered.

Buthotrephis pergracilis. S. N.

Stems very long and flexuous, about one millimetre in diameter, and obscurely striate longitudinally; sending off at their extremities short alternate or opposite branches. Allied to *B. gracilis*, Hall, of the Siluro-Cambrian, but much more elongated and slender. These plants are replaced by pyrite.

Note on Cyathophycus reticulatus. Walcott.

In the collection of minerals of the late J. S. Miller, Esq., of Ottawa, purchased for the University. are a few fossils, some of them Canadian, others from the phosphate deposits of South Carolina. Among the former are a few specimens of Utica slate fossils, which, from their appearance I suppose, have been collected in the beds of that formation near Ottawa, though it is possible that some of them may have been obtained from the United States. They include a specimen of the above species, which Mr. Ami, who has collected extensively in these beds at Ottawa, informs me has not yet occurred to him. The specimen is a small slab of the ordinary Utica shale, having an impression of a glabella of *Triarthrus* on the back, which proves its geological horizon. It has two specimens of *Cyathophycus* close together, nearly perfect at their bases and broken off at the height of about three inches. They are perfectly flattened and pyritized, which is also the condition of other fossils in these shales, with the exception of the graptolites, which seem to have resisted this kind of change.

The genus *Cyathophycus* was originally described by Walcott from specimens obtained at Trenton, Oneida Co., New York.[1] He regarded it as an alga, whence the termination "phycus," but subsequently, in the *American Journal of Science*, 1881, corrected this error, and referred it to the sponges. Hall (35th Regents' Report) properly places it with the reticulate sponges included in his family *Dictyospongidae*, but does not add much to Walcott's original description, to which the present specimens permit some additions to be made.

[1] Trans. Albany Instit., 1879.

The specimens are perfectly flattened, but show distinct indications of the two sides of the originally conical form. The wall of the skeleton has evidently been thin and composed of slender bundles, each of a few long simple spicules, and increasing both by bifurcation and the introduction of new bundles, so as to preserve nearly the same distances in the wider parts of the cone. They are very regular in the lower part, where there are about nine principal, with some intermediate secondary bundles in a centimetre, but become more irregular toward the top. This may, however, be an effect of decay and crushing. At the base these bundles become thicker, and in a specimen from the original New York locality, kindly lent to me by Mr. Ami, I have observed that they become expanded and converted into somewhat short clavate root spicules. This is, however, not apparent in Mr. Miller's specimens, which may have been broken off at the surface of the mud.

The vertical bundles are crossed at right angles by horizontal spicules much less regularly arranged, but dividing the surface into rectangular meshes. These are slightly oblique and rhomboidal in the specimens, but this is probably due to pressure. The horizontal spicules seem to be triacerate in form, and much shorter than those of the vertical system, though of very different lengths. They are sometimes in bundles and sometimes solitary.

In parts of the substance, apparently within the reticulate wall, may be seen a few cruciform spicules, and flocculent patches apparently of very small spicules, which seem to have been mostly internal and most abundant toward the base, but cannot be distinctly made out.

The whole of the spicules are completely pyritized, and appear under the microscope to be made up of rows of cubical crystals of pyrites. They were probably originally siliceous, but this need not excite surprise, as the silica of such spicules is in a condition which facilitates solution, and in some modern sponges the spicules are not purely silicious, but contain some animal matter. I have also noticed other cases in which silicious palæozoic sponges have experienced this change, while in many specimens the spicules have entirely disappeared.

This is the case with the Erian or Devonian sponges of the genus *Dictyophpton* and allied genera, which, owing to their apparently membranous character, I at one time believed to be fucoids, but abandoned this idea on seeing the specimen of *Uphantenia* (*Physospongia,* Hall) which Prof. Whitfield was kind enough to show me in the New York Museum in July, 1881. In a note communicated to Prof. Whitfield in August, 1881, I have made the following remarks on the pyritization of sponges :—

"The most puzzling fact in connection with the original silicious character of these sponges is their mineral condition, as being now wholly replaced by pyrite. Carbonaceous structures are often replaced in this way, and so are also calcareous shells, especially when they contain much corneous matter, but such changes are not usual with silicious organisms. If the spicules were originally silicious, either they must have had large internal cavities which have been filled with pyrite, or the original material must have been wholly dissolved out and its place occupied with pyrite. It is to be observed, however, that in fossil sponges the silicious matter has not infrequently been dissolved out, and its space left vacant or filled with other matters. I have specimens of *Astylospongia* from the Niagara formation which have thus been replaced by matter of a ferruginous color; and in a bundle of fibers, probably of a sponge allied to *Hyalonema* from the Upper Llandeilo of Scotland (since named *Hyalostelia* by Hinde[1]), I find the substance of the spicules entirely gone and the spaces formerly occupied by them empty. It should be added that joints of Crinoid stems and fronds of *Fenestella* occurring in the same specimen with the *Uphantaenia* are apparently in their natural calcareous state."

The type of structure of *Cyathophycus* is essentially that of the Hexactinellid sponges of the sub-order *Dictyonina* of Zittel, and under this, as has already been suggested by Barrois, it belongs to the family of *Dictyospongidæ*, established by Hall for *Dictyophyton* and the allied sponges of the Erian rocks. This type, already known as far back as the Utica slate, is now carried a stage farther by our discoveries at Métis.

While the above paper was in the press, Dr. Selwyn was so kind as to send to me for inspection, through Mr. Ami, of the Geological Survey, some slabs of gray and dark coloured shale from the Quebec group rocks of the Chaudière River, in which spicules of sponges had been detected some years ago, by Mr. T. C. Weston and Mr. Willmot of the Survey, but which have not been published. The specimens show two forms of cruciform spicules, one with very slender rays and as much as a centimetre in measurement from point to point, the other stouter and measuring about five millimetres in extent, and therefore more nearly resembling those of *Protospongia tetranema*. There are also long

[1] I have similarly explained *Pyritonema* of McCoy and *Eophyton explanatum* of Hicks, as has Hinde also, in Geol. Maga., 1886.

slender root spicules scattered on one of the slabs. On another specimen are large and strong forking spicules, the principal ray being about 1.5 centimetre in length, with a bulb or expansion at base, giving off two or more shorter and stout rays. They are quite different from any of the forms found at Metis.

These specimens are from beds referred to the Levis or Sillery formation, and are therefore approximately of the same age with those at Metis. They indicate the wide distribution of Hexactinellid silicious sponges in rocks of this period, and hold out the prospect of the discovery of additional species.

Mr. Ami also showed me a new sponge recently discovered by him in the Utica Shale at Ottawa. It consists of radiating groups of long slender simple spicules in a pyritized state. He hopes to make further collections from the same bed before describing these interesting forms, which resemble the spicules of the Pleistocene *Tethea Logani*, so common in the Leda clay of the St. Lawrence, but which may possibly be root spicules of a Hexactinallid sponge, as there are obscure cruciform spicules on the same slab.

Notes on Sponges from the Quebec Group at Mètis, and from the Utica Shale.

By George Jennings Hinde, Ph.D.[1]

Through the kindness of Sir J. W. Dawson, F.R.S., I have had the opportunity of studying a series of specimens of the fossil sponges lately discovered in the Quebec group at Little Métis by Dr. Harrington, and also of an example of *Cyathophycus reticulatus*, Walcott, from the Utica shale formation. The Metis specimens are specially interest-

[1] These Notes, kindly communicated by Dr. Hinde, arrived after the previous paper was in type; and are added without change. —J.W.D.

ing since they throw much fresh light on the character of the earliest known forms of these organisms, and their discovery is the more opportune from the fact that our knowledge of the existing hexactinellid sponges—the group to which all, or nearly all, these fossils belong—has been vastly increased by the work of Prof. F. E. Schulze, of Berlin, on the hexactinelled sponges dredged up by the Challenger expedition, and thus we are now better enabled than hitherto to compare the fossil and the recent forms.

Sir J. W. Dawson has already given a preliminary account of the character and stratigraphical relations of the rock in which the sponges occur, as well as some details of the fossils themselves, and at his invitation I now add some further comments thereto.

In the present specimens, the amorphous or soluble silica of which their spicular skeletons were originally composed, has entirely disappeared, and the spicules now consist of iron pyrites. This replacement by pyrites is of common occurrence, more particularly in a matrix of black shales; for example, the earliest known sponge, *Protospongia fenestrata*, Salter, from the Cambrian rocks of South Wales, is in the same mineral condition, and in a nearly similar matrix, as the specimens from the Quebec group and the Utica shale. When thus replaced, the general outline of the larger spicules is fairly distinct, but where the spicules are minute, and in close proximity to each other, their individual outlines are blurred by the tendency of the crystals of the replacing pyrites to amalgamate together so as to form a coutinuous film of the mineral in which the finer spicular structures are quite indistinguishable. This coalescence of the pyrites likewise makes it very difficult to determine whether the spicular elements of the sponge were organically soldered together into a silicious mesh, or whether they were merely held in their natural positions by the soft animal structures, and owe their present union to subsequent fossilization.

Next to the chemical changes, we have to take into account those produced on the original structures of these sponges by what may be termed the mechanical influences of fossilization. There can be no doubt that they were hollow sacci-form or vasi-form structures with very delicate walls of spicular tissue, supporting the soft animal membranes. They existed at the surface of the soft ooze of the sea-bottom, probably their basal portions were embedded in it, and they were furnished with elongated spicules whose extension into the mud served to anchor them in one spot. After the death of the animal, and the decay of the soft tissues, the delicate skeletal framework would be gradually buried in the accumulating sediments, until by their weight it became completely flattened. Under favorable circumstances, the outline of the sponge and the natural arrangement of the spicular skeleton would be preserved, and this is fortunately the case with the specimens of *Cyathophycus* from the Utica shale, and to a partial extent with one of the specimens of *Protospongia tetranema.* More frequently, however, probably owing to currents and other causes acting at the surface ef the ooze, the skeletal framework is partially or wholly broken up, so that only small patches of the connected skeleton, or merely the dislocated and detached spicules irregularly scattered over the rock surface remain for determination, and this is the present condition of the majority of the specimens from the Quebec gronp. For some reason, probably connected with the arenaceous character of the rock in which they occur, the nearly allied sponges belonging to the Devonian genus, *Dictyophyton,* Hall, usually retain their outer forms complete—that is, without being compressed—but most of these sponges exhibit only internal casts of their spicular skeleton, so that at present we know very little of their original structures.

As already mentioned, nearly all these Quebec sponges belong to the sub-order of the Hexactinellidæ, in which the fundamental type or elementary spicule of the skeleton consists of six equal rays, radiating from a common centre at right angles to each other, forming three equal axes. But this typical form is subject to great modifications through the unequal development or even suppression of one or more of the individual rays, so that spicules with five, four, three, or merely two rays only, are frequently present, and in the same species of sponge several modified forms of spicules may be found. Now, in the compressed condition in which the Quebec sponges occur, we can, as a rule, only perceive those rays of the spicules which lie in the exposed plane of the rock, these are generally the four transverse rays of the normal spicule, but the two rays forming the axis at right angles to the transverse rays, are not likely to be distinguished, for one would be concealed in the matrix immediately beneath the transverse rays, whilst the other, projecting above the exposed surface, would inevitably be broken away. Consequently it is very difficult to determine positively whether the forms with four transverse rays exposed on the plane of the sponge-wall, represent the entire spicule,—in which case it would be termed cruciform,—or whether one or both of the other rays of the normal spicules were originally present. Judging by the analogy of allied recent forms, it is probable that in most cases these spicules were furnished with a fifth ray at right angles to the other four. In the examples of *Cyathophycus* from the Utica shale, are distinct traces of a fifth ray in some of the larger spicules, and it can also be seen in a detached spicule on a slab from the Quebec group.

In both recent and fossil hexactinellids, many of the elongated filiform anchoring spicules terminate distinctly in four short recurved rays, and are thus five-rayed spicules in which one ray is greatly developed; but in other instances they have simple blunt or pointed ends, and may thus represent only one ray or one axis of the normal spicule. With one doubtful exception, all the anchoring spicules present in the Quebec sponges are merely pointed at their distal ends.

In recent hexactinellid sponges, in addition to the spicules forming the regular framework of the skeleton, there are much smaller spicules of varied forms, imbedded in the soft tissues. These, generally known as flesh-spicules, are very seldom met with in the fossil condition, but it is not improbable that the delicate film of pyrites, seen in places on the surface of the Quebec sponges, may arise from the replacement of the flesh-spicules by this mineral.

Sir J. W. Dawson has already classified and given provisional names to the Quebec sponges, and it will therefore be more convenient for me to refer to their generic and specific details under these names.

Genus, Protospongia, Salter.

Protocpongia tetranema, Dawson.

In the one specimen in which the outline of the sponge has been preserved, the body appears to have been elongated oval, measuring about 45 mm. in length by 30 mm. in width. Very probably there was an aperture at the summit, though it cannot now be distinguished. The wall of the sponge appears to have consisted—as in the other species of this genus—of a single layer of cruciform (?) spicules of various dimensions, disposed so as to form a framework with quadrate or oblong interspaces; the rays of the larger spicules constituting the boundaries of the larger squares, and within these, secondary and smaller squares are marked out by smaller spicules. Judging by the length of the rays of the larger spicules, the larger squares would be about 6 mm. in diameter, whilst the smallest do not exceed 1 mm. The rays of the individual spicules slightly overlap, and it is probable that they may have been lightly cemented by silica at the points of contact. The rays of the larger spicules are conical, gradually tapering from the central node to the blunted extremity; whilst the rays of the smaller spicules appear to be nearly cylindrical.

From the base of the sponge, four slender elongated filiform spicules project. They are approximately cylindrical, pointed at both ends, from .1 to .25 mm. in thickness, and from 50 to 70 mm. in length. Their proximal ends are inserted apparently in the basal wall only of the sponge, and they project in the same direction, though not in lateral apposition with each other. In some specimens their distal ends converge and appear as if united terminally, but this may be merely due to chance overlapping.

This species appears to have been the prevailing form at Métis. Four specimens have been sent to me; in two of these the spicular frame-work of the body of the sponge retains in places its natural arrangement; in the other two the framework has been almost entirely broken up, and its constituent spicules irregularly mingled and compressed together. But in every specimen there are four anchoring spicules occupying the same relative position to the framework or body-wall of the sponge, thus clearly showing that they are essential to the species. In the spicules of the body-wall only four transverse rays can be distinguished, but it is quite possible, as already mentioned, that a fifth ray may have been present. On one of the rock-slabs there is a detached spicule in which the fragmentary stump of a fifth ray can be clearly seen projecting from the central node of the transverse rays. The rays in this spicule are unusually long, one can be traced for 30 mm.

There can be no hesitation in placing this form in the genus *Protospongia*, since the same arrangement of the spicular mesh-work is present in it as in the type of this genus. In no other examples of the genus, however, has the presence of anchoring spicules been recognized, owing, no doubt, to their imperfect state of preservation, and this feature may now be reckoned as one of the generic characters.

There are also differences of opinion as to the character of the spicular mesh-work and the systematic position of *Protospongia*, and fresh light on the points contested is afforded by these Quebec specimens. It has been doubted whether the body-wall of the sponge merely consisted of a single layer of spicules, or whether this layer corresponded to the dermal layer in other sponges of this group, and, as in these, was supplemented by an inner spicular skeleton. The evidence of the Quebec specimens favors the view that the body-wall of the sponge consisted only of a single layer of spicules. Various opinions have likewise been held as to whether the body-spicules were free, and merely held in their natural positions by the soft animal tissues, or whether they were cemented together by silica at the points where their rays are in contact. Professor Sollas, in an able paper on the structure and affinities of the genus (Quart. Journ. Geol. Soc., Vol. 30, p. 366), asserts "that they are separate, and not united either by envelopment in a common coating or by ankylosis," whereas it has seemed to me that a certain degree of organic union must have existed to have allowed even the partial preservation of the mesh-work of the body-wall in the fossil state, and I have regarded the delicate film of pyrites which extends over the mesh-work in many specimens, as indicating a connected spicular membrane which served to hold the larger spicules in position. From the study of the Quebec specimens I still think a certain degree of organic attachment existed where the spicular rays were in contact, but I am quite prepared to admit that it was not of the same complete character as in typical Dictyonine hexactinellids. Prof. F. E. Schulze has clearly shown that a certain degree of irregular coalescence takes place in the body-spicules of undoubted Lyssakine sponges, and now that we know that *Protospongia* was furnished, like most of the sponges of this group, with anchoring spicules, there is good reason to regard this and the allied palæozoic genera as belonging rather to the Lissakine than to Dictyonine hexactinellids. This is the position assigned to them by Carter and Sollas.

Genus Cyathophycus, Walcott.

The two specimens of *Cyathophycus reticulatus*, Walcott, —the type species from the Utica shale*—exhibit the structural features so very clearly, that it seems desirable to refer to the generic characters, as shown in these specimens, before referring to the Métis specimens which have been placed in this genus.

The specimens are, as already described by Sir J. W. Dawson, compressed side by side on the surface of the same

*These specimens are from the collection of the late Mr. J. S. Miller, of Ottawa, and their locality is uncertain; but the formation is determined by a Trilobite on the same slab They perfectly resemble specimens from the original locality of Walcott in New York. J. W. D.

slab of shale; their spicules have been replaced by pyrites precisely the same as in the Métis specimens. The sponges were evidently vasiform, gradually increasing in width from the base upward, their summits have not been preserved, but with a length of 65 mm. they are 40 and 30 mm. in width, respectively. Owing to compression, the opposite walls are now nearly in contact, being only separated by a mere film of the shaly matrix, hardly half a millimetre in thickness. The shale has split in such a manner as to expose in some places the outer surface of the wall, and in others, the inner surface of the opposite wall.

The wall is very delicate, and consists of quadrate or oblong areas formed by slender longitudinal and transverse strands or fibers, of which the former are the more prominent. As in *Protospongia*, the quadrate areas are formed by the four transverse rays of cruciform, or five-rayed spicules, but these are disposed so that their rays overlap each other, and thus form fascicles of closely opposed parallel rays. The spicules in the transverse strands of the wall are less thickly grouped together, and even in some of the larger squares they may be arranged singly, whilst the smaller squares are generally bounded by single spicules only. The longitudinal strands principally consist of cruciform (?) spicules, but it is possible that elongated filiform spicules may likewise be present. There are plain indications of a fifth or distal ray in many of the principal spicules of the wall, shown by a very minute knob or blunted process projecting from the central node of the transverse rays, which may represent a partially developed ray, or the broken stump of a complete one. In some places, also, there is a continuous film of pyrites, probably indicating a membrane of very minute spicules or an agglomeration of flesh-spicules, now replaced by this mineral.

The basal portion of these specimens is incomplete, but there are indications of an extension of the longitudinal strands of the wall downward into the a tuft of anchoring spicules.

This genus is mainly distinguished from *protospongia* by the fascicular arrangement of the spicular rays in the principal longitudinal and transverse fibres. The regular quadrate areas of the body-wall also mark it off from *Plectoderma* and *Phormosella*, Hinde. (See Brit. Foss. Sponges pt. i. pl. iii., figs. 1, 2 and pt. ii. p. 124-5, Pal. Soc., 1886-7.) How far it may resemble *Dictyophyton*,* Hall, and the other genera associated therewith by Prof. Hall [35th Report of the State Museum (1884) p. 465, pls. 18-21], it is impossible to state, for, so far as I am aware, the structural features of this genus have never been sufficiently described, and the characters assigned to the other genera are mainly those of external form, which, as regards this group of sponges, are hardly of generic importance.

The structures of *Cyathophycus*, as shown in these specimens, bears a great resemblance to that of the recent genus, *Holascus*, Schulze, (Challenger Reports, Vol. xxi., p. 85) based on sponges dredged from depths varying between 1375 and 2650 fathoms in the South Atlantic and in the Southern Ocean. There is a striking similarity in the structure of the sponge-wall in the fossil and in the original specimens described by Schulze, now in the British Museum of Natural History.

Cyathophycus Quebecensis, Dawson. (No. 3 of previous paper.)

One of the specimens thus named is the basal portion of an apparently elongated tubular sponge, the wall of which consists of cruciform spicules disposed in longitudinal and transverse fibres, as in the type of the genus. The specimen is too imperfect and the spicular mesh too broken up to permit of minute discription. On other rock-fragments are fibres or strands of straight elongated spicules, either parallel with each other or irregularly scattered over the

* If the spicular structure of *Dictyophyton* should prove similar to that of *Cyathophycus*, this latter named will have to be suppressed in favor of the former, which has the priority. Both these names, applied under the supposition that the organisms were plants, are alike unsuitable, and it might be advisable, as suggested by Prof. Whitfield, to reinstate Conrad's original name, *Hydnoceras*. [In the only species of the Dictyospongidæ in which I have seen structure, that named by Whitfield *Uphantenia Dawsoni* (Am. J.

surface and intermingled with detached cruciform spicules. These various forms may well have been the anchoring and body-spicules of examples of the same species, now disintegrated and compressed together.

Hyalostelia Metissica, Dawson. (No. 2 of previous paper.)

This species is based on detached cruciform and anchoring spicules, the latter somewhat more robust than those placed as *C. Quebecensis*. In the present fragmentary condition of these forms it is impossible to give a satisfactory description, and the species must be regarded as provisional until better specimens are discovered.

Sponges of uncertain character. (Nos. 4 and 5 of previous paper.

On some of the slabs from Métis are small oval compressed patches, apparently consisting of small fusiform acerate spicules, sometimes parallel, at other times crossing each other irregularly. They do not stand out definitely as in the case of the hexactinellid sponge spicules, but appear to be embedded in some membrane. In two instances, anchoring spicules, like those of *Protospongia*, project from the base of the mass. I do not know of any monactinellid sponge furnished, as these appear to have been, with long anchoring spicules. Sir J. W. Dawson has suggested a resemblance to *Lasiocladia*, but they do not belong to this genus.

In another specimen an elongated space about 50 mm. in length by 16 in width, with well-defined margins, is covered with a thin film of pyrites, which may have resulted from the replacement of a mass of minute spicules, of which traces remain in some places, but no structure whatever can be recognized in it now. Sir J. W. Dawson has provisionally named the fossil *Halichondrites*.

Science, Aug., 1881, and Bulletin Am. Num. Nat. Hist., Dec., 1881), the spicules are apparently filiform and arranged in broad longitudinal and tranverse bund?es crossing each other, and with small, loose flesh-spicules in the meshes. They are therefore different from those of *Cyathophycns*, or, as it should now be called, *Cyathospongia*. *Hydnoceras* is liable to the objection that it was intended to indicate affinity to cephalopod shells. J. W. D.]

EXAMINATION OF SOME MANITOBA WATERS.

A. McGILL, B. A., B. Sc.

The following results of the examination of the solids contained in certain waters from the Province of Manitoba, possess interest as illustrating to a certain extent the character of the water supplies in the region from which they were taken; a region whose mineral peculiarities have, as yet, come but little under the notice of the chemist. The object for which the assays were made, required only the estimation of the substances given in the table. I am indebted to the courtesy of W. R. Baker, Esq., Superintendent of the Manitoba and North Western Railway, for information regarding the sources of the water:

No. 1. From the *White Mud River*, at Westbourne.

No. 2. From the *White Mud River*, at Gladstone.

No. 3. From a well 30 feet deep, through sand and clay, at Portage la Prairie.

No. 4. From a well 30 feet deep, through sand and clay, at Neepawa.

No. 5. From a well at Minnedosa. The well is 20 feet in depth, through clay, hard pan, shale and gravel; and is situated a few hundred feet from the Little Saskatchewan River.

No. 6. From a well at Strathclair. The well is 34 feet deep, through blue and yellow clay, with boulders, sand and gravel.

No. 7. From a well at Rapid City. The well is 12 feet deep, through hard pan, shale and gravel.

No. 8. From a well at Kelloe. Total depth of well, 91 feet. It was sunk through hard boulder clay to a 12-inch vein of clay, under which water was found, which rose to a height of 40 feet in the well.

No. 9. From a well at Basswood. The well is 20 feet deep, through a quicksand.

No. 10. From a well 195 feet deep, at Birtle.

No. 11. From a well at the 174th mile of the Man. and N. W. R. R. The well is 162 feet deep.

In the table appended, all the results of analysis are expressed in parts per 100,000.

Sodium was estimated only in No. 8—and iron only in No. 1.

PARTS PER 100,000.

No.	1	2	3	4	5	6	7	8	9	10	11
Total suspended matter, dry at 100° C.	Trace	Trace	Trace	Trace	Trace	Trace	2.0	2.5	1.6	17.5	11.7
Total dissolved matter, dry at 100° C.	99.8	89.0	56.9	......	50.5	114.5	......	294.0	57.1	132.4	310.6
Same on ignition	97.0	82.0	53.0	37.5	47.3	106.5	47.2	288.0	35.8	124.0	259 2
Silica, (SiO_2)	6.6	5.0	4.5	5.8	6.6	6.9	5.4	4.5	10.4	2.4	38.0
Chlorine (in chlorides)	5.98	2.16	0.77	0.63	0.84	0.77	1.11	20.88	0.696	4.176	5.29
Sulphuric Acid (stated as SO_3)	7.69	10.57	7.037	0.996	9.714	36.637	9.339	112.67	0.277	47.775	127.31
Lime, (CaO)	26.544	23.408	14.224	13.216	12.432	30.352	14.220	20.050	12.990	23.240	38.08
Magnesia, (MgO)	10.379	8.793	7.100	4.577	6.414	11.100	5.766	9.802	1.874	8.793	10.886
Sodium, (as $NaCl$)	......	......	......	......	......	......	......	177.0	......	......	......
Iron, (Fe)	0.36	......	......	......	......	......	......	......	......	......	......

On the Classification of the Cambrian Rocks in Acadia.

By G. F. Matthew, M.A., F.R.S.C.

[In continuation of a paper in this journal on a Basal Series of Cambrian Rocks in Acadia, Vol. III., No. 1, 1888.]

Our acquaintance with the Cambrian rocks of Eastern North America has now reached that point where it may be profitable to suggest the outlines of a general classification of these deposits, in accordance with the scheme laid down by the International Congress of Geologists.

By the term Cambrian, we understand the strata containing the Primordeal Fauna of Barrande, both those which contain it exclusively, and those which hold its later, modified representatives, mingled with the types of the Second Fauna; and also the antecedent forms, which lead up to the typical primordeal genera. The base of the system is defined in the preceding paper, and the summit is best marked by the appearance of the early typical graptolites of the genera *Tetragraptus*, *Didymograptus*, *Phyllograptus*, &c. These, with the associated trilobites of the Second Fauna, form the natural base of the Ordovician System.

Prof. Jules Marcou expresses a similar view in his limitation of the formations (terreins) which are included in the system called by him Taconic, but which is equivalent to the Cambrian, as defined above. His three divisions of the system are the Infra-primordeal, the Primordeal, and the Supra-primordeal. But, if Mr. Walcott is right in counting the Georgian Series as Middle Cambrian, the term Supra-primordeal hardly expresses the immense development in America of the Potsdam, in which many genera are analagous to those of the Second Fauna. Similar genera are found in the Regio Ceratopygarum of Angelin in Sweden, and in the "Fauna of Hof" in Bavaria, which Barrande did not exclude from the Primordeal Fauna.

At the base of the Cambrian System in Europe and other regions are comparatively barren measures, which, as their faunas are made known, will, no doubt, be bound to Primordeal Fauna by biological links. Such is the Regio Fucoidarum of Angelin in Sweden, and the Caerfai Group in Wales. The process of unfolding the faunas of these initial terreins and stages of the Cambrian is now in progress, and has already given some remarkable results, both in Europe and America.

Applying these data to the classification of the Cambrian System in Acadia and Newfoundland, we find indications of the following series :—

Series A.—The Basal Series, or Eteminian.[1]
" B.—The St. John Group, or Acadian.
" C.—The Lower Potsdam, or Georgian.
" D.—The Potsdam Sandstone and Limestone.

Series A.

The terreins which in Newfoundland and Europe are supposed to be of equal age with this series, have been described in the previous paper.

There are, however, in America, further west, formations (terreins) that have been described by geologists as pre-Cambrian, some of which may be of equal age with this series. But as the Series B. has not been recognized in the central and western parts of North America, and these terreins have not yielded distinctive fossils, the means of determining their relation to the Eteminian Series are wanting.

Such formations are the Kewenawan and Animiki of Lake Superior, and the Chuar Group and underlying strata west of the Rocky Mountains. Messrs. Hague and Walcott were at first disposed to class the Chuar Group as Cambrian, but the latter now thinks it is of greater antiquity.

In the Lake Superior region no fauna older than that of the St. Peter's Sandstone has been established; so there remains the whole range of the Cambrian, as well as possibili-

[1] Named from the Etchemins, the aborigines of New Brunswick and Maine.

ties of older formations, within which the terreins around Lake Superior may be classed. Until the controversies relative to the comparative age of those rock masses are settled by the discovery of characteristic faunas, we cannot tell how they compare with the older series, or the Cambrian System, in Eastern North America.

Series B.

In speaking of the sub-divisions of this series, the writer proposes to use hereafter the terms recommended for divisions of a rank inferior to "Series." The term "Stage" will therefore take the place of "Division," as heretofore used in describing the parts of this terrein.

Stage 1. This includes the lower part of the series, as high up as Paradoxides are found. The divisions of this stage are as follows:—

Band (Assise) *a*. Hard grey sandstone or quartzite. Fossils: none known.

Band (or Assise) *b*. Dark-grey sandstones and grey sandy shales. Fossils: *Ellipsocephalus, Agraulos, Hipponicharion, Beyrichona*, &c.

Band (or Assise) *c*. Grey shales. Fossils: *Paradoxides, Conocoryphe, Liostracus, Microdiscus, Agnostus*, &c.

Band (or Assise) *d*. Dark-grey shales. Fossils: *Paradoxides, Ptychoparia, Solenopleura, Microdiscus, Agnostus*, &c., of different species from those in Assise *c*.

Stage 2. This consists of grey flags and sandy shales. The sub-divisions have not been worked out, but the stage corresponds to the lower half of the Olenus Zone in Europe. No species of the genus Olenus have been found in it.

Stage 3. Dark-grey and black shales. Fossils: *Ctenopyge, Kutorgina, Orthis*, &c. This corresponds to the upper half of the Olenus Zone of Europe. The shales in Cape Breton, which contain *Peltura* and *Sphærophthalmus* belong here. There are in the St. Joh

Basin grey flags, which overlie the Ctenopyge beds, but no higher stage than the Olenus Zone has been established by fossils.

SERIES C.

This, the "*Lower Potsdam*" *of Billings, or* "*Georgian*" of Mr. Walcott, has not been recognized on the main land of Acadia, but is found in the island of Cape Breton, where the fossils are *Bathyurus* (sub-gen ?), *Orthisina, Orthis, Hyolithes princeps.*

We place this series *provisionally* above the Series B. for reasons that will appear in the sequel, but a few considerations militating against this view may be mentioned.

Mr. A. Murray, late provincial geologist of Newfoundland, in his reports and sections of the Cambrian formation in the peninsula of Avalon, in that island,[1] places the limestone beds of Topsail Head and Brigus, in Conception Bay, below the Paradoxides beds. But, perhaps, it would be more correct to say that this limestone, by his observations, appears to be included in the Paradoxides Zone, as the horizon of Conocoryphe at Manuel Brook, not mentioned by him, is found below the limestone.[2] Mr. Walcott asserts that the fossils of this limestone belong to his Middle Cambrian or Georgian fauna, and explains the anomaly of their presence in the Paradoxides measures of Conception Bay, on the ground that they form an unconformable overlying series.[3]

Dr. W. C. Brögger, of Stockholm, in his review of the "Eureka Palæontology," urges several reasons for regarding the Georgian series as older than the Acadian.[4] Some of these reasons will be referred to hereafter, in connection with the genus Olenellus, but one may be mentioned here.

[1] Geol. Survey of Newfoundland, London, 1881, pp. 238 and 239.

[2] Mr. Murray includes in his section the conglomerate of Manual Brook, which is immediately below the Concorphe shale.

[3] U. States Geol. Survey, Bull 30, p. 49.

[4] Om alderen af Olenelluszonen i Nord Amerika, p. 195, &c.

In Europe it has been found that there is a great preponderance of species of Agnostus in the lower part of the Paradoxides Zone. There are in the—

Ceratopyge limestone and shale, 2 species.
Olenus Zone (4 in the lower part), 5 species.
Paradoxides Zone (25 in the lower part), 29 species.
Zone of Paradoxides (?) Kjerulfi, 0 species.

Dr. Brögger calls the last named the Olenellus Zone, on account of the genetic relations of Olenellus to *P.* (?) *Kjerulfi*, and compares the absence of the genus Agnostus at this horizon in Europe, with the scarcity of it in the true Olenellus Zone in America, and then shows that species of Agnostus are more numerous in the Acadian than the Georgian Series in America, as they are in the Paradoxides Zone, when compared with the Zone of Olenellus (?) Kjerulfi in Europe. But if the Olenellus Zone of America be compared with the Ceratopyge beds of Europe, it will be seen that that group also is characterized by a paucity of species of Agnostus.

One of the most characteristic genera of the Georgian Series is *Olenellus.* Of its close relationship to Paradoxides there can be no question, and yet it is associated with an assemblage of species differing widely from those of the Paradoxides Zone in Europe. There is the further remarkable feature that Olenellus is more closely related to the older species of Paradoxides, than to the later; indeed, so close is this relation to the earliest Paradoxidean form in Scandinavia, that this form, *P.* (gen. ?) *Kjerulfi*, has been called Olenellus. As long as the pygidium remained unknown, there was much to sustain this view of its generic relations; but now that this part of the organism (a very important part in the economy of the trilobites) has been recovered, and is found to conform to that of Paradoxides, and not of Olenellus, it is evident that the species cannot be referred to the latter genus.

On the other hand, the admirable study of this species carried out by Gerhard Holm[1] shows that it differs from

[1] "Om Olenellus Kjerulfi," in "Geol. Fören. i Stockholm," 1887.

Paradoxides in such important points, particularly in the absence of adorsal suture, as well as in having three prominent furrows on the glabella (in place of the two or four of Paradoxides), and especially in its peculiar hypostome, that it must be regarded as a genus intermediate between Paradoxides and Olenellus.[1]

Since Olenellus thus finds its nearest relative in the fauna of Series B., at the base of that series, are we, therefore, to regard the fauna of Series C, of which Olenellus is a part, as older than that of Series B.? If Mr. Murray's stratigraphical work in Newfoundland is correct, this would appear to be the case. In any event there is the possibility that Olenelloid forms in some part of the world, were contemporary with Paradoxidean forms in another part: but only the possibility, as the Paradoxidean stem may have thrown off genera resembling Olenellus in the earlier, as well as in the later stages of its existence.

Having considered some points which favour the view that the Georgian Fauna is of greater antiquity than the Acadian, we may now take notice of those which have a contrary tendency.

A prevalent and very striking genus of this series is *Dorypyge* of Dr. W. Dames.[2] Of this genus, one species (the type) is known in China and four in America.[3] In the latter region the species of this genus are found in the same layers with those which contain Olenellus,[4] and, therefore, are of equal antiquity. In China the latter genus has not been found with Dorypyge, which has with it only a Ptychoparian[5] form, telling only that the enclosing strata are Cambrian. Dr. Dames compares Dorypyge to Peltura and Parabolina, as the most

[1] It is to be hoped that his countrymen will see reason to connect Holm's name with this new genus.

[2] Included by Mr. Walcott in Olenoides, U. S. Geol. Surv. Bul. 30, p. 221.

[3] D. quadriceps, D. Wasachensis, D. Marcoui and D. Fordi.

[4] U. S. Geol. Survey Bull. 30, pp. 26 and 32.

[5] Liostracus megalurus, Dames.

nearly related genera; to the former there is considerable resemblance, but the thorax and pygidium of the latter are of a different port. He also remarks of the rocks in China, in which this genus is found,[1] that there is, so far, no horizon in Europe to which, with confidence, they can be paralleled; but adds that there are some observations [which lead to the view] that the slates with Dorypyge belong to the horizon of the Scandinavian Ceratopyge limestone. Species of other genera occurring with the Chinese Dorypyge have been compared by Dr. Dames with those of the Potsdam sandstone in Wisconsin, especially with those of the central portion of that formation. These sandstones are regarded by Walcott as younger than the Georgian series; so in the associated genera there is nothing to lead to the supposition that Dorypyge marks an older horizon than the Ceratopyge limestone and shale. Dr. Brögger also admits that Dames places together the Chinese limestone with Dorypyge and the Ceratopyge limestone of Sweden.[2]

As for Olenoides (proper) of Meek, we see in it a much closer relation to Parabolina of the European Cambrian beds than can be observed in Dorypyge. To judge by the sections of the Cambrian rocks in Western North America, given by Mr. Walcott, the genus belongs to a somewhat higher horizon than Olenellus and Dorypyge, a conclusion which may also be gathered from the species of other genera associated with it. Olenoides may be considered as having its representatives in Europe in the upper part of the Olenus Zone.

Another consideration which militates against the greater antiquity of the Georgian Series is the presence in it of several genera of trilobites as *Protypus*, *Bathyuriscus* and *Asaphiscus*,[3] in which the size of the head-shield, thorax and pygidium are nearly equal. Such genera predominate in

[1] Cambrian trilobites of Liau-tung, China, p. 33. in Richthofen's China, vol. iv.

[2] On alderen, &c., p.

[3] Compare *Nileus* and *Niobe* of the Tremadoc and Ceratopyge beds, with these genera.

the Ordovician or Second Fauna, and in Europe they first appear about the horizon of the Ceratopyge shales.

Other trilobites help to establish this connection, as the Chinese Conocephalites,[2] and Dames himself compares the Chinese Agnostus with *A. cyclopyge* of the upper part of the Olenus Zone in Europe, and with species of Lower and Upper Potsdam age in America.

These observations on the trilobites serve to show that the fauna, of which they form a part, is younger than the Acadian series, or at least younger than Stages 1 and 2 of that series. If, on the other hand, we were to regard the Georgian Series as the older, we would be met by greater anomalies in the vertical distribution of the genera than if we adopt Dames' suggestion as to the age of the corresponding series in China, and place it with the Scandinavian Ceratopyge limestone.

Similar arguments as to the more recent age of the Georgian fauna might be drawn from the brachiopods; among which Orthisina may be referred to. This genus is unknown in the Acadian Series, and in Europe we do not know of it in the Cambrian at all; but it is a well-known genus of the Ordovician system. Hence the presence of three species of this genus in the Georgian fauna gives it, as a Cambrian fauna, a decidedly modern facies.

The palæontological relations of the Georgian fauna may be summed up in the table on the following page, from which it will appear that they are decidedly with the faunas of the upper rather than the lower part of the Cambrian System:—

[2] Compare *Conocephalites typus*, Dames, with *C. teucer*, Billings; also *Anomocare latilimbatum*, Dames, with *Ptychoparia Pichoensis*, Walcott; also, *A. planum*, Dames, with *Conocephalites Adamsi*, Billings.

AFFINITIES OF THE CHARACTERISTIC GENERA OF THE GEORGIAN FAUNA.

Cambrian in Europe, principal part.		Stages of the Acadian Series.
4. Ceratopyge limestone and shale.	Orthisina affinities, with species above 4. Bathyuriscus } Asaphiscus } affinities with genera in 4 and above. Protypus }	
3. Upper Olenus beds.	Bathynotus affinities with genera in 3 and above. Dorypyge affinities with genera in 3 and 4.	Stage 3.
2. Lower Olenus beds.	Ptychoparia " " species in 3 and 4. Agnostus " " " in 3. Olenoides " " genera in 3.	Stage 2.
1. Paradoxides beds.	Microdiscus " " species in 1. Olenellus " " genera in 1. Mesonacis " " genera in 1.	Stage 1.

A further point for consideration, seeing that the Georgian Series, by its fauna, is for the most part younger than the Acadian, is as to whether it overlaps the latter; that is, whether the Georgian epoch was cotemporary with the closing part of the Acadian. The majority of the trilobites of the Georgian may be said to compare with those which in Europe, mark the upper part of the Olenus Zone and the Ceratopyge beds; but this is by resembling genera only, while we know Stage 3 of the Acadian Series to be equivalent to the upper part of the Olenus Zone by identical genera, and even by identical species. The upper part of the Acadian would, therefore, be near the Georgian in time; but whether it is cotemporary with the latter or not, can only be established by an examination of the region where they come together, namely, in Cape Breton and Newfoundland. In the former island they are separated only by a low, narrow range of pre-Cambrian hills, and in Newfoundland, according to Mr. Walcott, they are in actual contact; yet we do not know that in either of these islands there it any mingling of the two faunas. In the St. Lawrence Valley and Gulf, the Georgian Series is present at several localities, but no trace of the Acadian has been found. These conditions seem to indicate that the two series are entirely independent of each other, in which case the Georgian would be the more recent.

But if there is no overlap, as would appear from these conditions, then the Georgian can be of no greater antiquity than the Ceratopyge beds, and the 4,800 feet of Middle and Upper Cambrian in the Eureka district west of the Rocky Mountains, would be represented by the 1,000 of the Tremadoc Group in Wales, or the very much thinner Ceratopyge beds of Sweden.

SERIES D.

Of the relation of the Potsdam Series to the Georgian there is less doubt than hangs around the connection of the latter with the Acadian Series. Mr. Walcott's fortunate discovery of the highest bed of this series in the Saratoga limestone, has enabled him to show its equivalency to the highest Cambrian sandstone in Wisconsin. This group, characterized by the genus Dikellocephalus of Owen, appears to be equivalent to the Ceratopyge limestone, or the Tremadoc Group, and would represent the upper part of the Tremadoc, as the Georgian Series probably does the lower.

This, the upper, or true Potsdam, appears to form in Eastern North America a fourth series of the Cambrian system, since its distribution is not coincident with that of the Series C.,, but it is apparently wanting in the region to which this article relates. The Potsdam series is present in the upper part of the St. Lawrence Valley, and in the middle and Western States, but absent, as far as known, from the eastern border of the continent.

In Eastern North America, then, the Cambrian System is represented by the following series:—

	New England.	N'w Brunswick	Nova Scotia.	Newfoundland.
Series D., (Potsdam)	present, at the western border.	not known.	not known.	not known.
Series C., (Georgian.	present, at the western border.	not known.	present.	present.
Series B., (Acadian)	present, on the Atlantic coast.	present.	present.	present.
Series A., (Etominian)	not known.	present.	not known.	present.

The Climate of the Canadian West.[1]

By Ernest Ingersoll.

It may seem presumptuous in me, the citizen of an outside power, however friendly, to come before an audience of Canadians as a lecturer upon their own country. But, in extenuation, I may plead that it has been my fortune to travel a great deal in all parts of Western America from Mexico to British Columbia; and, consequently, that I am not speaking from hearsay alone, but in the light of personal experience.

The climate, or rather climates, for there are several distinct climatic areas, of the vast western half of Canada, is, however, a matter of fact and science rather than of experience, and an intelligent man, though he had never been west of Lake Superior, nor heard a single word about its actual weather, could predict with much accuracy what kind of climate would be met by explorers in each of its various divisions, simply from knowing the physical situation of each.

For climate is very largely—almost wholly—a function, as mathematicians say, of, first, the latitude, and, second, the physical geography of the region under consideration.

[1] Abstract of a lecture in the Somerville Course, delivered in Montreal, March 15th, 1888.

By physical geography, I mean, here, the way in which the seas, mountains and plains of a sufficiently large district are disposed towards each other; and it is due to the close relation existing between these diversities of surface and climate, that the latter is not a whimsical thing, but one of the steadiest and most characteristic features of any region—even though the *weather* there may, at certain seasons, be most capricious.

The Canadian West I take to mean, for the purposes of this lecture, all of north-eastern America, from the limits of the forests around Hudson's Bay and Lake Superior, westward to the Pacific Ocean.

A glance at the map is the first thing in order.

We find that north of the International boundary line—or, better, let us say north of the watershed between Canadian rivers and those tributary to the Mississippi and the Missouri—there is an immense area of treeless plains nearly a thousand miles wide east and west, and stretching north-west, in triangular form, to the border of Alaska. This may be said to be *one* climatic area, which we may call that of the Plains.

West of the Plains stand the serried ranks of the grand old Rockies, forming a belt of snow-bearing mountains averaging 200 miles in breadth, and rising everywhere into tne zone of perpetual snow and ice. This belt has a climate of its own, which we may term that of the Rocky Mountains. Beyond this lies the interior basin of British Columbia, about as large as Manitoba, forming a third climatic area, which may be named the *Kamloops* Climate, for want of a better term. A fourth climate, that of the rainy Coast Range, is attached to the narrow but lofty rank of mountains improperly called the Cascades, which extend parallel with the Pacific coast in southern British Columbia, and form the coast itself in the northern part of that Province. Last of all, there is the strip of lowland and the tongue-like valleys along the coast itself, together with the islands bordering it, which constitute a fifth climatic area. Each of these divisions is, in fact, a long strip of country, north and south, conforming to the lines of coast and mountain ranges, by which their peculiarities in each case are governed.

We have, then, five separate and natural divisions of the West, each characterized by a climate of its own, depending upon its natural condition, as follows :—

1st—The Plains.

2nd—The Rocky Mountains.

3rd—The Interior of British Columbia.

4th—The Coast Mountains.

5th—The Pacific Littoral.

Let us take these up in reverse order, and so prepare ourselves for a study of the Plains, in which most persons are mainly interested.

It is almost needful, however, to consider the whole West as one, at first, in order to get at the philosophy of the subject in each separate ease.

Remembering the northerly position of Canada, which gives it the general climatic features belonging to the Temperate Zone, we may say that every local peculiarity of climate in the West—at least beyond the central part of the Plains—is due to the arrangement of the currents of the Pacific Ocean, and its winds, on one hand, and to the position of the mountains in reference to them on the other. The reaction of ocean and mountains—of their influences, that is—upon each other, is really what makes the climate; and as the ocean currents and world-winds flow uniformly and unceasingly, while the mountains stand as the very type of permanence,—this reaction is necessarily constant, followed, of course, by uniformity in the visible effects.

With the course of the Gulf Stream all are familiar, and rightly attribute to its indirect influence the warm and moist climate of Great Britain and France, though those countries are as near to the arctic pole as the frigid cliffs of Labrador, where perennial winter holds sway.

Now, in the Pacific the case is the same. A great warm current out of the tropical seas courses up the eastern coast of Asia until it is fended away by the headlands of Siberia and the Alaskan islands, and then turns to sweep southward along the coast of British America. The prevailing winds there, as everywhere else in the North Temperate Zone, are from the West; and these, after passi g across thousands of miles of unobstructed and well-warmed ocean, come to us loaded with moisture. Warm air, you must remember, because expanded by its warmth, will absorb more moisture than cold, so that these Pacific winds are saturated by the time they reach the shore.

Now the mountains begin to do their part.

One cannot appreciate how important is the influence of the mountains of the globe upon its climates, until he stops to think what a state of things would exist in their absence. Weather is simply the state of the atmosphere in respect to temperature, dryness or wetness and the like. What affects these conditions causes a change in the weather. Were the surface of the continents flat, temperature would decrease from the equator precisely in ratio with the latitude, subject only to the influence of winds from the ocean, which would blow with unfailing regularity and continuance, bearing a definite quantity of moisture and depositing it, probably unceasingly, in the same place, year after year. Heat and cold in climate would then be almost entirely a matter of summer or winter, or distance from the equator, and wet weather would belong wholly to certain zones, migrating with the seasons, while all the rest of the world would be arid.

But the irregularities of the surface of the globe interfere with this, and make it a tolerable place to live. Without mountains (if we can conceive of such a state of things) the earth would scarcely be habitable—or at any rate comfortable. But the hills rise up toward the spaces of eternal frost which encircle the globe only a few thousand feet overhead, and act as condensers. The damp ocean air coming near them is cooled down to its dew point—that is, to a point where the invisible vapor of water it carries is changed into perceptible drops, clouds are formed and perhaps rain falls.

The higher the mountains, of course, the greater must be the condensation, because lofty summits are necessarily colder than those of less altitude.

With these general facts in view, let us now enquire as to the particular climates of British Columbia, which is to an extraordinary degree, a region of mountains and sea coast.

Vancouver Island and the Queen Charlotte archipelago have a climate upon which the inhabitants congratulate themselves. They have a mild and even winter, with rain, (the annual rainfall is estimated at 45 inches) and occasionally snow; an early spring; a dry, warm summer, and a clear, bright and enjoyable autumn. Sometimes the frost is sufficiently hard to permit of skating, but this is exceptional. As a rule flowers bloom in the gardens of Victoria throughout the year. The climate is warmer than that of England, and the rainfall is periodic—not irregular. The summer is decidedly dry, so that dust is one of the greatest inconveniences in every settlement. But it is a curious fact that July, the dryest month on the coast, is the time of greatest wet in the interior. Fruits of all kinds indigenous of the temperate climates ripen in the open air, air, and amongst them some that are in England brought to perfection only under glass. Some of my hearers may remember an exhibition of apples, embracing some thirty varieties, all of extraordinary perfection, which grew near the mouth of the Fraser and were exhibited here in the early part of the winter. I have never seen plums and cherries to approach in size or flavor those of that region; and fruit culture will surely be one of the leading industries in the future of that coast. Thunder storms seldom break over the island. They can be heard in the distance but are rarely experienced. It is this climate, combined with the situation of Victoria, that makes that city so pleasing a contrast to those who visit it from the hot valleys of California.

Yet in the Interior of Vancouver Island mountains that rise more than 6,000 feet above the sea level not only hold the snow the year round, but even bear glaciers of large size; and the climate of the Queen Charlotte Islands is cooler and more rainy than that of Vancouver, whose northern end, in turn, is less pleasant than its southern part.

Between the western, or oceanic, border of Vancouver Island, and the mainland coast, there is considerable difference, in favor of increased dryness and greater thermometrical range. That is, it becomes colder in mid-winter, and hotter in mid-summer than on the outer coast of the island. But the extreme in neither season is a hardship, and, on the whole, New Westminster and the new city of Vancouver have an even more agreeable climate than Victoria. People wear the same clothes the year round, and an umbrella must be a pretty constant part of one's outfit, except during the long and beautiful autumn, which is like a far-extended Indian summer.

The explanation of this climate has already been hinted at. The water of the Pacific is warm—20 degrees warmer than that of the North Atlantic near Canadian shores.

The prevailing south-westerly winds, sweeping over its surface, are raised to the temperature of the water, and become saturated with moisture, abstracting from it, and rendering "latent," in conformity with well-known physical laws, a still greater quantity of heat. Wh n, on reaching the mountainous coast, this moisture is condensed and discharged, the latent heat becomes again apparent, and greatly raises the temperature of the atmosphere in which the reaction occurs. Hence the coast climate of the whole north-west coast of North America is warm. The mean annual temperature of Sitka is nearly the same as that of Montreal.

That the climate is wet as well as warm, is owing to the effect of the height of the coasts. The heaviest rainfall occurs in exact correspondence with the height to which the moist air is forced into the higher regions of the atmosphere, and cooled there by its expansion and loss of heat by radiation. In proportion to the elevation of the islands, and the degrees in which they shelter the mainland coast from the rain-bearing winds, the rain fall on the opposite coast is more or less. The comparatively less rainfall of the coast of the south-western section of the mainland, (New Westminster district) than farther north, is owing to the abstraction of part of the moisture of the rain-bearing winds by their striking the mountains on Vancouver Island (where it is very wet), and to the lowness of the land about the mouth of the Fraser river.

This dampness produces that extraordinary growth of gigantic forests and vegetation characteristic of the Pacific slope; but this vegetation is distinctly northern in type, and the climate is far removed from a tropical one, where summer is eternal and proportionately enervating to man and beast. It is, on the contrary, though drier and steadier than England, in ordinary seasons not unlike the western counties, more particularly Devon and Cornwall.

Passing over the uninhabited ranges popularly known as the Cascades, whose summits reach eternal frost, and whose gorges are wet and densely wooded, we emerge on this side into a wholly different region. Instead of the lowlands of the Fraser delta, and the forests of almost tropical luxuriance that choke the narrow mountain-valleys, whose slopes are running with copious streams fed by an almost incessant rainfall, we have here, in the interior of British Columbia, wide areas of grassy plateus and rounded hilltops. The rainfall of this southern interior is, in fact, slight and intermittent, and is insufficient for agriculture, so that farming must rely upon irrigation. For grazing, however, this condition of things is most favorable, and stockraising is likely to be the principal industry as far north as the rough, wooded country, which begins some 50 miles north of the railway. Yet the sky is often heavily clouded; but these clouds sweep overhead from west to east without shedding a drop of rain, though it may fall for days at a time on the mountains each side. The explanation, undoubtedly is: that the hot air, ascending from the heated and treeless plateau continually buoys up the clouds, and at the same time keeps them warmed above the point of condensation. Once in a while there is an interruption of this equilibrium in the shape of what is called a "cloud burst," when the rain will fall in a deluge upon some limited space. It may truly be said of a region like this, that it never rains but it pours. This steady dryness of climate, coupled with its small altitude, makes the Kamloops and Okinagan districts a most excellent retreat for persons with pulmonary maladies, and many men are living there in health, who, would not have survived within years of this time had they remained in eastern Canada. Here, where the thermometer rises occasionally to 110° in mid-summer, and the breeze is like the breath from the door of a furnace, the boastful natives have much to say of the refreshing effect of the cool nights. So they do on the coast, where the very air is sometimes greasy with warm steam and your strength dissolves as in a Turkish bath. But that claim is a matter of course! If there is one thing in this delusive world more certain than another, it is that every son of Adam will tell his friends (and most of all his enemies!) that where *he* lives the nights are cool and there are no mosquitoes.

But to resume: The winds that have swept ungenerously over the Kamloops downs are compelled to yield their burdens of moisture to the mountains on this side of the great Thompson River basin. Here the Gold Range, stretching north and south for 200 miles along the western bank of the Columbia, rears its ancient peaks into the sky and interrupts the westerly gales. Striking this cold barrier, the air is suddenly condensed and drops its rain. One would think, after seeing the downpour upon the Cascades that little would be left in the clouds for any region beyond; yet the Gold Range is as damp as the Cascade, and its fountains nourish the great group of the Shushwap and Okinagan lakes, and keep alive many rivers of the first class.

But the Gold Range is only the westernmost of three huge mountain-ranks, which together form the great *Cordillera* of Canada, a belt of snowy mountains 250 miles in width. It is fifty miles across the Gold Range from Great Shuswap Lake to the Columbia river: It is sixty miles across the Selkirks from the Columbia on the west to the same river on the east of the range; and it is 125 miles from that river across the Rocky Mountains to the plains. None of these three divisions is formed by a single line of elevations, but each consists of lines and groups of mountains almost untraceable in their confusion. They stand athwart prevailing winds, and hundreds of their peaks rise far into the chill regions of upper air, where winter is perennial. The highest are nearest the eastern border, and by the time the winds from the Pacific Coast have struggled between the crags, and swept across the wide snow-fields and ice-beds of the Selkirks and the Rockies, they are almost as dry as the dust of a flour-mill. Hence, of course, the rain-fall and snow-fall are far greater in the Gold and Selkirk ranges, first encountered, than in the Rockies; and the western side of each range is far more wet than the eastern. The snow-fall in the Selkirks amounts to about 30ft. in depth, yet winter there is hardly three months long, and the weather, as a rule, is so mild that explorers and workmen find little inconvenience in tents and shanties, and are only comfortable at work by taking off all their coats and laboring in their shirtsleeves. In the Rockies, on the contrary, the snow-fall is comparatively light, and what falls wastes rapidly, so that the railway is never incommoded in this range. The cold, on the contrary, is often very severe, and the winter of longer duration than in the Selkirks. This contrast is easily explained: We have seen that the warm and damp currents of air from the Pacific Ocean are gradually deprived of their moisture by condensation against the cold peaks of the Gold and the Selkirk ranges of mountains, so that they reach the Rockies almost dry. The very fact of its contact with the ice and snow must cool the air somewhat, of course, but the philosophical explanation is behind this—the *warm* winds of the coast are *cool* winds in the Rockies, because they have become dry winds. In giving up their moisture by condensation they have lost heat; and in their further rarification, due to their lofty flight over the high peaks, they have parted with still more heat, in exact proportion to the height or their ascent. Everyone who has climbed a mountain or gone up in a balloon, has noted how the coolness of the air increases in pace with its rarification. Professor McCleod, in the second lecture of this course, made this plain by his diagrams, showing how an increase of altitude above the sea is equal to an increase of latitude away from the Equator, until, on the tops of very lofty mountains truly polar weather exists. The summits of the eastern Rockies are not much higher, however, than the crests of the Gold and Selkirk ranges; and they are colder than their more western compeers, not because they are higher, but because they are more inland, and hence receive air already dry, rarified and well cooled.

It is this characteristic of the atmosphere of the eastern side of the Rockies—in the neighborhood of Banff Springs, for instance—which gives it such a sanitary value, particularly in diseases of the lungs and throat.

Now let us make a hasty review: The winds of British Columbia are, broadly speaking, from the west. They are warm from the ocean, and loaded with moisture. Condensing into fog at the coast, they give a uniform, English-like, muggy climate along the Pacific coast. Further condensed, they are less foggy, but produce a more cloudy sky and heavier rainfall on the coast mountains. Raised to the elevation of the crest of the Cascades or Coast range, they take a flying leap across the interior basin, discharging little rain on the Thompson valley,—leaving it subject to extreme cold in winter, excessive heat in summer, and drought all the time. Condensed again by the Gold Range, the moist winds give those mountains rain and heat almost equal to that of the Coast Range. Condensed still further, by the Selkirks, there is a copious rainfall and snowfall upon these mountains, and a further giving up of warmth, which greatly tempers the climate; but by the time the Selkirks are past, the winds have lost nearly all their moisture and warmth, and have been rarified by being forced to an average height of seven or eight thousand feet. Hence, when they pass to the Rockies they are dry and cool in summer—dry and very cold in winter. What little humidity and warmth they may retain is almost lost on the western slope, and at the summit of the Rockies the atmosphere is almost perfectly thin, dry and cold. The eastern slope of the Rockies is sparsely supplied with trees, and those of small size, while the rivers are scanty, except those fed by the glaciers and great snow banks conserved upon the cold central heights, and slowly doled out to keep the streams running. No great freshets occur, as happens upon the Pacific slope.

Yet the eastern foothills of the Rockies have a milder climate, and earlier spring and less snow than the western base of the range. Why? Owing to the Chinook winds. But what are the Chinook winds? Currents of warm air—broad sheets—cataracts—of warm air falling down in mid-winter from the top of the Rockies. But why, if the air on the crest, where the wide spaces of snow lie, is deadly cold, should the breezes decending from those snow-fields be comfortably warm in winter? Simply because they *do* descend.

Here is the reversal of the previous condition. The air ascending the western side and at the top of the Rockies is cold because it is losing its moisture and becoming rarified; the air descending the eastern slope becomes condensed, picks up moisture with every part of its descent, and correspondingly develops, or gives up, the latent heat which invariably accompanies condensation, The Chinook, then, is a warm dry wind, manufactured on the spot by the condensation of the mountain air as it sweeps down, increasing in density, absorbing moisture, and yielding up its latent heat. In summer the same breeze seems cool in comparison with the fierce radiation of the baked plains; but it is equally a Chinook.

This wind is marvelous in its effect. To it is due the pleasing dryness of even the deepest gorges and nooks in the rocks in summer, while in winter it clears the plains for hundreds of miles away from the mountains of nearly all the snow—always scanty in amount—with amazing celerity. A northern gale will blow for two or three days, forcing the mercury below zero, and bringing all the wide plains under a foot or two of drifted snow. Cattle, horses and wild game can only huddle in sheltered hollows or hide among the groves along the river banks and hope for better times. All the pasture is covered with a blanket of snow, too deep to let an animal get a bite of grass. Then the wind lulls and a breeze from the west springs up. It is warm—almost balmy in contrast to the biting easterly or northerly snow-gales. Near the mountains only a few hours suffices to lick up all the snow, except from the gullies, into which it may have drifted to a great depth. Cattle and horses find the grass exposed, and resume their feeding. The cold has done them no harm, for there has been no wet snow or sleet. The genial influence of the balmy west wind is felt far down the Mackenzie, enabling the buffalo to wander almost as far as the arctic circle in that part of the country. Winter there, in fact, is neither so long nor so severe as on the lofty plateaus fifteen hundred miles southward, for the height above the sea is only a few hundred, instead of several thousand feet. McKenzie found spring along Peace River, in latitude 56°, so advanced by the 10th of May that the buffalo and their young were cropping the new grass on some of the most exposed uplands.

Eastward from the mountains the influence of the Chinook gradually fades out, and is superseded by the northerly and southerly currents of Manitoba, which flow up and down the great trough of Lake Winnipeg, the Red River valley, and the valley of the upper Mississippi.

In respect to the climate of Manitoba and the Saskatchewan prairies, there is one man to whom all of us are indebted for information drawn from an untiring and early experience, and sustained by a sound judgment. I refer to Prof. John Macoun, of the Geological Survey. His book "Manitoba and the Great Northwest," is a most admirable compendium of information in regard to all the natural aspects of that great region, and I have had it constantly before me in writing out these notes.

The Canadian plains, as has already been said, stretch from Red River westward to the Rocky Mountains, and northward to the forests beyond the Saskatchewan — an area as spacious as Ontario and Quebec together. Over all this area a fair uniformity of climate prevails, characterized by a rigorous, but comparatively short winter, early spring, an intense and fairly rainy summer, and a prolonged dry autumn. The air is dry, healthy and invigorating, the warmth and rainfall favorable to agriculture, the winter weather and light snowfall well adapted to success in raising live-stock. Indian-corn and apples can be grown to the 50th parallel of latitude in Manitoba and still higher farther west; while wheat, barley and all the hardy vegetables attain full ripeness on the banks of the Peace River, in latitude 50°, —the parallel which touches the southern extremity of Greenland.

At Fort Dunvegan, on Peace River, thirteen degrees north of Toronto, or nearly as far as Cuba is south of it, the winters, as I have said, are milder than those of Manitoba or Ontario; and for the seven months, from April to October, constituting the period of cultivation, Dunvegan and Toronto do not vary more than about one-half a degree in average temperature; while, as compared with Halifax, the difference is in favor of Dunvegan. The frosts there do not linger in the spring as late as here in the neighborhood of Montreal, nor do they begin so early in the fall;—and everything which will grow here will ripen there, in many cases with greater luxuriance. Out of 212 species of plants seen along Peace River, near Dunvegan, 138 grow in the vicinity of Toronto, and the rest are such as belong to the Saskatchewan plains. The list includes a native cactus!

In view of these facts, it is evident that mere difference of latitude is of small account; and when we come to examine the isothermal lines marking similarity of mean summer temperature, we find that they curve far northward, the isotherm of an average summer temperature of 65°, which is that of this part of Quebec, curving through Georgian Bay, along the south shore of Lake Superior, and swinging northward through Manitoba and north of the Saskatchewan almost to Peace River. In other words, the temperature in summer of the North Saskatchewan and Peace River valleys is substantially the same as that of Montreal and Quebec. Similarly, the isothermal lines that pass through the thickly settled districts near the southern boundary of the plains are those of northern Ohio and Illinois. In fact, it is a truth proved by long observation, that the summer climate, in relation to agriculture, is warmer all over the western plains than it is in central Ontario. Spring opens earlier, too. Plowing is very often begun, all the long way from Red River to the Rockies, by the last week in March; and in Manitoba, which is the coldest corner, spring is never postponed beyond April 5. In the fall, on the other hand, plowing may generally be continued until the first of December, and sometimes much later. The Lethbridge *News*, of February 16th, this year, (Lethbridge is near Fort McLeod, 100 miles south of Calgary), says: " Winter is generally believed to be practically at an end. The thermometer registered 57° at noon." Early in April, then, the sun dissipates the light snow, the dry air evaporates it, leaving the ground dry, and plowing and seeding go on simultaneously. In a few days the seed germinates, owing to the hot sunshine. The roots receive an abundance of moisture from the thawing soil, and penetrate to an astonishing depth into the loosened loam. By the time the rains and heat of June have come, abundance of roots have formed and the crop rushes to quick maturity. The enormous crops are owing just as much to the opening power of the frost as to the fertility of the soil; this is a peculiarly favorable effect of the swift change from sharp cold to intense heat which characterizes the climate of that region. The summer weather is often extremely hot—frequently reaching 100 degrees; but this is a scorching, not a sweltering heat. It is the direct burning of the sun's rays —not a heat resident in the air: hence you mark an instantaneous and grateful relief when you step into the shade, or catch the breeze. Sunstrokes and loss of vigor through heat, which so often accompany summer days here when the mercury may not go so very high, are almost unknown effects in the West. I hesitate to mention the dear old claim of cool nights, dreading your smiles, yet it is a fact that as a rule they are too cool to sleep uncovered; and a *sultry* night is more rare, even, than a sultry day. This intensity of the heat makes up for the comparative shortness of the season of cultivation, urging grain to a far greater celerity of growth than proceeds in more southerly latitudes: nor should it be forgotten that the high latitude gives greater length of days—far more sunshine and growing time in each 24 hours—than can be had further south. On the Saskatchewan in midsummer the nights are only four or five hours long. It thus happens that vegetation has about as many working hours, so to speak—hours when sunlight is promoting growth—between seed time and harvest, as in the longer season but shorter days of Iowa.

This increased energy of growth has been remarkably manifested in some instances. The early spring wheat cultivated for forty years in the Selkirk settlement, before the birth of Manitoba, was originally an English winter wheat. More lately a winter wheat from Pennsylvania was transformed into a spring wheat in Manitoba after a single year's reproduction. The seed of a certain kind of Indian corn cultivated about Winnipeg was two weeks later in maturing when sown near St. Louis, whence it had originally been brought; but quickness in coming to maturity is in fact, characteristic of all the plants indigenous to the Northwest, and is a quality speedily acquired by imported plants—a point not only in agriculture, but a pretty fact for the evolutionist to ruminate upon.

Furthermore, the cool moist spring checks an undue luxuriance of stem, and allows the strength of the grain-plant to be expended on the head and fruit (that is the grain) which is what the prairie cultivator, unsolicitous in regard to manure, seeks to perfect. This vigor given to vegetation in cold climates is in accordance with the well formulated law that cultivated plants yield their greatest product near the northernmost limit at which they will grow. Rice and cotton are tropical plants, yet the products of both these plants in Georgia and South Carolina, almost at the northern limit of their range, stand first in commercial rank in their respective markets. Indian corn, or maize, is sub-tropical, and in the West Indies grows to a height of 30 feet, but bears only a few stunted seeds, instead of the 125 bushels to the acre sometimes gathered in New York state, where the stalks are hardly one-eighth as high; while the first prize for number of kernels and general perfection was given to corn grown last year near Winnipeg, in competition with the whole of the United States. The potato, indigenous to the equatorial zone, becomes really good only in the temperate zone, and finest of all in the more northerly localities. The Northwest can beat the *world in its potatoes and tuberous vegetables generally*— another outrage on poor Ireland!

As for wheat—everyone interested in these matters ought to read the remarkable facts stated by Mr. J. W. Taylor, U.S. Consul at Winnipeg, in his numerous writings and speeches on this subject. Here again it is along the northern part of its range that the best product is obtained The finest wheat grown in Europe comes from the Baltic shores; and in the United States from Minnesota and Dakota; and in this important grain we have our most striking example of what the climate of the Canadian West is in relation to agriculture. In southern Minnesota, Iowa, etc., more than two well-formed grains of wheat are seldom found in each cluster or fascicle forming one of the rows in a head In Manitoba and Assiniboia (where the shortness of the straw is surprising to a stranger), *three* grains are *habitually found. This is an addition of one-third to the* yield of each acre. That means 30 bushels on the average instead of 20—$15 instead of $10 an acre at present prices. But wheat grown along Peace River often shows four and five grains in the cluster!

This is not the whole of the story. The kernels are harder and better filled out than southward; and it is an established fact that varities of wheat classed as "soft" in the Mississippi states regain their flinty texture and become "hard" in the Northwest.

During May, June and July rain, generally in the form of thunder-showers, is of almost daily occurrence; so that there is no lack of moisture for the sustenance of the growing crops, just when they need it most. This diminishes toward the west, however, and when the plateau beyond the *Coteau de Missouri*, with an elevation of 3,000, is reached, summer showers are less frequent and certain. Even here, however, it is quite sufficient, as experience shows, until the very foot-hills of the Rockies are approached, when irrigation becomes necessary to success in farming. Over the great mass of the tillable prairies, however, drought causes no apprehension; and there is a belief abroad that as wire fences, railway lines, buildings and other lightning conductors spread over the plains, a greater electric equilibrium will be maintained, and rain will tend to fall more frequently and equably than heretofore.

After the middle of July rains are few, and during harvest cease altogether. This is another marked advantage over our eastern provinces, where farmers have to contend with wet harvest-weather nearly every year.

Harvest begins by the first of August, and is uninterrupted. Hay has been been stacked in the open air quite unprotected, for the farmer is sure that no deluging rains will fall upon, nor melting snows sink into it, to wash out its juices or mildew it underneath. The grain is stacked uncovered in the fields and threshed in the open air without fear of harm through dampness. You will see everywhere small stables for stock, some small granaries, and cellars for keeping vegetables; but hardly ever a barn for storing hay, straw or grain. The climate renders it unnecessary.

Over the whole of Canada's great west the climate is equally favorable for live-stock. As is is usual in northerly regions, the grasses are of the best, and by reason of the absence of fall rains and wet winter snows, they dry up on the stalk—are cured into real hay as they stand, instead of rotting; and their nutritious juices are never washed out of them. Horses, cattle and sheep fatten on this prairie grass as well as upon the richest meadows of Ontario, and cows give an extraordinary quantity of milk, while the dryness of the air and ground is especially favorable to sheep as well as cattle.

How the Canadian plains, in spite of their interior and northerly situation, come to have so warm and dry a climate is worthy a moment's consideration, though the instruction which this audience has already received from Professor McCleod, makes any remarks from me hardly needful. It is to be remembered that south of western Canada lies the vast plains-country of the United States, an arid space thousands of square miles in extent, towards which blow steadily the warm currents of air from the Gulf of Mexico, attracted by the heated air issuing from these ample spaces of treeless land. The ground becomes baked, and the air, heated by contact with it, rises rarified in enormous volumes, sucking in the northward-bound currents to take its place, and at the same time buoying them up and preventing the condensation or precipitation of moisture. This overflow of heated air continually drifts polewards, or northward, where, it must not be forgotten, the land is far lower; and as it goes it is joined by similar currents from the Nevada and Idaho deserts, and from the coast of California and Oregon. Combined, this current pours steadily northward, attracted by the rarified air now rising from the Canadian plains, and still bearing a large part of its original moisture.

But over the Saskatchewan valley it meets the cooler air flowing from the north, also attracted by the heated prairies, and in contact with this cooling current the moisture of the south and west winds is condensed into clouds and falls as rain. A secondary characteristic of this movement is the diversion of the northward-blowing wind eastward, although, as the earlier lecturers in this Course have shown us, the natural tendency of these antitrades is toward the west.

But as winter approaches the conditions are altered. The cooling of the plains diminishes their attractive power, and the warm southerly winds tend away from the east, toward the west, in accordance with cosmic laws. Down from the north come the cold and dry winds, unchecked by any obstacle, and the hot breath of Eolus is overcome by a frosty blast from Boréas' cold cheeks. How remarkably different would be the climate of Manitoba were there a high range of mountains between it and Hudson's Bay; or were the Saskatchewan occupied by an extensive inland sea!

It appears, then, that (apart from the influence of the Chinook, due to the presence of the Rocky Mountains) the reason the Canadian Northwest enjoys so warm and comparatively rainy a climate is, in a word, because it lies northward of arid plains of much higher elevation.

In this same condition seems to be found the valuable immunity which western Canada, and the northern border of United States enjoy from those fearful blizzards that devastate southern Dakota, and make cattle and cattlemen shiver even on the coast of Texas. These winds all come from the far Northwest, and have blown, perhaps, a thousand miles across Canada before they become blizzards. But their course over the Saskatchewan, Qu'Appelle and Assiniboine plains, and down the Winnipeg valley, is continually impeded. First, the country is everywhere uneven and often broken by respectable hills; second, large areas of it are covered with a scrub of bushes, or dotted with copses of trees, all of which check and divert the gale; third, these winds are moving steadily up grade, and their speed is as continuously checked by friction against the earth, as is that of a railway train climbing a gradient. A wind will blow down hill faster than up, just as a stone will roll down hill easier than it can be pushed up. Finally, the air in the north is so nearly the temperature of the gale that it is not sucked forward with greatly accelerated speed, until it nears the warmer latitudes where more heated and rarified air is rising from the more southerly plains, and this cold northern air is drawn in to fill the vacuum. But by the time the "norther" has reached Nebraska it finds itself blowing across plateau-lands, at the top of the hill, where there is not a bush nor tree nor range of hills to check it, and the vacuum is close in front. It has been a respectable wind in the Northwest; a terrible gale in Montana; in southern Dakota and Nebraska it becomes a death-dealing blizzard. Poor Nebraska and Dakota must always expect them; grateful Assiniboia and Alberta need never fear them. As for the Red River Valley region, its situation makes it subject occasionally to a very respectable imitation of a regular blizzard; but this is a far rarer and less severe visitation than in Minnesota, south of it.

How do the people who live in the North-west like this climate? They universally praise it and laud especially its healthfulness. They speak of it as extremely stimulating and conducive to good spirits and courage.

The secret of this is its dryness. The atmosphere is bright, and when in winter it is very cold there is seldom any wind. Let a man take ordinary care of himself, and he will live longer and grow stronger on these prairies than anywhere else in the world.

A peculiar exhilaration of body and soul belongs to the climate, especially in and about the Rockies, which is the choicest of regions for camping excursions and sporting trips. "No man should desire a soft life," wrote King Alfred the Great, but "roughing it," within reasonable grounds, is the marrow of a visit to the Rockies. What a pungent and wholesome savor to the taste there is in the very phrase. The zest with which one goes about an expedition of any kind in the Rocky Mountains is phenomenal in itself; I despair of making it credited by inexperienced lowlanders. We are told that the joys of Paradise will not only be greater than earthly pleasures, but that they will be still further magnified by our increased spiritual sensitiveness to the "good times" of Heaven. Well, in the same way, the senses are so quickened by the clear, *vivifying climate* of the western uplands in summer, that an outdoor life is tenfold more pleasurable there than it could be in the east. And then, one's *sleep* in the crisp air, after the fatigues of the day, is sound and serene. You awake at daylight, perhaps, readjust your camp-blankets, and want, again, to sleep. The sun may pour forth from the "golden window of the East," and flood the world with limpid light; the stars may pale and the jet of the midnight sky be diluted to that pale and perfect *morning* blue, into which you gaze to immeasurable depth; the air may become a pervading champagne, dry and delicate, every draught of which tingles the lungs and spurs the blood along the veins with joyous speed; the landscape may woo the eye with airy undulations of prairie or snow-pointed pinnacles lifted sharply against the azure; yet sleep claims you. That very quality of the atmosphere which contributes to all this beauty and makes it so delicious to be awake, makes it equally blessed to slumber. Lying there in the open air, breathing the pure elixir of the untainted mountains, you come to think even the confinement of a flapping tent oppressive, and the ventilation of a sheltering spruce-bough bad.

Notes on Fossils from the Utica Formation at Point-à-Pic, Murray River, Murray Bay (Que.), Canada.

By Henry M. Ami, M.A., F.G.S.

Whilst preparing my paper "On the Utica Formation and its fossils in Canada" for the Royal Society meeting of last spring, a very interesting though small collection of fossils was kindly placed at my disposal by Mr. Walter F. Ferrier, who had obtained the same in the black bituminous shales which crop out along the shore on the Murray River near its mouth, holding a fauna pre-eminently Utica in its *facies.*

The numerous and interesting geological features of Murray Bay and its environs have in years gone by received much attention and elicited careful study at the hands of geologists, notably Sir William Dawson, Dr. Harrington, members of the Geological Survey staff, and others whose contributions form a valuable series of articles in the *Cana-*

dian Naturalist and elsewhere. (See Dawson in Can. Nat., vol. vi., p. 138, *et al. loc.*)

In the "Geology of Canada, 1863," the geology of that district is sketched out carefully with the accumulated evidence at the disposal of the writer (Sir Wm. Logan) at that time, but neither here nor elsewhere have I been able to find any record made of the occurrence of rocks belonging to the Utica formation at Murray Bay. This is my only plea for the present notes, which are hereby submitted as a humble contribution to the knowledge of the geological history of the locality in question.

From the papers already published, and the lists of fossils therein contained, both the Bird's Eye and Black River and the Trenton formations are known to be well developed and easily recognized among the Cambro-Silurian or Ordovician strata of Murray Bay.

Sir William Dawson has recorded the occurrence of *Ambonychia radiata* (Hall) along with species indicating a lower horizon than that species, but its presence may certainly point to the development of strata of less antiquity than the Trenton formation in that district, most of which have been long since removed, either (?) by glacial action or by other denuding agencies at work everywhere. No distinction has as yet been made here, I believe, between the Trenton measures holding a characteristic fauna and the Utica formation, which holds a fauna very similar to the rocks ofthe same age at Ottawa, Whitby, Collingwood, and other places where that formation is developed.

From these shales, which are black, bituminous, somewhat indurated and calcareous at times, holding numerous organic remains, the following species of fossils were obtained in a tolerably good state of preservation :

Rhabdophora.

1. Diplograptus sp. (resembling D. pristis, Hisinger).

Polyzoa.

2. Pachydictya sp.

BRACHIOPODA.

3. Leptobolus insignis, Hall.
4. Siphonotreta, sp.
5. Leptæna sericea, Sowerby.
6. Orthis testudinaria, Dalman, *var.*

CEPHALOPODA.

7. Trocholites ammonius, Conrad.
8. Endoceras proteiforme, Hall.

TRILOBITA.

9. Triarthrus sp. (?)
10. Calymene senaria, Conrad.

OSTRACODA.

11. Leperditia (Primitia) cylindrica, Hall.
12. " " probably n. sp.

NOTES ON THE ABOVE FOSSILS.

RHABDOPHORA.

1. DIPLOGRAPTUS sp.—A few broken and imperfectly preserved stipes of a diprionidian, or petaloid graptolite, whose specific relations cannot satisfactorily be ascertained with the specimens before me.

POLYZOA.

2. PACHYDICTYA sp.—Several fronds of a species of this genus, or of a very closely related one, occur in the collection. They exhibit a considerably wide nonporiferous margin. The form in question may possibly fall under one of Mr. E. O. Ulrich's species, but which is not as yet definitely ascertained.

BRACHIOPODA.

3. LEPTOBOLUS INSIGNIS, Hall.—This species occurs in tolerable abundance in the collection, and is well preserved.

It is eminently characteristic of the Utica wherever that formation has been traced in its natural position overlying the Trenton formation in Canada and the United States; so that its presence at Murray Bay affords good evidence upon which to determine the geological horizon. The specimens from Murray Bay exhibit the radiating lines very well, showing no appreciable variation compared with Ottawa or Collingwood specimens.

4. Siphonotreta sp.—This is undoubtedly the most interesting and rarest form in the collection. A cursory examination of this form and the associated specimens was made some three years ago, but at that time it was considered and grouped along with the specimens of *Leptobolus insignis;* but a closer examination having been made last spring, it was found that the surface of the shell and other parts presented all the essential characters of a true *Siphonotreta* (de Verneuil). The specimen is preserved as a mould or cast of the shell, exhibiting the spines all around the outer margin and sides, and may possibly be a young individual of, or closely related to, *Siphonotreta Scotica* Davidson, a species recorded by Mr. J. F. Whiteaves in 1883 from the Utica formation in a paper read by him at the Montreal meeting of the A. A. A. S. Additional notes on that species were made by the writer in the "Ottawa Naturalist" for December, 1887, and in Vol. II. No. 3 of the Ottawa Field Naturalists' Club Transactions, No. 7, p. 347. The following notes are taken from the Murray Bay specimen, which is probably the larger value: Dimensions as follows:—*Length* of the shell, 1·75 millimetres; breadth, 1·8 millimetres; length of the setaceous spines in front, ·5 millimetre.

This minute form agrees very well with the characters such as a young form of Siphonotreta Scotica, Davidson, and its Canadian variety might assume or be expected to have from an examination made of many adult individuals collected in the Utica of Gloucester, near Ottawa, but there is also a very close resemblance between the Murray Bay specimen and the *Siphonotreta micula* described by Prof. McCoy[1] from the Llandeilo rocks of Great Britain, and which he himself recognized afterwards in rocks of similar age in Australia. Dr. Bigsby, in his "Thesaurus Siluricus," states that *S. micula*, McCoy, occurs in Meath, Ireland, England and S. W. Scotland, at Glenkiln, Dumfrieshire, and in several localities in Wales. The Murray Bay specimen differs from *S. micula* in having the concentric lines of growth or striæ more distant, there being only *twelve* in the space of one millimetre, whilst there are are said to *seventeen* in the same space in the latter. The spines, again, are comparatively longer in the Murray Bay form than in *S. Scotica*, but much more numerous than in *S. micula*. They are exceedingly slender and smooth. The specific relations of this form require better specimens before definite conclusions are arrived at.

5. Leptæna sericea, Sowerby.—Only a fragment of what appears to be this ubiquitous and common species occurs in the collection.

6. Orthis testudinaria, Dalman, var.—This species of Orthis resembles one which is found in tolerable abundance in the limestones at the foot of the Montmorency Falls, near Quebec. It is here provisionally referred as a variety of *Orthis testudinaria*, though there is good reason for a different specific designation. The costæ, especially about the beak and along the anterior margin, differ considerably as to their arrangement and distribution.

Cephalopoda.

7. Trocholites ammonius, Conrad.—The mode of occurrence, preservation and characters of the specimen referred to this species agree perfectly with the numerous individuals occurring in the Utica shales of Whitby, Ottawa and Collingwood.

[1] British Palæozoic Fossils, pp. 188 and 189; Pl. 1 H. fig. 3.

8. ENDOCERAS PROTEIFORME, Hall.—As is usually the case, with nearly all the specimens collected of this species in the Utica, the shells are flattened and broken, showing that it was exceedingly thin and brittle. There are four cepta in the space of 3·5 centimetres.

TRILOBITA AND OSTRACODA.

The trilobites and bivalved crustaceans mentioned in the list (*supra*) have been determined with as much accuracy as the state of preservation of the specimens warrants. When more specimens are obtained, and some more perfect ones than those before me, the relations, both generic and specific, may be changed, and a number of additional species recorded from that outcrop of the Utica at Murray Bay.

It may not be deemed out of place here to point out the entire absence of those species of fossils which characterize the so-called Utica shales along the south shore of the St. Lawrence, and on the northern side of the Island of Orleans. The geological horizon indicated by the fossils contained in this brief note is evidently that of the Utica formation. Nearly every species mentioned occurs in that formation at Ottawa and Whitby, in Ontario; so that the exposures of this formation at Murray Bay may be said to be the most easterly outcrop visible of the Utica on the north shore of the St. Lawrence.

THE RELATION OF CLIMATE TO VEGETATION.[1]

By D. P. PENHALLOW.

In conformity with the laws of Natural Selection, as stated by Darwin and accepted by modern biologists, conditions of environment are the determining factors in the growth, character and distribution of organic life. These conditions are nowhere uniform, and present numberless gradations and complications, in consequence of which organic life possesses characteristics which are everywhere subject to more or less striking variations; and if we are to form a correct estimate of the relations between cause and effect, it is essential that we first inquire into the specific influence upon functional activity of each one of the elements which, in the aggregate, constitute the environment of any individual or species.

Among these conditions we may note those of food supply and nutrition; varying intensity and quality of light; moisture; pressure; electricity; the presence or absence of certain gases and temperature; and in this latter element is found one of the most important of all the factors which determine the normal life of a plant. We are well aware that certain plants are found growing in hot springs at a temperature of 199.4° F. or within 12.6° of the boiling point of water, thus representing in modern times, although in exaggerated form, conditions under which, in the later Laurentian age; primitive vegetation very generally flourished. Other plants—the red snow—are found to complete their existence at a temperature so near the freezing point of water that the difference cannot be measured. But in each case the plant is equally sensitive to extremes of an opposite nature and would perish miserably were the temperature to be sensibly lowered in the one case or raised in the other. Between these two extremes, the majority of plants flourish at a much more moderate temperature, nevertheless, it is a well defined law of nature that each species thrives best at

[1] Abstract of a lecture delivered in the Somerville Course, at Montreal, March 1st, 1888.

a specific temperature, to which it is specially adapted. The seeds of wheat and barley will not germinate below 41° F., while they grow more rapidly at 83.6° F., and cease all further growth beyond 108.5° F. Corn will not germinate below 48° F.; its vegetation becomes most vigorous at 92.6° F., but ceases when the temperature exceeds 115° F. The squash seed demands at least 56.6° F., attains its best growth at 92.6° F., and beyond a superior limit of 115° F. its existence ceases. We thus find that the total range of temperature, between the superior and inferior limits, under which the life of wheat and barley can be accomplished, is 67.5° F. For corn, 67° F. and for the squash 58.4° F. From these simple facts, which might readily be extended to other species, we learn that each plant not only requires a certain degree of heat for the completion of its normal functions—a degree which varies with the species or with the type—but that the extremes of temperature which a plant can successfully withstand, may be much greater in some cases than in others. And also that when all the energies of the organism are dormant, it is in that condition best adapted to its resisting these extremes, especially of low temperature. Thus in our own locality, trees which, in the month of August, flourish under a mean temperature of 67.5° F., sometimes subjected to a maximum of 91°, still exist without apparent injury, when in January or February, they encounter a mean 6.8° F., and a possible minimum of 26° below zero, thus giving an extreme range of 117° F. We are aware, however, that as we approach the equator, the extremes are greatly reduced and the general conditions under which vegetation flourishes, become much more uniform.

From this we perceive that when the conditions of environment are of an unusual character, the organism must be affected in one or more of its functions, with a constant tendency towards permanency of variation according to the strength and duration of the modifying influences. It is true that the conditions to which any organism may be subjected—as in transfering a plant from an equatorial to a north temperate region—may be of so unusual and extreme a nature as to absolutely limit its existence. On the other hand, it is equally true that if the same conditions are applied with less energy for a given time, and thus the sum total of the modifying influences is extended over a much greater period, the organism not only becomes gradually adapted to its new conditions of life, but under their influence may even become permanently modified in one or more essential characteristics. This is a matter of common observation with those who are familiar with plant life, and such variations may be accomplished so rapidly as to be recognisable within the lifetime of a given observer. Thus it is well known that plants grown in botanic gardens, become so modified by their unusual conditions of life, that they no longer answer in a strictly scientific sense, to the description of the species in the original wild state. Similar variations are to be noted among wild plants as their surroundings vary. The same species growing under different conditions of moisture, as in wet and dry places, will present important differences in size, color and form ; or growing at different elevations, and thus under somewhat widely different conditions of temperature and pressure, its general aspect becomes wholly changed.

It is thus not difficult for us to appreciate the fact that since climate involves many of the factors already enumerated, and especially temperature, it as a whole, must exert a preponderating influence upon plant life, not only to determine its character in a given locality, but also the range of distribution for various species. With these general principles in mind, we are prepared to examine and understand some of the relations known to exist between climate and vegetation, which constitutes the subject of our lecture this evening.

Of the various important problems with which modern botanical science has to deal, that which is concerned in determining the relations between climate and vegetation is perhaps one of the most intricate and far-reaching.

Climatic conditions mean, primarily, temperature and moisture; but these in turn are variously modified by elevation, pressure and latitude, as well as those influences which *originate in the movements of air, proximity of* water, ocean currents and diversified character of the great land areas. Add to all these the influence of ocean currents, winds, animals and man, in effecting a wider distribution; while we also keep in mind that those very conditions of environment, which serve to induce wider distribution in some species, are the limiting conditions for other species, and some conception may be formed of the peculiarly complicated nature of the problem before us.

But if climate directly influences vegetation, it is also true, though in a much more restricted sense, that vegetation exerts a counter influence upon climate, with a tendency to modify it in more than an important respect. This will be found to hold true, chiefly, in plants of arborescent form, and instead of affecting wide areas, the influence is usually of a mere local nature. While, therefore, less *direct and certainly far less potent, the effect of* vegetation on climate is felt in the purity of the air; its relative humidity and consequently its temperature, local rainfall, and even upon the air, as a medium for the distribution of septic organism. At the same time, many of these effects, either positive or negative, are to a large extent susceptible of control at the hands of man. The changes which he effects in the vegetation of a given district, either through ignorant waste or to meet actual requirements, find their final expression in their climatic influence. This fact is so well attested, not only by our present experience, but by the history of the world for centuries, that it needs no special argument at this time to enforce it upon our attention.

As the influences already referred to are by no means uniformly distributed over the surface of the earth, which is also variously modified as to surface and geological character, there are found large areas between which extreme variations occur, in consequence of which there is a corresponding inequality in the distribution of vegetation. From this we perceive that while a study of climate will enable us to pretty accurately determine the character of the vegetation for a given area, conversely, the critical examination of a given flora will enable us to arrive at tolerably exact conclusions relative to the climatic conditions under which it flourishes. Therefore, while geographical botany enables us to solve many questions of importance so far as the present is concerned, it renders it possible, by comparing similar types of the present and the past, to accurately determine the climatic conditions which must have obtained in the various geological periods since vegetation first made its appearance. And finally, we may note that, as plants are influenced in their distribution, so will their regularity of development depend upon uniformity of climatic condition—periodicity in the latter enforcing periodicity in the former.

In instituting inquiries of the nature of those with which we are now dealing, we first of all naturally seek information respecting the number of plants known to man. Botanists in all parts of the world are bringing hitherto unknown species to our knowledge, and in some of the more imperfectly explored parts of the globe, the number thus constantly added is very considerable. It will therefore appear that we are wholly unable at the present time to make any exact statement relative to the number of existing species. Meyen in 1846, estimated the whole number of species at somewhat more than 200,000. Duchartre's estimate places the figure between 150,000 and 200,000, while De Candolle and Gray estimate somewhat more than 120,000 species of flowering plants alone.

But the distribution of this enormous number of plants is nowhere uniform. Each species or genus has its centre of distribution where the number of individuals is greatest, from which there is a more or less rapid diminution in all directions until the extreme limits are reached. This law may be illustrated in our own flora. Of the North American oaks, there are thirty-six species. These have their centre of distribution within a narrow radius centering upon the junction of the Ohio and Mississippi rivers. There at least fourteen species are found. If we now move northward, we find that a line passing through central New York, northern Pennsylvania and central Ohio, marks the limits of ten species. A line extending from central Massachusetts through the centre of Lake Ontario, touching the southern extremity of Lake Huron and thence into southern Wisconsin, marks the northern limit of eight species. *Four* species extend as far north as Montreal, and two to Quebec, while only one species extends a few miles further, and thus reaches the extreme northern limits of distribution.

The tulip tree has its center of distribution in Kentucky, Western Virginia and the eastern half of Tennessee. Its extreme limits reach southward, almost to the Gulf of Mexico, westward to the Mississippi, eastward to the Atlantic, and northwa. l to the Great Lakes, finding their termination just within the Dominion, along the northern shores of Lake Erie.

This law of distribution was fully recognized by the elder Michaux who, 102 years ago, undertook to determine the centres of distribution for all our North American trees, a task which led him over the greater part of the United States and Canada, and resulted in one of the most important contributions to American botany prior to this century.

Distri , tion of different species over a common area and therefore under similar conditions, constitutes a flora. Between one floura and another, there are no sharply dividing lines—each merges more or less into the other by insensible degrees, yet each is distinguished by certain prevailing forms. It therefore follows from what has thus far been stated, that any division, in point of distribution, of the vegetation which covers the surface of the earth, must be based upon purely arbitrary considerations.

Recognising these laws, Grisebach divides the surface of the earth into twenty-four great regions, each of which is distinguished by the characteristic or most prevalent forms of plant life, together with the part of the world in which it lies.

On this continent alone, there are wholly or in part, six distinct regions of vegetation, but in certain of these, at least, we note that the greatest range is from north to south, in consequence of which plants of widely different type and habits must be included in one common flora. Thus in the North American Forest Region, the flora of that portion lying north of the St. Lawrence and the Great Lakes is characterised bysuch trees as the white pine, spruce, hemlock, willows, birches and poplars; while such types as the oak, walnut, magnolias, chestnuts and long leaved pines, belong to the southern portions; the connection between these two groups being established through the maples, beeches and elms.

We may now direct our attention to another mode of division based upon temperature and variations in type.

If a person were to commence a journey at the equator, and follow due north until he reached the Pole, certain important facts—changes in the character of the vegetation—would force themselves upon his attention and demand explanation, however unobservant he might be. Starting in a region of richly luxuriant vegetation, remarkable for its great variety of forms, rich foliage, brilliantly colored flowers, as well as the rapid growth and often great size of all forms of plant life, he would by almost imperceptible gradations, find all these characteristics changing, until, on reaching the Arctic Regions, he would discover himself landed in a waste devoid of trees, bearing but scanty specimens of woody plants, which, instead of holding themselves proudly aloft, would be found trailing close along the ground or stunted into a most unseemly condition. Lichen covered rocks and moss grown fields would everywhere present the characteristic forms of plant life, while here and there, between the rocks, dwarfed herbs would rear their disproportionately large and abundant flowers, to catch the scant blessings of an altogether too brief existence. From a region where all nature seems to glory in existence, where plants appear in their greatest number and variety, and life is a perpetual joy, our traveller has passed to another region where variety and number are reduced to a minimum, and life appears to be one continual protest against the conditions imposed upon it.

The inquiring mind at once asks what produces this marvellous charge? To this the answer as naturally comes that, with an increased obliquity in the sun's rays as they strike the surface of the earth, there must be corresponding variation in the absorption and radiation of heat, and hence a lower temperature in the surrounding atmosphere. The climate has therefore changed with the progress of our traveller, and with it the vegetation of the various latitudes through which he has passed.

We therefore find that botanists are in the habit of dividing the surface of the earth into a certain number of regions or zones, between the equator and the pole, as determined by the most characteristic changes in climate and vegetation; and that this offers a somewhat more rational and convenient division than that proposed by Grisebach, is apparent. Those zones, therefore, with their corresponding mean temperatures, are as follows:—

The equatorial zone extending to lat. 15° N. with a mean temperature of 26° 30° C. Here the extreme heat, combined with a high degree of atmospheric humidity, calls forth the most luxuriant vegetation, such as impresses the reflecting mind in the most profound manner. Palms, bananas, rich orchids, luxuriant ferns and gigantic fig trees, over and among which swing enormous vines, give a peculiar character to the region, and bear witness to the highly favorable conditions under which organic life has its development.

The tropical zone, reaching from 15° lat. to the limit of the tropics, has a mean temperature of 23°-26° C. Here we meet with great variations in temperature. In summer, the mercury often exceed 30° C, while in winter it sometimes descends below the freezing point. Monsoons also constitute one of the characteristic features of the climate. Here we also meet with the palms, bananas and orchids; but the tree ferns and fig are the characteristic types.

The sub-tropical zone reaches from the tropics to 34° of lat., with a mean temperature ranging from 17°-21° C. We now meet with a vegetation in which evergreens prevail, and the myrtle and the laurel mark the type of the flora. At the same time, the high summer temperature induces the growth of annuals which properly belong to the tropical zone.

The warm temperate zone embraces the regions between 34° and 45° lat., with a mean temperature of 12°-17° C. Here we find the oak, chesnut, walnut, magnolias; while leguminous plants and the various grains flourish extensively.

The cold temperate zone includes a belt lying between 45° and 58° lat., with a temperature ranging from 6°-12° C. Here the prevailing forms of vegetation appear in the conifers, birches, maples, the heathers and junipers; while the rocks and trees are distinguished by an abundant growth of lichens, and mosses are everywhere abundant.

The sub-arctic zone, extending from 58°-66° lat., with a mean temperature varying from 4°-6° C., is much more restricted than the former, and its limits are not always clearly defined. Here the pines appear only along the southern border, and the poplar, birch and juniper give character to the region. Lichens and mosses are more abundant.

The Arctic region reaches from 66°-72° lat., with a mean temperature of about 2° C.=36° F. The prevailing tree here is the birch. Herbaceous plants are small, and their flowers disproportionately large and numerous. Lichens and mosses prevail.

In the Polar zone, herbaceous plants are rare, and even small bushes are wanting. The surface of the earth, during the short season when the snow is removed, is everywhere characterized by the extreme poverty of its vegetation. Beyond this is the Polar limit of perpetual snow.

If now we return to the equator and ascend a high mountain, with increasing altitude we pass through regions where the vegetation successively changes, until we ultimately reach the line of perpetual snow.

Thus at the plain we begin with the region of palms and bananas; at 1900 feet pass into the region of the tree fern and fig; 3800 feet brings us to the region of myrtles and laurels; at 5700 feet we encounter the evergreen dicotyledonous trees; at 7600 feet, the region of deciduous trees; 9500 feet, the region of spruces; 11,400 feet, the region of rhododendrons; 13,300 feet, we enter the region of Alpine plants, and at 15,200 feet encounter the snow limit.

We thus find that there are eight distinct regions, both with reference to latitude and altitude, in which corresponding forms of plant life occur, whence it appears that both increasing elevation and increasing latitude, through diminishing temperature, exert the same influence upon plant life.

Were the surface of the earth everywhere uniform, and no other modifying influence felt, the distribution of plants would also be tolerably uniform within the limits thus assigned; but even within the same line of latitude, great variations are to be noted both in climate and vegetation. Temperature decreases at the rate of 1° for every 200 or 400 feet of elevation, and were the surface of the earth sufficiently uniform, there would be a regular variation in vegetation and definite limitation of plant life with increase of elevation. But on steep mountain slopes, less heat will be absorbed and radiated into the surrounding air than upon plateaus even at a much greater elevation, whence it follows that plants which are confined to a relatively low elevation in the first case, become abundant at much higher altitudes in the second case. This affords an explanation, therefore, of the well known occurrence of certain plants at unusual elevations.

This fact finds a familiar illustration in the progress of vegetation on the slopes of mountains, where the same species extend from the plain, for some distance up the slope. As spring approaches, the plants on the plain will be found to come into bloom first, but as the season advances, the same species will come into bloom at successively later periods of one or more days, corresponding to difference in elevation.

Another fact that may be noted in this connection, is that plants of a more southern type not infrequently ascend to higher latitudes, and thus occur beyond the general limit of distribution for the species as a whole. This finds its explanation in part in the fact already cited, that great plateaus have a somewhat higher temperature than isolated mountains at the same elevation, but it is also to be referred in part to other causes. Such northern extensions of a flora will be found to be accomplished under the protecting influence of large bodies of water, which secure a more equable temperature, and tend to produce a somewhat higher annual mean than in more remote parts in the same latitude and at the same elevation above sea level. Warm ocean currents have a similar effect, and often produce the most striking modifications in the climate and vegetation of the shores they wash.

In the Atlantic, the Gulf Stream sweeps along the coast of Newfoundland, and reaches across to the northern shores of Great Britain, and even of Norway, giving to the former a climate whose mean annual temperature is that of New York, and a vegetation which, on this continent, flourishes only at several degrees lower latitude.

But if it is possible for such northern extensions of a flora to be made under special conditions, it is equally true that southern extensions of northern floras are possible. A notable instance of this is found in the arctic plants which, under the influence of the polar current reaching southward out of Baffin's Bay, extend along the coast of Labrador and into the Gulf of St. Lawrence along its northern shores, thus intruding an arctic flora into the north temperate flora.

As, however, an increase of temperature is, in general, more favorable to vegetation, it is found that plants more readily extend southward and adapt themselves to the conditions they there find, than in the opposite direction. Or to state it in a more practical way, plants may be transplanted from a northern to a more southern region, with far greater assurance of successful acclimatisation, than if carried in the opposite direction, the adverse influence of cold being far greater than that of heat, within the same limits. *In all such cases of forced or natural migration*, the species undergoes more or less striking and rapid modification. Thus the alpine plant carried to a lower latitude or elevation, gradually loses its dwarf habits of growth and ultimately becomes indistinguishable from the plants native to the region. On the other hand, southern plants, when carried north, if they survive the cold of winter, grow more slowly and fail to attain their former height. It more frequently happens, however, especially when the difference in latitude is great, that the plant experiences important changes in other respects. This finds a striking illustration in the castor oil plant so commonly grown here on the lawn. A tropical plant by nature, it is in its usual habitat a perennial, which not only becomes woody, but attains the form and dimensions of a tree. Planted in this latitude, it at once becomes reduced in size, rarely exceeds six or eight feet in height, and remains essentially an herbaceous plant, limited in its growth to one season.

On the other hand, the heat of summer, even in so high a latitude as this, is sufficient to bring to maturity many sub-tropical plants like the squash, melon and cucumber, which supply much needed variety to our diet. We thus learn that plants which, through natural means of distribution, would find it impossible to reach high northern limits, on account of the extremely low temperature to be endured at certain seasons of the year, may nevertheless, through the agency of man, who plants the seed at the return of each spring, be maintained at very high latitudes or altitudes. The influence of extreme temperature thus indicated, is apparently a determining factor in the distribution of plants, *but this can only be regarded as true when such extremes are severe and of long duration.*

Recognizing these facts, it is generally considered by botanists that the distribution of plants as a whole, is not determined by the extremes of temperature, but by the annual means. And if we follow the lines of distribution for any species, we will find them conforming to those lines of equal temperature which Humboldt designated isothermal. It is therefore easy to understand that the migration of plants is accomplished with the greatest difficulty in direction of latitude, but that it becomes a comparatively simple matter for them to extend in direction of longitude, It is a recognition of these laws which should guide us whenever we desire to introduce exotic plants for the adornment of our grounds, or to add new resources to our food or forest supply.

These laws are also expressed in the germination and growth of plants. It is a well recognized law of vegetable physiology, that while a certain temperature is essential to the germination of seeds, the requisite degree of heat is not the same for all plants, and in fact often differs widely. The same may be regarded as true of growth after germination. We may therefore indicate the lowest temperature at which germination can begin, and also the best temperature for growth as follows :—

	Germ.	Best Growth.
Wheat and barley	41° F.	83.6°
Pease	43.5°	79.9°
Corn	48.0°	92.6°
Beans	48.0°	92.6°
Squash	56.6°	92.6°

Such facts as these are significant and could readily be made to apply to all plants.

A very interesting, and in some respects important effect of climate upon vegetation, and more especially upon the arboreal forms, is to be seen in the correspondence between climatic periodicity, and periodicity in growth with corresponding modification of structure.

An examination in cross section, of any of our common trees such as the maple or elm, will show that the woody trunk is built up of a series of concentric rings, and if we follow the growth of such a tree from year to year, it will appear that these rings coincide more or less closely with the alternation of seasons, one ring for each year, in consequence of which they are usually designated as the annual rings. Advantage has been taken of this fact to reach an approximate estimate of the age of trees such as the great redwoods and sequoias of California, and it becomes of practical value to the surveyer in re-establishing old boundary lines.

In order, however, to correctly determine their relation to climatic influences, a few important considerations may be passed in review.

The formation of such rings or layers of growth, is referable to periods of physiological rest and activity, which alternate with one another, together with the secondary influence of internal tension established between the wood and bark. Whenever the change of seasons is sharply defined, and the conditions which obtain during summer are favorable to continuous growth, there will be but one period of activity and one of rest; consequently, but one layer of wood for a given year. There are notable exceptions to this, however. The red maple has been known to form several such rings in one season, and the same is true of other plants, but many such cases find at least a partial explanation in the attendant conditions, which induce repeated periodicity within the same season. In the tropics, where the conditions for continuous growth are more favorable, trees generally exhibit no rings whatever, and when they are developed, an explanation is usually to be found in local conditions. We therefore learn from this, that increasing cold, through inducing a more perfectly defined periodicity in growth, causes the formation of layers of growth which, in number, correspond approximately to the age of the plant, and this correspondence will be closer, other conditions being equal, the farther north, or the more remote from the equater, the location is.

Finally, we may turn our attention to a brief consideration of those influences which vegetation is supposed to exert upon climate. The history of Southern Europe and Asia Minor, as well as the more recent history of this continent, shows that with the removal of the large forests once covering these areas, certain pronounced changes have been effected in the frequency of rainfall and in the constancy of supply of water, as marked by the flow of rivers and small streams. It has, therefore, been a somewhat common practice to refer such changes to effect upon the total rainfall, and to ascribe to the presence or absence of abundant vegetation of the arborescent form, a definite influence upon climate. The question is of the greatest importance, as through its influence upon manufactures and water supply, as well as its effect upon tillage, it directly concerns some of the more important economic aspects of life. As at the present time, the changes referred to—de-forestation and re-forestation—are now taking place upon a large scale within the limits of the United States and Canada, we have a convenient field of observation at hand, as a basis upon which to determine how far such opinions coincide with known facts.

One of the most important functions of the plant is its power of transpiration, or its ability to liberate water from its structure in the form of aqueous vapor. Such transpiration is one of the important factors in determining the movement of water from the roots, where it has been absorbed from the soil, to the leaves, where it is utilized in the various chemical changes incident to growth. The capacity of plants in respect to this function, or the amount of water they will thus liberate within a given time, is extremely variable, though constant for any one species under uniform conditions of growth. Moreover, while many plants are structurally adapted to the freest possible transpiration, others are adapted to retardation of this function when the conditions of supply are limited, as must be the case in very hot and dry regions. In all cases, however, transpiration is controlled by conditions of light and heat, as well as by the extent to which the surrounding atmosphere is already charged with aqueous vapor.

The general tendency of this function will in all cases be to establish a constant movement of water upward from the soil through the plant, until it is liberated from the leaves, and the younger and more active these organs are, the greater will be the volume of water transpired within a given time. Upon the same principle, plants exposing large leaf areas, which retain their activity for a long time, are much more energetic agents in effecting this transfer and conversion than those which are more woody, have a less proportional leaf area, and mature earlier.

Various investigations have from time to time been made, to determine the actual amounts transpired under different conditions. It will answer our present purpose to cite only one or two of these results. Höhnel records that in an old beech forest somewhat more than 100 years of age, the whole volume of water transpired by one hectare or 2.47 acres, during the six months from June 1st to December 1st, amounted to between 2,400,000 and 3,500,000 kilos, or from 5,291,000 to 7,716,100 pounds, which, reduced to liquid measure, would give from 529,104 to 771,610 gallons. But these *figures* express only a portion of the water actually withdrawn from the soil, whence we can readily understand that plants serve as a drainage system as it were, for the soil.

This fact has of recent years, been somewhat largely taken advantage of, for the purpose of draining swamp lands with a view to improving them for purposes of tillage, and to remove their influence in promoting the dissemination of malarial organisms which are formed in the presence of large quantities of decomposing organic matter. For this purpose such plants as the sunflower, with its great expanse of leaf area, from which transpiration may proceed at a rapid rate, may be used. But the Eucalyptus globulus, or the blue gum of *Australia*, appears to answer this purpose even more fully, and is at the present time largely employed.

The liberation of large volumes of water by a forest, as indicated above, necessarily tends to reduce the temperature of the surrounding air and to bring it nearer the point of saturation—*i.e.*, it increases the relative humidity of the atmosphere. Any general influence which tends to still further reduce the local temperature, brings the air below the actual point of saturation and rain falls. It is therefore to be noted that forests affect precipitation in the form of rain or snow, to the extent that rains become more *frequent* in forest regions than elsewhere. This effect, then, is of a local nature, but has popularly been interpreted to mean that forests increase the total rainfall, which can hardly be regarded as true, since they do not increase the absolute amount of water in the atmosphere, but only the relative quantity. And, moreover, the weight of scientific evidence thus far available, shows that such influence is not produced. One of the most conclusive arguments bearing upon this point, is that of Mr. Henry Gannett in a recent number of *Science*. For this purpose he employs large areas in the United States where, since colonial times, deforestation and reforestation have been going on on a very large scale. The deforesting of 25,000 square miles in New England, prior to 1860, was found to be attended by an actual increase in annual rainfall. The deforesting of 40,000 square miles in Ohio was attended by an almost inappreciable diminution in rainfall, while the reforesting of 100,000 square miles of prairie in Iowa, Missouri, Minnesota and Illinois has been accompanied by a slight diminution. And Mr. Gannett's conclusion that it is useless "to discuss further the influence of forests upon rainfall from an economic point of view," is to be endorsed as essentially correct.

But the question is then pertinent, How do we account for the shrinkage of streams, the drying of springs and other changes which are known to attend the removal of forests? Southern Europe and some parts of Asia Minor have, by removal of their once abundant forests, become converted into dry wastes. The question here raised is of the greatest importance, and each year demands more serious consideration. In their report for 1885, the Forestry Commission for the State of New York, the chairman of which is no less an authority than Prof. C. S. Sargent, of Harvard University, give expression to the following views, based upon observed facts:—"The most important function of the Adirondack forests is found in the influence which they exert upon the streams heading among the hills of the Adirondack plateau, which distribute the heavy rainfall of this region. As reservoirs of moisture, these forests are essential to the continued prosperity of the State. Their influence is felt far beyond the limits of the State, and their destruction must be followed by widespread commercial disaster. The future of the rivers which flow from the Adirondack plateau may be judged by their past. Great changes have been noticed in these streams since the area of the Adirondack forests has been materially reduced. All the testimony which the commissioners have been able to collect upon this subject, indicates that the summer flow of the Adirondack rivers has been decreasing within the memory of men now living, from thirty to fifty per cent.

These effects have a simple explanation. Any land area covered by forest has its rate of evaporation reduced by the shade thus afforded to the extent of 38 per cent., as compared with cleared lands; and the reduced evaporation under such circumstances so far exceeds the loss of water by transpiration, that there is an actual accumulation of water in the soil of forest-covered areas. Moreover, the organic matter accumulated in the growth of a forest, and the abundauce of moss induced by the moist shade thus afforded, serves as a retaining medium to hold the excess of water and allow it to gradually flow away into the streams. It follows from this, that streams rising in a dense forest will be distinguished by the uniformity of their volume and rate of flow; drought and flood are rare; springs abound. A removal of the forest destroys all the conditions upon which these phenomena depend. The stream experiences strong fluctuations in volume and rate of flow; springs disappear, and drought becomes frequent; while every rainfall is immediately precipitated down the steep hillsides, rapidly merging into a flood, which carries disaster in all directions.