# TRANSCTIONS

OF

# The Canadian Institute

VOLUME IX

TORONTO
PRINTED FOR THE CANADIAN INSTITUTE
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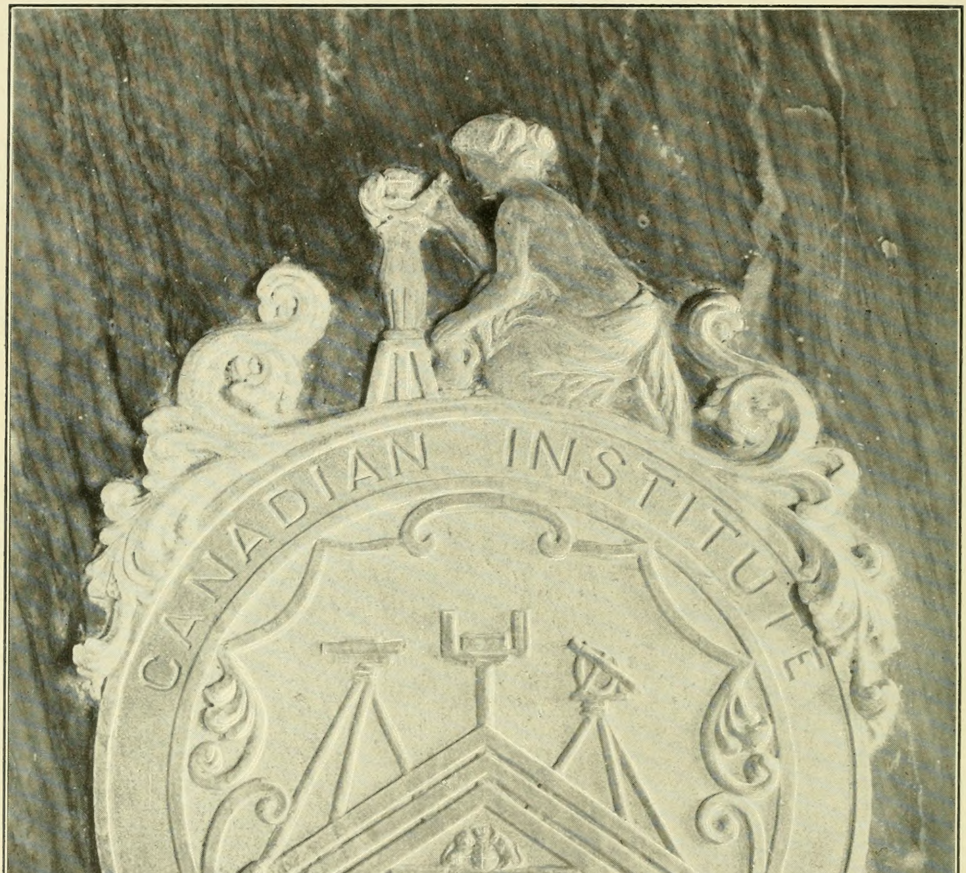
1913


CANADIAN INSTITUTE
ESTABLISHED 1849
ROYAL CHARTER 1851
TORONTO 1911

The Arms of the Canadian Institute shown on the opposite page were designed by Sir Sandford Fleming about the year 1850, shortly after the Institute was organized. On being submitted to the Council they received its hearty approval.

Sir Sandford then drew the design on wood, after which it was engraved by John Allavsen, a native-born Englishman, who had recently arrived in Canada from Leipsic, Germany.

On the shield are depicted some of the instruments employed by professional surveyors and engineers, such as a Level, Compass and Theodolite. Near the ground level a railway train is emerging from a tunnel. Over the shield and scroll, and forming the Crest, is a female figure typifying Science trimming the Lamp of Life.

For the past sixty-three years this beautiful design has been used as the proper Arms of the Canadian Institute. May it serve through very many coming years to keep before our members the high ideals with which the Institute was originally organized, and may the Institute itself continue to form a nucleus of quiet, thoughtful, scientific men in the midst of the business centre of the Province of Ontario.

The tablet here depicted is 2 ft. by 3 ft. in size. It is of marble from Bancroft, Ontario, and was engraved in relief by The Hoidge Marble Works of this city. It now occupies a conspicuous place on the wall in the Memorial Tower in Halifax.

J. B. TYRRELL,

*Toronto, February, 1913.* *President.*

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# TRANSACTIONS

OF

# THE CANADIAN INSTITUTE

## RECENT ARCHÆOLOGICAL INVESTIGATIONS IN ONTARIO.

By Henry Montgomery, M.A., Ph.D., F.E.S.A.

(*Read 19th February*, 1910)

There is a series of ancient artificial earthworks or mounds in the township of Otonabee, Peterboro County, Ontario, which to some extent I have recently investigated. At the request of the late Mr. Strickland of Peterboro, a former owner of the property, Mr. David Boyle in 1896 examined these mounds and afterwards published the results of that examination.

The following quotation is from pages 23 and 24 of Mr. Boyle's Report, published in 1897:—"Selecting the highest point of the mound left undisturbed, seventy feet from the end of the tail, I had a cut made five feet wide, extending from the north side to the middle of the bank, which is here twenty-four feet across the base, simply to examine the interior nature of the structure, the surface of which was here somewhat stony. Human bones were exposed within two feet of the surface, but like those of the egg-mound, all much decayed. Some of the boulders taken from this cut were all that a man could lift, but many of them did not weigh more than from ten to thirty pounds each. The placing of the earth was manifestly done by hand, layers and patches of dark soil being mingled with yellow clay; beyond this there was nothing to indicate man's agency, but the proof yielded was ample. A slight examination was made at the head of the mound, the result being to show that here also comparatively recent burials had been made, but lower than eighteen inches from the surface there was no sign of bones."

From his report, however, it appears that no objects of manufacture were found by Mr. Boyle, and only a few human bones were found in the largest mound, and a few skeletons in the others.

I visited the place during the past summer (1909), made a preliminary examination, and, in behalf of the University of Toronto, obtained permission from the owner to excavate the mounds and make collections therefrom for the University. On my return from the Western Provinces in October, I entered upon the work of excavation, and the purpose of this writing is to show the results of my work thus far in the largest tumulus of the series, my intention being to complete the investigation of the entire group of seven mounds during the present year. In general it may be stated, that, some of the group are nearly circular in form, others are oval or elongate. But, the largest mound is long and somewhat convolute or serpentine in shape. It varies in width and also in height. Its length is 192 feet. The width near the eastern extremity is twenty-eight feet; it soon narrows towards the west to a width of twenty-one feet which continues to a point about seventy feet from the extreme western extremity, and here for a distance of more than forty feet the mound is thirty-seven feet wide. Where its width is twenty-eight feet its height is nearly six feet; where the mound is only twenty-one feet in width its height is only three and one-half feet; and where it is thirty-seven feet in width its height is seven feet, its greatest height being in that portion which has the greatest width. The extreme western portion of this mound is low and narrow. At about the highest part there are two oak trees of considerable size growing upon it. See plate I, Fig. 2. The larger of these is about six feet in circumference. The decayed stump of another tree on this part of the mound had a measurement of thirty inches in diameter.

This is the earthwork to which the name "serpent" was given by Mr. Boyle. That it was intended by its builders to represent a serpent in shape is somewhat doubtful, there being little evidence in support of the view. There are but two convolutions in it; whereas there are seven convolutions in the Adams County serpent mound of Ohio which latter is also more uniform and natural in form. It is possible that this Peterboro County mound may be an aggregation of ordinary burial mounds erected in this way at different times for convenience' sake, and perhaps also for family reasons. In the great plains of the western States and Canada instances of several mounds attached together and forming one continuous irregularly shaped mound are of fairly frequent occurrence, and here in this Peterboro group there is also an example of this kind in a double mound situate immediately south of the large one. Some of the western ones are of such shapes that, even if regarded as unfinished, they certainly were never meant to represent serpents. This, however, cannot be said of the large Peterboro mound in question. Although irregular, and in length relatively short, its shape is such that it might be regarded as the beginning of an unfinished serpent.

Having secured the assistance of five men, I made four excavations, each being ten feet in width and from ten to fourteen feet in length. Three of these excavations (Nos. 1, 2 and 4) were made near the oak tree in the highest and widest part of the mound. The remaining excavation (No. 3) was near the eastern extremity of the mound, the part termed the head of the serpent.

### Excavation No. 1.

In the excavation designated number one there were three deposits of broken human bones, being portions of four skeletons. Probably the remainder of the skeletons had been previously removed by other persons. There were no manufactured articles found here with the exception of a little bit of decorated pottery. No stones were found; but, it is possible they may have been removed by others who had disturbed the place years before.

### Excavation No. 2.

Excavation number two, which was made near the larger oak tree, yielded fifty large stone boulders, ten human skeletons, a few little pieces of burnt bone, a small piece of a pottery vessel, and upwards of three hundred and fifty marine shell beads of three well-known genera of shells, constituting four varieties of ornaments as seen in plates II. and III. The boulders were together in a horizontal layer beneath more than two feet in depth of soil. As many of them were from eighteen inches to two feet in thickness the skeletons and relics under them were at a distance of four or five feet from the top of the mound. The skeletons, especially the skulls, were very much broken, evidently by the weight of the stones, as evidenced by their position, and the fact that the fractures showed great age. The pottery was a piece of the rim of a large vessel showing incised decoration.

Five of the shell beads are Olive shells, *Oliva literata*, (pl. II, Fig. 3), each having the top of its spire ground down so as to make an opening for the passage of a string. These univalve shells occur in tropical waters, and were probably procured by trade from the vicinity of Florida. They have been found in Ohio mounds and other localities in the United States; but, so far as known to the writer they have not been reported from the mounds of Ontario.

Twenty-eight of the beads are small univalve sea-shells known as *Marginella apicina*, whose nearest habitat is the ocean or gulf near Florida. Like the olive shells these have been but slightly altered by the manufacturing process. In every case the shoulder of the spire near the top has been ground, doubtless by the use of a stone, in such a manner as to produce a suitable opening for the piece of hide or other string by which they were held together as a necklace or armlet. All were ground in a similar way, the whorls and columella within the shell being visible, and thus probably adding to their beauty. (See pl. III, Fig. 4).

There are three hundred and twenty small circular beads of various diameters and lengths (plate IV, Fig. 5). These were cut out of some large, heavy marine shell. The structure of the shell substance resembles that of the shell of the large gasteropod *Fulgur perversa* from the Mexican Gulf and the south-eastern coast of the United States. Many of the mounds of western Canada and the Dakotas have yielded large beads which have been made from the shells of this mollusc.

One larger ornament, probably a pendant for the neck or breast, is a piece of sea-shell two and one-half inches in greatest length, evidently cut from two of the whorls of *Fulgur perversa*, and having the aperture for suspension bored from both sides. Like all the others it shows great age. (See plate IV, Fig. 7).

All of the remains were above the original surface of the ground, and were not deposited in any special pit or excavation. There were no skulls or bones of any large animal above them, nor was there a layer or covering of wooden poles or of a calcareous material present. Stones alone constituted their covering along with the vast heap of soil above.

### EXCAVATION NO. 3.

Excavation number three was made within twelve feet of the eastern end of the mound at a place where the height was about six feet. This excavation was ten by fourteen feet. At a depth of two and one-half feet I found a layer of twelve large glacial boulders. Below and between the boulders there were a few inches of soil covering seventeen human skeletons. The soil helped to save the skulls from being crushed to pieces by the stones. In this respect the work of burial appeared to have been more carefully done than in excavation number two. Many of the crania found here are fairly well preserved, although the condition of all of them indicates that a considerable length of time has elapsed since they were deposited in that place. The human skeletons were irregularly deposited in different directions and mostly in an extended or nearly extended position. They covered an area about seven by ten feet in size, and they lay upon a stratum of burnt earth about three inches in thickness and containing fragments of burnt or charred bones. This stratum rested upon six large stones and soil which had been placed upon the original surface of the ground. A small rudely formed bone article some what like an awl was found with the skeletons.

The humerus is perforated in many of the skeletons, and there are supernumerary or Wormian bones in some of the crania.

But, as to the form and capacity of the human crania it must be observed, that, when compared with those of other races they stand fairly high.

## Excavation No. 4.

Excavation number four was in that part of the mound immediately east of the trench dug by Mr. Boyle in 1896. It had plainly been disturbed by some one in former years. But, at a depth of two and one-half feet I found almost one hundred stone boulders, many of which were very large. Most of these were limestone, and the remaining were gneissoid. The entire heap was seven feet across and extended from a little more than two feet to four and one-half feet below the surface. Beneath these stones were found only a few broken human bones and one small fragment of pottery. The bones included vertebræ, ribs, parts of the maxillæ and crania of both an adult and a youth, a patella, bones of the leg and of the foot. There were a dozen or more shells of the fresh-water mussel (Unio), most of which were entire. Broken bones of deer were found also, as well as part of an incisor tooth of a beaver. Small pieces of charcoal occurred at a depth of four feet.

Although it is possible that many of the burials may have been secondary, no evidence of secondary burial was observed in any of these four excavations. The usual evidence was not there. Nor was there any evidence of intrusive burial noticed.

## PREHISTORIC ARTIFACTS FOUND IN THE VICINITY OF THE MOUNDS.

In addition to the foregoing account of the Peterboro County "serpent" or zigzag mound, I herein enumerate a number of archæological artifacts which were found in the same locality, some of them last year and others previous to that time. Some of these were discovered upon the mounds or near them; others were either found upon the surface of the ground or ploughed up in the neighbouring fields. A few were obtained about four miles distant from the mounds. While nothing can be positively stated as to who their manufacturers were, it is almost certain that the copper objects are the work of the mound-builders, similar objects having been found in mounds in other parts of the continent. It is also probable that some of the stone implements were made by the same people who reared the earthworks. But, regarding many of the articles of manufacture, until further evidence shall have been procured there must continue to be doubt as to the people who made them.

### COPPER OBJECTS.

1. A copper axe or celt, about six inches in length (pl. V, Fig. 8). Careful inspection of it shows it to have been made from native copper, such as that which occurs in rocks about Lake Superior. It is flat upon one side, and has a raised medium longitudinal ridge upon the opposite side, and a sharp edge at its wider end. Altogether, this copper celt is well-formed, being a neat, handsome implement. It was found within three hundred yards of the mounds.

2. Copper spear, nearly ten inches long and possessing two projections or barbs at the base of the blade (pl. V, Fig. 9). It is bevelled from a median ridge on both faces.

3. Copper knife, a little more than twelve inches long, and having a narrow extremity apparently for insertion in a wooden or other handle (pl. V, Fig. 10).

4. A piece of a thin sheet of native silver and copper greatly resembling the pieces of naturally mixed silver and copper seen in northern Michigan. This sheet is remarkably uniform in thickness. It is quite even and smooth throughout, and forcibly reminds one of the uniformity of many of the metallic artifacts of Colombia, Peru and Central America. Having only stone and bone implements the prehistoric workman must have exercised great skill and patience in its manufacture.

## STONE OBJECTS.

5. Stone scraper, made of mottled limestone. See pl. VII, Fig. 14. A piece has been broken off. A thick ridge extends along its back. This ridge would aid the hand in holding and using the scraper. Its edge is curved or somewhat semicircular. The length is seven inches.

6. Banner-stone or gorget slightly broken (pl. VII, Fig. 15). This is a flat, rectangular piece of reddish coloured hæmatitic slate, with a single central aperture showing the marks of the flint borer which was used in making the perforation. This banner stone is five inches long.

7. Stone adze, made of hornblende rock. Length 8 inches. (pl. VII, Fig. 16).

8. Stone gouges, made of hornblende. Most of these are well made and highly polished.

9. Stone celts or axes, also of hornblende. These are usually well finished tools. Pl. VII, Fig. 17.

10. Slate spears and arrow heads, barbed and having a tang serrated on the sides.

11. Flint and chert scrapers and arrow heads.

12. Bird amulet of limestone, somewhat broken. This is very large, being nineteen inches long and six inches high. There are two holes bored from side to side through its neck and back.

## OBJECTS OF POTTERY.

13. Sherds of pottery (pl. VI, Fig. 12). These pieces of broken pottery show decoration by textile impression as well as by incision with sharp flint or shell tools.

14. Large pipe of pottery with incised decoration upon its bowl (pl. VI, Fig. 11). Height of bowl, two inches. Length of stem, two inches.

## SHELL OBJECT.

15. Cowry shell, *Cypræa moneta* (pl. IV, Fig. 6). This shell is not perforated, and, therefore, it is not likely that it was used as an ornament. It probably served the purpose of money. The home of this cowry is in the Pacific Ocean near California.

## LEADEN OBJECT.

16. A flat, circular piece of lead a little broader and thicker than a Canadian copper cent. It has two similar perforations about equally distant from the margin and from each other. The edge or margin is rudely decorated by notches, and one face has seven rough indentations in a circle between the two holes and the edge. This is nearly similar to the few leaden discs which have been found in Wisconsin. It was likely made from the galena or lead ore of some of the deposits now being mined in Illinois, Wisconsin and Iowa, and was used either as a coin or as a pendant. The diameter of this disc is about an inch and a quarter, that is, three and two-tenths centimetres.

## CONCLUSIONS.

1. This is an artificial mound.

2. It was intended for the burial of the dead.

3. The interment was above the surface of the ground; there are no pits or excavated receptacles for the remains. After the burning of fires upon the ground, perhaps for several days, and probably for ceremonial or religious purposes, the bodies and relics were placed upon the spot where the fires had been, and were then covered with soil scraped from the surrounding locality wherever it could be most conveniently obtained. Boulders were then brought and placed in a layer above them, and apparently separated from the remains by a few inches of soil. More soil was dug up or scraped and heaped upon the stones to a height of four or five feet more, making a total elevation above the surrounding land at the time of completion of perhaps eight or ten feet. At later times other burials took place either by building separate mounds or by attaching new mounds to the original one.

4. The protective covering and monument is of stone boulders alone. No wooden poles have been found. No cement or calcareous layer, and no skulls of deer or other large animals have thus far been discovered. This method of burial occurs in Manitoba and some other places; but, it is usually found along with other forms of interment.

5. The artifacts are chiefly of marine shells from the Gulf of Mexico, including Oliva, Marginella and Fulgur. In addition to shells only two fragments of pottery and one bone article have yet been found within this tumulus.

6. Conclusions as to the relationship of the builders of this mound to other peoples of America must be left for future consideration. Although it is too early to form an opinion from the evidence before us regarding the precise relationship of the builders of this zigzag mound to the existing tribes of America, yet, there appears to be sufficient to justify us in considering whether or not these Ontario mounds were built by the Huronic people. Attention is here called to a slight resemblance of the skeletal remains to the Huron type. In the form and size of the cranium this resemblance is somewhat noticeable. Of course, it is known with certainty that the Hurons of historic time, that is, of the seventeenth century, interred their dead in deep pits or ossuaries and did not erect mounds above them. But, the probability of their ancestors' having interred their dead in mounds five or six centuries previous to that historic time, although doubtful and difficult may, I think, be a proper question for study and investigation. The late Sir Daniel Wilson, of Toronto University, in his writings expressed the opinion that the crania of the Hurons varied so greatly that it could not be said that any Huronic type existed. I cannot agree with this view. The evidence regarding the conditions of the discovery of a number of the crania examined by Sir Daniel Wilson is far from satisfactory. It is very probable that many of them were not Huron skulls at all; but, were more likely to be those of the Iroquois and perhaps some of them belonged to the Algonquins and one or two to the mound-builders. In plates VIII. and IX, Figs. 19 and 22, are presented two views of a cranium which I regard as the Huron type. This cranium was found by me in a Huron ossuary in the year 1878, and has been exhibited to several eminent archæologists and craniologists. Views of a cranium found in the "serpent" mound of Peterboro County last October are also shown on plates VIII. and IX, Figs. 18 and 21. A comparison is greatly in favor of the mound builder. The latter possessed greater frontal development, as shown by the lateral views.

In the investigation so far there has appeared evidence of a relationship of these earthworks in Ontario to those of some parts of the state of Ohio, which relationship, of course, also forms a legitimate subject for future study. From the skeletal remains as well as from the character of the artifacts I am at present inclined to regard these Ontario mounds as being closely related to those of Ohio.

7. The mound was reared in prehistoric times. With regard to the age of this mound it may be stated that the condition of the crania and other bones of the skeletons as well as of the shell objects indicates a period of time of great length, probably about a thousand years. The trees growing upon the mound, and especially that whose decaying stump I

measured, would afford proof of the lapse of nearly two hundred years, and we have no means of knowing how many trees may have grown up on the summit of this mound, and have died, decayed and wholly disappeared previous to the present ones. There is no evidence of contact with the white people; and it could not have been erected within historic times. The mound stands on high and rapidly sloping ground. Hence no water would be likely to penetrate it. All rain and snow would soon disappear from it and the ground immediately surrounding it. Consequently, decomposition of its organic contents must have been very slow indeed. Yet, I found them in an unusually advanced state of decomposition when compared with those of many other mounds which have been excavated elsewhere, and also when compared with the remains of the Hurons which were buried in ossuaries under less favorable conditions nearly three centuries ago. It may, perhaps, be safe to place the date at about the tenth century, or about five hundred years previous to the arrival of Columbus at the shores of America.

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## ILLUSTRATIONS.

FIG. 5.—Circular beads made from a marine shell. Found in excavation No. 2 in the "serpent" mound.

FIG. 6.—Cowry shell, *Cypræa moneta*, ploughed up in a field near the mounds in Peterborough county.

FIG. 7.—Pendant made from the marine shell, *Fulgur perversa*. Found in excavation No. 2 in the "serpent" mound.

FIG. 8.—Copper celt or axe, six inches long. Found in field near the mounds.

FIG. 9.—Copper spear, ten inches long. Ploughed up in field five miles north of the mounds.

FIG. 10.—Copper knife, showing both sides of blade. One foot in length. Ploughed out of the ground in a field about five miles north of the mounds.

FIG. 11.—Pipe of pottery, decorated. Two inches high, and the stem two inches long. Ploughed up in a field five miles north of mounds.

FIG. 12.—Sherds of pottery, showing decoration. Found near the mounds.

FIG. 13.—Sherd of pottery decorated by a textile impression. Found in the "serpent" mound, October 1909.

FIG. 14.—Knife or scraper of mottled limestone, showing ridge for a handle. Seven inches long. Edge part is somewhat broken. Found in field near the mounds.

FIG. 15.—Banner stone of hæmatitic slate, with a single perforation. Five inches in length. Ploughed up near the mounds.

FIG. 16.—Two views of a hornblende adze found near the mounds. Eight inches long. Heavy, owing to the presence of magnetic iron ore in it.

FIG. 17.—Hornblende celt or chisel. Found near the mounds.

FIG. 18.—Facial view of human skull taken out of excavation No. 3 in the "serpent" mound, October, 1909.

FIG. 19.—Facial view of Huron cranium found in an ossuary, county of Durham, Ontario, by H. Montgomery, in 1878.

FIG. 20.—Facial view of human skull taken out a mound in Dakota Territory by H. Montgomery in 1889.

FIG. 21.—Lateral view of human skull (whose facial view is seen in Fig. 18) from the "serpent" mound.

FIG. 22.—Laterial view of human cranium (whose facial view is shown in Fig. 19) from a Huron ossuary.

PLATE I.

FIG. 1.

FIG. 2.

PLATE II.

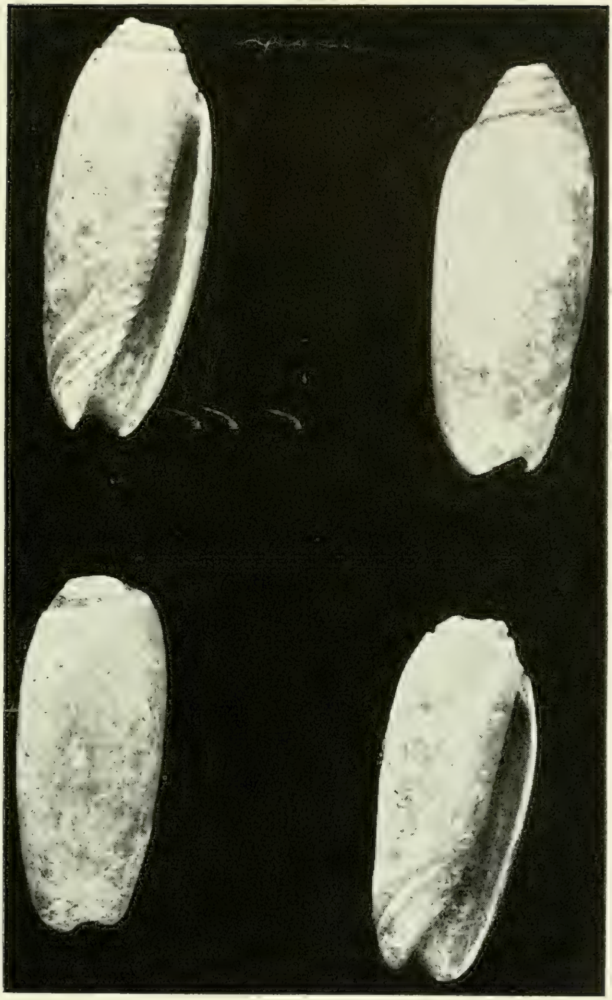


FIG. 3.

PLATE III.

FIG. 4.

PLATE IV.

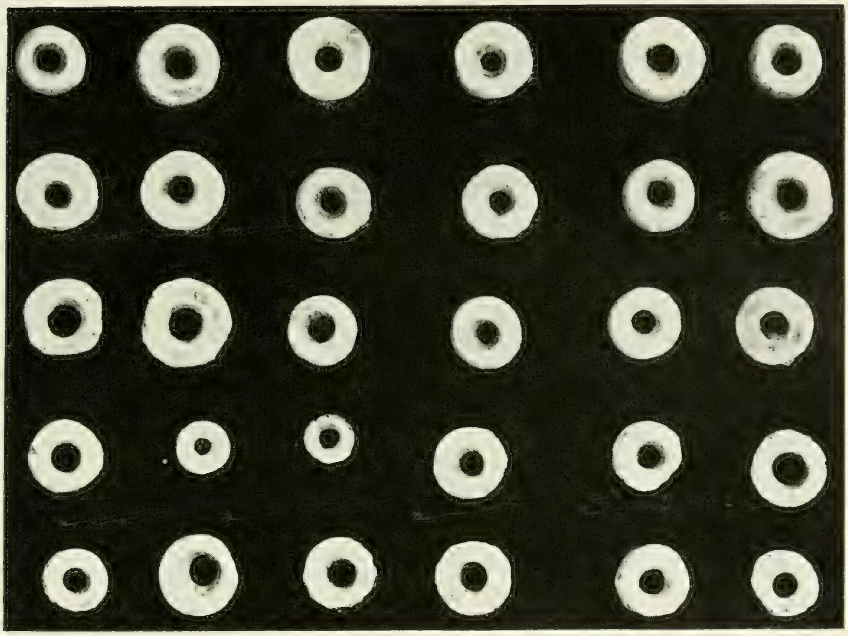


FIG. 5.

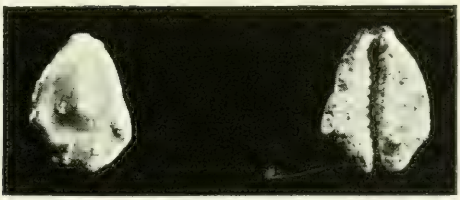


FIG. 6.

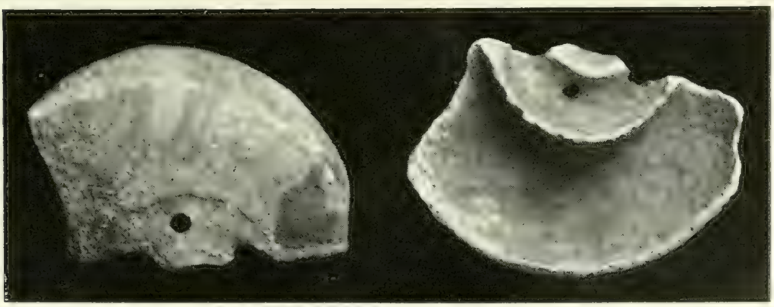


FIG. 7.

PLATE V.

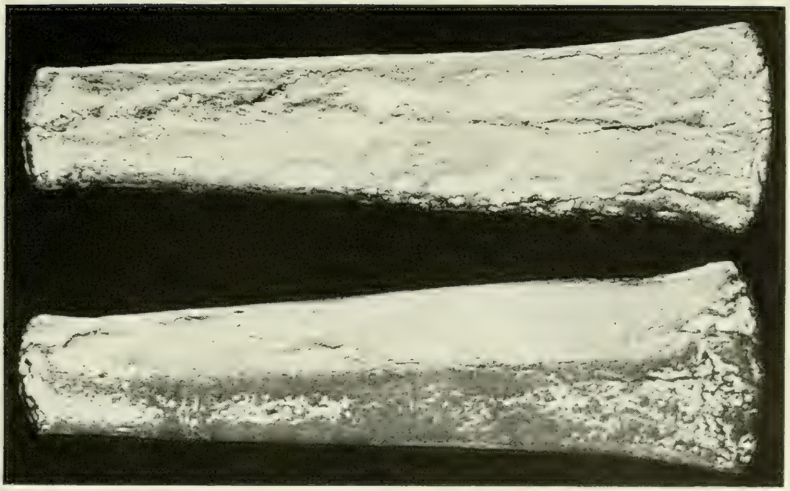


FIG. 8.

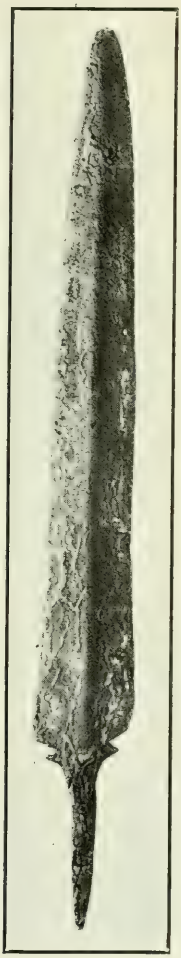


FIG. 9.

FIG. 10.

PLATE VI.

FIG. 11.

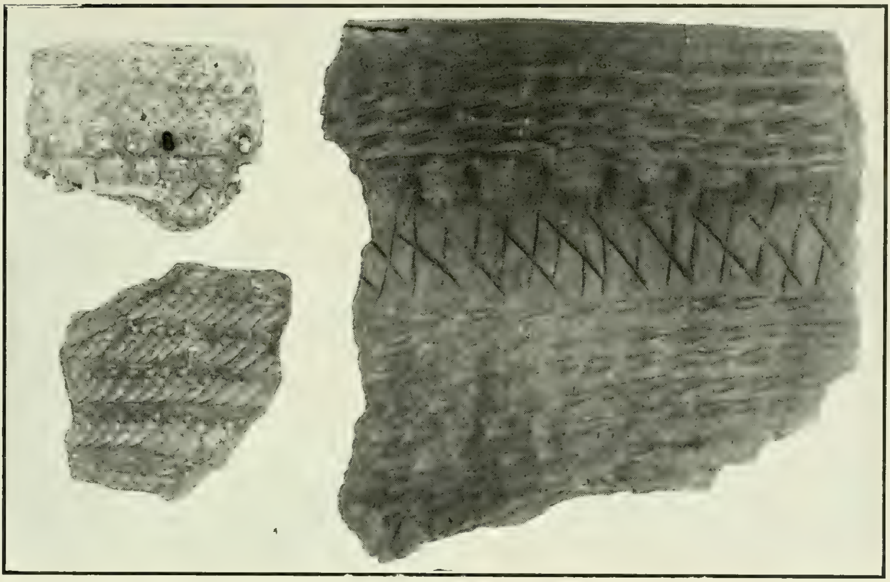


FIG. 12.

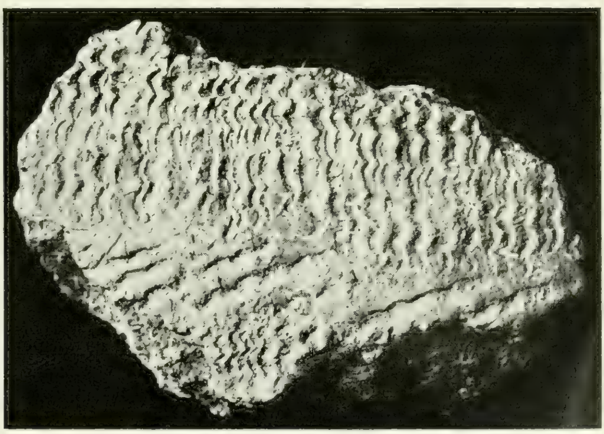


FIG. 13.

PLATE VII.

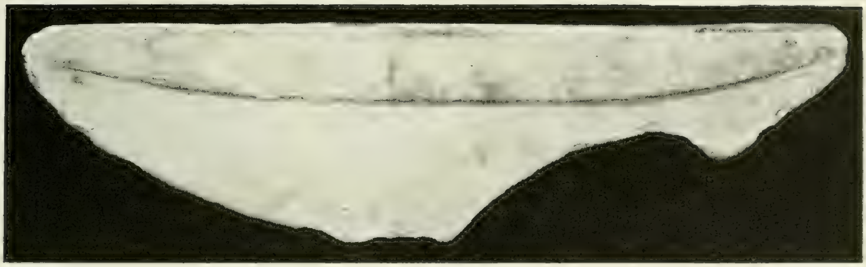


FIG. 14.

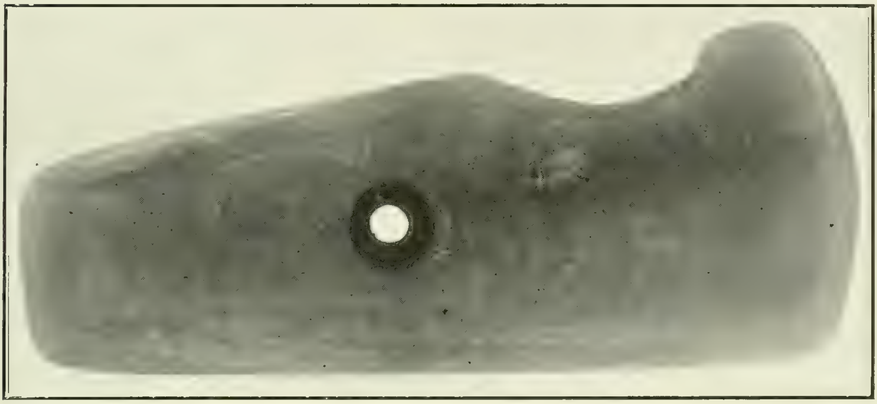


FIG. 15.

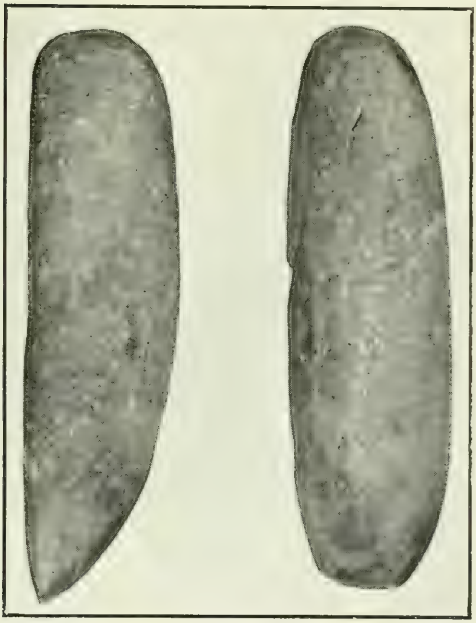


FIG. 16

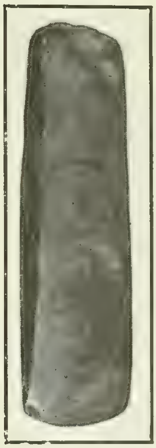


FIG. 17.

PLATE VIII.

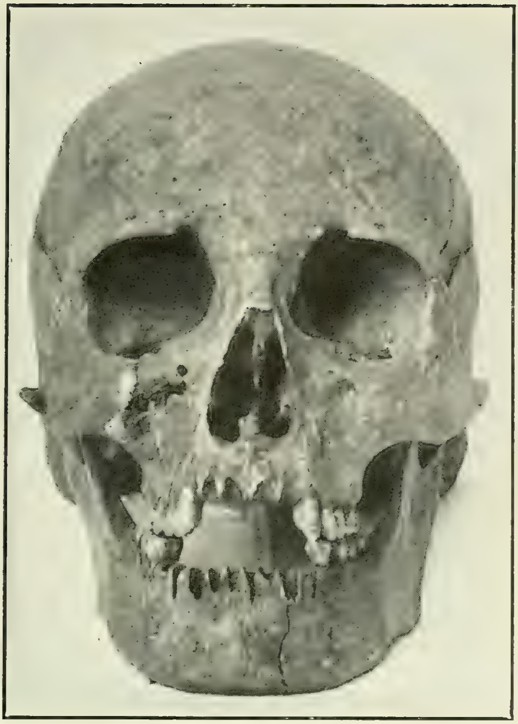


Fig. 18.

Fig. 19.

Fig. 20.

PLATE IX.

FIG. 21.

FIG. 22.

# ICE ON CANADIAN LAKES.

BY J. B. TYRRELL, M.A., F.G.S., &c.

*(Read 20th November, 1909)*

LAST week your president, in his address, complained that he had been under the necessity of delivering two presidential addresses in two consecutive years, but he is in an exceedingly comfortable condition compared to the one that I find myself in, for in looking over the list of six lectures to be delivered in this hall before next New Year, I see that five are by professors whose business it is to talk impressively and accurately for three or four hours a day and to whom an extra hour, more or less, is mere added enjoyment, while I am placed in the middle of this list of talkers and am expected to compete with them on even terms though my business is to work and keep silence, for if I should say a word about any mine that I had examined my reputation would be gone for ever.

Though mining is the most interesting subject to me and probably one of the most interesting to the people of Ontario, as it is certainly one of the most important to them, nevertheless we will step aside for a little while and consider a subject that might occupy our attention profitably and enjoyably through the coming winter.

Most of us in Canada have opportunities for observing the formation and character of the ice which covers our lakes during the winter, for though Lake Ontario, on the shore of which we in Toronto live, is never entirely covered with a coat of ice, Toronto Bay, which is a small and almost isolated lake in itself, does freeze over, and the thousands of lakes, large and small, scattered throughout Northern Canada, which are occasionally visited by many of us, are covered every winter with solid ice from shore to shore.

It will be interesting for us to attempt to follow the method of formation of this ice and any changes that may occur in it from time to time from the beginning of winter until the bright sunshine of the long spring days breaks it up and dissolves it into water again.

First let us understand that ice is much lighter than water and floats with great buoyancy on its surface. A cubic foot of water at 32°F. weighs

62.4 lbs., while a cubic foot of ice at approximately the same temperature weighs 57.2 lbs. A cubic foot of ice will, therefore, float with its upper surface an inch above the water and will support a weight of 5.2 lbs. before it sinks, and a square foot of ice an inch thick will support a weight of .43 lbs. Like other solids, it contracts with decrease of temperature, the linear coefficient of expansion varying from .00005 to .00002 or from 3-1/6 to 1-1/4 inches per mile for each degree F.

At the end of autumn as the days become rapidly shorter and colder with the approach of winter, the temperature of the water in the lakes gradually lowers until about the beginning of November it has fallen to freezing point and ice begins to form around the shores where the convection currents can carry the heat quickly up and down through the shallow water and the earth or stones at the bottom can be cooled by radiation into the air.

At the same time the moisture in the air, which, during the summer, periodically descends to the earth in the form of rain, now begins to fall in the form of snow, and as the snow falls into the lakes part of it remains unmelted in the cold water and adheres or freezes to the edge of the shore ice. Every cold day or night the shore ice becomes thicker by the freezing of additional particles to it from below, as the heat is abstracted from the water by conduction through the ice, and at the same time its edge extends farther and farther into the lake until it completely covers the water. In this way a smooth covering of ice may be formed over the lake. On the other hand a period of very cold weather may suddenly cause the formation of a sheet of ice several inches in thickness over the whole lake.

On some of the large lakes, just after they have been frozen over, one of the heavy storms, so common in the autumn and early winter, may arise, and the wind and waves may break the ice into irregular masses and fragments, drive them towards the shore, or pile them up against it. At the same time, however, some of the first-formed ice will remain frozen fast to the shore and form an efficient protection to it. Thus the fragments of ice broken up by the storms in the early part of the winter have very little influence in displacing the sand and boulders which compose the shore, though they may throw up tree-trunks and floating masses of timber high up over it.

These storms are often followed by cold, calm weather and during this cold spell the broken ice will be frozen into a rough, irregular covering. Such a rough refrozen sheet of ice may very often be found on many of the larger northern Canadian lakes.

When I crossed Lake Winnipeg in December, 1893, it had been frozen with a smooth surface, and had remained in that condition, so that we travelled over it in our dog-sleighs with ease and comfort; but when I travelled down the same lake in the following year it had evidently been frozen over early in the autumn, the ice had afterwards been broken up by a heavy storm and it had frozen again with the jagged points and edges of the masses of ice projecting in every direction, so that it was quite impossible for us to take a straight course over the ice as we had done in the previous year. In consequence of this we were obliged to keep to the shore and to follow all its bays and indentations, which made our journey very much longer and more arduous. The irregularities in the surface of the ice would in time be filled with the snow which had been constantly drifted over it, and it is quite likely that towards the end of winter the general surface would have been rendered flat and regular. In that case it might be impossible to say that the ice had not frozen quietly, except that it would be a foot or two thicker than usual and that it would not have its usual regular structure.

The Yukon River furnishes some of the best examples of rough ice to be seen on any of our inland waters. Every year after the ice freezes, parts of it break up again and the broken masses are carried down by the current and piled up against the smooth unbroken ice which remains here and there across the river. Thus an ice-jam, sometimes many miles in length, may be formed, and as this freezes into a solid mass it makes a very rough irregular surface over which it is difficult to travel with sleighs or even on foot. (See Plate VI.)

The old winter trail from Skagway to the Klondike used to run down the Yukon River. The smooth unbroken ice made an excellent road, but when the broken and refrozen ice was encountered it was found practically impossible to travel over it and it was often necessary to search out a trail through the woods on one side or the other of the river, perhaps for several miles at a time, in order to find some easy way around the rough ice.

The rains, common in the autumn, usually raise the water in the lakes and rivers to a high stage about the time that the severe cold of winter sets in, and that the ice begins to form. After the ice has formed and the winter has set in, almost all the moisture that falls on the surface of both the land and water falls as snow. A small portion of this snow evaporates into the air, but the greater portion of it remains and accumulates on the surface of the ground throughout the winter. It thus gives rise to a set of conditions which differ materially from those which prevail during the summer, for in the latter season, though the forests and swamps may act as efficient reservoirs, the moisture which falls as rain runs off continuously and rapidly into the streams and lakes as soon as it falls, while in the winter the moisture which falls as snow continues to pile up day after day and week after week, very little water soaks into the ground to supply springs, the surface run-off is almost entirely stopped, the supply of water flowing into the lakes is greatly reduced, and consequently the level of the surface of the water in the lakes drops very considerably. As the ice is floating on the surface of the water it necessarily falls into the water, except along the shallow shores where it was first formed and where it is now frozen to and rests on the sand and gravel of the bottom.

If it were possible for the water to drain completely out of the lakes the ice which had first formed on them would then sag down and rest on the bottom everywhere, but this is not possible, for the outlets of the lakes are sufficiently high to prevent the water from draining entirely out of them, but, nevertheless, the ice sags down as much as the outlet of the lake will permit and therefore it slopes downwards for a certain indefinite distance from the shore towards the lake and then merges into the general level ice which is floating on the water.

As I have already stated, most of the ice is floating on the water, and for a longer or shorter time, according to its thickness, its has buoyancy and strength enough to hold up the load of snow that falls on it. If snow falls to a considerable depth soon after the ice is first formed it will press the ice down into the water, for an inch of ice will only carry about five-sixths of an inch of dry snow, so if the ice is three inches thick it will carry two and one-half inches of dry snow but no more. In such a case, if the fall of snow has been greater than two and one-half inches it will press the ice down and the water will rise up through air holes, fissures, etc., and wet the under part of the snow. It is very well known to men living in the north that the ice on the lakes is certain to be wet, and that travel over them is unpleasant and even dangerous for a long time, if there has been a very heavy fall of snow soon after the ice has first formed.

A good illustration of these conditions was seen on Gowganda Lake, where the ice had attained a thickness of about twelve inches. There had been a heavy fall of snow which had accumulated to a depth of from two to three feet in the surrounding forest, and as there had been but little wind accompanying the snow, it might have seemed reasonable to look for a similar depth on the lake. But ice a foot thick will not support the weight of two feet of dry snow, and consequently it had been pressed down into the water, so that while it was completely covered to a depth

PLATE I.

Lane of water between the ice and the shore on Lake Temiskaming, May 6, 1909.

Lane of water between the ice and the shore at Haileybury on Lake Temiskaming, May 6, 1909.

PLATE II.

Lake Temiskaming covered with loose floating ice which has been shoved up on the shore by the wind. Logs and stones may be seen lying in front of the wall of ice. May 6th, 1909.

PLATE III.

Lane of water between ice and shore on Dubawnt Lake, August 12th, 1893.

Shore of Aberdeen Lake, showing boulder wall and stones shoved up by loose ice, August, 1893.

PLATE IV.

Boulder on north shore of Lake Winnipegosis, which has been pushed to its present position by the loose ice on the lake in the spring. The upper picture is looking towards the lake, while the lower picture is looking towards the shore. On it a wall of boulders which have been pushed back by the loose ice is seen in the background.

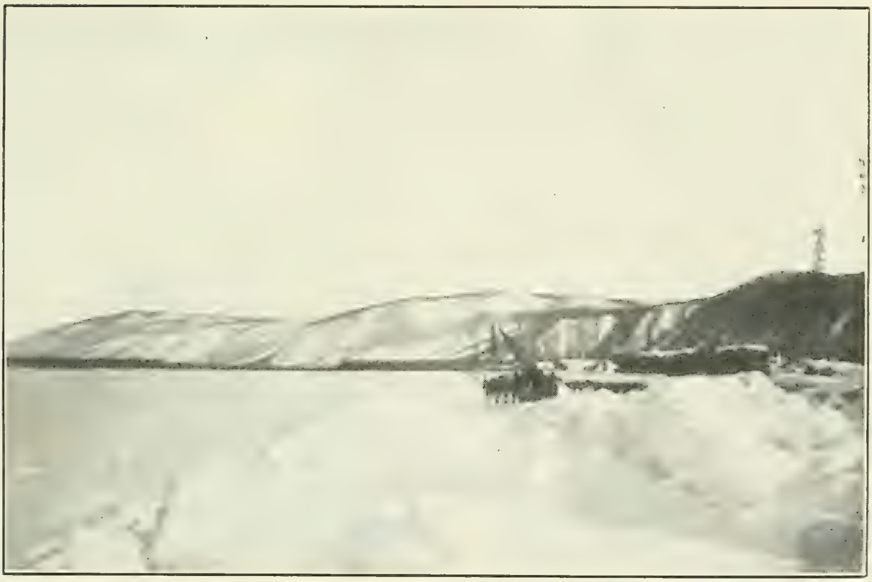
PLATE V.

Boulders shoved up on shore of Lake Winnipegosis by loose ice.

Boulders shoved up on shore of Lake Winnipegosis by loose ice.

PLATE VI.

Rough ice on Yukon River at Dawson.



Rough ice on Yukon River below Selkirk.

of ten or twelve inches, from four to six inches of the lower part of the snow was soaked with water. Shortly after the snow storm very cold weather set in and this wet snow was frozen to ice, and thus the general thickness of the ice was greatly increased by freezing from above and not from below.

Later in the winter the weight of snow would again become too great for the buoyancy of the ice and would press it down into the water, which would rise through and over it and cover it, possibly to a depth of a foot or more, with watery slush. The surface of this slush might be again frozen during the spells of extremely cold weather which occur in the latter part of the winter. In this way two sheets of ice might be formed, separated by a foot or more of water and slush. These two thicknesses are very commonly found on our northern lakes in the latter part of the winter and a man or team of horses may break through the upper and still be supported by the lower layer. Instead of freezing and forming a second upper thickness of ice, the water may melt the snow and carry it off the surface or down again beneath the ice. Thus relieved of its load of snow and slush, the ice will again float to the surface and may become quite dry and hard. The formation of this dry, hard ice just at the approach of spring, after it has been very wet and sloppy for some weeks, is a condition that is well known to lumbermen and others who have occasion to travel in the north.

In regions where the snowfall is light, a sudden fall in the temperature of the air will have considerable effect in increasing the thickness of the ice. While the cold weather causes the ice to thicken, it also causes it to contract, for as stated above, ice has a fairly high coefficient of expansion, and a change of one degree F. in temperature causes it to expand or contract to the extent of about two or three inches in a mile. In extremely cold nights this contraction often causes extensive cracks or fissures, which are formed with the accompaniment of loud reports so that the booming of the ice, while these fissures are forming on the larger lakes in the north, can often be heard for many miles. The fissures usually cross a lake in the same place each year, probably between salient points on the shores, and give rise to lanes of open water. On Lake Winnipeg these stretches of open water often cause obstructions in the ice roads which are used in teaming from place to place over the lake.

Now as it is quite clear that these fissures are formed by the contraction of the ice with the lowering of the temperature it was reasonable to infer that the ice would expand again horizontally when its temperature was raised. The fissures formed by contraction freeze over quickly in the cold weather and as the temperature rises the ice expands and closes these open lanes of water or even crushes the new ice which had formed in them, thus giving rise to ridges of ice where the open water was before.

But farther than closing these open lanes of water, the ice does not expand horizontally with the rise of temperature.

It has been argued by many, and even by as high authorities as Professor G. K. Gilbert, of the United States Geological Survey, and by Professors Chamberlin and Salisbury in their Geology, Vol. I., p. 371, that the ice expands with irresistible force and that it presses on the shores and shoves the gravel and sand, to which it freezes, back each year until it piles up walls of this gravel, sand and boulders around the shore. My attention was drawn to statements such as these more than twenty years ago and since that time I have spent many winters beside the frozen waters of our north country and have watched closely for evidence of the pushing of the ice towards the shore in winter, but have never been able to detect any evidence of such action. The shores remain perfectly undisturbed all winter except for the formation of the slope towards the water previously described, and if there is any change in the shore it would appear to be in the nature of a drag towards the water rather than in the opposite direction. Trees and boulders were seen lying just at the edge of the ice and no tendency was ever observed for the ice to move up toward them away from the lake. The ice was frozen too hard to the ground to permit of any shoreward movement.

That the ice must expand with almost irresistible force is unquestionable, but my observations have clearly shown me that, even with very rapid rises in temperature it does not expand horizontally, except to close the lanes of open water. If such horizontal movements did occur a rise of temperature of 50°F. would mean that the ice on Lake Temiskaming, which may be taken as a fairly typical example of our northern lakes, would expand thirty-five to fifty feet between its opposite shores, while between New Liskeard and Fort Temiskaming, a distance of eighteen miles, it would expand from one hundred and fifty to two hundred and twenty-five feet, instead of which it does not appear to expand at all, for it does not shove up on the shore during the winter. On Lake Winnipeg, which has a width of sixty-six miles and a length of two hundred and sixty miles, and which is frozen over completely every winter, a similar rise in temperature would cause an expansion of five hundred feet to eight hundred feet in the width of the ice, and two thousand to three thousand feet in its length, while the only evidence of this expansion consists in the closing of some few narrow lanes of open water. The expansion with increase of temperature must, therefore, be taken up by a vertical thickening of the ice, in other words, the viscosity of the ice must permit practically the whole of the expansion with increase of temperature to act vertically.

While the effect of horizontal expansion, if it occurred, would be very great, the influence of expansion vertically has very little effect in increasing the thickness of the ice.

Now as the spring approaches, and the weather becomes bright and warm, the ice begins to melt rapidly, at first around its edges close to the shore where the heat from the sun, and also the heat rising from the earth beneath the water, have the greatest combined effect. This melting of the ice along the shore in the early spring loosens it from the sand, gravel and rock so that it is no longer frozen tight to the beach, and consequently it cannot then press the materials forming the shore back by expansive force. The ice is then free from the shore, and is floating loosely on the water, while the snow is melting on the surrounding country, and is discharging a large quantity of water into the lake, which is rapidly rising in consequence. From that time onwards until it melts away, the floating ice is moved backwards and forwards on the surface of the water by the varying winds. One day with a south wind, it may be drifted on the north shore, while the next day the north wind may drive it with equal or greater force on the south shore, and while it is pressed against the southern shore there will be a lane of water between the ice and the land on the north shore and *vice versa*.

During the time in which the ice is driven backwards and forwards by the varying winds for days and even weeks before it finally breaks up and melts away, it is a very efficient instrument for ploughing up the beach, since the force with which it is driven against the shore is almost irresistible, and wherever it strikes against loose materials, such as sand, gravel or boulders, it drives them back, and often piles them in a wall behind the shelving beach.

Dubawnt Lake, one of the large bodies of water out in the Barren Lands of Northern Canada, is always more or less completely covered with ice. In August 1893, when I was travelling in canoes through a lane of water between the ice and the shore, the ice was sometimes several hundred feet away from the land and at other times was tight up against it. One night the ice was resting tight against the shore and we camped, intending to portage across a long point of land in the morning, but on the following morning, when we arose, the ice had withdrawn a hundred feet or so from the shore and we were able to paddle easily and comfortably around the point across which we had expected to have been obliged to make a long and difficult portage. The shores of this and of many other lakes in the vicinity showed abundant evidence of the shoving and pounding of floating ice, and in fact such evidence may be seen on almost any of the Canadian lakes in the spring, before the waves, caused by the summer and autumn storms, have reassorted the loose material on the beaches.

The pictures of the shore of Lake Temiskaming at Haileybury show a lane of water between the ice and the land and a number of places where boulders and logs have been pushed up by the ice.

Some excellent examples of the work thus accomplished by the ice in the spring were seen on the wide flat shores of the lakes in the Province of Manitoba. On these shores shallow clay flats extend long distances out into the water and boulders are scattered here and there through the mud over them. As the loose ice was driven backwards and forwards over the lake it was often shoved up on these flats and it acted as a scraper and carried the larger stones and boulders on ahead of it.

The following remarks were made in 1887 and referred to the shore of Lake Winnipegosis, the second largest lake in Manitoba:—"In this protected bay, and especially on its north side, which is bordered by a fringe of rushes, are some of the best examples of ice-grooving that have ever come under the writers observation. Boulders are lying here and there, and most of them show signs of having been moved from three inches up to thirty-three paces. The sand and pebbles of the beach are generally piled up on their landward side, while a groove extends towards the lake. The majority of the shorter grooves on the north shore trend N. 60° to 75° W. One, ten paces long, trends N. 10° W., and in this the boulder is seen to have at first lain transversely to the direction of the groove, and to have been turned round and shoved with its greater axis along the groove. A group of six boulders have been shoved in a direction S. 70° W. Another boulder 44 x 45 x 22 inches has taken the following course, turning sharply at the changes of direction: From its starting place in the water N. 50° W. for fourteen feet six inches, then N. 25° W. ten feet eight inches to the stone. Another boulder is now lying in the water at the end of a straight groove about fifty feet long, running from it in a direction N. 35° W. towards the shore, and pebbles are piled up on its lakeward side, showing that it has been shoved out from the shore when the ice was carried out by the wind. The shore throughout this distance has a constant direction S. 50° W."

"The irregularity in length and direction of these grooves on a soft, straight shore shows clearly that they are caused by the irregular pressure of broken ice in the spring, rather than by the regular expansion of the ice during the winter with the variations of the temperature."

"Behind this low beach is a wall of boulders that have been shoved back against the higher ground within the edge of the woods, and have reached their permanent resting place, where they can no longer be affected to any considerable extent by the waves and ice of the present lake. Within the woods is a ridge twenty feet high scattered with gneissoid boulders."*

The observations and conditions cited this evening establish the following points, viz.:

In regions of heavy snowfall the ice is being constantly pressed down into the water by the weight of the snow, and therefore there is often water over it and beneath the snow.

In these regions the ice increases in thickness mostly from the top, by the freezing of the overflowing water.

In regions of light snowfall it increases in thickness mostly from the bottom.

It expands laterally with decrease in temperature, but most of the expansion with increase in temperature is vertical.

Throughout the winter, it remains firmly frozen to the shore, and quite immovable, except that it falls with the lowering of the water in the lakes.

In the spring it thaws first along the shore, and around any stones, etc., which attract the heat.

The loose ice floating on the water of the main body of the lake in spring is pushed against the shore by the wind, and sand and stones are shoved up by and in front of it.

These stones are often shoved in this way to the back of the beach and are there piled into rough and heavy walls or ramparts.

* Report on North Western Manitoba by J. B. Tyrrell, An. Rep. Geol. Sur. Can. Vol. 1890-1, pp. 64-5 E., Ottawa Govt. 1893.

# THE LIFE HISTORY OF THE PACIFIC SALMON.

By Professor J. Playfair McMurrich.

(*Read 18th December,* 1909)

There is probably no group of fishes that has a greater or more varied interest for us than the Salmonidæ. The gameness of many members of the group makes them exceedingly attractive to followers of the "gentle art," the abundance with which certain species may be taken and the richness and delicacy of their flesh make them a food supply of great value and of great commercial importance, and, finally, in connection with the life histories of those that are commonly known as Salmon there are many interesting and important problems that have long attracted the attention of scientists.

The family contains two well-marked groups or sub-families, one of which includes the White-fish, the Ciscoes, and the interesting arctic Stenodus or Inconnu. This group need not be further considered at the present time. In the second sub-family, that of the Salmoninæ, are included a number of forms which are popularly known as salmon, trout, or by combining these two names, as salmon-trout, and it is certain of the Pacific Coast forms of this sub-family that I wish to consider in the present paper. It may be well, however, first to call attention to the principal Salmoninæ that occur on this continent.

The typical representative of the genus Salmo is the *Salmo salar* or Atlantic Salmon, which inhabits the North Atlantic and, at the spawning seasons, enters many of the rivers of northern Europe and also many of those of the eastern coast of this continent, from Cape Cod to Hudson's Bay. This is the well-known Salmon of our Quebec and New Brunswick rivers and to the same species are to be referred as varieties certain forms which have become permanent residents in freshwater lakes, such as the Land-locked Salmon of Sebago Pond, and the Ouananiche of Lake St. John.

This species does not occur on the Pacific coast, but closely related to it, although by some authors regarded as representatives of a subgenus or even a distinct genus, are the black-spotted trout of that region. Of these three species are usually recognized, although there is great variation in each, so that it becomes exceedingly difficult in some cases to determine the proper position of individual fish, although typical forms are readily distinguishable. One of these species is *Salmo mykiss*, the Cut-throat or Rocky Mountain trout, which occurs in clear streams of the Pacific coast all the way from Alaska to California. It derives its somewhat disagreeably suggestive popular name of Cut-throat from a blotch of red which is always present on the under surface of the head, between the rami of the lower jaw. Those found in the coast-wise streams are anadromous, periodically running up from the sea, but like the Atlantic salmon it is also found as a permanent resident of various inland waters, the Yellowstone trout, for example, being such a variety. A second species is the Steel-head trout, *S. gairdneri*, a splendid anadromous fish reaching a weight of twenty pounds or more and ascending the coastal rivers from California to British Columbia. It also occurs as a smaller land-locked variety in the Okanagon, Kootenay and other British Columbian lakes. Finally, the third species of this group is the *S. iridens* or Rainbow trout, abundant in the mountain streams of the Coast range from Puget Sound to California. It receives its specific and popular names from the brilliance of its colouration, which otherwise resembles that of *S. gairdneri*, from which, however, it may be distinguished by its smaller size (½-6 lbs) and by the larger size of its scales. These three forms are American representatives of the European trout, *S. trutta*, and it is to them that the term trout is especially applicable.

Distinguished from the genus Salmo by various structural peculiarities, among which is the greater length of the anal fin, are the Pacific Salmon, which have been assigned to the genus Oncorhynchus and of which five species are recognized. The first and most important of these is the *O. tschawytscha*, variously known as the Spring, Quinnat, Chinook, King, Columbia River and Sacramento River Salmon, a fish which forms the main basis of the canning industry on the Columbia and Sacramento Rivers, although it also occurs farther north in smaller numbers, being taken in the British Columbian and Alaskan rivers and also in those of northern China. In the Sacramento River it averages sixteen to eighteen pounds in weight and in the Columbia as much as twenty-two pounds, although much larger individuals, even up to seventy or one hundred pounds, have been taken. Second in importance to the Spring salmon is the Sockeye, *O. nerka*, also known as the Fraser River or Blue-back salmon or as the Red-fish, on account of the reddish hue assumed in the breeding season. This is the most important species in the British Columbia rivers and constitutes by far the greater portion of the pack of the Canadian and Puget Sound canneries. In the Fraser River it averages from six to seven pounds in weight. The three remaining species are of much less value, since, although taken in large numbers, they are, for reasons to be explained later, much less suitable for canning purposes than either the Spring or Sockeye salmon. They are the Silver salmon or Coho (*O. kisutch*), the Humpback (*O. gorbuscha*), so named from the large hump which the males develop just back of the head during the breeding season, and the Dog salmon (*O. keta*), the least valuable of all as a food fish.

To complete the list of American Salmonids there still remain for brief mention the lake and brook trout, which are really not trout in the strict application of that term, but are more properly spoken of as Charr, being comparable to the European forms known by that name. The lake or salmon trout have been assigned to the genus Cristivomer, the species to which all our varieties may probably be assigned being *C. namaycush*; while the brook trout belong to the genus Salvelinus, our common species being *S. fontinalis*. A number of other species of Salvelinus have been described by various authors as inhabiting the streams of this Continent, but the determination of their systematic position is a very difficult question and they have been regarded by Jordan and Everman as, in certain cases, varieties of *S. malma*, the Dolly Vardon trout of the streams of the Cascade Mountains, or, in other cases, as sub-species either of *S. alpinus*, the Saibling or European Charr or of *S. oquassa*, the Blue-back trout of the Rangeley Lakes.

It is especially the members of the genus Oncorhynchus that I wish to consider at present and more especially *O. nerka*, the Sockeye salmon, and in giving an account of the life-history of this fish it will be convenient to start with the adult form. The Sockeye is an anadromous fish, spending a considerable portion of its life in the sea and ascending the rivers for the purpose of spawning. This habit is by no means peculiar to the Sockeye, but is common to all the Pacific Salmon and to all the typical members of the genus Salmo. It is also found in fishes of other families, as for instance, in that of the Herrings or Clupeidæ, of which the Shad and the Gaspereau are typically anadromous in their habits, and is perhaps an exaggeration of the migratory habits possessed by many fish and notably exemplified by the Sea Herring.

In the case of the Pacific Salmon, however, some of the peculiarities of the life history of the other Salmonidæ are intensified and some modified in a very material manner, In the spring of the year and early summer the Spring and Sockeye salmon begin to make their appearance in considerable numbers on the coast as plump, well-fed fish, with bright red, solid flesh; they feed voraciously so long as they remain in salt water and take the trolling spoon readily. As they come under the influence of the tides the Spring salmon are said to be influenced by them in their movements, coming in against the ebb and going out against the flow, so that their actual progress toward the rivers is slow, although there is a certain daily progress, owing to the ebb-tide running somewhat longer than the flow. Reaching brackish water sooner or later, they remain in it for some time, but eventually they enter fresh water and begin their ascent of the river. Here also their progress is slow, especially in the case of the earlier arrivals, the Spring salmon of the Columbia River requiring, it is estimated, from one to three weeks to reach Clifton, situated about twenty miles from the mouth, and arriving at the falls of the Dalles, two hundred miles up stream, only after the expiration of about two months from the time of their appearance at the mouth. The Sockeye of the Fraser River is a little later than the Spring salmon of the Sacramento and Columbia Rivers in beginning its migration, but both species continue to enter the rivers throughout the summer in numbers which in good years may be literally described as countless. Toward autumn their numbers diminish, although at the coming of the fall rains and the consequent swelling of the rivers a late run of Spring salmon usually occurs, known to the fishermen as the fall run, and late runs of Sockeye also occur in some years. In the case of the other species the commencement of the migration is later in the year, coinciding in the case of the Dog salmon with the fall rains, so that this species has only a late run, a fact which, as will be seen later, diminishes its commercial value very materially. The Coho, however, appears in the coastal waters some time before entering the rivers and for this reason is of more value as a food fish than either the Humpback or the Dog salmon.

The distance that the fish travel up the rivers depends to some extent on the time of the year at which the migration begins, those fish which run in the earlier part of the year continuing their course to the head waters of the streams, while those running only in the fall remain in the lower reaches. Consequently it is only the Spring and Sockeye salmon that reach the head waters, and of these only those fish that start their migration early, the later fish, together with the Humpbacks and Cohoes, spawning lower down, while the Dog salmon, the latest of all to run, never go far from the sea. In the Salmon River of Idaho, a branch of the Snake River, itself a branch of the Columbia, the Spring salmon, according to Jordan and Evermann,* ascend to the head waters, more than a thousand miles from the sea, spawning there in August and the early part of Sep-

*D. S. Jordan and B. W. Evermann. The Fishes of North and Middle America. —Bull. U. S. National Museum. No. 47. 1896.

tember, and in the Snake River itself they reach the Salmon Falls in southern Idaho where they spawn in October and November. The enormous extent of the migration in the Columbia is well shown in a map given by Col. Marshall Macdonald.* In the Fraser River the Sockeye spawn in large numbers in the Shuswap Lakes, at Quesnel Lake at a distance of about three hundred and fifty miles from the sea, and they also reach the head waters, spawning in Stuart and Tatla lakes and in Lake François in considerable numbers, five hundred miles from the ocean. The Humpbacks do not extend so far up, none being observed in a big run of that species in 1907 above Kamloops on the Thompson River, a distance of two hundred and fifty miles from the sea, and in the Fraser River proper none were seen above Seton Lake. "In the rest of the watershed the streams were crowded with countless thousands. The Nicola River was a wriggling mass of fish from a point about half a mile from Nicola Lake to the river's mouth, and they literally filled all the other tributaries of the Thompson and the Fraser below the points named."†

This description by Commissioner Babcock gives a vivid picture of the enormous abundance of the fish during the run in the good years. The number of fish at a given point of the river will, of course vary from time to time, but at the height of a good run they may be seen in such numbers as to justify some of the stories one hears concerning them, such as it being possible to cross the river practically dry shod on their backs or that they have overturned a stage coach while it was fording the stream. They certainly would readily overturn a rowboat, not to speak of a canoe, and in the great run of 1905 an observer at the fish-way at Quesnel Lake states that "There were days when the fish were two or three feet deep going through the ladder. It ran red with them."‡

The Fraser is the largest and longest river of British Columbia, and it is in it that the run is greatest. Some idea of the extent of a good run may be obtained from the statistics of the pack produced by the canneries operating on the river and the adjacent waters. In 1905, the last "good" year for which I have complete figures, the Canadian canneries of the Fraser River district put up 877,136 cases of salmon of all varieties, each case consisting of forty-eight pounds. In addition to this the canneries operating in the State of Washington, which make use of fish migrating toward the Fraser River, put up 1,057,295 cases, so that the total pack of Fraser

*Bull, U. S. Fish Commission. XIV. 1894.

†J. P. Babcock. Report of the Commissioner of Fisheries for British Columbia for the year 1907. Victoria, B.C., 1908.

‡Report of the Fisheries Commissioner for British Columbia for the Year 1905. Victoria, 1906.

River salmon for that year amounted to 1,934,431 or well on toward 2,000,000 cases, 96,000,000 pounds. But it is not in the Fraser River alone that the fish run. In the north there are two other rivers of fair size, though much smaller than the Fraser, which also contribute largely to the salmon pack. On the Skeena River, which drains Lake Babine, a favourite spawning ground, the pack of 1905 amounted to 114,085 cases and from the still smaller Naas River, opening into Portland Canal, the pack in that same year amounted to 32,725 cases. Furthermore, along the coast in various inlets a sufficient number of salmon are taken to warrant the operation of canneries, Rivers Inlet, for instance, yielding a pack in 1905 of 83,122 cases, Dean Channel 13,890 cases, and the Bella Coola district 10,029, while smaller packs were put up at other points on the mainland and on the West Coast of Vancouver Island as, for instance, in Clayoquot Sound and the Alberni Canal. Taking the entire pack of the Canadian canneries for 1905, it will be found to amount to 1,167,460 cases, and if to this be added the pack of the State of Washington canneries operating on Puget Sound there results the enormous amount of 2,224,755 cases, in round numbers 106,800,000 pounds, as the total pack of British Columbia salmon in 1905. It may be added that the value of the pack from the Canadian canneries was $6,621,942.

But the cannery pack constitutes only a portion of the salmon catch, for the Dominion Fishery Report contains the following additional items:

| | |
|---|---|
| Salmon fresh or on ice............ | 8,456,960 lbs. |
| Smoked salmon.................. | 446,000 lbs. |
| Dried salmon.................... | 15,494,600 lbs. |

Adding these items to the cannery pack we get 131,185,896 pounds as the 1905 catch, without counting 5,220, barrels of salted fish. These additional items bring the value of the catch of Pacific Salmon in Canadian waters in 1905 up to $8,330,713.

This catch is almost entirely made up of fish taken in the sea on their way to the rivers or in the rivers near their mouths, for as the fish ascend the rivers they undergo marked changes which greatly diminish their value for food purposes. As it comes from the sea throughout the summer the Sockeye salmon is a splendid, graceful fish, whose lines suggest great activity and power. In colour he is silvery throughout, although on the back the silver overlies a ground of clear bright blue, whence the name "Blue-back" applied to the fish in some localities. But as the spawning season approaches the colour alters very remarkably; the skin becomes thicker and softer, so that the scales appear to be more deeply imbedded in it and the bright silvery sheen almost disappears; the blue of the back gives place to a blood-red colour and the sides also become red, though of a darker shade. In the males a further change occurs in that both the upper and lower jaws elongate to form a snout and become greatly hooked, large teeth at the same time developing upon the terminal portions of the jaws, so that from its original graceful form the head assumes a decidedly grotesque appearance. The body also changes somewhat in shape, becoming deeper and flatter, especially in the region of the shoulders, and in the Humpback salmon a distinct hump appears upon the back just behind the head, and may reach a considerable size.

But the changes are not confined to the external form and colouration; the internal organs are also materially affected. So long as the fish remain in salt water they feed voraciously, but as soon as they enter fresh water they practically cease to feed and, unlike the Atlantic salmon will not as a rule rise to a fly and hence possess little interest for anglers. Indeed, it is said that we owe the loss of certain islands in the Gulf of Georgia to this peculiarity of the Pacific salmon. For, so the story goes, it being a matter of discussion, during the framing of one of the boundary treaties, as to which side of the islands the boundary line should pass, the British Government instructed the admiral in command of the warships at the time on the Pacific coast to visit the islands and report as to the advisability of disputing their possession. The admiral, hearing that salmon occurred in the streams of the islands and being a keen fisherman, looked forward to combining some excellent sport with the performance of his duties and was so disappointed by his failure to get the fish to rise to his flies that he reported unfavourably regarding the islands and advised his government that it was not worth while to insist upon their retention.

The cessation and long continued abstinence from feeding brings about a marked loss of weight, so that the fish when they arrive at the spawning grounds are in this respect, as well as in general form, greatly fallen from their former estate. I cannot give any figures showing the extent of this loss of weight in the Sockeye, but may quote an observation made by Rutter* on three Spring salmon which were captured at Rio Vista, not far from the mouth of the Sacramento River, and, after careful weighing, were marked so that they could be recognized if taken again and were then released. Sixty-four and fifty-six days later two of these fish were taken at the Mill Creek fishery and after sixty-six days the third was taken at Battle Creek, and when again weighed these fish were found to have lost respectively twenty-six per cent., fifteen per cent. and twenty-

*C. Rutter. Bull. U.S. Fish Commission. XXII. 1903.

five per cent. of their former weight. This loss is partly due to changes in the flesh, which becomes less firm and at the same time loses much of its bright red colour. This colour change may also take place independently of the other alterations that have been mentioned, since in the Columbia River a few Spring salmon are taken in the early run and many in the fall run whose flesh is almost white, and in the Fraser River the great majority of the Spring salmon taken in the fall are white or partly so. The flesh of these pale fish may be just as firm and quite as palatable as that having the normal salmon colour, but it is less esteemed by consumers, who demand the colour they are accustomed to associate with salmon. Hence the canners distinguish between Red Springs and White Springs in the tabulation of their catch.

And not less remarkable than these changes are those undergone by the digestive organs. The stomach of the sea run salmon is a well marked organ, and clustered around the intestine immediately below it there is a number of finger-shaped outgrowths, known as the pyloric cæca. These vary in number in the different species, the Coho possessing about sixty-three, the Sockeye somewhere between seventy-five and ninety-five, while in the other species they number somewhere in the neighbourhood of one hundred and eighty. In fish that have spawned or are on the spawning grounds the entire digestive tract has shrunken to a mere shadow of its former condition, the stomach is hardly distinguishable and the pyloric cæca form merely a short fringe around the upper part of the intestine.

These changes have been ascribed to the influence of fresh water, but the weight of evidence is entirely opposed to such a supposition. The modifications are undoubtedly associated with the maturation of the reproductive organs and may occur independently of the migration of the fish to fresh water. Thus it has already been noted that the change in the colour of the muscular tissue occurs in the Spring salmon of the fall run, that is to say, these fish enter fresh water already changed in this respect. So, too, Sockeye taken at the mouth of the Fraser late in the year already show the hooked snout and the changed colour of the skin, and, indeed, the fish of the late runs are inferior in quality to those arriving earlier in the year. It is owing to the fact that the Spring and Sockeye salmon migrate in quantities so early in the year that they are most suitable for canning. The Humpbacks are of much less value owing to their run being later, although if taken in its earlier runs and fresh from the sea it is a most excellent fish and by some even preferred to the Spring salmon. The Dog salmon, which is the latest to run, is almost useless as a food fish and is practically neglected by the canneries, the Indians alone finding any great use for it.

But in addition to all these physiological changes the fish suffer many mechanical injuries during the spawning operations from violent contact with the stones and gravel of the bottom of the streams. Their fins become torn and ragged and the soft skin suffers abrasions which may serve as suitable growth centres for the Salmon fungus. And, finally, the exertions of spawning frequently produce even more serious internal injuries, so that the spent fish is but a sorry spectacle compared with the graceful creature that entered the river.

Indeed, so exhausted are the fish from their prolonged fast and from the subsequent exertions in spawning that enormous numbers of them die at the conclusion of the latter process. At times the bottoms of the lakes and streams in which they spawn are white with dead fish, which form a grateful feast for the bears and crows. It is highly probable that none of the fish that spawn in the upper reaches of the rivers ever return to the sea, and since these constitute the main bulk of the run there must be a very small percentage, if any, that do not die on the spawning grounds. Indeed, even in the case of the Humpback and Dog salmon, which do not ascend so far up the rivers, death seems to be the sequel to reproduction. The difficulty does not seem to lie in any material obstacles in the way of a return downstream, but in the absence of a stimulus urging the fish in that direction. Evermann* describes an observation which he made at Alturas Lake in Idaho, which is very pertinent in this connection. A net was placed across the outlet of the lake so as to take any fish that might be migrating downstream, and on September 6th the lake was found to contain about one thousand salmon. By September 14th the number of fish alive in the lake was reduced to two hundred and sixty-three, and by September 22nd not more than twenty-five were left. Throughout this time no fish were caught in the net, except a few that were in such a feeble condition that they could not swim and were passively carried down by the current. No fish voluntarily left the lake after the spawning period; all died on the spawning ground and this seems to be the fate of all the species of Oncorhynchus. In this respect the Pacific salmon differ from the Atlantic species; they spawn only once in their lifetime, the journey up the river being a journey leading to the sacrifice of the individual for the good of the species.

The spawning of the Sockeye usually begins in the Fraser River in

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*Bull. U.S. Fish Commission. XVI. 1897.

August and continues until the early part of October, although it may be prolonged into November or even later when, as happens in some years, the run is continued later than usual. There are some slight differences in the spawning habits of the different species; the Sockeyes, for example, spawning principally in lake-fed streams, while the Spring salmon and Humpbacks seem to prefer streams which do not issue from lakes. But in general the process is essentially the same in all the species. The female chooses a situation where the current is fairly rapid and passes over a gravelly bottom, forming what is locally known as a "riffel." Placing herself at the upper end of the riffel, with her head pointing upstream, she extrudes a number of ova and then moves away, the male immediately taking her place and shedding a portion of his milt. The female again returns to her original position and deposits more eggs and so the process goes on day and night for one or even two weeks. In their struggles to set free the reproductive elements the fish usually excavate a more or less distinct hollow in the gravel of the bed of the stream, and this has frequently been taken to be a nest prepared for the reception of the eggs. As a matter of fact the current usually carries the eggs below the so-called nest, and it seems more in accordance with the facts to regard the "nest" as a mere accidental hollow produced by the exertions of spawning.*

The ova, when extruded, are carried a short distance downstream, but they quickly settle to the bottom, lodging between the particles of gravel, and if fertilized, they develop in that situation. They are relatively large ova, about quarter of an inch in diameter, and are of a bright orange colour and hence are rather conspicuous, so that they fall an easy prey to other fish, such as trout, and to water birds. Under ordinary circumstances the young fish from the eggs deposited by the earlier running salmon hatch out in about two and a half or three months, but those deposited by the later fish may require four or even four and a half months before they leave the egg, the difference being due to the lower temperature of the water. When the young fish is first hatched the yolk, which forms the main bulk of the egg, is not all absorbed, but distends the intestine and ventral body wall into a globular projection and greatly interferes with the swimming powers of the alevin, as the fish at this stage is termed. The bright orange colour of this unabsorbed yolk also renders the alevin a very conspicuous object when it emerges from under cover of protecting pebbles, and as the young fish on occasion gathers in schools they

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*In this description of the spawning process I have followed closely the account given by Rutter (*l. c.*) for the Spring salmon of the Sacramento River, but from what is known regarding the Sockeye it seems that the process is essentially the same in that species.

become an easy prey to various enemies. Indeed the alevin stage seems to be one of the critical periods of the life of the salmon.

In time, however, the yolk is absorbed and the young fish, now known as fry, as the spring advances, begin their migration to the sea. Not all, however, for apparently a considerable number remain until the following spring in the waters where they were spawned. At least this is the conclusion to be drawn from the observations of Commissioner Babcock.* In 1903 the Fraser River district and in 1904 in Wannach River which empties into Rivers Inlet, he observed the migration in the spring of great numbers of young fish, the migrants consisting of two sizes, those of the one size averaging in the Wannach River one and one-eighth inches in length, while those of the other size varied from two and a quarter to three inches, some even reaching a length of five or six inches. The smaller fish were the more numerous and may be supposed to be the fry hatched from eggs spawned in the preceding fall, while the larger ones were probably a year older and hence have been called yearlings.

Starting on their journey in the spring both fry and yearlings descend the river to the sea, at least so we may suppose, although little is known as to their history during the voyage, nor are we more fully informed as to their life while they are in the sea. We may, perhaps, assume that they increase in size very rapidly in the salt water, but where they go when they reach it, whether they remain fairly close to the mouths of the rivers from which they came or whether they wander out into the deeper waters is at present uncertain. Here is a whole chapter in their life history whose pages are almost blank. From the time the young fish start on their seaward journey until they return again to the mouths of the rivers to ascend as an adult fish to the spawning grounds, their history is practically unknown to us.

We do possess data, however, which give us fairly certain information as to the time they remain in the sea. One of the facts throwing light upon this question is furnished by the records of the cannery pack of the Fraser River, which shows that the run of every fourth year in that river is greatly in excess of those of the intervening years, so that each fourth year is now recognized by the fishermen and canners as a "big year." How marked are these big runs in each fourth year is well shown in the diagram (Fig. 1), which represents the pack of Sockeyes in cases of forty-eight pounds put up by the Canadian canneries for successive years from 1893 to 1908 inclusive. In 1893 the pack did not greatly exceed those of

*Reports of the Fisheries Commissioner for British Columbia for the years 1903 and 1904.

the succeeding three years, perhaps owing to the fishing industry being in these earlier years much less perfectly organized than it was later, but when we come to 1897 we find the pack taking a sudden leap to 850,000 cases as compared with 325,000 in the preceding year. In the following year it again fell, having reached only 216,000 cases; it rose somewhat in the next year but in 1900 it fell again to 166,045. And then came in 1901 a run which is *par excellence* the "big run," the pack reaching nearly a million cases, or to be exact 962,682. I may add that in this year the Puget Sound canneries packed 1,086,637 cases, so that the total pack of

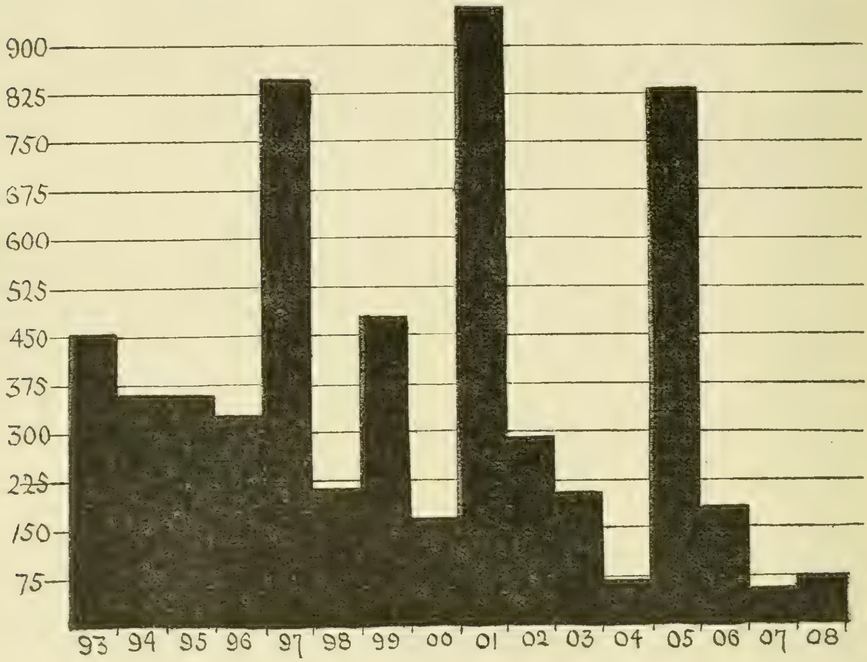


FIG. 1—Sockeye Pack Fraser River.

Fraser River Sockeyes reached, in 1901, the amazing amount of 2,049,319 cases. Following this big year came three lean years and again, in 1905, the pack rose, this time to 837,498 cases, and then followed again three lean years, the pack of 1907 being the smallest since 1892. The present year should again have been a big year, but the official figures have not yet been compiled. I have, however, by the kindness of Commissioner Babcock, been furnished wth an estimate of the pack, according to which the Canadian pack probably amounts to about 600,000 cases, a good deal less than in the preceding good years but still greatly in excess of that of the three preceding lean years. The pack of Puget Sound canneries, however, undoubtedly greatly exceeds the Canadian pack, probably reaching well toward, if not exceeding 900,000 cases, so that the total Fraser River Sockeye pack will fall but little below that of 1905 and will probably exceed that of 1897. There are certain obvious objections to taking these figures of the cannery pack at their face value as indications of the extent of the run of fish in any year. The greater pack in certain years may, for instance, be due to a greater number of canneries being in operation. I have, however, plotted out the average pack per cannery for the same period of sixteen years and the results are essentially the same as those obtained by plotting the total pack. The averages, however, bring out more clearly the periodicity in the years prior to 1893 when the number of canneries in operation was much smaller than in later years. Indeed, by them the four year periodicity can be distinguished clearly as far back as 1885. Beyond that, however, a new feature is revealed, namely the occurrence of large runs in two of the years constituting a four year period. This does not invalidate the conclusion as to the existence of the period; it merely indicates the probable occurrence of two good four year periods in these early years instead of the single one which alone persists. I shall have, however, occasion to return to this method of comparing the runs later.

It is worthy of note that this periodicity of the big runs is evident only in the Fraser River. The runs in the Skeena and other northern rivers, though varying materially in different years, do not show any definite periodicity. What brought about the periodicity of the big runs in the Fraser is entirely unknown. How long it has existed we do not know, nor can we clearly picture the conditions, geological or climatic, that may have produced an especially favourable year for the fish or three succeeding unfavourable ones or a combination of both. But the facts presented demonstrate the existence of the periodicity; it is a fact so far as the Fraser River Sockeye are concerned and not a theory.

Granting then its occurrence what bearing has this four years periodicity upon the life history of the salmon? Let us recall the fact that none of the fish that reach the spawning grounds return to the sea; the runs of future years must be composed solely of fish that are for the first time ascending to the spawning grounds. Further, it is to be expected that in the years of the big runs more fish will reach their normal destination and therefore that there will be a greater number of eggs spawned than in the poor years. That this expectation is fulfilled is shown by Commissioner Babcock's observations of the spawning grounds in different years and he produces concrete evidence* concerning it from the take of eggs by the

*Report of the Fisheries Commissioner for British Columbia for the Year 1906.

hatcheries, which take depends upon the abundance of fish on the spawning grounds. In 1901, the year of the "big" run, the hatcheries were running to their full capacity and could have obtained far more eggs than they could accommodate. In 1902 their take amounted to only seventy-three per cent. of their capacity, in 1903 to twenty-five per cent. and in 1904 to only ten per cent., but in 1905 it again rose to ninety-three per cent., notwithstanding an increase in the number of hatcheries in operation from two to five.

These data point clearly to a relation between the abundant spawning in 1901 and the large run of 1905, and similarly a relation between the diminished amounts of spawn in 1902, 1903 and 1904 and the diminished runs of 1906, 1907 and 1908. It seems probable, therefore, that the life of the Sockeye extends over four years. In other words, the eggs spawned this fall will produce fish that will reach the spawning grounds, spawn and die in 1913.

The chain of argument outlined seems fairly reliable, but there are reasons for supposing that there may be exceptions to the rule. It has already been noted that each spring there are two sizes of young fish starting on their migration to the sea, fry and yearlings. The fry, it may be presumed, will return to fresh water three years later, but do the yearlings, which have already spent a year in fresh water accompany the fry with which they descended on their return migration or do they return a year earlier with the fish that were spawned in the same season as themselves? In other words, do they remain two or three years in the ocean. On this point we have no definite information and we are in the same position as to the causes that determine their prolonged stay on the spawning grounds. And yet these may be matters of no little importance in connection with the possibility of favourably modifying the runs in the poor years, especially in that of the year succeeding a good run.

Some fish also seem to return to fresh water before they have reached the fourth year of their existence. At least this seems to be the most plausible explanation of the occurrence of greatly undersized fish on the spawning grounds. These fish, which are relatively few in number compared with those that are full grown, are less than half the size of their companions, weighing only two to two and a half pounds and measuring sixteen to eighteen inches, and they are all males. Notwithstanding their small size they are sexually mature and deposit fertile milt. No similar precociously mature females have been observed. They have been taken in lakes tributary to the Columbia River and in Nicola, François, Stuart and Shuswap Lakes, tributaries of the Fraser River. In the

Columbia they are known as Little Redfish or Kennerley's salmon and were for a time regarded as permanent residents in fresh water, but according to Jordan they have been observed by Gilbert in the lower reaches of the Columbia and are probably anadromous.

If this be the case they probably correspond to the grilse of the Atlantic salmon and, like these, are fish that have returned to fresh water earlier than usual, perhaps as the result of a precocious maturing of their reproductive organs. It is worthy of note that these fish show less of the red colouration than the adult males and the beak formation, so characteristic of the latter, is much less developed. More information is needed concerning these grilse and while it would be interesting to correlate their occurrence with that of the yearlings, such a suggestion would be at present too much in the nature of pure speculation.

But while it is possible that some fish may delay their return to fresh water until the fifth year and others may hasten it, yet it seems, from the facts that have been presented that the upward migration of the immense majority of fish takes place in the fourth year of their life. And I have recently been able to obtain confirmatory evidence of this from a structural peculiarity presented by certain organs of the fish. In 1899 Hoffbauer* showed that the age of Carp could be determined by a study of the concentric rings on their scales, and later Thomson† found that this was true also for several members of the Cod family. In 1906 Maier‡ extended the observation to the Flat-fishes and found further, that the so-called ear bones or otoliths of these fishes showed series of concentric rings similar to those occurring in the wood of exogenous trees and like these indicating the age of the fish. Recalling this fact and in the hopes that the otoliths of the salmon might show a similar structure, I obtained through the kindness of Inspector Sword of New Westminster, B.C., the heads of six Sockeyes taken in September on their way up the Fraser River, and on examining the otoliths of four of these fish I was delighted to find that they all showed growth rings and, furthermore, there were in each case four such rings. Sketches of the right otoliths of these four fish are here shown (Fig. 2) and it will readily be perceived that in each four distinct growth lines occur. The observation requires repetition on a much larger number of fish and the otoliths of fry, yearlings and grilse ought also to be examined before this present finding can have full value,

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*Jahresbericht des Schlesischen Fischerei-Vereins. 1899.

†J. S. Thomson. Journ. Marine Biological Assoc. Vols. VI and VII. 1902 and 1904.

‡H. N. Maier. Wissenchaftl. Meeresuntersuchungen. Abth. von Kiel. VIII. 1906.

but, so far as it goes, it furnishes a striking confirmation of the results obtained from a study of the statistics of the annual packs. I may add that an examination of the scales of the fish at my disposal gave entirely negative results.

We have now completed our study of the life history of the Sockeye salmon and I may restate it concisely, so far as the majority of the fish are concerned. The eggs are deposited in fresh water in the fall of the year and the alevins hatch out in from one hundred to one hundred and twenty days. In the ensuing Spring the fry start on their migration to the sea, where they remain until the Spring or summer of their fourth year

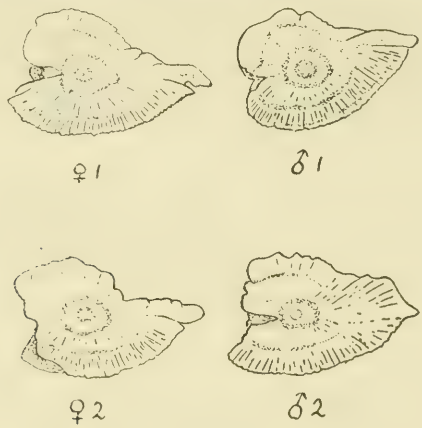


FIG. 2—The right otoliths of four adult examples of *O. nerka*, showing growth rings.

of life, when they again return to fresh water and ascend to the spawning grounds. On the completion of the spawning the parent fish, both males and females, die.

There is one further point, however, of a psychological nature that I would like to consider briefly. It has been maintained that each generation of fish returns to the identical grounds upon which they themselves were spawned. This is certainly an enormous strain on that mysterious faculty which we call instinct. That the young fish, but a few months old, can travel a thousand or even five hundred miles downstream, and that for a great part through rapid rushing water, then spend some three years in the ocean and, finally, retrace this long journey upstream to their original nursery, surely such a supposition requires not a little serious consideration before it can be accepted. True, many birds do something of the same sort, but birds are very different creatures from fish, their migrations are annual and not quadrennial and the old birds do not all die off when the eggs for the next generation are laid, but take part in the migration. If it really exists the homing instinct of the Pacific salmon is more wonderful than that of any birds.

To obtain direct proof that the fish return to the very streams in which they were spawned is naturally very difficult, and the evidence in favour of this idea is entirely circumstantial. Thus it is said that the Indians can distinguish between the fish which belong to the various side streams when they are taken in the main Fraser River, but it is not stated how the identifications of the Indians were checked. Further it is stated that there is a marked difference in the size of the eggs deposited by the fish frequenting different tributaries of the Fraser, those of Silver Creek, for example, laying eggs that average seven thousand to the quart, the eggs from Morris Creek averaging eight thousand, and those from Harrison River six thousand, and although the latter two streams are close together it is said that the fish with the larger eggs are never taken in Morris Creek and *vice versa*. In other words it is held that there are different local races of Sockeye which never commingle on the spawning grounds.

Rutter gives an interesting observation bearing upon this question. It is known that before 1897 no spring salmon bred in Paper Mill Creek, which opens into Tomales Bay, California. In that year 855,000 fry were set free in the creek and in 1898 2,000,000 alevins were added. In 1900 a few salmon were seen in the stream and in 1901 they were abundant. This seems a very pertinent observation, but it does not by any means prove the existence of a homing instinct. And on the opposite side of the account may be set an observation by Babcock. In 1898 a dam was built across the outlet of Quesnel Lake which effectually prevented access to the lake by fish; but in 1904 a fishway was built on the dam and in the following year large numbers of fish spawned in the lake. In this case the occurrence of fish in the lake cannot be assigned to a homing instinct since no fish had spawned in the lake for seven years.

President Jordan, who has the right to speak authoritatively, expresses himself very sceptically concerning this theory. He believes that there is no definite homing instinct, but that the fish when they reach the sea never wander very far away from the mouths of the rivers in which they were spawned and hence when the stimulus to seek fresh water seizes them, they are apt to encounter their native rivers rather than any others. It is a question of accident rather than instinct. This seems to be the most plausible view to take of the matter and may be accepted until more definite evidence is brought forward in favour of the existence of a homing instinct.

I have already given some figures which may serve to convey some idea of the extent of the salmon fishing industry in British Columbia. When one thinks of the hundreds of thousands of salmon that are taken annually one cannot avoid wondering whether the supply will in the future continue to equal the demand. Can the fisheries continue to be carried on at their present rate without seriously impairing the supply?

It must be remembered that the fish are taken on their way to the spawning grounds and it is upon the arrival of a sufficient number of fish on these grounds that the size of the run of the fourth succeeding year depends. It is not directly from the size of the catch of any year that the size of the catch four years later can be estimated, but from the number of fish that may be found on the spawning grounds, having escaped the nets of the fishermen and other enemies on the way. An accurate estimate of such fish cannot very well be made, although the number of eggs taken at the hatcheries will give a certain idea of their abundance. It may, however, be assumed that the larger the run the greater will be the number of fish that escape the nets and ascend the river, and that this assumption is fairly correct is shown by a comparison of the hatchery take of eggs and the size of the run as determined by the cannery pack.

We may, therefore, take the cannery pack as a basis of information on the question, or better, perhaps, the average pack per cannery, or better still, the average pack per line of machinery in operation, for after 1897 several canneries enlarged their output by adding additional lines of machinery. There are objections to such averages as a basis for argument, but for our present purpose they are more suitable than the statistics of the total pack. I have plotted out these averages for the years 1876–1904, the figures being taken from the Dominion Fisheries Report for 1905, and in plotting them I have distinguished the various runs of the four year cycles (Fig. 3). It will be seen that in the early part of the period three classes of runs may be distinguished: good, intermediate and poor. In the earlier years there were two good runs, those of the 1877 and 1878 series, one intermediate, that of 1879, and one poor, that of 1876. The 1878 run was about equal to that of 1877, but four years later it was appreciably better. In the following fourth year, however, it suddenly sank to the poor class, for what reason I do not know. In the two following fourth years it made brave attempts to regain its original position, but finally failed and ended in the poor class. The 1877 series has remained good throughout and has never descended from the good class, and the 1876 series has remained pretty uniformly in the poor class, although in 1896 it suddenly reached the intermediate class, only to fall again to its original estate. Finally, the 1879 series remained fairly constantly in the intermediate class until 1899, with some ups and downs however, but in 1903 it fell to the poor class. In 1904, accordingly, the distribution of the runs in the three classes was greatly altered for the worse, there being but one series in the good class, none in the intermediate class and three in the poor class. I regret that I have not yet been able to obtain the figures necessary for plotting the years since 1904, but from

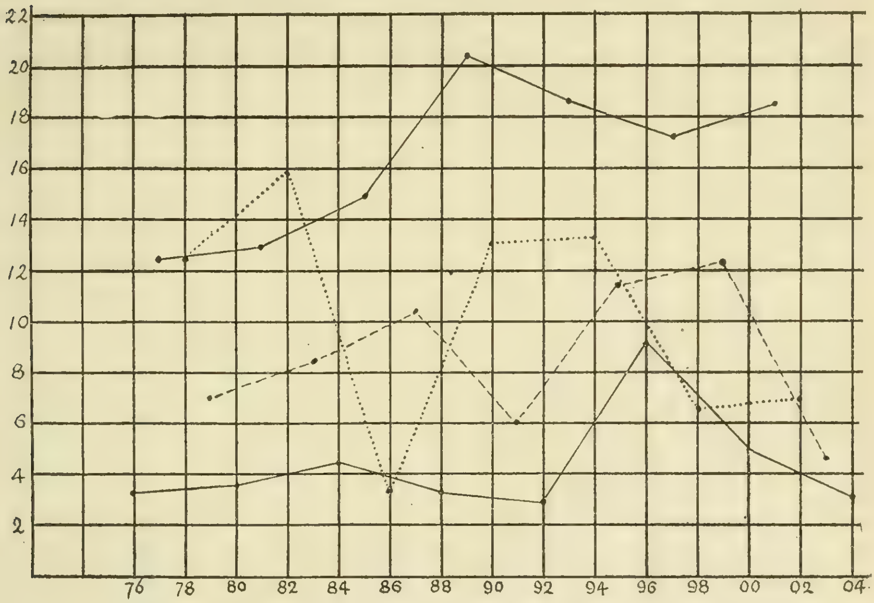


FIG. 3—Puget Sound and Fraser River Sockeye Pack. Average per Line of Machinery.

the cannery averages it is clear that the situation remains practically unchanged, except that the 1876 series shows a second marked improvement in 1908, extending well up towards the intermediate class.

It is not possible to affirm absolutely that the cause of the general decline in the fishery is due to over fishing, but it seems difficult to explain it on any other hypothesis. Indeed, it has been generally admitted by those interested in the fisheries with whom I have conversed that the future of the industry is in danger from this cause, but, so far as I am aware, the extent of the danger has not hitherto been presented as clearly and concisely as it is shown in the diagram Fig. 3. The Government has recognized the danger and has sought to avert it by imposing certain restrictions on the fishing and by engaging extensively in hatching preparations, in which latter they have been aided by the British Columbia Legislature, which maintains a hatchery at Seton Lake, and by the British Columbia Packers' Association, which supports a hatchery at Nimpkish, V.I. These hatcheries have capacity for the hatching of 100,000,000 eggs, but what effect their operation has had on the runs there are no means of estimating. It seems clear, however, that there are two sets of conditions to be considered. As has just been pointed out there are two classes of runs, a good class now consisting of a single run every fourth year, and a poor class which includes the runs of the three intervening years. Up to the present it would appear that the good run has been quite able to take care of itself under the present regulations, but these do not seem quite adequate in the cases of the poor runs. The different conditions require different treatment and more stringent regulations seem necessary for the poor runs if these are to be prevented from becoming even poorer in the future.

The matter is by no means a simple one, however, since it presents international complications. A very large proportion of the fish returning to the Fraser River to spawn travel along the southern shore of Puget Sound in American waters and an extensive salmon fishing industry has developed in these waters. It began about 1891 and for some years its pack remained far below that of the Canadian canneries. It grew apace, however, and in 1898 the American pack and Canadian pack were about equal, but since then the advantage has, with the exception of two years, 1903 and 1905, been on the side of the American canneries. And that advantage is increasing; for in 1907 the American pack amounted to 93,934 cases as against a Canadian pack of 59,815 cases, in 1908 the American pack was 170,951 cases and the Canadian 74,574 and according to the estimates for this year that I have received the American pack probably amounts to over 900,000 cases, while the Canadian totals only about 600,000.

These figures may well arouse indignation when we consider that it is fish that have been bred in our waters and by our hatcheries and that are returning to our streams to spawn that our neighbours to the south are catching at a rate which threatens the industry. And a further cause for indignation may be found in the fact that the American authorities have been much more lax in imposing restrictions on the fishery than has our Government. Indeed, up to within recent years there were no limitations whatever imposed upon American fishermen, and whatever was done towards preservation of the industry was done by our Government and the restrictions imposed were imposed upon our fishermen. However, an international commission, which sat in 1906, modified this unsatisfactory condition to a certain extent and it is to be hoped that the pending treaty will aid in bringing about a more satisfactory state of affairs. It is to the interest of both Americans and Canadians that the industry should be maintained, and the co-operation of both governments is demanded and should be ungrudgingly given. But the conditions are at present such that legislation of one year may be ineffective or unnecessary in the next and what is needed is a permanent International Commission charged with the regulation of the international salmon fisheries. It seems to me that in no other way will the desired results be secured.

And what are these results? First and foremost undoubtedly the averting of the threatened danger that the runs of the poor years may be still further diminished, possibly to practical extinction. But that is by no means all. Turn again to the diagram, Fig. 3, and note the conditions shown by the 1878 series of runs. Equal to the 1877 run and in 1882 considerably surpassing that of 1881, in 1886 it has dropped to the poor class. Why this happened I do not know, but if it could happen to that good run we may suppose that it may also happen any year to the present big run. It is this run which saves the situation at the present time and yet in any year it may fail us and our famous Fraser River fisheries be reduced to a series of poor runs. But note again how the 1878 series in 1890 and 1894 endeavoured to regain its former magnitude only to fail ignominiously, and the failure may justly be attributed to over fishing. If efficient protection had been afforded in those years it seems not improbable that we would now have two big runs in every four year cycle. Both the 1876 and 1879 series show temporary improvements, and the question suggests itself whether these improvements might not be made permanent by the adoption of proper precautions. And here we have a glimpse of the path that must be followed to gain these results. These temporary improvements are clearly independent of the fishing. Regulations of the fishing would be a help, but it is not the only factor at work. We need a more thorough study of the entire life history of the Sockeye than has yet been made and with this a detailed investigation of the conditions under which the fish live at different periods of their existence. Until we know these we cannot understand the fluctuations that occur in the runs, nor can we take intelligent steps toward their permanent improvement. We should be able, and with sufficient knowledge we would be able to predict accurately the extent of the run for any year of a four year cycle, and what is more important, we would be able to take advantage of favourable conditions or even to modify or control unfavourable ones and so instead of impotently watching the gradual diminution of this wonderful treasure that lies within our gates we would see it increasing year by year until every year yielded a maximum return.

I have considered this matter of the salmon fisheries of our West Coast in this place because I have felt that it was not appreciated on this side of the continent to the extent that its importance deserves. It is not merely a local question; it is a matter that affects us materially here on the Eastern seaboard and also, indeed, the lands across the seas. A few additional figures will bring this side of the story home. The total salmon pack of British Columbia in 1905 amounted to 1,167,460 cases, and of this we in Eastern Canada received 152,118 cases, or 7,300,000 pounds. To Great Britain were sent 551,668 cases or 26,500,000 pounds, while Australia and New Zealand received 53,847 cases or 2,500,000 pounds. May we not well say that the preservation and improvement of our West Coast salmon fisheries is an imperial question?

UNIVERSITY OF TORONTO, *December 18th*, 1909.

# THE LEGEND OF THE "RESURRECTION BONE."

BY J. PLAYFAIR MCMURRICH, M.A., PH.D.

(*Read 16th April*, 1910).

IN the anatomical works of the seventeenth century which treat their subject from a more or less pronounced encyclopædic standpoint, in the volumes of Bauhin, Riolan and Diemerbroeck for example, one finds mention of an *os luz* or "Resurrection bone," whose existence had been predicted by Hebrew theologians and whose properties have thus been described by Butler in his Hudibras:

The learned rabbins of the Jews
Write, there's a bone, which they call Luez
I' th' rump of man, of such a virtue
No force in nature can hurt to;
And therefore, at the last great day,
All th' other members shall, they say,
Spring out of this, as from a seed
All sorts of vegetables proceed;
From whence the learned sons of art,
*Os sacrum* justly call that part.

Part III, Canto II.

The account of the supposed bone given by Bauhin* is more complete than that of any of the other authors known to me and, indeed, seems to have formed the basis for their statements concerning it, Diemerbroeck's account† being, in fact, principally a quotation of Bauhin's words. Hyrtl‡, too, in his discussion of the significance of the word *luz*, seems to have relied very largely, if not entirely, upon Bauhin's statements, and it seemed that it might be of interest to trace the legend back, as far as possible, to its original sources. The fact that these sources were the writings of the Hebrew commentators formed a very serious bar to the carrying out of my inclinations, but recently I have been able to avail myself of the efficient services of one of my students, Mr. S. J. Birnbaum, who has sought out and translated for me the references to the bone that are contained in the Rabbinical writings. I am greatly indebted

*Caspar Bauhin. Theatrum anatomicum. Francof. 1621. The 1605 edition contains no mention of the os luz.

†Isbrandus Diemerbroeck. Opera omnia, anatomica et medica. Ultrajecti. 1685

‡Joseph Hyrtl. Das Arabische und Hebräische in der Anatomie. Wien. 1879

to Mr. Birnbaum for the trouble he has taken in this matter and for the interest he has shown in my endeavours to obtain some idea as to the methods of the Hebrew commentators.

Apparently the foundation for the legend is to be found in the necessity which the commentators felt existed for an explanation of the concluding sentence of verse 20 of Psalm XXXIV. In the Authorized as well as the Revised English Version this verse reads thus, "He keepeth all his bones: not one of them is broken," and the words have generally been regarded by Christian commentators as a Messianic prophecy referring to the circumstance related in the account of the Crucifixion contained in the Gospel by St. John (Chap. XIX, v. 33), "But when they came to Jesus, and saw that he was dead already, they brake not his legs." A literal translation of the Hebrew version of the Psalm referred to yields, however, a distinctly different meaning to the concluding words of v. 20, these taking the form "One of them shall not be destroyed," and this is the rendering found in the Septuagint (*φυλάσσει πάντα τά ὀστᾶ αὐτῶν ἓν ἐξ αὐτῶν οὐ συντριβήσεται*), in Wycliffe's version made from the Septuagint (The Lord kepith alle the boonys of hem; oon of tho schal not be brokun) and in the Vulgate (unum ex illis non confringetur). Here then was a statement in the sacred text of an indestructible bone existing in the human body, and this was sufficient warrant for the rabbinical belief in its existence and a nucleus for the legend which Hebrew mysticism elaborated.

The legend cited by Bauhin and quoted from him by Diemerbroeck and also by Hyrtl, is contained in the Midrash, a commentary of the Pentateuch written a little later than A.D. 200. Since Mr. Birnbaum's translation of this differs slightly from the account given by Bauhin, I will quote his version of it in its entirety. "When the Emperor Hadrian was once grinding bones he asked Rabbi Joshua ben Chanania 'Whence will God form man at the Resurrection?' 'From the Luz of the vertebral column' answered the Rabbi. 'How knowest thou?' And he answered 'Bring me a Luz and I will show thee.' And when he got one he ground it in a mortar, but it was not crushed; he burnt it in fire, but it was not burned; he put it in water, but it was not softened; he placed it on a board and beat it with a hammer, the board was broken, the hammer shattered, and the Luz remained whole." (Bereschit Raba, 28. The same legend is repeated in the Vayikra Raba and in the Kohalet Raba).

In the Midrash Neelom, pars Toldoth, the bone is again referred to as follows:—"Rabbi Huna said 'I was in the marine cities and heard that the name given the immortal vertebral bone is Bethuel mendax. I asked why it is thus called and was told that it was because it was the most deceitful of all bones from the very beginning (i. e., all other bones tasted of the tree of Knowledge, it did not); as Rabbi Simeon has taught us, why does that bone remain after the destruction of all others; because it enjoys not the relish of human foods and on this account it is the strongest of all bones and will be the nucleus of the body at the Resurrection. Rabbi Simeon hath further said it is deceitful, has from the very first been deceitful and is neighbour to the evil impulse, which is also deceitful, and both are together as a yoke of oxen."

The existence of this "Resurrection bone" seems to have been accepted during the Middle Ages not only by theologians but also by anatomists, Ibn Roschd (Averroës), for example, considering the legend true, according to Kohler,* and Hyrtl states that the bone was known as the "Judenknöchlein" by the old German anatomists. This same author also quotes a statement from Cornelius Argippa† assigning to the bone the qualities predicted for it in the Talmudic legend and concluding with the words "et hæ virtutes non declarantur ratione, sed experientia." The quotation from the Bereschit Raba given above shows that the bone was believed to belong to the vertebral column, although no definite position in the series of vertebræ is assigned to it.‡ Mr. Birnbaum has, however, drawn my attention to the concluding words of the quotation from the Midrash Neelom as possibly indicating a location for it. It is there described as being "neighbour to the evil impulse," and both in the Midrash and in the Talmud the "evil impulse" is stated to have its seat in the heart. Consequently to be a neighbour to the evil impulse the bone must have been one of the thoracic vertebræ.

It seems, however, very doubtful whether the early Rabbinical writers had any intention of giving the *luz* a definite location. The Talmudic anatomy does not give evidence of any considerable amount of scientific definiteness, the vertebral column, for instance, being described as consisting of but eighteen vertebræ, and, furthermore, for reasons to be considered later, it is probable that the Rabbi Simeon was more intent on the collocation of the deceitful elements of the body, than on a definition of the anatomical position of the *luz*. Attempts were not lacking, however, on the part of later writers to assign it to a definite position, the Baal Aruch stating that "It is a small vertebra at the end of the eighteen

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*Jewish Encyclopædia. Vol. VIII. 1904.

†De occulta philosophia. Lib. I, cap. 20. 1530.

‡Hyrtl (*l. c.*) was apparently in error in stating that it is placed by the Bereschit Raba "in fine octodecim vertebrarum". This location of it was made by later commentators.

vertebræ; the whole body of man decays except that vertebra and it resembles an almond." The identification of the bone with the coccyx naturally resulted from this definition, and this has been the usually accepted identification and is that given in the recently published Jewish Encyclopædia, in which the *luz* is said to be "the Aramaic name for the os coccyx, the 'nut' of the spinal column." It may be added that the references to the almond in the Baal Aruch and to the nut in the Encyclopædia are due to the fact that the word *luz* was also the Aramaic term for the almond.*

Other identifications have, however, been proposed. Thus Bauhin states that according to Munsterus† the rabbinical writers located the bone in the neck, that by others it was identified wth the seventh cervical vertebra and that according to Hieronymus Magius others placed it near or even in the base of the skull. Hyrtl adds that according to Kühn it was identified with the triangular bone occasionally occurring at the junction of the sagittal and lambdoid sutures and now generally known as the os Incæ. Vesalius, also, suggested its identity with the medial sesamoid of the great toe, his words being as follows: "Quinetiam in pede (quem homo quadrupedibus multe breviorem obtinet) totidem ac in manu exigua occurrent ossicula, quæ sesami semini comparamus; quanquam primo pollicis internodio hic duo longe grandiora quam in manu subjici–antur, harumque interius illud sit, quod occultæ philosophiæ sectatores corruptioni neutiquam obnoxium esse affirmant, et tantisper in terra asservandum nugaciter contendunt, dum id resurrectionis tempore seminis nodo hominem producat."‡ The same suggestion is made somewhat more positively in the De Fabrica. "Num tamen Arabes, et vero occulti illi tenebricosique philosophi, ex hoc ossiculo, ipsis Albadaran nuncupato, hominem rursus propagandum recte sentiant. Theologis disceptandum relinquo, qui liberam sibi de resurrectione, animarumque immortalitate ac eventu, disputationem et sententiam vendicant." ||

These identifications all belong to periods later than the original rabbinical writings and, as I have already indicated, it seems very probable that the earlier Hebrew teachers made it no concern of theirs to inquire into the exact position of the bone. Their Scriptures seemed to require

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*Gesenius. Hebraisches und Aramâisches Handwörterbuch über das alte Testament. Ed. XI. Leipzig, 1890.

*Levy. Neuhebräisches und Chaldâisches Wörterbuch. Bd. II. 1879.

†Sebastian Münster. 1489-1552.

‡Vesalius. Epitome anatomica. I quote from the Paaw edition, 1633.

||Vesalius. De fabrica corporis humani. I quote from the Boerhaave edition of 1725.

the existence of such a bone; that was sufficient for the assertion of its existence and for the growth of legends concerning it. The suggestion of the Baal Aruch that the supposed bone was named *luz* from its resemblance to an almond, would be plausible if the coccyx really showed such a resemblance. But, as I shall endeavour to show, it seems probable that the name has been applied to the bone by a peculiar process of association of ideas of which many examples may be gathered from the rabbinical writings. It may be remarked, however that the use of the word *luz* for the bone is not inappropriate, on account of the property possessed by it of reproducing the entire body, just as from the nut the entire tree is reproduced, and attention may also be called to the fact that in addition to the Aramaic word *luz*, the word *shaked*, the awaker, is also employed in the Old Testament to denote the almond, the appellation being derived from the tree being the earliest to awaken from the winter's sleep. In this there is also a suggestion of the resurrection idea, and this might have had some effect in rendering the term *luz* appropriate in the eyes of the Rabbis in its application to the "resurrection bone." This, however, is pure conjecture.

If the tendency of the Hebrew commentators to associate ideas primarily quite distinct but linked by some common element be borne in mind, the quotation from the Midrash Neelom given above possesses a considerable amount of interest. It will be noticed that in this quotation the point chiefly insisted upon is the *deceitfulness* of the bone, which is said to be known in the marine cities as Bethuel mendax, Bethuel the deceiver. In Genesis XXV, 20 we read "And Isaac was forty years old when he took Rebekah to wife, the daughter of Bethuel the Syrian of Padan-aram, the sister to Laban the Syrian." The word translated as Syrian in our version is in the Hebrew *Aramai*, and might be better rendered as Aramaean. It has, however, some resemblance to a Semitic (?) word *aremai*, meaning deceiver, and was apparently employed in this sense by the Rabbi Huna. But why should the name of the father of Rebekah be thus conferred upon the "immortal bone?" Here again there has apparently been a confusion of two similar, but altogether distinct words. In Genesis XXVIII, 19 it is stated of Jacob "And he called the name of that place (i. e. the place of his dream) Bethel; but the name of the city was called Luz at the first." (Cf. also Gen. XXXV, 6: Josh. XVIII, 13; Judges I, 26). It would seem that we have here first a confusion of *luz*, the name of the bone, with Luz, the name of a place, and then a further confusion of the later name of that place, Bethel, with the name of Bethuel the Aramaean.

But an explanation of the prominence given to the idea of deceit is

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not yet evident, and it would seem that it was the mistranslation of the word Aramæan as deceiver that led to the confusion of Bethuel with Bethel. A suggestion bearing upon this point is furnished by the fact that the word Luz also occurs in the Book of Judges as the name of a city in the land of the Hittites, the story of whose foundation is, briefly, as follows. On the partition of the land of Canaan among the twelve tribes, the city of Bethel or Luz fell to the lot of the children of Joseph. On entering into possession of their province the Josephites sent a party to reconnoiter Bethel, and having captured a man from the city they made him reveal, as the price of his life, the secret entrance into the place. According to the Bereschit Raba the city was completely hidden from view and was approached through a cave, whose entrance was concealed by an almond tree, growing in front of it. In the tree was a hole, through which access to the cave might be obtained. With a knowledge of this secret entrance the children of Joseph took the city, "they smote the city with the edge of the sword; but they let go the man and all his family. And the man went into the land of the Hittites, and built a city, and called the name thereof Luz: which is the name thereof unto this day." (Judges Chap. I, vv. 25, 26).

Here again we have the idea of deceit in the betrayal of the secret entrance. But more interesting, perhaps, is the legend concerning the Luz of the land of the Hittites that is recorded in the Sotah (p. 46, fol. 2). "This is the Luz against which Sennacherib went, but he could not destroy it; Nebuchadnezzar, but he could not raze it. Even the Angel of Death has no power to enter it, but the old men in it when their minds become weakened go outside the wall to die." Here we have the idea of indestructibility and immortality associated with the word *luz* in such a way as to be highly suggestive of the legend contained in the Bereschit Raba.

With these various associations of ideas in mind it would seem that we are in a position to attempt a reconstruction of the steps in the growth of the belief concerning the *os luz* and its properties, somewhat as follows. The words contained in Psalm XXXIV, v. 20 form the foundation for the legend, that is to say, they required the predication of an indestructible bone in the human body. With this idea the legend concerning the city of Luz in the land of the Hittites became associated, the idea of indestructibility being prominent in that legend. But it also contains the idea of immortality, and this would naturally call up the idea of the Resurrection, that doctrine being of such cardinal importance in Hebrew theology. And so we obtain the complete framework for the legend of the Bereschit Raba, even to the name given the bone. Finally the confusion of Luz of the Hittites with Luz of the Canaanites, the replacement of the name of the latter city by Bethel, the confusion of the names Bethel and Bethuel and the mistranslation of *Aramai*, possibly suggested in part by the deceit connected with the capture of Bethel by the children of Joseph, these various associations combine to give a plausible explanation for the passage quoted from the Midrash Neelom.

# THE DIALYSIS OF COLLOIDAL FERRIC HYDROXIDE.

By E. F. BURTON, B.A., PH.D.

(*Read 27th November*, 1909.)

SOME time ago Duclaux (1) published results of his experiments which seemed to throw doubt on the accepted notion of the action of Electrolytes on colloidal solutions. In particular he challenges the work of Hardy (2), which was borne out so well by the previous work of Linder and Picton (3). Duclaux experimented upon colloids which were produced by the action of two salts upon one another, giving an insoluble finely divided suspension: for example, the action of potassium ferrocyanide on copper chloride producing the insoluble copper ferrocyanide, or the action of bases on ferric chloride producing colloidal ferric hydroxide. Duclaux suggested the following law with regard to these reactions:

"A precipitated colloid, *i.e.*, one capable of giving a colloidal solution in pure water, produced by the mixture of two crystalloidal salts contains the four radicals of the two salts in proportions varying continuously. One must consider them as combined, for they do not react either among themselves, or with the surrounding liquid, according to their ordinary properties."

In the case of the colloid with which this paper deals, viz., ferric hydroxide, Duclaux believes that the particle consists of a nucleus corresponding to the formula $Fe_2Cl_6.n.Fe_2.O_3$ in which he found $n$ to have a value varying from 30 to 500. The electrical charge possessed by the particle he ascribes to the small part of chlorine, or, perhaps, the ferric chloride, which for that reason he calls the active part of the combination making up the colloidal particle. When the colloid is coagulated the action is due to the substitution of some other acid radical for the chlorine; this action is affected by several circumstances, such as whether the ions producing the coagulation form with the chlorine ions of the particle an insoluble compound or not. Consequently Duclaux doubts the truth of the valency law as perfected by Hardy. In support of his position Duclaux cites experiments carried on with ferric hydroxide,

(1) Jour. de Chim. Phys. V. 1, 2, 3., p. 29.
(2) Jour. of Physiol. V. XXIX, 1903, p. 26.
(3) Jour. of Chem. Soc. Vols. LXI, LXVII, LXXI, LXXXVII.

which had been gradually denuded of its chlorine content, and found good evidence of the charge being due to the presence of the chlorine in the particle. The purpose of the present paper is to examine this theory from another point of view.

Duclaux's decisive experiments are those determining the coagulative power of various salts on a given sample of colloid and the coagulative power of the same salt on various samples of the colloid. Undoubtedly the surest way of testing the charge on a colloidal particle is to measure its velocity in a given electric field. This method has been used by the writer and leads to an extension of our knowledge of the charge possessed by the ferric hydroxide particle.

The experiments may be divided into three sections:

*a*. Continued dialysis of ferric hydroxide against conductivity water to find if the charge on the particle decreases as the chlorine is eliminated:

*b*. Test of the action of the addition of electrolytes on the size of the charge on the particle:

*c*. Test of the coagulating power of ions of different valency on a selected sample of the dialysed colloid.

### *a*. RELATION OF THE CHARGE TO THE CHLORINE CONTENT.

Ordinary commercial ferric hydroxide solution sold by druggists under the name of "Dialysed Iron" was used for the work. It is prepared, according to the method indicated above, by the action of a base on ferric chloride and is dialysed by the manufacturer, I presume against ordinary water. When analysed it gave proportions of chlorine and iron corresponding to the formula, $Fe_2Cl_6$. 13.6 $Fe_2O_3$. The original solution was very dense in colour and had a very high electrical conductivity. The velocity with which the particles moved in a given electric field was measured by the direct method with a U-tube similar to that used in previous work (4). If the conductivity of the liquid under consideration is very high the surface, the displacement of which we observe, does not remain distinct and so the method fails. In order to overcome this difficulty, whenever a velocity measurement was to be taken about ½ ccs. of the colloidal solution was mixed with 50 ccs. of conductivity water and the velocities of the particles in these samples was measured. Of course it is quite apparent that we are not then dealing with the exact solution which we are dialysing, but, as each sample from time to time was

(4) Phil. Mag. S. 6, Apr. 1906. (Burton).

treated in exactly the same manner, valuable conclusions may be drawn from the collected results.

The ferric hydroxide was suspended in a parchment sleeve in a glass beaker through which distilled water was allowed to pass constantly. When the wash water was analysed it showed the presence of large quantities of ferric chloride. Chemical analysis of samples of the colloidal solution showed that the ferric chloride was taken out during eight weeks' dialysing until the formula changed from that given above to $Fe_2Cl_6.120\ Fe_2O_3$.

At certain fixed times during the course of the dialysis samples of the ferric hydroxide were removed for chemical analysis; at the same time a sample was prepared as indicated above and the velocity found. The results of this series of experiments are tabulated in table I, in which we have given in the various columns the results of the chemical analysis (in terms of the ratio between the chlorine and the iron content of the solution under dialysis), the resistance of the solution as it is taken from the dialyser, and the velocity of the particles in the diluted sample of the colloid.

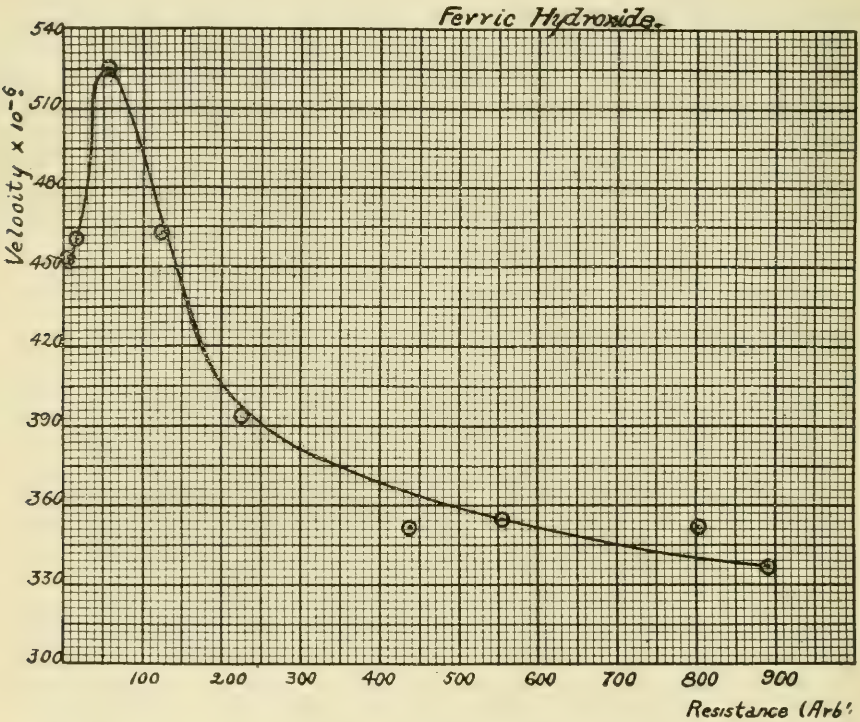
TABLE I. (FERRIC HYDROXIDE).

| Date. | Ratio between the Cl and the Fe in the sol. | Resistance of colloid at 18°C, (arb. units). | Velocity of the particles in cms. per sec. per volt per cm. |
|---|---|---|---|
| June 14 | .131 | 7.7 | $45.4 \times 10^{-5}$ |
| June 15 | .113 | 18.4 | $46.1 \times 10^{-5}$ |
| June 19 | .052 | 56 | $52.5 \times 10^{-5}$ |
| June 26 | .016 | 124 | $46.3 \times 10^{-5}$ |
| July 3 | .011 | 167 | $42.6 \times 10^{-5}$ |
| July 10 | .005 | 226 | $39.4 \times 10^{-5}$ |
| July 17 | * | 439 | $35.2 \times 10^{-5}$ |
| July 24 | * | 553 | $35.5 \times 10^{-5}$ |
| August 7 | * | 801 | $35.2 \times 10^{-5}$ |
| August 14 | * | 888 | $33.8 \times 10^{-5}$ |

* The chemical analyses for these solutions were not obtained.

Careful comparison of the results recorded in columns 2 and 3 will show that the conductivity of the colloid bears a very direct relation to the amount of chlorine in the solution: for this reason we may illustrate the relation between the velocity of the particles and the amount of chlorine in the colloid by examining the relation between the velocity and the resistance. At any rate the measurements of the resistance are much more reliable than the chemical analyses for such extremely small portions of chloride as we would be dealing with in the later samples.

The curve in Figure 1 represents the relation between the velocity of the particles in the diluted samples of the colloid and the resistance of the undiluted sample taken at the same time. We notice at once the curious result that, as the chlorine is removed from the liquid the velocity




of the particles at first increases, reaches a maximum, and then gradually decreases. As far as the dialysis was carried there is not an indication that the velocity of the particles would soon reach a zero value.

Although we cannot say from these results that the particle owes its charge entirely to the chlorine present, we see that the charge is affected to a large extent by the chlorine. However the fact that, as the amount of chlorine in the solution is increased beyond a certain limit, the charge on the particle begins to decrease again, shows that, in such a solution, we are dealing with a very complex set of phenomena; further, any work on the coagulating power of salts with such solutions as this would depend on the stage at which the dialysis had been carried.

Similar experiments were performed on soluble Prussian Blue (Berliner Blau). The dialysis and measurement were carried on just as in the case of the ferric hydroxide. The corresponding results are given in Table II and illustrated in the curve of Figure 2. A glance at these will show that the same effect is apparent with this second colloidal solution. The charge seems to be due to some absorbed potassium ferrocyanide which then plays the part of the ferric chloride in the colloidal ferric hydroxide. In the case of the ferrocyanide the stabilizing ion is the potassium and the particles are charged negatively, while as is well known the ferric hydroxide particles are positively charged.

TABLE II.—(PRUSSIAN BLUE.)

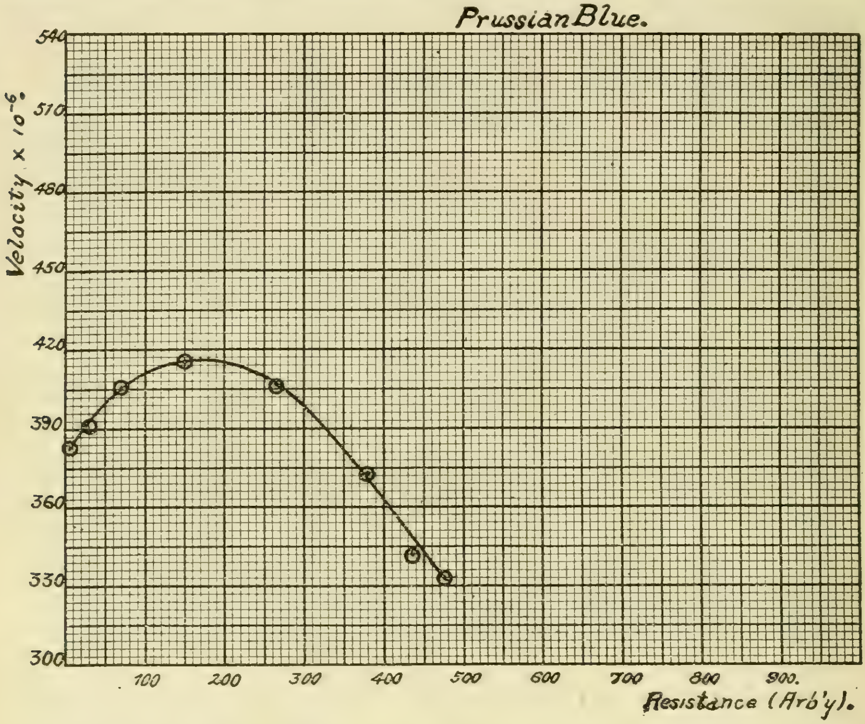
| Date. | Resistance of the colloid at 18°C. (Arb. units). | Velocity of the particles in cms. per sec. per volt per cm. |
|---|---|---|
| June 22 | 7.4 | $38.3 \times 10^{-5}$ |
| June 24 | 31 | $39.1 \times 10^{-5}$ |
| June 30 | 70 | $40.6 \times 10^{-5}$ |
| July 13 | 151 | $41.5 \times 10^{-5}$ |
| July 20 | 264 | $40.7 \times 10^{-5}$ |
| August 3 | 380 | $37.3 \times 10^{-5}$ |
| August 10 | 435 | $34.2 \times 10^{-5}$ |
| August 17 | 476 | $33.3 \times 10^{-5}$ |

### *b*. EFFECT OF POTASSIUM PHOSPHATE ON FERRIC HYDROXIDE.

Papers have been published by the writer (5) in which the action of added electrolytes on the velocities of the colloidal particles has been

(5) Phil. Mag. S. 6, Nov. 1906, and April 1909.

dealt with. In the case of sols, the particles of which are negatively charged, the important factor in the added electrolyte is the valency of the positive (or metal) ion, while, in the case of the oppositely charged particles, it is the valency of the acid radical which is the determining influence. In every case the valency of the added ions bearing a charge




the same in sign as that of the particle does not seem to have the slightest effect on the power of the electrolyte to produce a decrease in the value of the velocity of the particle in an electric field and, consequently, coagulation.

As the particle of the ferric hydroxide is positively charged, potassium phosphate was chosen because the acid radical is trivalent and therefore of very great discharging power. At the end of the time recorded in Table I, 5ccs. of the dialysed ferric hydroxide were mixed with 250 ccs. of conductivity water, the mixture still giving a rather highly coloured solution. The velocity of the particles was taken and then to various samples of 50ccs. of this solution 10, 15, 24, and 36 drops of 1/1000 normal* potassium phosphate were added respectively. The effect of the salt on the velocity of the particles is recorded in Table III.

*The meaning of normal here is one gram molecular weight per 1000 ccs. of water.

TABLE III.

ACTION OF K3PO4 ON COLLOIDAL FERRIC HYDROXIDE SOLUTION.

| Amount of 1/1000 normal Potassium Phosphate added per 100 ccs. of colloid. | Velocity of the particles in cms. per sec. per volt per cm. at 18°C. | Resulting coagulation. |
|---|---|---|
| 0.0 | $33.7 \times 10^{-5}$ | Stable for months. |
| 0.42 ccs. | $31.7 \times 10^{-5}$ | No immediate sign. |
| 0.25 ccs. | $26.6 \times 10^{-5}$ | No immediate sign. |
| 2.0 ccs. | $23.8 \times 10^{-5}$ | Partially in ½ hr. Entire in 3 hrs. |
| 3.0 ccs. | $18.8 \times 10^{-5}$ | Complete at the end of a few mins. |

These results are quite in accord with the action of the same salt on the Bredig copper colloidal solution already reported by the writer. There is a marked divergence in the fact that quite complete coagulation had set in before the velocity of the particles is reduced to anything near zero. However, in the case of the last two samples coagulation began by the formation of flocculent masses in the body of the liquid while the measurements were in progress. These flakes began to settle at the bottom of the velocity tube so that the reading was really carried out on the finer particles left in suspension in the liquid. As a result, the velocity numbers given in these two cases are in the nature of the velocities of the particles bearing the maximum charges at the time.

There remains, however, no doubt of the keen action of the potassium phosphate in discharging the particles and producing coagulation.

### c. COAGULATING POWER OF IONS OF DIFFERENT VALENCIES.

A mixture of 5ccs. of the dialysed ferric hydroxide and 250 ccs. of conductivity water was made up for this test. The coagulative influence of various salts on this sample was tried. The following salt solutions were made up: Normal potassium chloride, 1/30 normal potassium sulphate, 1/100 normal aluminium sulphate, and 1/1000 normal potassium phosphate. In this way was obtained a series of solutions containing univalent, divalent, and trivalent negative ions in ratios which are the inverse of those representing the coagulative powers of the various ions according to the Hardy-Linder-Picton law. By adding gradually increasing amounts of these salt solutions to samples of the colloidal solution, it was found that the coagulative power of these solutions was practically the same, thus bearing out the truth of the above law.

### *d.* SUMMARY.

From the above results we may conclude that:

1. As the ferric chloride is removed from a colloidal solution of ferric hydroxide, the charge on the particle at first increases, reaches a maximum, then gradually decreases.

2. The trivalent phosphate ion has a strong discharging and coagulative action on these colloidal particles.

3. Coagulation experiments on samples of dilute dialysed ferric hydroxide seem to bear out the truth of the law due to Linder, Picton and Hardy.

In conclusion, I desire to thank Dr. M. C. Boswell for the chemical analyses.

Department of Physics, University of Toronto,
June 20th, 1910.

# NOTES REGARDING RAILWAY REGULATION.

BY S. J. McLEAN, LL.B.

MEMBER OF THE BOARD OF RAILWAY COMMISSIONERS FOR CANADA.

(*Summary of Paper Read 19th March,* 1910)

THE corporate form of management has great financial and productive power. At the same time it is recognized that the large volume of capital invested in a corporation renders competition less immediately effective. As a result of this we find a large amount of regulative legislation dealing with corporations.

In the modern state regulation has been worked out in two ways; First, by publicity, Second, by direct regulation.

It has been recognized that the field of railway transportation requires direct regulation. The part played by railway transportation in modern history may be exemplified in many ways. For example, east bound shipments of wheat from the North West; British Columbia shingles and lumber east bound; west bound shipments of manufactured products, and also the agricultural products such as potatoes, etc. In an older country, for example Great Britain, railways assist development which has already taken place. In a new country, like Canada, the railway is a colonizing factor as well. An example of this may be obtained from the expansion of the Canadian Pacific Railway in the West and the construction of the Grand Trunk Pacific Railway and the Canadian Northern Railway. At present about seven-tenths of the C. P. R. mileage is west of the lakes. About 37 per cent. of the total railway mileage of Canada was on the basis of the figures of 1909 west of the lakes.

Two types of policy have been pursued in regard to railways—(a) Government ownership, (b) Private ownership. In Great Britain and Ireland, United States and Canada which have a little more than one-half of the railway mileage of the world, the policy is to have private ownership plus Government regulation.

In the development of regulation England has led the way. As early as 1854 it affirmatively recognized that competition might work out unequally in railway transportation. Legislation in that year dealt with the topics of "Reasonable Facilities" and "Undue Preference." In 1873 a Commission was organized. In 1888 the Railway and Canal Commission for England was reorganized and given more extensive powers. In the United States regulation by Commission developed in New Hampshire as early as 1845. The majority of the states of the Union have carried on the regulative policy through commissions. The Federal Government organized in 1887 the Interstate Commerce Commission which has been given increased powers by the Act of 1906. In Canada, by the legislation of 1903, there was organized the Board of Railway Commissioners for Canada. This organization has a very wide power over rate matters. Its decisions on questions of fact are final. There may be an appeal on a question of law or jurisdiction to the Supreme Court, and there may be an appeal from any Order of the Board to the Governor-in-Council. The Governor-in-Council may also, of his own motion, over-rule or modify an Order of the Board. The reason for the provisions regarding the Governor-in-Council power is, that it is desired to maintain the principle of ministerial responsibility. Before the organization of the Board of Railway Commissioners for Canada the powers exercised regarding regulation were in the hands of the Railway Committee of the Privy Council, and this Committee as a sub-committee of the ministry was responsible through the Ministry to Parliament.

In addition to rate regulation the Commission has wide powers regarding operation and train service, various engineering matters connected with railway inspection, opening for traffic, etc., questions of accident inspection, and in general protection of the public safety. Many other phases might be referred to, but these will be sufficient to indicate the scope of the Commission's powers. No other regulative Commission in the world has as far reaching powers as the Commission.

The question of rate regulation has been looked upon as the central feature of railway regulation. There are two phases to the question of rate regulation—Is the railway rate reasonable in itself? Are the rates relatively reasonable?

Under the question of relative reasonableness develops the law in regard to undue preference as it is called in England, or discrimination, as it is commonly called in Canada and the United States. The law does not forbid all discriminations, but simply those which are undue or unjust; consequently each discrimination must be examined on its merits. A discrimination is allowed in respect of quantity, that is to say, a carload may have a lower rate per hundred pounds than less than carload shipment.

It has to be recognized that many phases of competition bring about apparent discriminations. It depends upon the facts whether these are undue or unjust. Some factors bearing upon this, are water competition both by lake and river carriers and ocean carriers. Again where two railways connecting the same terminal differ in point of mileage, the short line mileage will govern the through rate of the railway with the longer mileage. Again, competition of markets will govern a rate. For example, the rate which Canadian bacon laid down in Liverpool can stand from the initial point of shipment will depend upon railway and water rates and prices of Danish bacon laid down in the same market.

Rate regulation is a very complex matter. There is no rigid three foot rule to measure reasonableness. It might seem that a fixed rate per mile would be the most obvious method of fixing rates. The result of the application of this would be that low grade bulky articles could not be hauled a long distance. Hay, or brick, for example, would have a local market, while silk or tea, whose value is comparatively high, could be brought from a long distance. In practice we find railways giving in various instances blanket rates which appear to disregard distance. For example, oranges are shipped from California to Toronto at $1.15 per hundred pounds in carloads. This rate applies to points in the United States from the Mississippi east. Toronto takes the same rate as Buffalo. This rate is in part governed by the competition of oranges from Europe.

It must be recognized that many factors must be considered when investigating the reasonableness of a rate or rates, and that one important factor is the market value of an article. This is not a recognition of a right to extortion. It recognizes not only that silk may stand a relatively high rate. It recognizes that stone, brick, and hay can stand only a relatively low rate. It recognizes that the lower the market value of the article the lower must be the rate.

The regulative policy attempts to protect the general public interests without trenching on the legitimate field of private interest. Railway Commissons in this country as well as in other countries, have exercised educational functions and their preventive work is even more important than their remedial work. One thing which every regulative tribunal of this kind must keep before it is, that it stands for fair play to all sections of the public railways and shippers alike.

# TECHNICAL EDUCATION OF A MINING ENGINEER.

BY WILLIAM FRECHEVILLE,

Past President, Institution of Mining and Metallurgy.

(*Read 2nd November*, 1910)

WHEN asked by your President to speak to you, I rather wished to avoid doing so, as I did not think that, in my present hurried trip, I would be able to do justice to any subject. However, he wished me to speak to you, and, since he kindly let me choose my own theme, I have selected the rather broad one, "The Technical Education of a Mining Engineer," which, however, I shall treat from a rather narrow aspect. I will speak from the point of view of what I should like my boy to be taught if he should elect to follow the profession of a mining engineer.

In the first place, up to the age of eighteen I should favour a broad training, no specialization, but a good, all-round education, including mathematics and science, and also the classics and languages. A good education in one's own language and a capability to use it thoroughly should be sought after. Next to English language I should consider the French of highest importance, for, no matter where one goes, we find French used quite extensively by officials, and in connection with mining its use is quite important. The language occupying third place in the consideration of the mining engineer is undoubtedly Spanish, the language spoken in Mexico, and the great mining countries in South America.

Having completed this preliminary education, a student should be entered into one of the large schools of mines. I should advise a four-year course. Some years ago the Royal School of Mines had but a three-year course, but at present it has a four. Four years is short enough time into which to crowd the foundation work for this profession. The first two years the various underlying sciences should constitute the course, as, for instance chemistry, geology, mineralogy, physics. The last two years would be well spent upon mechanical engineering, metallurgy and kindred subjects perhaps a little more relative to the practical after life. I should advise that not too many subjects be studied at the same time. The best arrangement would be, possibly, to take two allied subjects along together, as chemistry and physics. I thoroughly believe, from my own experience, that this is the best procedure. I should further emphasize the teaching of mechanical engineering for the training of a mining engineer. This brings up another question, which was discussed in England by some of the most eminent scientists and authorities on scientific training, namely, the question of how far machinery should be used in the training of students as object lessons and for demonstration purposes. Many expressed the opinion that it is a mistake to have the machinery itself to show, but I disagree with this view. I believe the best way to teach the parts and workings of a machine is to show not only its plans on paper, but to show and work the machine. The knowledge of a steam engine would be fuller if the engine could be seen and handled and worked. I would favour even the introduction of other mining machinery, as, for instance, a stamp mill. Furthermore, a man who has worked these machines in practice should be obtained, and should give the gist of his experience of years to the class. I could give a knowledge of a stamp mill, for example, which it took years of experience and some mistakes to obtain to a class in a few hours, comparatively. Many warnings and much valuable information, which could only be gathered in years of experience, could thus be imparted to the student. With regard to the teachers, the best ought to be sought for our schools of mining. While buildings and equipment are, indeed, necessary, nevertheless they are only secondary to teaching staff. That should be of the best, and sufficient salaries should be paid to such teachers to be worth their while. In London the salaries are far too small, as some teachers are getting one-tenth of what a practice of their profession might bring them, the other nine-tenths had to be taken out in glory and honour.

Having spent four years in actual training in a School of Mines, a good start is all-important for the young mining engineer. In England, at least, there has been difficulty in this direction. Mining companies sometimes do not want the man just graduated, but prefer to get him a little later. A postgraduate course partially to tide over this period of uncertainty has been formed in England. In this, about twenty or thirty students are sent each year to South Africa, Australia, United States, and now to Canada. Large companies take them on a living wage, and in a sort of an apprenticeship of one or two years. In return they are expected to be employees of the company, put in the full time of working hours, and they are given opportunity to learn all procedures at the mine. I should like to see this idea grow in favour, as it has proven very satisfactory to all concerned, oftentimes those sent out remaining on the permanent staff, or else returning with very favorable impressions.

When the engineer is once launched upon his career finally, he should consider the first ten or fifteen years as a period of the continuation of his training. Experience is what he needs, and is what afterwards commands large fees. Of a choice of two positions, one of which extends one's experience and the other does not, I should certainly favour the former, even though the immediate pay may be much less; it will be far better in the long run. A student should go to some large centre of operation preferably to going as manager of some small unimportant mine.

This is an age of scientifically trained men, and it will be still more so in future. Thirty or forty years ago scientific training was often scoffed at as impractical, but not so to-day, although, of course, practical experience, linked with scientific training, constitutes the success of the best men.

I do not wish to lay down the law in this matter, but only to give these remarks as expressing my conception of the necessary and best training. I shall be glad if these remarks will lead to discussion and criticism.

PARTIAL LIST

— OF —

# CANADIAN FUNGI

COLLECTED BY THOMAS LANGTON, M.A.

(Chiefly in the neighbourhood of Toronto and in the Districts of Muskoka and Parry Sound.)

(*Read 15th April*, 1911)

## BASIDIOMYCETES

### HYMENOMYCETES.

### I. AGARICACEÆ.

1. LEUCOSPORÆ (white-spored).

*Amanita muscaria* Linn. (Poisonous).

In woods; Muskoka and near Toronto, August and September. Common.

*Amanita phalloides*. Fr. (including *Amanita verna*, Bull.) (Deadly poisonous).

On the ground in woods; Muskoka and near Toronto. August and September. Common.

*Amanitopsis strangulata* Fr.

On the ground in open woods; Glasgow head, Canso, N.S. and at Brackley Beach, P.E.I. July and August.

*Lepiota procera*, Scop. (Edible).

On the ground in open woods; near Toronto and Caledon Mountain. September.

*Lepiota naucina*, Fr. or *L. naucinoides*, Pk. (Edible).

On the ground in open grassy places; near Toronto and Caledon Mountain. September.

*Lepiota gracilenta* Krombh. (Edible but of indifferent quality).

On rotten wood in woods; Muskoka. September.

*Armillaria mellea*, Fr. Vahl. (Edible; with a peculiar bitter but not disagreeable taste).

On stumps or buried wood everywhere. August to October. Common.

*Tricholoma album*, Schaeff. (Edible).

On the ground amongst rotting leaves and wood; Muskoka and near Toronto. July to October.

*Tricholoma personatum*, Fr. (Edible).

On the ground amongst leaves in woods. September.

*Clitocybe infundibuliformis*, Schæff. (Edible).

On the ground, generally amongst leaves, in woods; Muskoka and woods about Toronto. July to September.

*Clitocybe nebularis* Batsch. (Edibility doubtful; some persons said to have suffered from eating it).

On the ground in woods about Toronto. September.

*Clitocybe clavipes*, Pers. (Edible).

On the ground in woods near Toronto. September.

*Clitocybe media*, Pk. (Edible).

On the ground in woods near Toronto. September.

*Clitocybe robusta* Pk. (Edible).

In woods amongst leaves, (and grass cuttings at the edge of woods on Golf grounds) near Toronto. September and October.

*Clitocybe decastes*, Fr. (Edible).

In a ditch at the roadside; Highland Creek near Toronto. October.

*Clitocybe laccata*, Scop. (Edible).

On the ground in damp places in woods; Muskoka. June to October. Common.

*Clitocybe amethystina*, Bolt. (Edible).

On the ground in woods; Georgian Bay. September.

*Clitocybe ochropurpurea*, Berk. (Edible).

On the ground in woods; Georgian Bay and Muskoka. September.

*Clitocybe gilva*, Pers.

On the ground near or upon decayed wood; Caledon Mountain. September.

*Collybia radicata*, Relh. (Edible).

On rotting logs and stumps or near them on the ground. Common everywhere. August and September.

*Collybia longipes*, Bull. (Edible).

Found in the same places as *C. radicata*.

*Collybia platyphylla*, Fr. (Edible).

Found in the same places as *C. radicata*. Common.

*Collybia velutipes*, Curt. (Edible).

On trees and stumps near Toronto. September to November. Common.

*Collybia confluens*, Pers. (Edible).

Common amongst fallen leaves ; Muskoka and near Toronto. July to October.

*Collybia dryophila*, Bull. (Edible but said not to agree with some persons.)

Common in woods and groves, on the ground amongst leaves and decaying wood; Muskoka. August.

*Mycena galericulata*, Scop. (Edible).

Common on trunks, logs and fallen leaves; woods near Toronto. August.

*Omphalia campanella*, Batsch. (Edible).

Common on decaying stumps and logs; near Muskoka and Toronto. May to November.

*Omphalia umbellifera*, Linn. (Edible).

Common on decaying stumps and logs chiefly of conifers: Muskoka. May to November.

*Omphalia epichysia*, Pers.

On logs near Toronto. October.

*Pleurotus ulmarius* Bull. (Edible).

On a horse-chestnut tree ; Queen's Park, Toronto. September.

On *negundo aceroides*; Black Creek near Toronto. September.

On elm trees; The Grange, Toronto. November.

*Pleurotus ostreatus* Jacq. (Edible).

On decaying trunks and lying logs of beech, maple and birch. Muskoka. June to October.

*Pleurotus sapidus* Kalchb. (Edible).

Found in the same places as *P. ostreatus*.

*Pleurotus sulphureoides*, Pk.

On a decaying beech log, Caledon Mountain. September.

*Pleurotus petaloides* Bull. (Edible).

On logs in woods. Muskoka. October.

*Pleurotus serotinus* Fr. (Edible but of indifferent quality).

Common on dead trunks, stumps and lying logs in woods; Muskoka and near Toronto. September to November

*Pleurotus dryinus* Pers.

In a hollow in an elm tree; Toronto, October.

*Hygrophorus miniatus*, Fr. (Edible).

Common amongst moss in marshy and wet places. Muskoka and Caledon Mountain. July to October.

*Lactarius volemus* Fr. (Edible).

On the ground in a wet spot in woods at margin of lake; Muskoka. August.

*Lactarius piperatus*, Scop. Fr. (Edible).

Common on the ground in woods, Muskoka. July and August.

*Lactarius torminosus*, Fr. (Considered edible in Russia; not recommended in Canada).

On the ground in woods; Muskoka, Caledon Mountain, neighbourhood of Toronto. August and September.

*Lactarius theiogalus*, Fr. (Edible but coarse).

On the ground in woods; near Toronto. September.

*Lactarius deliciosus*, Fr. (Edible).

On the ground in woods; Muskoka and near Toronto. August and September.

*Lactarius Gerardii*, Pk. (Edible).

On the ground in woods; Muskoka. July.

*Russula atropurpurea* Pk.

On the ground in woods, amongst leaves; Toronto. October.

*Russula virescens*, Schæff, Fr. (Edible).

On the ground in woods; Muskoka and Rosedale woods near Toronto. August and September.

*Russula emetica*, Fr. (Commonly reputed to be poisonous but by some experimenters pronounced edible).

Common on the ground in woods; Muskoka. July to September.

*Russula heterophylla*, Fr. (Edible).

On the ground in woods; Muskoka. July and August.

*Russula cyanoxantha*, Schœff. Fr. (Edible).

Common on the ground in woods. Muskoka. July and August

*Russula aurata*, Fr. (Edible).

On the ground in woods; Baddeck. August.

*Russula roseipes*, (Secr.) Bres. (Edible).

On the ground in woods; Muskoka. August.

*Russula fœtens* Fr.

On the ground amongst leaves, in woods; Muskoka. July,

*Cantharellus cibarius*, Fr. (Edible).

On the ground in thick woods, especially under spruces, Muskoka. August. Caledon Mountain; September. Canso; July.

*Cantharellus lutescens* Bull. (Edible).

On the ground in woods, near Toronto. September.

*Marasmius oreades*. Fr. (Edible).

Common in pasture fields, lawns, golf links, near Toronto. September.

*Lentinus lepideus*, Fr. (Edible, but tough).

On sleepers of disused Railway track near Toronto. July and August.

*Lentinus Lecomtei*, Fr. also called *Panus rudis*.

On stumps at side of Railway track. Muskoka. August.

*Panus stypticus*, Fr. (Not Edible).

On stumps and lying logs, Muskoka and near Toronto. August to November.

*Panus strigosus* B & C (Edible when young).

Coespitose on lying beech logs; Muskoka. August.

*Schizophyllum commune*, Fr.

Common everywhere on fallen trunks and branches; Muskoka and near Toronto. August to November.

*Trogia crispa*, Fr. (Not edible).

On stumps and fallen trunks; Muskoka and woods near Toronto. September.

*Lenzites betulina*, Fr. (Not Edible).

On dead birch and other trunks and branches; Muskoka and near Toronto. September to November.

*Lenzites saepiaria* Fr. (Not edible).

On pine and hemlock wharfs, etc. ; Muskoka. July, August,

2. RHODOSPORÆ.

*Volvaria bombycina* Schæff. (Considered to be Edible).

On maple trunk; Muskoka. July.

*Pluteus cervinus* Schæff. (Edible).

Common in woods on decaying wood; Muskoka, Caledon Mountain, Toronto. July to September.

*Clitopilus cæspitosus* Pk. (Edible).

On the ground in woods; Caledon Mountain. September.

*Claudopus nidulans*, Pers. (Edible but of indifferent quality).

On half-buried pine timber ; Muskoka. October and November.

3. OCHROSPORÆ.

*Pholiota præcox*, Pers. (Edible).

On the ground in a ravine near Toronto. May, June.

*Pholiota adiposa*, Fr. (Edible).

On decaying logs; Humber banks near Toronto. September and October.

*Naucoria semiorbicularis*, Bull. (Edible).

In lawns; Toronto. June.

*Galera tenera* Schæff.

In lawns; Toronto. July.

*Crepidotus versutus*, Pk.

On dead branches of poplar; Woods, near Toronto. November.

*Cortinarius collinitus* Fr. (Edible).

On the ground in open woods; E. Toronto. October.

*Cortinarius alboviolaceus*, Pers.

In woods near Toronto. October.

*Cortinarius squamulosus*, Pk.
On the ground in woods. August.

*Cortinarius armillatus* Fr. (Edible.)
On the ground in woods; Muskoka. August.

*Paxillus involutus*, (Batsch) Fr. (Edible).
On or near stumps and decayed logs in or near woods; Muskoka August and September.

*Paxillus atro-tomentosus*, (Batsch). Fr.
In woods on stumps and decaying logs. Muskoka. August and September.

4. PORPHYROSPORÆ.

*Agaricus campester*, Linn. (Edible).
In pastures Cape Breton, August. Near Toronto, September.

*Agaricus silvaticus* Schæff. (Edible).
On the ground in woods; Caledon Mountain, and E. Toronto. September.

*Agaricus silvicola* Vitt. (Edible but in its early stages the dangerous *Amanita phalloides* may be taken for it.)
Woods; Caledon Mountain, and E. Toronto. September.

*Agaricus magnificus* Pk. (Edible).
In High Park, Toronto; 8 in. across and 11 in. high. September and October.

*Stropharia semiglobata*, Batsch. (Edible).
In lawns, Toronto. July.

*Hypholoma sublateritium*, Schæff. (Edible).
Common on stumps and logs in or near woods; Muskoka and near Toronto. September to November.

*Hypholoma appendiculatum*, Bull. (Edible).
On stumps and wet logs, in damp cellar. Toronto. July.

*Hypholoma incertum*, Pk. (Edible).
On an uprooted pear tree stump, on damp wood in cellar stairway; Toronto. July.

5. MELANOSPORÆ.

*Coprinus comatus* Fr. (Edible when young).
In lawns, roadside ditch, embankment of a disused railway; Toronto. June and September.

*Coprinus atramentarius* Bull. (Fr.) (Edible when young).
Roadsides, in ditches and gardens; Toronto. June to October.

*Coprinus micaceus* (Bull.) Fr. (Edible when young).
At root of trees and stumps in streets and parks; Toronto. July to October.

*Coprinus fimetarius* Fr.
Common on manure heaps; Toronto. April, May.
*Panœolus retirugis*, Fr.
In a bed of poppies in a garden; Toronto. July.

## II. POLYPORACEÆ.

*Boletinus pictus*, Pk. (Edible).
On the ground in damp woods; Muskoka. August.
*Boletus edulis*. Bull. (Edible).
On the ground in hardwood woods; Muskoka. Caledon. July to September.
*Boletus felleus*, Bull. (Not edible).
Common on decaying stumps; Muskoka, Caledon, Toronto. July and August.
*Boletus Americanus*, Pk.
On the ground in woods; Muskoka, Cape Breton. August.
*Boletus luridus*. Schæff.
On the ground in or near woods; Canso; Muskoka. August and September.
*Boletus Ravenelii*
In woods; Cape Breton, August. Georgian Bay, September.
*Boletus subglabripes*, Pk.
On the ground under cedar and hemlock trees; Muskoka. August.
*Boletus Russelli*. Frost. (Edible, *McIvaine*).
On the ground in mixed woods; Georgian Bay. September.
*Boletus speciosus*, Frost.
On the ground in mixed woods; Georgian Bay. September.
*Boletus scaber*, Fr.
On the ground in woods; Muskoka and Georgian Bay coast. September.
*Boletus chromapes*, Fr.
On the ground in woods; Baddeck C.B. August.
*Boletus cyanescens*, Bull.
On the ground in mixed woods; Muskoka. August.
*Strobilomyces strobilaceus*, Berk.
On the ground in woods; Muskoka and Georgian Bay coast. September.
*Polyporus picipes Fr.*
On lying beech logs; Muskoka. August.
*Polyporus elegans*, Fr.
On beech trunks; Muskoka. August.

*Polyporus brumalis* (Pers.) Fr.
On beech log; Muskoka. August to October.

*Polyporus umbellatus* Fr. (Edible).
On the ground in mixed woods; Muskoka, August; near Toronto, October.

*Polyporus sulphureus* Fr. (Edible).
On elm stump Toronto. July. On dead pine, Muskoka; August. Also on the ground amongst buried wood in open woods (with a distinct stem); September.

*Polyporus betulinus* Fr. (Edible.)
On living and dead birch tres; Muskoka, Toronto and Ottawa. September.

*Polyporus lucidus* (Leys) Fr.
On decaying stumps and logs of hemlock; Muskoka. July and August.

*Polyporus applanatus* (Pers.) Fr.
Common on trunks and logs of maple and beech; Muskoka. July to October.

*Polyporus volvatus*, Pk.
On standing trunk of dead hemlock; Muskoka. October.

*Polyporus albellus*, Pk.
On decaying poplar trunks; Muskoka. August.

*Polyporus adustus*, Fr.
On dead willow trunk in woods near Toronto. October.

*Polyporus fumosus*, Fr.
On stump; E. Toronto. October.

*Polyporus radicatus*. Schw.
On stumps. August.

*Polyporus pubescens*
On decayed beech log, Rosedale; Toronto, July. E. Toronto; October.

*Polyporus rutilans* or *nidulans*
On dead hemlock; Muskoka. August, September.

*Polyporus distortus*.
At the foot of stump in woods, Rosedale, Toronto. July.

*Polyporus gilvus*
On rotten log; Muskoka. September.

*Polyporus Schweinitzii*.
At the foot of a stump; Muskoka. August.

*Polyporus benzoinus*.
On fallen dead hemlock; Muskoka. October.

*Polyporus squamosus* Fr.
On dead trunks; Toronto, May.

*Polystictus versicolor* (L.) Fr.
Common everywhere on decaying stumps and trees. July to October.

*Polystictus hirsutus*, Fr.
On dead poplar; Muskoka. August.

*Polystictus perennis*, Fr.
Common on the ground and on stumps; Muskoka. September.

*Polystictus pergamenus*, Fr.
On birch and poplar trunks, High Park, Toronto. November.

*Polystictus cinnamoneus*, Fr.
In moss; Muskoka. August.

*Polystictus cinnabarinus* Schw.
On dead birch and poplar and hemlock; Muskoka ; near Orillia. August to September.

*Polystictus circinnatus*, Fr.
On the ground in woods ; Muskoka. August.

*Poria odora*
On dead logs; Caledon Mountain. September.

*Poria ferruginosa*
On birch ; Toronto, September.

*Dœdalea unicolor*, Fr.
On beech trunks ; Muskoka. October.

*Dœdalea confragosa*. (Boten)
On birch and alder; Caledon and Muskoka, August and September; on oak about Toronto, October.

*Favolus Europœus* (*Favolus Canadensis*, Klotsch).
On fallen branches; Muskoka. August, September.

*Fomes fomentarius* Fr. (The same as *Polyporus leucophœus* and *Fomes leucophœus* Mont).
Common on trunks and logs; Muskoka. Perennial.

*Fomes pinicola* (Swartz) Fr.
Common on conifers; Muskoka. Perennial.

*Fomes igniarius* (L) *Fr.*
Common on trunks in woods; Muskoka.

*Fomes connatus* Fr.
On dead conifers; Muskoka. August.

*Merulius aureus* Fr.
On dead conifers; Caledon Mountain. September.

## III. HYDNACEÆ.

*Hydnum coralloides* Scop. (Edible).
On fallen beech trunk in woods; Muskoka. August.

*Hydnum caput-ursi*, Fr. (Edible).
On fallen beech trunk in woods; Muskoka. August.

*Hydnum erinaceum*. Bull. (Edible).
On dead beech trunk in woods; Muskoka. October.

*Hydnum repandum L.* (Edible).
On the ground in woods; Muskoka. August.

*Hydnum septentrionale* Fr. (Edible but coarse and woody).
On wounds in a living, and at the base of a decaying maple tree in woods; Muskoka. August.

*Hydnum albonigrum*, Pk. (Not edible).
On ground in woods near Toronto. September.

*Hydnum aurantium*
On the ground in woods ; Muskoka. August.

*Hydnum ferrugineum* Fr. (Edible).
On the ground amongst rotting wood; Muskoka. August.

*Hydnum adustum* Fr. (Not edible).
On decaying wood in woods; Muskoka. August.

*Irpex lacteus* Fr.
On fallen branches in beech woods; Muskoka. September, October.

*Phlebia radiata* Fr.
On fallen beech logs, Muskoka. September and October.

## IV. THELEPHORACEÆ.

*Craterellus cantharellus* Schw. Fr., (Edible).
In woods; Whycocomagh, Cape Breton. August.

*Craterellus cornucopioides* Fr. (Edible).
On the ground in open woods; Georgian Bay. September.

*Thelephora intybacea*.
Amongst moss in swampy woods; Muskoka. August.

*Thelephora Schweinitzii*.
On grassy ground in open woods; Muskoka and about Toronto. September.

*Coniophora puteana*.
On the bark of birch tree; Muskoka. October.

*Stereum versicolor* Fr.
Common on logs and stumps. Summer and Autumn.

*Stereum sericeum* Schw.
On fallen twigs and branches in woods; Muskoka and about Toronto. September.

*Sterium spadiceum* Fr.
On dead trunks; Toronto. October.

*Stereum rugosum* Fr.
On decaying wood; Orillia, August.
*Stereum tabacinum*
On dead branches; Toronto. October.
*Stereum rufum*
On dead branches; Toronto. October.

### V. CLAVARIACEÆ.

*Clavaria aurea*, Schæff, (Edible).
On the ground in woods, Muskoka. August.
*Clavaria ligula.*
On fallen leaves in woods; Muskoka. October.
*Physalacria inflata*
On pine log; Caledon Mountain. September.

### VI. TREMELLACEÆ.

*Tremella mycetophila*, Pk.
On *Collybia dryophila* in woods; Muskoka. August.
*Tremella frondosa* Fr.
On uprooted and decaying oak stumps; E. Toronto. August to October.
*Tremellodon gelatinosum* Pers. (Edible).
On decaying logs in woods; Muskoka. September.
*Gyrocephalus rufus* (Jacq.) Bref.
On buried decaying wood; Rosedale woods, Toronto. September and October.
*Guepinia spathulata.*
On decaying wood; Muskoka. August, September.
*Calocera carnea.*
On decaying moss covered logs; Muskoka. September.

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## GASTEROMYCETES.

### I. LYCOPERDACEÆ.

*Lycoperdon pyriforme* (Schaeff).
On logs; Muskoka. August.
*Lycoperdon gemmatnm* Batsch.
On the ground and wood in woods; Muskoka. August.
*Geaster triplex.*
In woods; Caledon Mountain and near Toronto. September.
*Geaster limbatus.*
In woods; Caledon Mountain and near Toronto. September.
*Calvatia gigantea*, Batsch. (Edible).
On the ground in grassy places near Toronto. September.

*Calvatia cyathiformis*, Batsch. (Edible).

On the ground in grassy places near Toronto. September.

*Schleroderma vulgare*. Fr.

On the ground under trees; common.

II. PHALLOIDEÆ.

*Phallus Ravenelii*, (B. & C.).

On the ground in open woods; Muskoka. August.

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**ASCOMYCETES**

I. SPHÆRIACEÆ.

*Xylaria polymorpha*, Grev.

On decaying logs and stumps in woods; Muskoka. August to October.

*Daldinia concentrica*.

On beech logs; Muskoka. August.

*Hypoxylum coccineum*.

On bark of beech logs; Muskoka. July to September.

II. HELOTIACEÆ.

*Chlorosplenium versiforme* Pers.

On watersoaked log in swampy woods; Black Creek, near Toronto. June.

*Helotium confluens* Schweinitz.

On watersoaked log in woods; Muskoka. October.

III. PEZIZACEÆ.

*Peziza scutellata* Linn.

Common on water soaked wood; also on recently dried up swampy ground ; also on cow-dung in swampy place. Woods near Toronto and Muskoka. Summer.

IV. HELVELLACEÆ.

*Morchella esculenta* Pers. (Edible).

On the ground in flats of Black Creek and elsewhere near Toronto. May, June.

*Gyromitra esculenta* Fr. (Edible).

On sandy banks or pits near Toronto. May, June.

*Helvella elastica* Bull. Var. *fusca*.

On watersoaked log in swampy woods; Black Creek, near Toronto. October.

*Helvella lacunosa*. Afz.

On watersoaked log in swampy woods; Black Creek, near Toronto. October.

*Helvella crispa.*

On the ground in a wet ravine in woods, near Toronto. September.

*Helvella infula.*

On a log in swampy woods; Black Creek, near Toronto. October.

*Spathularia flavida* Pers.

In woods, Muskoka. August.

*Spathularia velutipes*, C & T.

On moss covered logs in woods; Muskoka. August.

# BRITISH RULE IN INDIA.

By J. PATTERSON, M.A. (Cantab.).

Late Imperial Meteorologist to the Government of India.

(*Read 12th November*, 1910.)

When your secretary asked me to give a lecture on India it occurred to me that I could not do better than give you an account of some of the things that the British Government are attempting to do for India, because you hear very much about discontent in that country and very often a strong criticism of the Government, so much so that you may at times think that it would have been better for India had Britain never conquered the country. I wish to correct that impression from my own personal experience after a residence of seven years.

Greece and Rome, Egypt and Palestine, Assyria and Babylon—countries which have long since ceased to play a part in the drama of humanity—are the subjects of text-books in our schools and universities, while India which is a modern reflex of the ancient world and has become part and parcel of the British Empire is to this day practically unknown to most of us. It seems to me therefore that before dealing with my subject proper it would be well to give a brief synopsis of Indian History before the British appeared on the scene, so that you may better appreciate the difficulties and the task that Britain assumed when she was compelled by force of circumstances to take up the reins of Government.

India has been governed by three dynasties, Hindu, Mohammedan and British. As you know the earliest histories of Greece and Rome are contained in great epic poems in which it is difficult to separate truth from fiction and myth, so in India, the earliest history is contained in the great Hindu epic poems, called the Vedas, which are the basis of their religion and philosophy. From these poems we learn that India was originally inhabited by an aboriginal race and that in the migration of the Indo-European peoples which inhabited the Central Asia plateau, one branch of them extended down through the mountain passes into India and drove the aborigines into the mountains and jungles, just as our forefathers drove back the Indians in their day. The invaders overran the whole country and their descendants are now known as

Hindus and Buddhists. Of their history there is little authentic, except what is contained in the Vedas, out of which disjointed and inconsistent material it is difficult to realize the actual conditions of ancient India. One thing, however, is abundantly evident, the whole Indian Continent was a chaos of conflicting elements, evolving large ideas of the universe, but utterly lacking in political life and cohesion; that is about all that can be said about Hindu rule.

Next the Mohammedans took their turn at evolving a united India, by trying to compel the Hindus to become Mohammedan but failed. They commenced the definite conquest of India about the 10th century A.D., and gradually extended their sway over the whole of India, allowing the Hindus to retain their religion on condition that they paid tribute. Their history is chiefly a record of wars and plundering. Up to 1500 the Mohammedans from Afghanistan and Persia overran the country and then gave place to the Moguls. The Moguls were descendants of a race called the Tartars; they were Mohammedans of a rather unorthodox type and in India their armies consisted of both Hindus and Mohammedans, so that in any uprisings or wars they could send out the army that would be most desirous of fighting the enemy. The Moguls appeared just about the same time as the Portuguese and for 200 years they ruled the country with the rod of despotism. The great Mogul kept all power in his own hands and appointed his viceroys or Nawabs to govern the different parts of the empire, but on the death of Auranzeb in 1707 the Mogul empire went into rapid decline and the great Mogul could no longer control his subordinates; they then set up semi-independent kingdoms in different parts of the country in which there was always a war between the different sons of the rulers for the succession and it usually ended by the one who gained the upper hand murdering or imprisoning the others. As the Mogul empire declined the Mahrattas gained the ascendancy. They originally inhabited the country known as the Western Ghats and were simply freebooters, levying blackmail wherever they could. In time, they collected it from almost all parts of India. If a state paid a certain sum yearly in black mail, that state was not molested, but if it refused it paid dearly for its refusal in pillage and plunder. Born horsemen, requiring no provisions and no camp, they were swift in their movements and if defeated in one place they appeared a few days afterwards miles distant to pillage and plunder again. The country was thus in a state of utter confusion and chaos from one end to the other and such scenes as the following were not uncommon. One of the conquering armies (Persian by the way) sacked Delhi, and from 8 a.m. to 3 p.m. the streets were filled with shouts of the brutal soldiery, and the shrieks of their helpless victims. The atmosphere was reeking with the blood and butchery of human beings. Houses were set on fire and numbers perished in the flames. Husbands killed their wives and then murdered themselves, women threw themselves into wells, children were slaughtered without mercy and infants were cut to pieces at their mother's breasts. Such then, was the system of Government worked out by the Mohammedans and it is little better up to the present day in Persia.

At this turning point in the downward career of the once great Mogul another star appeared on the horizon; the Mogul empire was shattered never to be restored. The foundations of a new empire were being laid by English traders in Calcutta and Madras which was destined to extend its paramount power over the whole of India from sea to sea, and form the sandy deserts of the west to the Himalayan barrier on the north. The Hindu nationalities of India after centuries of oppression were to be educated by British administrators into a knowledge of that civilization which has regenerated the western world and established the reign of law and order. In this manner the peoples of India are being trained and disciplined by British rule for a new career of national life which can only be revealed in the unknown world of the future.

The British during the first half of the 18th century were simply traders under the East India Co. They purchased small tracts of land at Madras, Calcutta and Bombay for which they paid their yearly rental and they had no influence on the government of the country nor did they take any interest in it. They were there for commercial purposes and so conducted their affairs from a business standpoint only. This policy of isolation, however, was not destined to outlive the first half of the century. On the succession of Suraj-ud Daula as Nawab or Viceroy of Bengal in 1756, one of his enemies took refuge in Calcutta and he demanded his surrender but was refused. The Nawab next demanded the dismantling of new fortifications but was told that no new fortifications had been built except to repair some lines of guns to prevent the place from being captured by the French. This made the Nawab furious and he marched a large army against the place. The English were taken completely by surprise and the sequel is familiar to all, in what is known as the black hole of Calcutta. From that time it was impossible for Britain to remain outside the pale of Indian politics. Circumstances compelled her to interfere more and more in the internal affairs of the country although the home directors and Government did their best to keep out, until by the end of the 18th century she had become the paramount power in India.

In 1798 the Marquis of Wellesley landed in Calcutta, as Governor-General. He was appointed by the British Government and came out with three objects in view, namely, to drive the French out of India, to revive the confederacy with the Nizam and the Mahrattas against Tippu Sultan of Mysore and to establish the balance of power in India, the last being the darling object of the English ministry. I may just say here that at that period the object of the English Government was to allow the different native states to maintain their independence and Britain would hold the balance of power among them, and as she fondly imagined keep the peace. He soon disposed of the French, and Tippu Sultan, but he had not been long in India before he found out that it was utterly impossible for Britain to remain in the position of holding the balance of power owing to the intrigues that were carried on by the different rulers so he proposed the following:—The native states were to surrender their international life to the British Government in return for British protection. They were to make no wars and to carry on no negotiations whatever with any other native state without the consent of the British Government. They were not to entertain Frenchmen or any other Europeans in their service without the consent of the British Government. The greater principalities were each to maintain a native force commanded by British officers for the preservation of the public peace, and they were each to surrender territory in full sovereignty to meet the yearly charges of this force. The lesser principalities were to pay tribute to the paramount power. In return the British Government was to protect them one and all against foreign enemies of every sort and kind. The Marquis of Wellesley was a true imperial statesman of the highest order who brought the political experiences of Western culture to bear upon the conditions of Asiatic rule. His genius was untrammelled by the narrow limits of a trading monopoly which had swayed the better judgement of Clive and Warren Hastings. He valued the security and prestige of the British Empire in India at a higher value than the commercial privileges of a trading company and raised up a host of enemies in consequence. But in the teeth of all opposition he established the sovereignty of Britain over the greater part of India and put an end forever to the English born fantasy of a balance of power. He also separated the civil service officers from those in charge of the company's service. His policy was carried to its completion by the Marquis of Hastings about 20 years afterwards,and it has been the guiding principle of British administrations to the present day although native misrule has compelled the Government to take over many native states since that time. This was notably the case during Lord Dalhousie's term of office and was one of the causes of the great mutiny, but as you are all more or less conversant with this great event I shall pass it over. I may explain here that there are many native states in India and when combined they form a large part of the country. Each state has a British resident, but they manage all their own internal affairs and Britain does not interfere unless their rule becomes a farce. At the close of the mutiny Britain cancelled the East India Co.'s charter and took over the administration, and from that time forward she has striven steadily and consistently for the uplifting and bettering of the conditions of the peoples of India.

In this country with its democratic institutions, one is apt to think that democratic government is the only possible government in which people can enjoy full liberty and, that all other kinds of governments are or savour of tyranny and oppression, but is that true? It may be that for the Anglo-saxon, democratic government is the best, but does it not depend very largely on the character of the people what government will suit them best? Then can we honestly say that democratic government has been a perfect success on this continent and that no better government could be obtained? I trow not. I think that it is possible to conceive of an autocratic government in which the people have no voice in the administration, if wisely conducted and ably administered to be just as good as or better than the most democratic and that under it the people can enjoy just as much liberty and be as free as any in the world. I believe that that type of Government is to be found in British India. Why should it not be so ? The British officials in India are of the same race and blood as ourselves and are actuated by the same motives; they belong to an old and honorable service, the finest civil service in the world, and they are anxious to maintain the best traditions of that service. How then could the British rule be otherwise than just and beneficent? It seems to me that the principal duties of a government towards its subjects are:—The preservation of peace, law and order, the honest administration of justice, the proper development of the country in its natural and manufactured products, providing transportation, preservation of health, care of the sick, education and the amelioration of the conditions of the people. It would make my lecture far too long if I were to attempt to give a proper conception of what the British in India are attempting to do along these different lines, and I shall select only two or three of the lines of activity which can only be fully appreciated by those who have lived in the country. For the rest I shall simply say that since the mutiny India has had peace, and law and order have been established, while no greater tribute could be paid to the honesty and impartiality of British judges than the universal desire throughout India to have British rather than native judges to try any case that comes before the courts.

## MEDICAL SERVICE.

In India as in all oriental and uncivilized countries the practice of medicine is usually associated with charms and spells to drive away the evil spirits so much so that among the densely ignorant and illiterate they have such a firm belief in the efficacy of such means of cure that it is difficult to get them to submit to proper treatment. The bettering of such conditions as these must surely be one of the things that any Government who has any regard for its subjects would seek to do. In the days of the company rule, hospitals were established towards the end of the 18th century, primarily for the servants of the company but others could be treated also. In these days the Government maintains out of the public funds an efficient medical service, the superior officers of which must all be qualified practitioners in Britain. The Government provides medical colleges for the proper education of the Indians, and public hospitals and dispensaries under the supervision of the superior officers to which all classes may go for treatment. These officers are generally skilled surgeons as well as medical men, in fact they have to be if they would be of the greatest service to the people ; they certainly can get all the practice they want. The people are realizing more and more the benefits of hospital treatments and are coming in ever increasing numbers so that now something like 30,000 000 people are treated annually. The Government has not been unmindful of the sanitary condition of the people and in this line probably their most important achievement has been in the introduction of waterworks systems. All the large towns in India have complete waterworks systems that would put to shame most, if not all the systems in this country. These have caused a very great decrease in the epidemics that used to work such frightful havoc among the people.

## EDUCATION.

Among the Hindus their brahmins or priests carried on a system of education in oriental literature from time immemorial, but it was confined to this one caste. The priest gathered a number of pupils about him and they always accompanied him and learned orally from him the stories contained in the Vedas. The Mohammedans also gave a certain amount of education to their priests and well-to-do, but the great mass of the people have been absolutely illiterate for untold generations, in fact several of their greatest native rulers as Akhbar, the greatest of the Moguls, Tippu Sultan of Mysore and Runjat Singh, the great Sikh leader could neither read nor write.

The first attempts at extending an education to the Indians were made by the missionaries and many of the institutions founded by them in the early days are still among the best in the land. Many of the Governors-General in the days of the company rule took an interest in the subject and did what they could towards laying the foundation for an educational system. They did not believe that the proper way to treat a conquered race was to keep it in ignorance, nor that a nation's strength lay in its illiteracy. After India passed under the crown the educational movement has advanced steadily but surely though slowly.

When the state assumed the responsibility for the education of the people it had to face a condition unique and unparalleled in Europe. The population was as large as or larger than that of all the European countries and the languages and customs were just as varied, and in the higher branches it was to receive an instruction in a foreign language. The magnitude of the task was such as to make it impossible of achievement by any direct appropriation of the resources of the empire, while the popular demand for instruction had in a great measure to be created.

The careers for educated men in India are not as varied as in western countries and the public service is by far the most important ; the greatest attraction for a man to have his son educated is to get him into Government service.

These are some of the difficulties to be overcome and to do so the Government provides out of the public revenues a state aided or state controlled system of education, which attempts to give an education suitable to the different classes for whom it is intended. In the primary schools the work is all done in the vernaculars and the children are taught, mainly, to read, write and do a little arithmetic; in the next grade higher they are taught English if they wish to take a university course, or if not the teaching is in the vernacular. Then there are the Universities where all subjects are taken up, and all teaching is done in English. The work is all supervised by European officers and the head professors in the Government Colleges are generally Europeans. For the proper training of the teachers for the primary and secondary schools well equipped training colleges are now provided, and by this means the quality of the teaching is being improved. In the matter of technical education the British Government is also endeavoring to improve the workmanship of the Indians. In India with its multitudinous numbers of castes it has been the custom and religion of the people for the son to follow the same trade as his father from generation to generation. The Government has now established many industrial schools where under the direction of skilled artisans the children can learn their trade to better advantage and become more proficient in their work. An Indian cannot as a rule, do two things well. He can probably do one particular kind of carving very well, but he is absolutely incapable of doing any other kind of carving or carpenter work. The schools help him very much and they can turn out work of the very highest class. The students, are of course, paid for their work, otherwise they would not come, for the boy has to help support the family as soon as he is able to work. In India the existence of creeds differing widely from one another and from that of the faith of the ruling power has made it essential for the state to assume a position of strict religious neutrality in its relation to public instruction. No religious instruction is given in Government schools, but in all others, provided a sound secular education is provided, the Government gives a grant for its support be it Hindu, Mohammedan or Christian. As no religious training is given in Government institutions, other means have to be found for improving the moral welfare of the students and all work with this end in view is encouraged and aided by the Government. One of these means is the provision of hostels where the students can be kept under strict discipline and control and these are now springing up around most of the large colleges. Then again the teachers and professors supervise the school games and encourage athletics and gymnastics all of which tends to the upbuilding of the Indian character. Nowhere does a professor get a better insight into student character than on the athletic field, and he there discovers the childishness of the character. In this way the Government is trying to uplift the millions of subjects placed under its charge from a condition of slavery and ignorance to that of freedom and intelligence. The path may be long and tortuous, the results meagre and perchance often superficial, but you cannot change habits that have been fixed from time immemorial in one or even two generations, for it is only by improvement from generation to generation that the people can be elevated to a position of intelligence comparable with that of the western nations.

## CO-OPERATIVE CREDIT.

In India there is a class of people known as Bunias, they are the native bankers and grain merchants of India, and a curse to the country. The poor people who have produce to sell have to sell it to the bunia and he generally advances them their grain and food, so that once a poor native gets into their hands he is never known to get free from debt. Owing to the illiteracy of the people, the bunia can so manipulate accounts and charge such exorbitant rates of interest that the man is always in his clutches, and the bunia allows him about enough to keep body and soul together. To rid the people of this evil the Government has established what are called co-operative credit societies on the lines of the Agricultural Banks in some European countries, notably Germany. The principal objects of these societies are the encouragement of thrift, the accumulation of loanable capital and the reduction of interest on borrowed money by a system of mutual credits. These societies are carefully controlled and supervised by European officials, otherwise their affairs would soon be in a hopeless condition.

At first they met with not only apathy but opposition from the very people whom they were intended to benefit and also from the educated Indians. They looked upon them as infringing on an ancient right and custom of the people. As the people understood them and became familiar with them their opposition and apathy disappeared and now they are extending very rapidly to the great advantage of the Agriculturalist. So much so that many of them who were always in debt have now a small bank account. The Bunias fought the movement by every means in their power and special legislation was required to compel them to accept payment of the debts owing to them. This is one of the best illustrations of what the Government is endeavouring to do to ameliorate the conditions of the people.

### FAMINE.

I come now to deal with one of the most awful and terrible scourges that can afflict any nation, namely famine. From the days of Buddhist pilgrims from China to the latest administration report issued by the Government of India, famine lies broad written across the pages of Indian history. The accounts of early famines are indeed meagre for in the chronicles of courts, which cared little for the people, social calamities find scant record. We know that famines were frequent in India and frightful when they came, whether during native or British rule. Severe Famines are now caused solely by the failure of the rains but in the days of native rule they were frequently caused by war and plunder also. In order to understand this better I shall briefly explain the weather conditions.

In the cold weather pressure is highest in the north of India,and lowest in the south and the gradients and winds are feeble. During this period from December to the middle of March the winter rains occur. They give a fair amount of rain, especially in northwest India, while heavy snowfall occurs in the neighboring hills,but over the rest of the country the rainfall is unimportant. From March to June the weather gradually warms up until in May and June the shade temperatures are generally over 100° and in some places they exceed 125°. During this period the soil has rest. The leaves fall from the trees owing to the heat just as they do here from the frost, and everything is parched. The people sit in their villages and literally gasp for rain. In the meantime important changes have been going on; the pressure gradients have become reversed, pressure now being high in the south and low in the north, and the winds show the existence of two great air currents flowing into India; they are the Arabian Sea and Bay of Bengal currents. These currents bring the monsoon or rains to India, normally in June. After the first heavy shower ploughing begins, and millet and rice which provide the food for the poorer classes are sown. These occupy the ground from two to four months and the rains last for from three to four months. During the period of growth the distribution of rainfall is even more important than its amount; should a long break in the rains occur accompanied by hot dry winds, serious loss would be caused. After the rains are over in October and November, wheat, barley, oats, pulse, etc. in the north and millets in the south are sown. These are harvested in March and April and give employment to millions. Such then are the normal agricultural operations in India.

A widespread failure of either harvest will cause distress, but it depends on several conditions whether there will be famine or not; such as the character of the previous harvest and the degree to which agricultural operations are affected. It is not in the power of man to prevent drought in India, nor so long as the country is mainly agricultural, to prevent drought from causing famine. All he can do is to restrict and mitigate the resultant suffering. Modern famine policy is thus a struggle against nature and as such it has two distinct objects in view, namely protective and remedial. The one seeks to prevent famine and the other seeks to relieve distress when it comes.

I shall first deal with the protective measures and under this head the most important is irrigation. Irrigation has been carried on in India to some extent from remote ages and by very primitive means, but it was not until British rule was established that the more important irrigation works were carried out. No similar works in other countries approach in magnitude the irrigation works of India and no public works of greater utility have ever been undertaken in the world. There are three distinct systems of irrigation in use, namely, lift, storage and river works, which are illustrated by wells, tanks or reservoirs and canals. In lift irrigation, the water is lifted by manual or animal labour from a lower level to that which will command the area to be irrigated. The Persian wheel is one of the best examples of this method. Then in many parts of the country the water which falls during the rains is collected into great reservoirs and stored there until it is required for irrigation purposes, but in this case the supply cannot be relied upon as it depends upon the rains whether or not there will be sufficient rainfall to fill the tanks. Some of these tanks have areas of two or three square miles and may be 20 or 30 feet in depth. In the case of river works the water is carried in canals to the places where it is needed, and as the grade of the canal is always less than that of the river it is possible to carry the canal up out of the valley of the river unto the high land and in some cases even across the watershed. The river works are by far the most important in India and all the great rivers in northern India except the Brahmaputra are utilized. They all rise in the great Himalayan mountains region to the north of India and are fed by the eternal snows; there is thus always a supply of water available. In this way a very large part of the Punjab and parts of the United Provinces have been irrigated, so that in these areas the danger of famine has almost disappeared. One of the largest canals is the Chenab and it irrigates 2,000,000 acres, while the total number of acres irrigated over the whole of India amounted to more than 14,000,000 acres in 1902 and the area has been very much increased in recent years.

Under native rule there was little thought for and no effective means of remedial action, but then primitive transport could not enter fodderless and roadless country and so broke down when most required by those who wanted to send in food. The East India Co. by degrees introduced systematic relief but it was not until India passed under the crown that the modern view of the responsibility of the state was reached. In 1868 the famous order was issued that every district officer would be held personally responsible that no deaths occurred from starvation, which could have been avoided by any exertion on his part or that of his subordinates. Then from the experience gained from famine relief the policy assumed its final shape in the declaration made by the secretary of State in 1877 as follows:—The object of saving life is undoubtedly paramount to all other considerations but it is essential in the pursuit of that policy, your officers should sedulously guard against the danger of inducing the population to rely upon Government aid rather than upon their own industry and thrift. In the interests of the distressed population itself and the taxpayer generally, you are bound to adopt precautions against indolence and imposition so far as the circumstances of India will permit, to those with which in this country it has always been found necessary to protect the distribution of public relief.

This has been the great aim of all relief administrations ever since. It is the problem of how to guide the bark between the rock of distress and the whirlpool of demoralization. The principle is briefly that Government does not give relief without work. In times of famine the Government opens out what are called relief works. These are the building of canals, railways or other public works, that require to be built in that section. They may not be urgently needed but they would be of material benefit to the country to have them constructed. In famine all who are in need of work and are physically fit whether man, woman or child can go there and get work. The pay is just sufficient to keep them in food but is not sufficient to induce them to leave other work for it. This is the main system of relief but in carrying it out great practical difficulties occur. The people are infinitely varied in habits, customs, creeds, castes and languages. Thousands would sooner die than resort to relief camps or touch food which they thought might have been touched by christian, or some other caste. One caste will not eat with another. The shy folk of the hills will not work with the people from the plains. Skilled weavers will not go to ordinary relief work for fear of losing their delicacy of touch. Then there are the sick, the aged and the very young to be cared for. To deal with all these sensitive, suspicious masses the Government has to organize vast temporary establishments. Truly a most tremendous and seemingly hopeless task. But British genius for administration has in a great measure overcome these difficulties. The difficulties are lessened by the general orderliness of the people and their willing submission to discipline. On the other hand it is enormously increased by the corruption of the native officials. They have to be employed in large numbers and it is only by the strictest supervision by European officials that discipline can be maintained and corruption kept within reasonable bounds.

The preparations for famine in India are now just as complete in time of plenty as are the preparations for war among European nations in time of peace. Programmes of suitable relief work, are revised annually in every district, the country is mapped out into relief circles of convenient size, reserves of tools and plants are stocked, and a list of persons suitable on emergency for famine establishments are annually drawn up. Daily reports of rainfall, weekly reports of the condition of the people and of the crops are received by the Government so that their information is as complete as possible. When the rains show signs of failing preliminary enquiries are started, a forecast of the probable failure is made and a careful look out is kept for the regular danger signals. Prices begin to rise, the people become uneasy, aimless wandering in search for work occurs, petty crimes against property increase, credit becomes more difficult and grain dealers make large purchases. As soon then as these signals show that famine is imminent the Government provides the funds and declares its policy, so that a telegram from headquarters is sufficient to put relief work into instant operation.

Famine relief generally begins about September and the numbers naturally go on increasing until the following May when the supreme test comes. Naturally food becomes more difficult to obtain as the days go by, and while the railways may supply this deficiency to a very great extent they cannot prevent the decrease of the water supply and its consequent contamination, so that by the end of May when the weather is hottest and the whole earth seems to be a fiery furnace the greatest danger of epidemics (especially cholera) occurs. Then you see the quality of the men of the civil service and medical service and the missionaries for throughout it all they will be found at their posts even if their life is the price of their duty. As an illustration:—In the Panch Mahals district in the Bombay Presidency in the famine of 1900 cholera broke out suddenly in one of the relief camps and with such violence that in three days the dead numbered thousands. The people fled panic stricken and spread the disease far and wide, while the native assistants and camp attendants deserted in large numbers, leaving the European officers themselves to collect and burn the dead. On the other hand the power of efficient organization was well displayed in the management of a cholera outbreak in 1897 in a relief camp in the United Provinces. The country had been divided into circles in which small works were mapped out. On the first outbreak of cholera the people on the large relief work were broken up into parties of about 500 and marched with full staff and equipment to the circle in which their villages were situated. Here they found small works ready for them, the wells had been disinfected, work was commenced at once; there was no panic and the pestilence was stayed.

As the monsoon approaches the policy changes, it is in the interest of the country at large as well as of the people themselves that ordinary agricultural conditions should be restored with the least possible delay, and that as large an area as possible should be sown. For this purpose the people are moved from the large works to small works near their villages about the end of May, and liberal advances are made for the purchase of ploughs, cattle and seed. Then as soon as ploughing begins most of the people leave the works but they are left open until the first harvest is ripe and at the close of the rains large quantities of quinine are distributed free as fever usually follows. Then the works are gradually closed and the famine is over.

Such then is in brief outline the general policy of the Government to meet famine conditions, but this account would not be complete without giving you some idea of what an Indian famine means. As an example under native rule a great famine occurred in parts of the Bombay Presidency in 1631. A Dutch trader visited part of the afflicted country and gives the following description. Only 11 out of 260 families at Swally survived the famine in that year. The road thence to Surat was covered with bodies decaying on the highway where they died. In Surat, that great and crowded city, hardly any living persons could be seen, but the corpses at the corners of the streets lie 20 together, nobody burying them. 300,000 had perished in the town alone. This, that was the garden of the world, is turned into a wilderness. A brief account of two or three of the great famines in our time will suffice to show you something of their extent. In 1895 the rains failed in the province of Agra and next year also over the United Provinces, the Central Provinces, parts of Madras, Bombay, Bengal, the Punjab, Upper Burma, Rajputana, Central India, and Hyderabad so that all these areas were plunged in famine. The total area affected was 307,000 square miles, an area larger than Ontario and Manitoba, with a population of 69,500,000. Well might any Government stand appalled in the face of such a catastrophe. Here the Government was called upon suddenly to make provision for fighting the famine and at the same time to carry on the ordinary routine work of Government. The numbers on relief exceeded at times 4,000,000 and throughout the famine over 821,000,000 units were relieved. The famine ended in 1897 when the autumn harvest was ripe but it was followed by heavy mortality from fever and a plague of rats. Altogether about 750,000 perished in British India alone, but much of this was due to the reluctance of the wild tribes in the hills to accept relief on ordinary terms.

The effects of this famine had scarcely disappeared before the country was plunged into a still more intense famine. In 1899 the rains failed over the west and centre of India. The total area was 475,000 square miles, or an area almost equal to Ontario and Quebec, with a population of 59,500,000. In July 1900 no less than 6,500,000 were receiving daily relief. The distress was further aggravated by the failure of fodder and the water supply. Cattle died by the millions. Then this famine was most severe in native states. These states manage their own affairs and to within a few years ago did practically nothing to relieve famine, with the result that in this famine the people of the native states migrated by the hundreds of thousands into British India and disorganized the administration, for by starvation and wandering they were so exhausted that it was impossible for medical skill to save them. Then the failure of the water supply with its consequent pollution caused very virulent outbreaks of cholera so that 200,000 are estimated to have died from it. Then the unhealthy autumn caused a further heavy mortality so that almost 1,000,000 perished in this famine in spite of all the work the Government did.

Yet while these figures are appalling they are nothing to what they used to be before the British Government organized proper relief, and in the last great famine of 1906-7 in the United Provinces and adjacent districts, although from one to two millions were at times receiving relief, no one is known to have died from starvation. An excellent testimony to the results of British rule and the perfecting of their famine system.

## UNREST.

I have endeavoured to give you some idea of what British rule has meant for India, but the question naturally arises, could not the Indians have done this for themselves if Britain had never conquered the country? It seems to me that the best answer to this question is given by the oriental nations surrounding India. Take China, Afghanistan, Persia, and Turkey, nations whose civilizations are as old as or older than that of India and it is hardly necessary to tell you what they have accomplished for you all know it is practically nothing. All these nations are of one race and religion and so had everything in their favour for developing a strong and progressive country; but look at India with its races and languages as numerous as in Europe and the one hating the others with a deadly hatred. How then could they possibly change the country from what it was at the advent of the British ? They were a prey then to a stronger power and they would have been a prey still. In famine relief works the various native states have had many opportunities of showing their skill in administration, but almost without exception they have miserably failed. The Raja is generally willing enough to spend large sums of money on relief work, but the amount that filters through the hands of the native officials for actual relief is infinitesimal and the officials often retire after a famine as wealthy men.

This leads to the question of the unrest in India. While there is undoubtedly much unrest in certain quarters, the newspapers have certainly not diminished its importance. The unrest is chiefly confined to parts of Bengal, especially Calcutta, and its various ramifications have extended from there to various parts of India. The causes are many and the Government is by no means free from blame, especially the home Government. The freedom of the press has always been considered as one of the great bulwarks of British liberty and this liberty has long been extended to the native press in India. They were thus permitted to pour out their fulminations against the British Government, to misrepresent it and to fill their papers with the grossest and vilest lies that it was possible for an Indian Editor to conceive. The people who read these accounts believed every word because their own countrymen had written it, especially was this true of the student class. You know how at a certain age the young in this country believe everything their political party says or does, more so in India. Then the Bengalis are born cowards and orators. When the Crown took over the Government it required that all its native officials should be educated and then the demand exceeded the supply. Now when the opposite is true the Bengali cannot see the difference between the two propositions, "Government requires all its native officials to be educated," and, "All educated natives should be employed by Government." So those who do not get Government positions are dissatisfied and are fully persuaded that they are the only ones who know how to govern India. They, by many orations, also carried on the campaign of calumny against the Government and the inevitable result has been that many of the students have become fanatics and in that condition they are ready to do anything. It is a melancholy fact that all the bomb throwing and murdering of officials have been done by youths under 20 years of age.

These orators are forever proclaiming the high sounding phrase of a United India and you would imagine that they were martyrs for the people, but to those who know India it is known that such a dream is an absolute impossibility and that should they get their desire of driving the British out of the country they would be the very first to be silenced by the first military power to arrive on the scene. No greater punishment could befall India than for the British to withdraw. These nationalists have absolutely no care for the people and their religion teaches it. If they had they could show their fitness for Government in the relief of famine and plague, but what do you find instead? They spread reports that the British Government is sending the plague among them by poisoning the wells, and while the Civil Servants and Medical Officers under a burning sun are striving with all their power to combat the famine and the pestilence, they are inciting the people to deeds of violence against their greatest benefactors.

In the discussion which followed the lecturer was requested to give the statistics of the irrigation works of India, and a brief statement of them is hereby appended.

Irrigation works in India are divided into "Major and Minor," and the former are again subdivided into "Productive" and "Protective." Productive works are built by borrowed money and are expected to pay at least the interest on the capital outlay; on the other hand the Protective works are built by money taken from the general revenue of the country, and are constructed in order to provide food grains as a protection against famine.

The Minor works include a miscellaneous collection of works of different kinds, and while very numerous are generally of small extent. In many cases there is no record of their original cost.

The capital cost of the Productive works up to 1908 was about 151 million dollars and the area irrigated 13.7 million acres. The profit derived from these works was about 7.4 per cent. The capital cost of the Major Protective works was seven million and the area irrigated 400,000 acres. Minor works irrigate over 7½ million acres but the exact cost of them is not known.

The total outlay on irrigation works up to 1908 was about 180 million dollars and the total area irrigated over 21 million acres.

The crops grown on the irrigated areas are about equal annually to the capital cost of the works and it is estimated that about a third of this is due in normal years to irrigation, but in famine years the story is entirely different. One example will suffice. In the famine year 1896-97 the land irrigated by the Sone Canal in Bengal produced a crop valued at 8.9 million dollars and the canal cost 8.96 million dollars. The crop on all the surrounding country was an absolute failure. In this one year the people realized in crop almost the total cost of construction of the canal, while they paid in water rates only 7 per cent. of the value of their crops.

# CANADIAN COAL RESOURCES.

By D. B. Dowling,

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(*Read 25th February*, 1911.)

The coal areas of North America, as outlined at the present day, show a sufficiently large amount to warrant the statement that the first evidence of the shortage of coal will come from the older countries. Canada and the United States having 18 times the amount of coal that there is in England and Germany or 35 that of England. The large area in Canada which is underlain by older beds than those producing coal will probably be found rich in other minerals. The remainder and possibly the portion destined to become the most thickly populated is well provided with fuel. The fact that the continent possessed coal in mineable areas seems not to have been published by any of the early navigators till about 1670. The French had settled Cape Breton and explored a large portion of its area. Nicholas Denys was appointed governor of the eastern part in 1637. Like modern prospectors, he applied for a concession (which was granted in 1654) for the privilege to mine gold, silver, copper and other minerals on the whole island, paying therefor a royalty of ten per cent. of the profits. His prospectus, published in Paris 1672, states that there were mines of coal throughout the whole extent of the concession near the sea coast of a quality equal to the Scotch. The first attempt at mining was, on the authority of Mr. Richard Brown,* made upon the 10 ft. seam on the north side of Cow Bay in 1720, when the construction of the Fortress at Louisburg, was begun. Cargoes of coal were exported to Boston in 1724 and the French shipped some few cargoes to Martinique in 1728. Later the explorations of the English settlers farther south brought to light the presence of coal deposits in Virginia and coal was mined near Richmond. Other early mines were opened in New Brunswick by the French near Grand Lake.

Following the early discoveries of coal along the Atlantic coast the tide of settlement moved ever westward and in its progress there was ac-

* The Coal Fields and Coal Trade of Cape Breton, by Richard Brown, London, 1871.

cumulated a wider knowledge of the resources of the new land. Our own portion of the continent has been thus far explored by the expenditure of the energies of the most dauntless of the two races—represented in the early days by the fur traders of the Hudson's Bay Company and the French Canadian adventurers of Lower Canada. Many thrilling tales of these and later travellers are so modestly told that their full appreciation comes only to those whose experience enables them to read between the lines. Nor can we in any manner assume that this age of heroic service has passed away since it is hard to find in even the latest journals of explorers, whether in the national service or not, any undue stress laid on personal matters. Our conception of the resources of our country is still being enlarged by undertakings in the nature of explorations and also by the systematic examination of more accessible fields. Part of our knowledge is thus definite and part general. The older known fields and those where coal mining is becoming stable have as a rule been fairly well studied. Many samples from remote localities have been examined and we are enabled in this way to predicate the value of the fuels. With probably only some minor differences there is no known kind or quality of coal that can not be duplicated from some part of Canada. From the little altered vegetable remains found in the peat bogs to the rock like anthracite, the remains of early highly altered vegetation, the scale seems complete. Lignites in which the woody fibre is prominent are found to be succeeded by black lignites resembling true coal. These again are followed by the bituminous coals with which may be classed the ultra bituminous cannel coals whose more earthy varieties are known as oil shales. Any of these latter varieties by local conditions assume the harder anthracitic forms, in localities where the beds have been subjected to extra pressure.

In age the Arctic Islands divide the honours with New Brunswick in holding in their rocks coal which is the remains of the first vegetation which appeared in any abundance on the margin of the sea. Very little of this appears to have been a truly land flora. The Horton and Albert shales of New Brunswick and the Lower Carboniferous of the Arctic Islands owe their carbon constituents probably to aquatic plants of primitive type with an admixture probably of the lower minute forms of marine fauna. The great coal formation of the Carboniferous Period is represented in the New Brunswick and Nova Scotia coal fields. Elsewhere in Canada where rocks of this period are found, such as in the Rocky Mountains and British Columbia, no land appears to have been near and the shore deposits of the western coast of the continent as then constituted have been swept away. A long interval in time separates these deposits from the coal producing Cretaceous (so named in Europe from the chalk cliffs of this formation) the rocks of which (shales and sandstones) form the prairies of the west. Three distinct land intervals are marked in this age by coal deposits. The first at the beginning furnishes the steam coals of the Rocky Mountains and vicinity, and other areas in British Columbia. The second, the coals of the Lethbridge area in Alberta and possibly those of Vancouver Island, and the third the greater areas of the plains producing all grades of lignite. Tertiary coals later than the Cretaceous occur in British Columbia and in Alberta. Last of all during the closing portion of the Glacial Period, peat bogs and forests were covered by the advancing ice and finally left with a burden of boulder clay which preserved the material. In places it is in mineable quantities of brown lignite. An example of this last coal formation is to be found in Northern Ontario on the James Bay slope. Many of the areas in the remote parts especially in the north are but little known and their extent is estimated from the general knowledge which we have of the distribution of the containing rocks or formations.

A summary estimate of the amount of coal with area and character is appended.

## COAL AREAS IN CANADA.

### PROVISIONAL ESTIMATE.

| Province or District | Square Miles | Anthracite | Bituminous | Lignite | Total |
|---|---|---|---|---|---|
| Yukon | 400 | 9 mill. | 32 mill. | 850 mill. | 891 mill. |
| Arctic Islands | 6,000 | | 3,840 " | | 3,840 " |
| Mackenzie | 400 | | | 1,000 " | 1,000 " |
| British Columbia | 1,123 | 20 " | 38,642 " | 414 " | 39,076 " |
| Alberta | 16,786 | 400 " | 35,780 " | 65,002 " | 101,182 " |
| Saskatchewan | 7,500 | | | 20,000 " | 20,000 " |
| Manitoba | 48 | | | 330 " | 330 " |
| Ontario | 10 | | | 25 " | 25 " |
| New Brunswick | 112 | | 155 " | | 155 " |
| Nova Scotia | 992 | | 6,250 " | | 6,250 " |
| | 33,371 | 429 mill. | 84,699 mill. | 87,621 mill. | 172,749 mill. |

## DETAILS.

### YUKON.

| | | Anthracite (Million Tons) | Bituminous (Million Tons) | Lignite (Million Tons) |
|---|---|---|---|---|
| North east of Dawson | 300 square miles at 4 feet coal | | | 750 |
| Tantalus areas | 10 square miles at 5 feet coal | | 32 | |
| White Horse and Vicinity | 3 square miles, various | 9 | | |
| Pelly river areas | 50 unexplored possibly | | | 50 |
| Liard river areas | 50 unexplored possibly | | | 50 |
| | 400 sq. miles maximum | 9 | 32 | 850 |

### ARCTIC ISLANDS.

Exposures of cannel coal are noted by many of the Arctic explorers. Although not available at present, this coal forms an asset. The beds are dipping at low angles so that the mineable areas are wide. The exposures reach across the following Islands:—

| | |
|---|---|
| Banks Land | 150 miles |
| Melville Island | 150 " |
| Bathurst | 50 " |
| North Devon Island | 50 " |
| | 400 miles |

The coal is found within a belt 30 miles wide so that a possible area 400 by 15 or 6,000 square miles would for each foot of coal have 3,840 million tons.

### MACKENZIE.

At the mouth of Mackenzie and on the coast eastward lignite bearing rocks are reported.

| | | Lignite |
|---|---|---|
| Near Fort Norman | 200 square miles, 4 feet. coal | 500 mill. |
| Peel River | 200 square miles, one 30 ft. seam | 500 mill. |
| | 400 square miles | 1,000 mill. |

### BRITISH COLUMBIA.

| | | Anthracite | Bituminous | Lignite |
|---|---|---|---|---|
| Vancouver Island: | | | | |
| Koskeemo | 10 square miles at 4 feet | | 25 | |
| Susquash | 20 " " " 5 " | | 64 | |
| Comox | 75 " " " 4 " | | 192 | |
| Nanaimo | 350 " " " 5 " | | 1,225 | |
| Cowitchin | 50 " " " 4 " | | 125 | |
| Kluane | 10 " " " 4 " | | 25 | |
| Graham Island: | | | | |
| Cowgitz | 60 square miles at 8 feet | | 300 | |
| Massett | 100 " " " 4 " | | | 250 |
| Mainland: | | | | |
| Elk river area south | 230 square miles at 100 feet | | 22,600 | |
| Elk river area north | 140 " " " 100 " | | 14,000 | |
| Nicola River | 12 " " " 4 " | | 30 | |
| Princeton | 30 " " " 5 " | | | 96 |
| Similkameen | 6 " " " 7 " | | 26 | |
| Hat Creek | 5 " " " 20 " | | | 68 |
| Telkwa | 10 " " " 5 " | | 30 | |
| Skeena north | 15 not explored | 20 | | |
| | 1123 sq. miles | 20 | 38,642 | 414 |

### ALBERTA.

| | | Anthracite | Bituminous | Lignite |
|---|---|---|---|---|
| Rocky Mountains: | | | | |
| Coleman | 45 square miles at 50 feet | | 2,000 | |
| Blairmore / Frank | 50 " " " 30 " | | 1,500 | |
| Livingstone | 60 " " " 25 " | | 1,500 | |
| Moose Mountain | 15 " " " 15 " | | 250 | |
| Cascade | 40 " " " 25 " | 400 | 1,200 | |
| Palliser | 6 " " " 6 " | | 20 | |
| Costigan | 12 " " " 8 " | | 60 | |
| Bighorn | 60 " " " 35 " | | 1,400 | |
| Nickanassin | 20 " " " 10 " | | 150 | |
| Jasper Park | 38 " " " 20 " | | 600 | |
| Foothill: | | | | |
| Pine River | 40 " " " 10 " | | 300 | |

| | Anthracite | Bituminous | Lignite |
|---|---|---|---|
| Embarass and Pembina.......100 square miles at 12 feet.............. | | 800 | |
| South. Foothills, 2000 " " " 8 " .............. | | 11,000 | |
| Lethbridge......3500 " " " 4 " .............. | | 15.000 | 5.000 |
| Edmonton.....10800 " " " 7 " .............. | | | 60,000 |
| Fort McKay........ small area 3 feet seam.............. | | | 2 |
| 16,786 square miles | 400 | 35,780 | 65,002 |

SASKATCHEWAN.

| | Lignite |
|---|---|
| Southern part of province.......4000 square miles 4 feet........... | 15,000 mill. tons. |
| Eastern part of Lethbridge area..3500 square miles 2 feet........... | 5,000 mill. tons |
| 7500 square miles................. | 20,000 mill. tons |

MANITOBA.

| | Lignite |
|---|---|
| Turtle Mountain area 48 square miles........................................ | 330 |

ONTARIO.

| | |
|---|---|
| Interglacial lignite on Moose and Abitibi drainage 10 square miles............ | 25 |

NEW BRUNSWICK.

| | Bituminous |
|---|---|
| Grand Lake and Dunsinane areas 112 square miles, 2 feet.................. | 155 mill. |

NOVA SCOTIA.

Estimate by Hon. Robert Drummond.

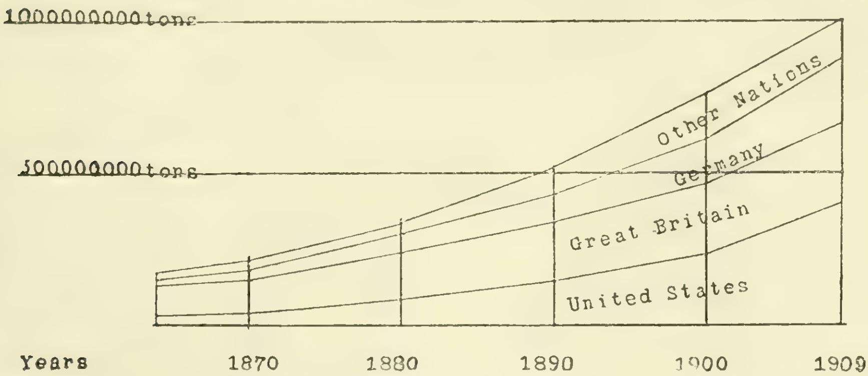
| | |
|---|---|
| Cape Breton.................. | 450 square miles. |
| Cumberland.................... | 300 " " |
| Inverness...................... | 128 " " |
| Richmond...................... | 84 " " |
| Pictou.......................... | 30 " " |

992 square miles averages 9½ feet coal=6,250 mill.

Areas beneath sea and minor areas with thin seams should raise the total to 10,000 mill.

NOTE—A subsequent revision based on explorations of 1911 has added to totals especially for British Columbia. The above estimate is for easily mined coal and not for total amount of coal in deep measures or for thin seams.

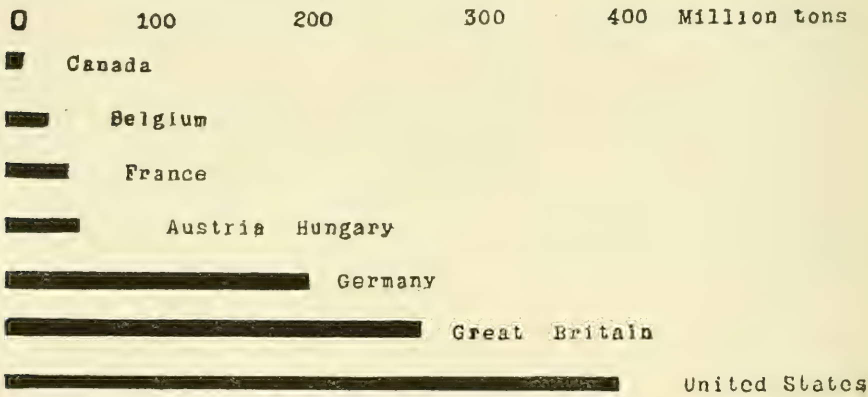
Worlds Production of Coal




| | | |
|---|---|---|
| 1864. | 173,770,000 | metric tons. |
| 1870. | 217,823,000 | " " |
| 1880. | 339,370,000 | " " |
| 1890. | 513,130,000 | " " |
| 1900. | 766,935,262 | " " |
| 1909. | 1,084,521,101 | " " |

The use of coal either by the individual or the nation may be assigned to two distinct uses, a fairly constant domestic requirement which may be said to be for the comfort of the people and a commercial demand which fluctuates with the activity of the nation or individual. In looking at the diagram illustrating the amount of coal used by the world since 1864, there is an increase in the total which can not be attributed to the increase in population and it is apparent that the use of coal in transportation and manufacturing is largely responsible. The noteworthy increase to which our attention is at once called is that given for the United States.

The fact, that in point of population it was on even terms with Great Britain probably before 1870, shows that its commercial activity was much less. Its phenomenal growth in population argues for a lowering rate, if any, in domestic use of coal so that its commercial activity shows the most rapid strides and now probably gives a per capita production equal to that of Great Britain.

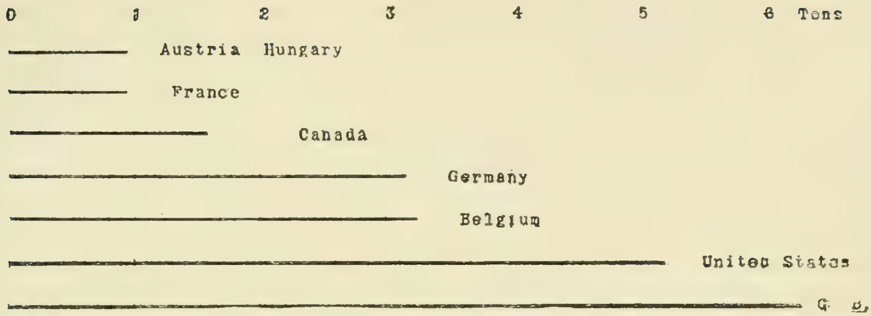



Output of Coal for 1905

The elements of the production for 1905 are shown plotted in the second diagram to include that of Canada, which mines only about half of the coal it consumes. To eliminate the question of relative population a third diagram for the same countries is submitted showing the per capita production for the same year.

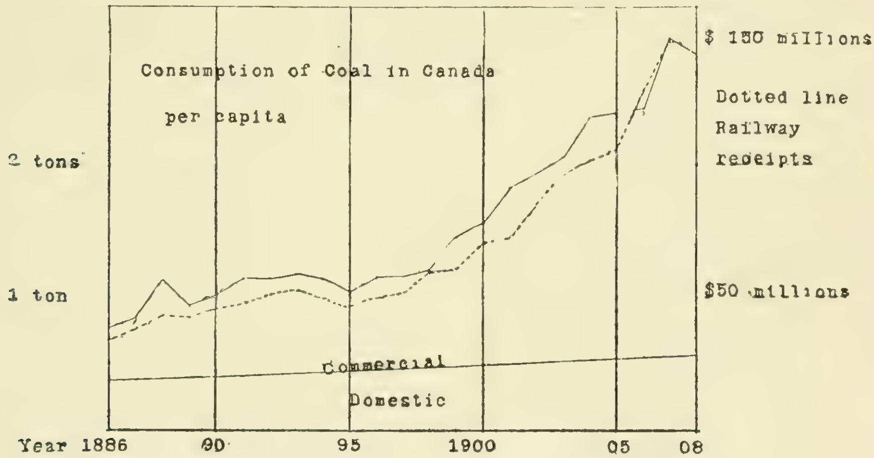
PER CAPITA.

In this an indication is shown of the struggle for supremacy in commercial activity between the United States and Great Britain. In considering that of Canada let me add that our commercial demand in excess of our mined coal owing to proximity of markets was made up by the purchase of enough coal to bring us up to about even with Germany and Belgium. Added to this our water power in course of development will soon put us, since our naval demands are not of alarming




Per Capita Production for 1905

proportions, in the position of using as much power per individual as the larger and more assuming nations.




Studying now, our own affairs more particularly, we will enquire as to what we have done in the way of consumption both of Canadian mined and purchased coal. Confining our enquiry to the individual, we find an increase from 1886 to about 1891 in the demands and then, a fairly stationary consumption to about 1898 or through the "hard times" that affected the whole continent. Arguing as before that the domestic coal, or that needed for comfort, would not necessarily increase irregularly we have to assume that the increase since is largely due to manufacturing and transportation. That this increased activity would be reflected in the earnings of the railroads should be evident and as sustaining our first assumption that our increased use of coal shows increased commercial activity. The railway earnings for these years are plotted on the same diagram. With the growing expenditure of energy drawn largely from the coal reserves and the oil and gas pools for the means of production it becomes apparent that more economy must be used in mining and waste of gas minimized. Less expensive means of power production are also necessary, since it has been proven that even the best type of steam engine gives scarcely 50 per cent of the power capable of being obtained from coal. The utilization of all the natural water power and the use of fuels that can be replaced or regrown (such as alcohol made from straw, wood, &c.) will be necessary.

The coal reserves of Great Britain and Germany are being anxiously scrutinized and mining methods carefully supervised so that little waste is allowed. By careful mining Great Britain estimates a reserve of 60,000 million tons. Germany, although exact figures are not to hand, estimates a total reserve of 52,000 millions, and the United States claims of easily mineable coal 1.922,000 million tons.

We have with this estimate in Canadian territory over three times the amount of coal that the British Isles contain, and four times that of Germany. The United States claims about 10 times the amount given for Canada. This represents a block of coal 7½ miles square and of the same depth. The Canadian reserve is a modest cube 3½ miles on each edge, or a thickness of 30 feet for an area the size of Lake Ontario.

The indication of the possible approach to hard times is given by the fraction of the reserves that is being used each year. For 1909 the figures for Great Britain, Germany, United States, and Canada are:—

| Country. | Reserve | Output 1909. | Fraction of reserve. |
|---|---|---|---|
| Great Britain | 60,000 mill. | 264 mill. | 1/227 |
| Germany | 52,000 " | 217 " | 1/239 |
| United States | 1,922,000 " | 492 " | 1/4807 |
| Canada | 172,000 " | 11 " | 1/15636 |

These figures show the time required to exhaust the coal at the present production. This is the maximum unless, as was noted before, the production is kept down. The United States production is still increasing at an enormous rate and when it has reached the per capita production of Great Britain it should then follow about the increase of population even this change of rate will not assure the U.S. a supply for much over 400 years.

Canada is possibly better supplied with water power, so that our production per capita for power need not be drawn exclusively from coal and we may be in a position to supply some coal to the neighboring country to the south.

# THE STORY OF THE STEAMSHIP.

By Sir Sandford Fleming, LL.D., K.C.M.G.

(*Read 11th February*, 1911.)

In January of the present year I read in the "Evening Star" published in Dunedin, New Zealand, an interesting article on the history of Steam navigation. The article is illustrated by a plate of the "British Queen" which is set forth as the *first steamship to voyage across the Atlantic.*

The subject was brought to the consideration of the Canadian Institute many years ago and I felt warranted in advising the editor of the "Evening Star" of Dunedin, and in setting right the readers of that publication in the Dominion of New Zealand. I alluded to the facts stated in the Transactions of the Canadian Institute for 1891-92 when they offer a note on Ocean Steam Navigation (page 165) and on early steamboats (page 174). I further communicated with the highest authority known to us viz, Mr. James Croil, author of *Steam Navigation.* Mr. Croil confirmed all the facts submitted and enabled me to mention to our fellow citizens in New Zealand that a Canadian built ship, "Royal William" was six years ahead of the British Queen and that it is quite a mistake to award to Fulton of New York the credit of having in 1803 solved the problem of propulsion by steam on lake or sea.

Among the early efforts to propel vessels by steam, the most successful were those of Patrick Miller, on Dalswinton Loch in Scotland, in 1788 and of Symington on the Forth and Clyde Canal, in the years following. In 1801 an experiment in steam navigation was made on the Thames, and in 1802 under Symington's supervision the "Charlotte Dundas" was put in operation on the Forth and Clyde Canal; in the latter case it happened that Robert Fulton of New York and Henry Bell of Glasgow were both present. The latter afterwards made successful efforts in establishing steam navigation on the Clyde, as also did Fulton on the Hudson at New York. Mr. Bell's memory is perpetuated in an obelisk erected by the city of Glasgow on a picturesque promontory on the Banks of the Clyde. Fulton constructed in 1807 at New York the "Clermont"; the following winter she was enlarged, renamed the "North-River" and for a number of years plied on the Hudson as a passenger boat. In 1809 the first steamboat appeared on the St. Lawrence. The "Accommodation" was built by the Hon. John Molson, the father of steamboat enterprise in Canada. The "Accommodation" made her maiden trip from Montreal to Quebec, in the year mentioned 1809.

The first vessel to cross the Atlantic under steam power was undoubtedly "The Royal William". This vessel was built by a joint stock company at Quebec in 1831. The hull when constructed was towed to Montreal to receive the machinery; and on being fitted for sea, her first voyage was to Halifax. Before setting out for England she traded for two years between Quebec, Halifax and Boston. The "Royal William" left Quebec for England August 5th, 1833, called at Pictou, Nova Scotia, to be replenished with coal. She re-started from Pictou August 18th. The passage from Pictou to Cowes, Isle of Wight occupied nineteen and a half days. The "Royal William" did not return to Canada, she entered the service of Dom Pedro as a troop ship, was sold to the Spanish government, converted into a war steamer and renamed the "Isabel Secunda." After an eventful service she was laid up in Bordeaux where her Canadian hull remained. The machinery made in Montreal was transferred to a new hull and formed a second "Isabel Secunda" which afterwards was wrecked on the coast of Africa.

The record incontestably goes to establish that the Canadian built "Royal William" was the pioneer of Atlantic Ocean Steamships.

Bearing on the subject and vouched for by Mr. Croil, the following facts are submitted in chronological order.

In 1833 the "Royal William"—363 tons, made the voyage from Canada to England in less than twenty days, the first ship to cross the ocean under steam.

In 1838 the "Sirius"—700 tons, crossed from London to New York in seventeen days.

In 1838 the "Great Western"—1340 tons, from Bristol to New York, in fifteen days.

In 1839 the "British Queen"—1863 tons, from Portsmouth to New York in seventeen days.

In 1840 the "Britannia" first of the Cunard line, from Liverpool to Boston, in fourteen days and eight hours, including detention at Halifax.

In 1845 the "Great Britain" the first to introduce screw propulsion 3270 tons, crossed to New York—was stranded the following year in Dundrum Bay, Ireland. The "Scotia" of the Cunard line in 1862 (withdrawn in 1875) was the last of the ocean paddle wheel steamers.

In 1849 the "Atlantic" of the Collins line, from New York to Liverpool.

In 1850 the "City of Glasgow" of the Inman line—1610 tons, Liverpool to Philadelphia.

The first steamers to enter the St. Lawrence after the "Royal William" from Boston and Halifax were the "Unicorn" in connection with the Cunard line; later on the "Genova" in 1853—the "Cleopatra" in 1854—the "Canadian" of the Allan line in 1854.

In 1905 the turbine engine was adopted by the Allan Line in the "Victorian" and "Virginian" with excellent results.

In 1896 the "Parisian" 5365 tons, made the voyage from Moville to Ramouski in six days and thirteen hours.

In 1909 the "Victorian" made the voyage from Liverpool to Quebec in six days and twenty eight minutes

The Lusitania and Mauritania of the Cunard line are both fitted with turbine engines.

The "Empress of Ireland" of the Canadian Pacific Railway line, made the voyage from Halifax to Liverpool in January of the present year 1911, in five days and sixteen hours.

The "Royal Edward" of the Atlantic Royal line, made the passage between August 4th and August 10th, 1910, from Bristol to Quebec in 5 days, 20 hours.

The same steamer made the passage between November 23rd and November 29th, 1910, from Bristol to Halifax in 5 days, 12 hours.

The Royal Edward, accordingly, holds the record up to date for the fastest westbound passage between Great Britain and Canada.

# ASCIDIANS FROM THE COASTS OF CANADA.

By A. G. Huntsman,

Biological Department, University of Toronto.

(*Read 8th April*, 1911.)

## The Ascidians of the Marine Biological Stations of Canada.

The writer has spent a portion of each summer for the last three years at the Marine Stations, in 1908 and 1909 at Departure Bay, British Columbia, and in 1910 at St. Andrews, New Brunswick. As the collections and observations were made during a very short time in each year, little knowledge has been acquired as to the annual and seasonal variations. However, sufficient has been learned to give some idea of the forms that are available for study at the two stations.

(A). The Atlantic Station.

The month of July, 1910 was spent at St. Andrews. Several rocky points were visited repeatedly at low tide and much material obtained. The most favourable places are rocky ledges on precipitous shores, where can be found plenty of flat stones. The lower surfaces of these stones are usually covered with Ascidians. The shores on either side of the station wharf and the shore of Sand Reef Point were the most productive of those that were visited. All the species that were found at low tide, occurred in the dredgings as well, but the majority of them could be obtained more easily and in greater quantity at low tide.

The facilities at the station and the willing co-operation of the station staff made possible a large amount of dredging. The writer was especially indebted to Dr. Stafford, the curator of the station, for generous assistance in every way, both in dredging and in other collecting. Dredgings were made at various points (1) in the St. Croix River, (2) in Passamaquoddy Bay, (3) in the approaches to Passamaquoddy Bay (Letite Passages, Quoddy River, Indian River &c.), (4) near L'Etang and (5) out in the Bay of Fundy around and near the Island of Grand Manan. It was only in the last locality that any Ascidians were obtained from muddy or sandy bottoms. Nearly everywhere, they were obtainable on hard bottom, stones, shells and gravel.

Of Compound Ascidians, *Amaroucium glabrum*, *Tetradidemnum* [*Leptoclinum*] *albidum* and *Holozoa* [*Distaplia*] *clavata* were generally distributed. Two colonies of *Aplidium spitzbergense* were obtained near Grand Manan. *Didemnopsis tenerum* occurred at Grand Manan and in the approaches, though sparingly.

Of the *Cionidae*, a single specimen of *Ciona intestinalis* was dredged near Grand Manan. Verrill has reported it as abundant in the Bay of Fundy.

Of Phallusiids [Ascidiids], *Ascidiopsis prunum* was obtained in quantity at low tide and considerable numbers were taken in the dredge. *Phallusioides obliqua* was common at Grand Manan and a few specimens were obtained in the approaches, but none near the station.

Of the *Chelyosomatidae*, a single specimen of *Chelyosoma macleayanum* was dredged in the approaches.

Caesirids [Molgulids] are very abundant. At low tide were found *Caesira papillosa*, *C. littoralis*, *C. canadensis* and *C. retortiformis*. In addition to these, the dredgings gave in the approaches, at L'Etang and near Grand Manan a fifth species, *C. pannosa*. At the last locality, a number of *Eugyra pilularis* were dredged in 10 fathoms, sand.

Of Styelids, *Dendrodoa carnea* was rather numerous at low tide, and occurred sparingly, but well distributed, with *Goniocarpa placenta*, in the dredgings. Two specimens of *Cnemidocarpa mollis* and numbers of *Pandocia fibrosa* were found near Grand Manan.

The Tethyids [Cynthiids] are well represented. *Boltenia ovifera*, *B. hirsuta* and *Tethyum pyriforme americanum* occurred in large numbers at low tide and were found generally distributed on hard bottom.

To sum up, the following are obtainable in fairly large numbers near the station:—

*Amaroucium glabrum*,
*Tetradidemnum albidum*,
*Holozoa clavata*,
*Ascidiopsis prunum*,
*Caesira papillosa*,
*C. littoralis*,
*C. canadensis*,
*C. retortiformis*,
*Dendrodoa carnea*,
*Boltenia ovifera*,
*B. hirsuta*.
*Tethyum pyriforme americanum*.

The following can be procured less easily (those found at Grand Manan only are not included):—

*Didemnopsis tenerum*,
*Phallusioides obliqua*,

*Chelyosoma macleayanum*,
*Caesira pannosa*,
*Goniocarpa placenta*.

In addition to the above species, the following have been found or are to be expected in this locality, but were not obtained in 1910:—

*Aplidium pallidum* Verrill,
*Lissoclinum aureum* Verrill,
*Botrylloides aureum* Sars,
*Pelonaia corrugata* F. & G.

The fauna is subarctic, consisting of species that are peculiarly subarctic, most of which are closely related to, if not identical with, European species, and other species that are found in both subarctic and arctic regions or that have their nearest allies in arctic regions.

(B). The Pacific Station.

From June to August of both 1908 and 1909 were spent at the Departure Bay Station, and in the latter year three days were spent at Ucluelet on the outer coast of Vancouver Island as the guest of Prof. Macoun.

At the station, the best collecting places at low tide are the precipitous shores of the small rocky islands in the bay. The roofs of small caverns, the under surfaces of projecting rocks and the under surfaces of flat stones that are to be found on many of the rocky ledges are the favourite spots. A considerable amount of dredging was done at various depths ranging to about 25 fathoms. The curator of the station, the Rev. G. W. Taylor, assisted me in every way and through his courtesy I enjoyed several dredging trips to Northumberland Straits on the other side of Nanaimo and one trip to Burrard Inlet near Vancouver. The best dredging places were the channels, where the bottom was stony, shelly or gravelly, although the sandy bottoms frequently yielded an abundance of a few species. Much of the bottom gives poor results, because of the absence of stones, &c. of a size that can be brought up by the dredge, although these same bottoms are doubtless well populated with Ascidians.

*Compound Ascidians*. A species of *Amaroucium* occurs in quantity at low tide and is occasionally dredged. A very dark *Trididemnum* with few or occasionally no (?) spicules was taken several times in the dredge.

*Cionidae*. *Ciona intestinalis* occurs rather frequently as shown by the dredgings, but not in quantity.

*Phallusiidae*. *Ascidiopsis columbiana* was growing in large numbers at low tide and was occasionally dredged. *A. paratropa*, a large handsome species, occurs sparingly in 10 fathoms or more and 3 specimens of *A. nanaimoensis* were found outside the bay and at Northumberland Straits. *Phallusia ceratodes* grows in large beds in the bay south of Brandon Rocks and also in a sponge bed near the entrance to the bay. Elsewhere only occasional specimens were obtained.

*Chelyosomatidae. Chelyosoma productum* is occasional at low tide and abundant in deeper water. *C. columbianum* was found in from 10 to 20 fathoms but was not abundant. *Corella inflata* was growing in numbers near low water mark and *C. rugosa* in deeper water.

*Caesiridae. Caesira apoploa* and *C. cooperi* were dredged in sand in about 10 fathoms in front of the station.

*Styelidae. Katatropa vancouverensis* and *Cnemidocarpa joannae* were abundant at low tide and the latter occurred frequently in deeper water. *Goniocarpa coccodes* was dredged in small numbers from stony and shelly bottoms and with it was found *Styela gibbsii*. The latter was very abundant in many places in from 5 to 15 fathoms, sand.

*Tethyidae. Boltenia villosa* was growing in quantity at low tide and was abundant in the dredgings. *Pyura haustor* was found in large masses in from 5 to 20 fathoms, sand and occasionally elsewhere. *Boltenia echinata*, *Tethyum aurantium* and *T. igaboja* were obtained only very rarely and in from 10 to 25 fathoms, stones and shells.

The list for this station is as follows:—

(1) in quantity.

*Amaroucium* sp. A,
*Ascidiopsis columbiana*,
*Phallusia ceratodes*,
*Chelyosoma productum*,
*Corella inflata*,
*C. rugosa*,
*Katatropa vancouverensis*,
*Cnemidocarpa joannae*,
*Styela gibbsii*,
*Boltenia villosa*,
*Pyura haustor*.

(2) occasional.

*Trididemnum* sp. A,
*Ciona intestinalis*,
*Ascidiopsis nanaimoensis*,
*A. paratropa*,
*Chelyosoma columbianum*,
*Caesira apoploa*,
*C. cooperi*,
*Goniocarpa coccodes*,
*Boltenia echinata*,
*Tethyum aurantium*,
*T. igaboja*.

The completion of the railway from Nanaimo to Alberni will make it possible to reach the outer coast of the Island in a short time by means of the railway and the Alberni Canal. This is of importance, as the fauna of the outer coast appears to differ markedly from that of the inner coast. The following account is based on collections made at Ucluelet on Barkley Sound near the mouth of the Alberni Canal by Prof. Macoun and his assistants in 1909 and by myself at the same point at the end of July and the beginning of August of the same year.

The rocks at low tide on the exposed coast are rich in Ascidians, especially the compound forms. The following were found:—

(1) in quantity.

*Amaroucium* sp. A,
*Synoicum* (?) sp. A,
*Trididemnum* sp. B,
*Sycozoa* [*Colella*] sp.,
*Holozoa* [*Distaplia*] sp. A,
*Polycitor* (*Eudistoma*) sp. A,
*Clavelina sp.*,
*Perophora annectens*,
*Katatropa yakutatensis*,
*Styela montereyensis*.

(2) occasional.

*Corella rugosa*,
*Chelyosoma productum*,
*Caesira pacifica*,
*Katatropa vancouverensis*,
*Cnemidocarpa joannae*,
*Boltenia villosa*,
*Pyura haustor*,

Dredgings made in a few fathoms (5 to 10) yielded the following:—

(1) in numbers.

*Amaroucium* sp. A,
*Synoicum* (?) sp. A,
*Trididemnum* sp. B,
*Clavelina* sp.,
*Ascidiopsis columbiana*,
*A. paratropa*,
*Corella rugosa*,
*Chelyosoma productum*,
*Caesira apoploa*,
*Cnemidocarpa joannae*,
*Boltenia villosa*.

(2) occasional.

*Amaroucium* sp. B,
*Synoicum* (?) sp. B,
*Leptoclinum* [*Diplosoma*] (?) sp.,
*Holozoa* [*Distaplia*] sp. B,
*Polycitor* (*Eudistoma*) sp. B,
*Katatropa ucluelelensis*,
*Styela gibbsii*,
*Pyura haustor*,
*Tethyum aurantium*,
*T. igaboja*.

Dall has remarked that the fauna of the inner channels of the British Columbian archipelago is of a distinctly more northern character than that of the open coast. This is well shown in the Ascidians. The list from Departure Bay includes arctic forms that are not represented at Ucluelet and among the Ucluelet species are a number of southern forms that do not occur at Departure Bay. It may be noticed that the arctic species of Departure Bay are not as plentiful and are not found in as shallow water as the corresponding species of the Atlantic Coast at St. Andrews.

(C). Some general features of interest.

Material for studying the early development of many of the Ascidians can be obtained very easily, as in many cases the eggs are retained in the parent and only the free-swimming larvae escape. This is the condition of affairs in practically all of the compound Ascidians, (those found at the stations). In the majority of the simple forms the eggs are not retained, apparently because the oviduct opens into the atrium very near the base of the atrial siphon and the strong current present at that point carries the eggs out. In some genera and species the oviduct opens at some distance from the atrial siphon, where the current is not as great and as a result the eggs are usually retained. This retention of the eggs may be quite constant in a genus, may be characteristic of certain species only of a genus, or may occur only in occasional individuals of a species. In some cases the eggs are, though retained, laid in lots, so that practically only one stage can be obtained from one individual and all the individuals of one locality may have their eggs at the same stage of development. The following is a list of the simple forms of the stations that retain their eggs:—

Genera—*Dendrodoa*, eggs produced continuously.
*Katatropa* " " "

Species,—*Caesira cooperi*, eggs produced continuously.
*C. canadensis*, " " "
*C. littoralis*, " " "

Occasional individuals of
*Ascidiopsis prunum*, eggs produced in lots.
*Corella inflata*, " " "
*Boltenia hirsuta*, (?)

Young individuals, for studying the post-larval development, can be obtained in the case of the commoner species by carefully examining the free surface in individuals of those species which have a roughened test. Individuals, that were anaesthetized with cocaine, killed in the extended condition and well fixed, have furnished me with an abundance of stages of some of the commoner species. A series of sections made of an adult *Dendrodoa carnea*, yielded in addition, (1) an almost complete series of stages of the same species from the fertilized egg up to the free-swimming larvae, (2) a 'young adult' of the same species, (3) two 'young adults' of *Ascidiopsis prunum* and (4) a 'young adult' of some species of *Caesira*!

As is well known, the Ascidians harbour many commensals. *Protozoa* are to be found in the pharynx and atrial cavity in many of the simple forms of both coasts, the majority being attached to the oral tentacles. Various kinds of Copepods and Amphipods are to be found in the same cavities. Pea-crabs occur in the atrial cavity in most specimens of *Tethyum igaboja*, *Ascidiopsis paratropa* and *Phallusia ceratodes* of the West Coast. A hydroid* is abundant at Departure Bay, coating the prebranchial zone of certain species of Ascidians and small colonies were occasionally found on the wall of the atrial cavity. Nearly every individual of *Phallusia ceratodes* contained this form and it was also found in *Ascidiopsis paratropa*, *Ciona intestinalis*, and *Tethyum aurantium*.

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*Mr. C. McLean Fraser has recently described this form (Bull. Lab. Nat. Hist. Univ. Iowa, vol. VI, No. 1) as the type of a new genus, belonging to the family *Turridae*. He has given it the name *Crypta huntsmani*.

Parasitic *Protozoa* occur in the glandular folds of the stomach in most species and in the 'liver' of Caesirids [Molgulids] and Tethyids [Cynthiids]. An Isopod was found in the endostylar vessel of *Styela gibbsii* and *Pyura haustor.*

Although Ascidians are not used for food on this continent, there are a number of species that might be so used. In most of the forms the musculature is so small in amount that when the test has been removed the great bulk of the animal consists of sea-water. In the Styelids and Tethyids, however, the musculature is well developed and frequently quite thick. Two species of *Tethyum,* very similar to or the same as those of our coasts, are, according to Oka, eaten by the Japanese. The inhabitants of Peru and Chili use as food two species of *Pyura* that occur on their coasts and species of the genus *Microcosmus* are exposed for sale in the markets of southern Europe (Grube).

## THE HOLOSOMATOUS SPECIES OF THE WEST COAST.

The complete account of these species was sent in July, 1910, for publication in the Report of the Biological Stations of Canada. In the following account it is intended to give provisional diagnoses of the new genera and species, as well as some notes on the other species. The full extent of the variation noted in the various species is not always given in this account. Further study has shown that certain changes should be made in the original account and these have been incorporated in this article.

The writer is indebted to the Rev. Mr. Taylor for a large amount of material from Departure Bay, Hope Island, Banks Island, Goose Island, Lowe Inlet, China Hat, Stephen Island, Port Simpson, Prince Rupert, Rose Spit and Hecate Straits. Prof. Macoun communicated to the writer the collection of the Geological Survey, which contained a few specimens collected by Dr. Dawson in 1885, and a large amount of material from Departure Bay and Ucluelet, collected by Prof. Macoun and his assistants in 1908 and 1909.

Many of the Ascidian genera are inconveniently large and heterogeneous, e.g. *Tethyum* [*Cynthia, Halocynthia seu Pyura*], *Styela, Caesira* [*Molgula*], and *Phallusia* [*Ascidia*]. It would be a distinct advance to have these genera divided into smaller natural groups, so that the relationships of the species would be shown. I have attempted a division of *Tethyum, Styela* and *Phallusia* as far as the material at my disposal would permit. Some of these groups are quite small and it is questionable whether they should have the rank of genera. If they are given generic rank temporarily, it will call attention more forcibly to the characters which seem to be of importance in separating these groups. Many of these characters are entirely neglected in descriptions of new species. The final determination of their rank may be left until our knowledge of all the species is such as to make revisions of the various families possible.

Family—*Perophoridae.*

*Perophora annectens* Ritter. Proc. Cal. Ac. Sc., ser. 2, vol. IV, p. 37.

In numerous colonies from Ucluelet the zooids differ from Ritter's description only in being yellowish-orange instead of yellowish-green and in having a maximum of 24 stigmata in a row instead of 18. These differences seem unimportant. The individuals in all cases formed typical social colonies and in no case were imbedded in a common test.

Family—*Agnesiidae.*

The genus *Agnesia* Mchlsn. should not be placed in the family *Corellidae* (*Corellinae*) or *Chelyosomatidae* (*Chelyosomatinae*), as has been done by Michaelsen, Seeliger and Hartmeyer. The position of the intestinal canal on the left side of the pharynx is of major importance and shows that its closest allies are the *Cionidae* and *Phallusiidae*. It differs sufficiently from either of these groups to warrant its being placed in a separate family.

*Agnesia septentrionalis* sp. n.

Shape oval, laterally flattened. Dimensions of largest specimen, 15×11×8 mm. Oral aperture terminal, atrial at anterodorsal angle. Surface entirely sand-covered, sand adhering to filamentous processes of the test. Apertures indistinctly 7- and 6-lobed respectively.

Dorsal and ventral bands of transverse muscular fibres in addition to the usual siphonal musculature.

About 30 simple tentacles, varying in size, scattered over inner surface of oral siphon. Dorsal tubercle apparently behind peripharyngeal groove, its aperture transverse and slightly bent. Six very large dorsal languets, with long 'roots.' No longitudinal bars. Transverse vessels carry a number of large sickle-shaped processes. Stigmata forming short infundibula, as many as three turns in each spiral; two rows of infundibula between successive transverse vessels.

Stomach large, smooth-walled. Intestine with the usual forwardly directed loop on the left side of the pharynx.

Ovary a rounded mass in the intestinal loop. Testicular lobes scattered over the intestinal loop near the ovary. Gonoducts accompany rectum.

Collected near Stephen Island in 1906 by Rev. Mr. Taylor.

This form differs from A. *glaciata* Michaelsen (Zoologica, Bd. 12, Ht. 31, p. 6), the only other species described, in details concerning the surface of the test, pharyngeal wall, &c.

Family—*Cionidae.*

*Ciona intestinalis* (L.)

Specimens were taken frequently in and near Departure Bay, but never in quantity. They seem to differ from European specimens only in the small number (5) of muscular bands on each side of the body. To judge from the published figures, the number is variable in European specimens (6 or 7).

Family—*Phallusiidae.*

Genus—*Ascidiopsis* Verrill (*sens. nov.*). (=*Ascidia seu Phallusia auct. partim*).

The type species is *Ascidia callosa* Stimpson (=*A. prunum* Müller). Verrill instituted this genus for the type because of the plicated condition of the pharyngeal wall. This is a character common among Phallusiids and one that cannot be used as a distinctive feature. The diagnosis may be changed so as to include those forms with the pharynx extending beyond œsophageal aperture but not beyond the posterior side of the stomach, longitudinal bars bearing papillæ and intermediate papillæ, and renal vesicles occurring over intestinal loop and in the adjacent parts of the body-wall. Also the ganglion is close to the dorsal tubercle. This genus is intermediate between *Ascidiella* (as restricted by Hartmeyer) and the typical *Phallusiae* (e.g. *P. mentula*).

*A. nanaimoensis* sp. n.

Oblong, laterally flattened; attached by left side. Up to 27 mm. in length. Oral aperture terminal, 7- (or 5-) lobed; atrial, distant from oral from one-third to one-half the length of the body, 6- lobed. Surface nearly smooth (minute papillæ over part of surface). Musculature practically confined to right side of body.

From 45 to 105 tentacles. Prebranchial zone with indistinct papillæ. Aperture of dorsal tubercle crescent-shaped, opening between horns directed forwards. Ganglion is the width of peripharyngeal groove behind tubercle. Dorsal lamina prominently ribbed, its margin with coarse teeth corresponding to the ribs. Longitudinal bars, from 41 to 50 on the left side and from 48 to 66 on the right. Plications fewer than the bars. From 3 to 6 stigmata in each mesh.

Stomach with 17 shallow folds; intestine without typhlosole. Ovary in intestinal loop and on right side of first part of intestine. Testicular lobes in intestinal loop posteriorly, on both sides of first part of intestine and on right side of stomach. Gonoducts pass along posterior side of last bend of intestine.

Three specimens obtained at points near Departure Bay.

This species somewhat resembles in appearance *Ascidia adhærens*

Ritter from Alaska, but differs from it in the number of stigmata in each mesh, in the number of plications between successive bars and probably also in the number of bars.

*A. columbiana* sp. n.

Oblong, laterally flattened, attached by the entire left side. Up to 4.5 cm. in length, 3.5 cm. in width and 2 cm. in thickness. Apertures placed as in last species. Surface more or less roughened, with numerous short papillæ, which differ greatly in size in several varieties of this species which occur. Those near the apertures are always very distinct and longer than the others. Musculature as in last species.

From 20 to 45 tentacles. Prebranchial zone smooth. Aperture of dorsal tubercle horseshoe-shaped, the horns frequently bent inwards or outwards. Ganglion directly behind tubercle. Dorsal lamina strongly ribbed, its margin with teeth corresponding to the ribs and occasionally from 1 to 5 indistinct intermediate teeth. From 19 to 24 bars on the left side and from 21 to 26 on the right. From 1 to 2 plications between successive bars. From 4 to 20 stigmata in each mesh.

Stomach with from 12 to 22 shallow folds; intestine usually with typhlosole. Anus at level of anterior end of intestinal loop or somewhat behind it. Ovary chiefly on right side of first part of intestine. Testicular lobes on left side of loop and on both sides of stomach. Oviduct passes across lower (left) side of last bend of intestine and then along posterodorsal border of rectum.

Numerous specimens from Departure Bay, Ucluelet and Port Simpson.

Differs from *Ascidiella incrustans* Herdman from Puget Sound in the plain prebranchial zone and the toothed condition of the dorsal lamina. *Ascidia adhærens* Ritter is without the papillated surface and the peculiar course of the oviduct. Its closest ally is *A. prunum* (Müller) from the North Atlantic, which differs from it chiefly in the absence of the papillæ of the surface, and in the smaller number of bars (rt. 18 to 20, lt. 15 to 19).

*A. paratropa* sp. n.

Short cylindrical, attached by small area at posterior end. Up to 11 cm. in length and about 4.5 cm. in diameter. Oral aperture terminal, 7-lobed, turned toward the right side; atrial aperture, 6-lobed, at the end of a short siphon which extends from the anterodorsal angle to a point in front of the level of the oral aperture. Surface with large irregular tubercles. Musculature, extensive on the right side, consisting chiefly of longitudinal fibres; on the left side, longitudinal fibres from the siphons extend nearly to intestinal loop.

From 15 to 30 rather short tentacles. Prebranchial zone smooth. Aperture of dorsal tubercle as in last species; horns may be slightly coiled. Ganglion about width of peripharyngeal groove behind tubercle. Dorsal lamina ribbed on left side, its margin irregularly toothed, the largest corresponding to the ribs. On right side of œsophageal aperture and extending posteriorly is another lamina also toothed. From 28 to 34 bars on the left side and from 32 to 42 on the right. From 1 to 1.5 plications between successive bars. From 4 to 12 stigmata in each mesh.

Stomach with from 40 to 46 shallow folds; intestine with typhlosole; intestinal loop directed forwards but not bent toward dorsal side. Ovary in intestinal loop, on both sides of loop anteriorly and on right side of stomach. Testicular lobes in the loop and on both sides of posterior part of loop, as well as on both sides of stomach. Gonoducts pass along posterior side of last bend of intestine.

About 30 specimens from Departure Bay, Ucluelet, Banks Island and Goose Island, in from 5 to 20 fathoms.

No Phallusiid that has been described seems to have the peculiar shape and tubercles of this species. *Ascidiella griffini* Herdman from Puget Sound may be near it, but, as described, it differs in shape, character of surface, number of tentacles (60-70) and the presence of prebranchial papillæ.

Genus—*Phallusia* Savigny (*sens. restr.*)

Syn. *Ascidia seu Phallusia auct. part.*

This genus may be restricted to those forms that can be grouped around the type species (*Ascidia mentula* Müller ?) and which have the pharynx extending behind the posterior border of the stomach, longitudinal bars with papillæ, dorsal lamina extending behind œsophageal aperture, ganglion a considerable distance behind dorsal tubercle and renal vesicles restricted to the intestinal wall (or absent ?).

*P. ceratodes* sp. n.

About twice as long as broad, laterally flattened, attached by greater part of left side; up to 7 cm. in length, 3.2 cm. in width, and 1.5 cm. in thickness. Apertures sessile or on short siphons; oral 6- or 7- lobed, terminal; atrial 5- or 6-lobed, placed about half the length of the body back along the dorsal edge. Surface irregularly wrinkled and minutely roughened. Musculature practically confined to right side.

From 50 to 150 tentacles. Prebranchial zone smooth. Aperture of dorsal tubercle horseshoe-shaped, horns incoiled, with one turn in each coil; opening between horns directed forwards. Ganglion from 3 to 7 mm. behind tubercle. Dorsal lamina ribbed on left side, its margin finely toothed; from 2 to 5 teeth between successive teeth corresponding to the ribs. Bars, 35 to 54 on right and 32 to 51 on left side. Papillæ at junctions, but not between. One plication or less between successive bars. From 3 to 9 stigmata in each mesh.

Intestinal canal occupies from ⅓ to ½ of left side, leaving from ⅓ to ¼ of length of pharynx uncovered at both anterior and posterior ends. Stomach with about 17 folds. Intestinal loop bent forwards and somewhat upwards. Ovary in intestinal loop and on its right side. Oviduct follows posterior margin of last bend of intestine and postero-dorsal margin of rectum. Testicular lobes in a thick layer on right side of stomach and scattered over both sides of intestinal loop. *Vas deferens* on right side of first part of oviduct and in groove on the left side between second part of oviduct and rectum. As a result of this, when one looks at the lower side of the body (test removed) only a short terminal part of the *vas deferens* is seen.

In and near Departure Bay, in from 10 to 30 fathoms, locally abundant.

Its closest ally appears to be *P. longistriata* Hartmeyer from Japan, from which it differs in having the margin of the dorsal lamina toothed and in the situation of the gonads.

### Family—*Chelyosomatidae*.

As is shown farther on, the intestinal loop in the genus *Chelyosoma* is always on the right side of the pharynx. Whether it is on the right or left side of an arbitrary median plane, is of little moment. With this genus brought into line, we have the utmost constancy in the position of the intestinal loop with reference to the pharynx in each of the genera of Ascidians. The only exceptions are those individuals that show an *inversio viscerum*. It seems right, therefore, that the genus *Agnesia* should not be placed in this family.

*Corella willmeriana* Herdman.

One specimen from Elk Bay was collected by Dr. Dawson, in 1885.

The surface is smooth. The atrial aperture is not on a distinct siphon. There are 24 bars on right side of pharynx and 22 (?) on left side. Spirals of infundibula are for the most part broken up into short stigmata.

*C. rugosa* sp. n.

Syn. *C. willmeriana* Ritter, Ann. N.Y. Ac., vol. 12, p. 604.

Oblong, laterally compressed or more or less cylindrical. Attached by posterior end or by right or left side. Apertures on same level at anterior end; atrial often at the end of a short siphon. Surface irregularly wrinkled and rough with fine irregular processes of the test. Up to 4 cm. long, 2 cm. wide and 1.5 cm. thick. Musculature consists of the usual siphonal fibres and of longitudinal fibres extending from the siphons for a short distance back over the body.

From 50 to 80 tentacles. Aperture of dorsal tubercle varying from a transverse slit to a horseshoe-shaped opening. From 14 to 20 languets. From 20 to 22 bars on each side, with a few rudimentary ones near dorsal and ventral margins of pharyngeal wall. Stigmatic infundibula deep and nearly square; the spiral of each with 5 or 6 turns, often slightly divided into shorter stigmata, the divisions occurring at the angles of the square.

Intestinal loop of the usual form, placed across posterior end of pharynx. Rectum long, reaching nearly to base of atrial siphon. Gonads on both sides of intestinal loop, the testicular lobes, but not the ovary, usually extending to beginning of rectum.

Numerous specimens from Departure Bay, Burrard Inlet, Ucluelet, Banks Island and Hecate Straits.

This species differs from the last in the more anterior position of the atrial aperture, the roughened test and the smaller number of longitudinal bars.

*C. inflata* sp. n.

This is very similar to the preceding species. No intermediates have been found. It was obtained only at Departure Bay, occurring there in quantity at low tide and in very shallow water (8 fathoms or less). The most characteristic feature is the great enlargement of the atrium (the median part of the peripharyngeal cavity just beneath the atrial siphon). As a result of this, the shape is more nearly cubical than in the last species and the rectum is very much shorter (less than half the length of the body). There is a smaller number of tentacles (40 to 60) and also of longitudinal bars (16 to 18). Many of the latter (especially dorsally) are represented only by T-shaped processes, the pharynx not reaching, even in large individuals as complete a stage of development as that of the last species. The testicular lobes do not extend as far as the beginning of the rectum. The apertures are at the same level and the surface of the test is roughened with small irregular processes.

Genus—*Chelyosoma*.

There have been divergent accounts of the position of the intestinal canal in members of this genus. The most recent statements are that the loop is sometimes on the right side of the body and sometimes on the left side. As its position in other genera is quite constant, this seemed rather remarkable. An examination of a large number of specimens belonging to two species which occur on the West Coast and of a single specimen of the type species from the East Coast has shown that, in all, the loop is on the lower attached side of the body, which in this case corresponds for the most part with the right side of the pharynx, as the endostyle has been displaced toward the left side. Although the loop is sometimes more to the right, sometimes more to the left of a plane passing through the apertures perpendicularly to the disk, it is always on the morphological right side of the pharynx, just as in *Corella*. It is directed forward, however, instead of transversely.

*C. productum* Stimpson.

Numerous specimens from Departure Bay and Ucluelet and one from Hecate Straits.

Characteristic of this species are the symmetry of the disk, the large size of mature individuals and the absence of muscle bands across many of the lines between the plates of the disk.

*C. columbianum* sp. n.

Usually flattened and depressed, attached by a broad area on side opposite the disk. Margin of disk sharp, not raised above level of disk. Disk broad behind. Apertures nearer right margin of disk than left. There are typically 2 central, 12 marginal and 2 left intermediate plates, but there is a fairly wide range of variation. Up to 19 mm. in length and 14 mm. in breadth. In addition to the siphonal and marginal muscles, there are short strands crossing all the lines that are some distance from the margin.

From 50 to 100 tentacles. From 12 to 22 languets. Aperture of dorsal tubercle a transverse slit. Funnel asymmetrical, the duct connecting with left side of tubercle. From 33 to 42 bars on each side of pharynx. Stigmata more or less coiled, with as many as 2 ½ turns in a coil, irregularly disposed.

Gastric folds for the most part longitudinal. Intestine narrow. Loop narrow, some distance to right of posterior half of endostyle.

About 40 specimens from Departure Bay and Burrard Inlet in from 10 to 20 fathoms, stony and shelly.

Easily distiguished from the last by the presence of the series of muscle fibres connecting the central plates. It reaches maturity at a much smaller size. It differs from *C. sibogae* Sluiter of the East Indies and Japan, in the irregularity of the musculature, in the coiling of the stigmata and in the aperture of the dorsal tubercle being transverse instead of longitudinal.

Family—*Cæsiridae* [*Molgulidae*].

*Cæsira apoploa* sp. n.

Nearly spherical. Usually free in the sand. Siphons equal, in length about half the diameter of the body. Surface covered with sand grains, with the exception of that of the siphons and a variable part of the surface near them. Long simple radicoid filaments over the sand-covered surface. Up to about 15 mm. in diameter. In addition to the usual siphonal musculature, there are two circular bands (deficient ventrally) of short fibres on either side of the median plane.

From 18 to 37 tentacles, the largest bi-pinnate. Aperture of dorsal tubercle horseshoe-shaped; horns slightly inturned; opening between horns directed backwards and slightly towards right side. Dorsal lamina narrow, its margin smooth. Seven folds each side (in one specimen a rudimentary eighth on right side dorsally). As many as 4 bars on a fold, on the ventral side only. Stigmata forming the usual infundibula, each stigma forming from ¼ to ¾ of a circle. An occasional small accessory infundibulum between folds.

Intestinal loop very narrow, bent into a semicircle, the concavity of which is entirely filled by the left gonad. Anus with thickened smooth margin. Gonads oblong, massive, with central ovary. Testicular lobes massed along upper and lower sides of the ovary. Oviduct short, projecting upward from posterodorsal angle. Several (in one case 6) *vasa deferentia* of medium length projecting inwards along the middle of each ovary. Renal organ about equal in length to right gonad and of the usual sausage shape.

About 30 specimens from Departure Bay, Ucluelet, Alert Bay and Hecate Straits.

This form appears to be more nearly related to the following species than to any other.

*C. hecateia* sp. n.

Rounded oblong, laterally flattened. Apertures rather close together on dorsal edge near anterior end. In the contracted condition, they are at the bottom of a shallow furrow. Apertural lobes pointed. Surface (except a narrow zone around each siphon) closely covered with sand and fragments of shells. Up to 32 mm. in length, 20 mm. in depth and 15 mm. in thickness. Musculature as in preceding species, but the circular bands of fibres are more numerous (2 to 4 on each side) and irregular.

Probably about 35 or 40 tentacles, the largest bushily branched, bipinnate or slightly tripinnate. Aperture of dorsal tubercle horseshoe-shaped, directed toward right side. Dorsal lamina rather broad; its margin incised, presenting about 7 large teeth or lobes, which are most distinct posteriorly. It extends behind œsophageal aperture. Seven folds each side. Up to 6 or occasionally 7 bars on each fold, on the ventral side only. Stigmata as in last species, but the accessory infundibula are more numerous.

Intestinal loop narrow, horizontal, nearly straight. Gonads much as in last species. Eight *vasa deferentia* were counted in the right gonad of one individual.

Several specimens were collected in Hecate Straits by Rev. Mr. Taylor.

*C. pugetiensis* (Herdman) from Puget Sound differs from this species in the extent of its musculature, in having fewer longitudinal bars (3 to 4), and in the direction of the dorsal tubercle (backwards).

*C. occulta* (Kupffer) of Europe is still nearer this species, but the short descriptions that have been given of it permit of only a few points of difference being given, viz. the shape of the body and the positions of the apertures. These seem unimportant, but it would be best to keep them separate until they can be more closely compared.

*C.* sp.

A small specimen was obtained by Dr. Dawson in 1885 between Cortez and Hernand Islands. It appears to differ from the two preceding species in the extent of the musculature (the circular or transverse fibres covering practically the whole body) and in the condition of the dorsal tubercle (a longitudinal slit).

*C. pacifica* sp. n.

Nearly spherical, 15 mm. long, 13 mm. deep and 10 mm. thick Attached by lower surface and part of right side. Siphons contracted, atrial the longer. Surface overgrown with seaweed &c., the lower half, at least, with radicoid filaments. In addition to siphonal musculature, there are irregularly scattered fine, short fibres over the surface of the body.

About 40 tentacles, the largest slightly tripinnate. Aperture of dorsal tubercle horseshoe-shaped, directed toward right side, the horns approximated. Dorsal lamina short and narrow, its margin smooth; it extends only a short distance behind œsophageal aperture. Seven folds each side. Bars on both sides of each fold, as many as 11 on a fold. Stigmata form the usual infundibula, each stigma extending from ¼ to ½ of a circle. No accessory infundibula.

Intestinal loop narrow, bent into a semicircle. Renal organ and gonads as in *C. apoploa*, but only 2 *vasa deferentia* could be seen (right side).

A single specimen was obtained at Ucluelet at low tide, attached to rock.

It differs from the preceding species in having bars on both sides of each fold, and from *C. pannosa* of the East Coast in the direction of the dorsal tubercle. There are other differences in both cases.

*C. cooperi* sp. n.

Nearly spherical or flattened against the object of attachment. Apertures with small pointed lobes. Siphons very short. Surface, including that of siphons, entirely covered with closely placed sand grains, which adhere to the usual filaments. Up to 15 mm. in length. In addition to the usual siphonal musculature, there is an almost uniform layer, continuous with the circular fibres of the siphons. It is thin over the intestine, gonads, &c.

About 75 (?) tentacles. Aperture of dorsal tubercle crescent-shaped, turned toward the left. Dorsal lamina narrow, its margin smooth; it does not extend beyond œsophageal aperture. Six folds on each side, their posterior ends fringed. Up to 14 bars on a fold, occurring on both sides of each fold. Stigmata forming the usual infundibula, with 10 or more turns in each spiral. Each stigma represents ¼ of a circle, so that more or less regular transverse rows are formed, such as are characteristic of the genus *Ctenicella* as defined by Hartmeyer.

Intestinal loop narrow, bent into a semicircle. Margin of anus smooth. Gonads much elongated. The left is in the concavity of the intestinal loop and anteriorly bent over the tip of the loop. It is thus closely applied to the intestine for a considerable distance. The right gonad is much longer than the renal organ, to which it is closely applied. The latter is of the usual shape. Each gonad consists of an axial ovary, with the testicular lobes scattered along its upper and lower margins. The *vas deferens* runs along the inner side of the ovary and projects upward with the oviduct from the posterior end of the gonad.

Several specimens were obtained in 5 to 15 fathoms, sand and gravel, in Departure Bay.

This species is doubtfully distinct from *C. regularis* (Ritter) from California. From the data available at present, there are the following differences,—a smaller number of tentacles (10), the absence of siphons (?), the aperture of dorsal tubercle a longitudinal slit, which is not curved, and the larger diameter of the stomach in *C. regularis*.

*Rhizomolgula globularis* (Pallas).

Syn. *Ascidia globularis* Pallas, Nov. Act. Ac. Petr., vol. 2, p. 241.
? *Rhizomolgula gigantea* Redikorzew, Mem. Ac. St. Peters., ser. 8, vol. 18, no. 11.

Laterally compressed, somewhat elongated parallel to a line joining apertures. Largest specimen is 19 mm. long, 17 mm. deep, and 12 mm. thick. Apertures about 7 mm. apart, not on distinct siphons. Surface sparsely covered with sand grains. On the side of the body opposite the apertures there are usually 2 short 'roots,' each with numerous long branches. The usual siphonal musculature; on each side near the 'roots' a few bands of longitudinal fibres over the surfaces of the glands; a median band of short transverse fibres encircling the body in the median plane; and a short band of similar fibres extending downwards on each side about half the length of the body. That of the left side connects with the atrial siphon and that of the right side with the oral.

From 17 to 20 tentacles, the largest tripinnate. Aperture of dorsal tubercle horseshoe-shaped, directed forwards and slightly toward the left. Dorsal lamina narrow, its margin smooth; it does not extend beyond œsophageal aperture. Six folds on each side. Bars on both sides of each fold, as many as 7 on a fold. Stigmata form the usual infundibula and some small accessory infundibula between folds. The stigmata are short and not numerous nor closely placed.

About 12 shallow gastric folds. Intestinal loop broad anteriorly, straight. Inner margin of anus fused with pharyngeal wall, outer margin smooth or with a single tooth. Gonad fills the intestinal loop and covers its inner side, consisting of a central ovary (its duct following rectum) and an upper and lower mass of testicular lobes. The *vasa deferentia* are numerous (9 in one specimen), their free portions short, placed in an irregular row above the middle of the gonad on its inner side. Renal organ below stomach. Heart along right side of renal organ. Glands small, disk-shaped. Ectodermal processes of mantle few or absent.

Several specimens were collected by the Rev. I. O. Stringer at Herschel Island, Arctic Ocean and communicated to me by Prof. Wright.

Pallas' *A. globularis* is undoubtedly a *Rhizomolgula*. The identification of these specimens with his species rests upon external characters alone. He has given very characteristic figures. Redikorzew's *R. gigantea* appears to be the same species.

Family—*Styelidæ*.

Subfamily—*Polyzoinæ*.

*Metandrocarpa dermatina* sp. n.

Colonies thin, encrusting, dark red or purplish in colour. Individuals irregularly disposed, about 2 mm. distant from each other. They are flattened parallel to the surface of the colony or elongated perpendicularly to it, depending upon the thickness of the colony. They are from 4 to 5 mm. in length. The colonies are up to 10 cm. in length. The apertures are transverse slits.

About 24 tentacles. Aperture of dorsal tubercle a transverse slit. Dorsal lamina narrow, its margin smooth. Five bars on each side, the two uppermost approximated. Small transverse vessels cross stigmata. Stigmata narrow, about 50 in a row.

About 15 gastric folds. Apparently about 12 atrial tentacles. Up to 10 or 11 tentacles grouped at anterior end beneath pharynx. A row of testes on each side posteriorly and ventrally. In the right row there are from 6 to 12 and in the left from 3 to 5. They are imbedded in the test.

Several colonies were obtained on the beach at Hope Island, by Rev. Mr. Taylor in 1906.

This form is doubtfully distinct from *M. dura* Ritter from Santa Barbara, California. It differs from the descriptions of the latter, given by Ritter and Michaelsen, in having a smaller number of oral tentacles and a larger number of gastric folds. The differences in the reproductive organs are probably referable to the greater maturity of the colonies from Hope Island.

*M. taylori* sp. n.

This is a social species, the individuals being connected by stolons alone. The largest individuals are $7 \times 5 \times 4.5$ mm., in shape more or less hemispherical. Apertures are transverse slits. The surface is smooth or slightly wrinkled. The test is thin.

The structure of the pharynx is the same as has been described for the last species.

Thirteen or 14 gastric folds. Atrial tentacles minute. In one individual there were counted 11 ovaries, 9 testes on the right side and 11 testes on the left.

This form is so nearly identical in anatomical details with the preceding species, that one considers the possibility of their being different forms of the same species, just as Ritter has considered that *Perophora annectens* may form either social or compound colonies. With our present knowledge we must consider this form distinct from *M. dermatina*, the differences being,—'social' instead of compound colonies, larger individuals and colonies white instead of dark purple.

Subfamily—*Styelinae.*

Genus, *Katatropa* nov.

Syn.—*Styela auct. part.*

Siphons with spinules.

Four folds on each side, the second from above smaller than the first or the third. Aperture of dorsal tubercle horseshoe-shaped, directed toward left.

Normally 2 gonads on each side, placed obliquely; the anterior ends which bear the ducts, being directed downward toward endostyle. Ovary tortuous, rather short; testicular lobes grouped along either side of ovary, little (if at all) branched; their long axes are perpendicular to plane of body-wall and not bound together, but each projects freely into peripharyngeal cavity. Eggs retained.

Siphonal vela narrow, adnate to siphonal wall, the atrial with scattered short filiform tentacles on its lower (inner) surface. Alimentary canal more or less Z-shaped. Anus with lobed margin.

Type species—*K. vancouverensis.*

This genus comprises a small group of species all from the West Coast of North America. In the current classification they would be placed in the genus *Styela.*

*K. vancouverensis* sp. n.

Short cylindrical, length being about twice the diameter. Attached by posterior end and part of ventral surface, therefore ascending from the attached surface. Surface minutely roughened, with indistinct tubercles on siphons. Up to 25 mm. in length and 9 mm. in diameter.

From 10 to 22 tentacles. Formula for longitudinal bars,—example,

Right side. 2 (10) 1 (6) 1 (9) 1 (6) 1.

Intermediate (internal) transverse vessels. From 9 to 13 long narrow stigmata in each mesh.

From 12 to 18 gastric folds. From 8 to 12 anal lobes. Testicular lobes chiefly along the ventral side of the posterior part of each ovary.

Numerous specimens attached to rocks at low tide mark, Departure Bay and Ucluelet.

*K. uclueletensis* sp. n.

Cylindrical, attached by posterior end, which may have radicoid processes.

From 30 to 36 tentacles, for the most part two sizes which alternate with each other.

Eighteen gastric folds. About 16 anal lobes. Testicular lobes along both sides of posterior part of each ovary.

In other respects this species is the same as the last. They are doubtfully distinct, but as yet I have seen no intermediates.

Two specimens were obtained in a few fathoms at Ucluelet.

*K. yakutatensis* (Ritter).

Syn. *Styela yakutatensis* Ritter, Proc. Wash. Ac. Sc., vol. III, p. 239.

This is a stalked species, with smooth surface, and the oral aperture bent ventrally.

It occurs in numbers near low tide mark, attached to rocks, at Ucluelet.

*K. greeleyi* (Ritter) of Bering Sea is another stalked species of this genus. It differs from this one in having a shorter body, a longer stalk, longer testicular lobes and spinules which are acicular. In the three

British Columbian species the spinules are short, channeled above, with truncated toothed extremities.

Genus—*Styela* (*sens. restr.*).

Dorsal tubercle directed forwards or to left.

Gonads very long, ending just beneath atrial siphon, hence directed dorsally. Testicular lobes large, more or less branched. Eggs not retained. Otherwise as in last genus.

Type species—*S. canopus* (Savigny).

This genus is widely distributed in the tropical and temperate zones. *S. canopoides* Heller, *S. variabilis* Ald. & Hanc. and *S. partita* (Stimpson) belong to the genus as thus restricted and probably many other species as well, which are too insufficiently described for one to be certain of their position.

*S. gibbsii* (Stimpson).

Numerous specimens from Departure Bay, Ucluelet and Banks Island, taken in from 5 to 30 fathoms sand, gravel or shells.

*S. montereyensis* (Dall).

The stalked form of this genus.

Numerous specimens taken at low tide, attached to rocks, at Ucluelet and one specimen from Hope Island (Mr. Taylor).

Genus—*Goniocarpa* nov.

Syn. *Styela auct. part.*

Dorsal tubercle directed forward or to left.

One gonad on each side, bent more or less in the form of a right angle. The vertical limb of the gonad ends in the genital ducts, just beneath the atrial siphon. Ovary tortuous; testicular lobes grouped around horizontal limb of ovary, each one lobulated, the lobes bound together into a biscuit-shaped mass. Eggs not retained. Otherwise as in *Katatropa*.

Type species—*G. loveni* (Sars), as described by Hartmeyer (Fauna Arctica, Bd. III, 1903).

The species of this genus would currently be placed in *Styela*. It is apparently a northern group and includes *G. rustica* (L.), *G. armata* (Lac.-Duth. & Del.), *G. granulata* (Alder), *G. coriacea* (Ald. & Hanc.), *G. northumbrica* (Ald. & Hanc.) and *G. placenta* (Packard).

*G. coccodes* sp. n.

Exceedingly variable in shape, from scale-like to elongated oval. Surface pebbly, owing to the presence of rounded tubercles, from 1/16 to 1/8 mm. in diameter. Siphons short. Up to 2 cm. in length.

From 25 to 35 tentacles. Formula for longitudinal bars,—example–

Right side— 4(19) 4 (11) 4 (18) 6 (9) 4.

From 1 to 3 internal transverse vessels crossing each stigmatic row. From 3 to 7 long narrow stigmata. From 20 to 26 gastric folds. About 12 anal lobes. Testicular lobes chiefly ventral to horizontal limb of ovary.

A number of specimens from Departure Bay, Burrard Inlet, Lowe Inlet, China Hat and Prince Rupert, in from 10 to 30 fathoms, stony or shelly.

Most nearly related to *G. placenta* of the East Coast and *G. coriacea* of England, from which it seems to differ in certain details. Further study may show the necessity of uniting them into one species.

*Pelonaia corrugata* F. &. G.

A few specimens were obtained by Rev. Mr. Taylor at Rose Spit in 1906 in a few fathoms, sand. They do not appear to differ in any respects from the descriptions of European and Arctic specimens.

This form does not deserve to be placed in a separate subfamily, the only respect in which it differs markedly from its nearest relatives (e.g. *Styela, Goniocarpa* &c.), being the absence of folds in the pharyngeal wall. This condition may be approximated in other forms when the pharynx is expanded (e.g. *Styela gibbsii*). The current statement that the intestinal canal is behind the pharynx is only partially correct. It is distinctly on the left side of the pharynx and only slightly farther back than it is in *Styela gibbsii.*

Genus—*Cnemidocarpa* nov.

Syn. *Styela auct. part.*

Spinules rudimentary or absent.

Gonads variable in number, 3 or more on each side, elongated, tortuous, radiating more or less from atrial siphon. Ducts at upper ends. Each gonad consists of an ovary on the inner side and a layer of testicular lobes on the outer side. The *vas deferens* runs along the inner side of the ovary.

Siphonal vela broad, applied to walls of siphons and reaching nearly to the margins of the apertures. A single row of tapering atrial tentacles at base of atrial velum.

Having examined only two members of this group, I am unable to give more characters. The members of this genus are currently included in *Styela*. It includes *Polycarpa finmarkiensis* Kiaer, *Styela elsa* Hartmeyer, *Glandula mollis* Stimpson, *Styela vestita* Alder and probably a large number of other species, but it is difficult to be certain in most cases because of the incomplete descriptions.

*C. joannae* (Herdman).

Syn.—*Cynthia coriacea* Stimpson, Proc. Ac. Phil., ann. 1864, p. 160.
*Styela joannæ* Herdman, Tr. Liv. Biol. Soc., vol. XII, p. 264.
*Styela stimpsoni* Ritter, Ann.N. Y. Ac., vol. XII, p. 602.

Numerous specimens from Departure Bay, Ucluelet, China Hat and Banks Island, attached to rocks &c., from low tide mark to at least 20 fathoms.

From the abundance of the material in my possession, all, as far as examined, agreeing with Ritter's description, I judge that Herdman's and Ritter's species are the same and that Herdman was mistaken in describing the dorsal lamina as being a 'plain membrane.' Stimpson's name was preoccupied by Alder & Hancock in 1848.

Family—*Tethyidæ.*

[*Halocynthiidæ seu Pyuridæ, auct., non Tethyidæ* Hartmeyer, 1909]

In my opinion, the valid type of the genus *Tethyum* Bohadsch is the *Ascidia papillosum* of Linné. *Cynthia* and *Halocynthia* will then be absolutely synonymous with *Tethyum* and are to be replaced by it. *Halocynthiidæ* and *Pyuridæ* are to be replaced by *Tethyidæ.*

Genus, *Boltenia* (*sens. nov.*)

Syn. *Boltenia auct. part.*+*Halocynthia auct. part.*

Body elongated parallel to a line joining apertures. Surface covered with simple or branched spines. Short, channeled, siphonal spinules.

Aperture of dorsal tubercle bent, opening between horns directed toward right side. Dorsal groove with languets. At least 6 folds on each side, the second and sixth, counting from above, being the smallest. Stigmata transverse, arranged in longitudinal rows, which are traversed from end to end by the longitudinal bars.

One gonad on each side, the left in the intestinal loop. The ducts are at the posterior end of each. Each consists of an axial ovary and peripheral testicular lobes.

Type species—*B. ovifera* (L.)

This is a very sharply defined group and includes only a few of the stalked forms that have been referred to this genus. It appears to be confined to the Arctic and Subarctic regions. In addition to the species mentioned in this article, it includes *B. thompsoni* Hartmeyer of Bering Sea. Some of these species have been placed in the old genus *Boltenia* and some in the genus *Halocynthia* or *Pyura.*

*B. echinata* (L.)

Syn. *Cynthia echinata plur. auct., non Boltenia echinata* Ritter, 1907.

A few specimens were obtained in 10 to 20 fathoms, stony or shelly, at Departure Bay. Hartmeyer has recently (S.-B. Ges. naturf. Freunde

Berlin, ann. 1910, p. 231) come to the conclusion that the series of forms which have been referred to the *Ascidia echinata* of Linné, cannot be divided into two distinct species. These Pacific specimens agree well with the descriptions that have been given of Arctic specimens.

*B. villosa* (Stimpson).

Syn. *Cynthia villosa* Stimpson, Proc. Ac. Phil., ann. 1864, p. 160.
*Cynthia castaneiformis* v. Drasche, Denk. Ak. Wien, Bd. 48, p. 373.
*Boltenia echinata* Ritter, Univ. Cal. Publ. Zool., vol. IV, p. 14.

Numerous specimens from Departure Bay, Ucluelet, Goose Island and Prince Rupert, from between tides to 30 fathoms, attached to rocks, sea-weed &c.

In a series of specimens taken at one locality such a range of variation is shown, that it seems impossible to consider the species listed above in the synonymy as distinct.

Genus, *Pyura* (*sens. restr.*)

Syn. *Cynthia*, *Halocynthia*, *Pyura auct. part.*

Surface rough with irregular warts, corrugations &c. Test usually more or less encrusted with sand. Siphons usually rather long. Siphonal spinules acicular (always ?).

Aperture of dorsal tubercle bent, directed forwards. Dorsal groove with languets. Six folds on each side. In very young specimens the second and sixth folds are much smaller than the others. Stigmata longitudinal.

One gonad on each side, the left in the intestinal loop. Each is divided into (usually) two rows of hermaphroditic masses, the genital ducts passing back between these rows and ending near the anus.

Type species, *P. chilensis* Molina.

Michaelsen has described what purports to be Molina's species (Mt. Nat. Mus. Hamburg, Bd. XXI, p. 15). It would be included in the group of species with the above characters and hence becomes the type. Other species are *P. dura* (Heller), *P. jacatrensis* (Sluiter), *P. riiseana* (Traustedt), *P. karasboja* (Oka) &c. I have been able to examine only the one species of this group and consequently the diagnosis given above is more or less tentative. Further study will show the correct limits of this group. The most important characters seem to be the irregularity of the surface, the number of folds and the division of the gonads.

*P. haustor* (Stimpson).

Syn. *Cynthia haustor* Stimpson, Proc. Ac. Phil. ann. 1864, p. 159.

Numerous specimens from Departure Bay, Ucluelet, Hope Island and Banks Island, from between tides to 30 fathoms, usually in sand.

Genus, *Tethyum* (*sens. nov.*)

Syn. *Cynthia*, *Halocynthia*, *Pyura auct. part.*, *non Tethyum* Hartmeyer, 1909.

Oral aperture terminal, atrial on dorsal side. Siphonal spinules acicular. Surface with simple or branched spines.

Aperture of dorsal tubercle curved, usually forming two cone-shaped coils; opening between horns directed forwards and to left. Dorsal groove with languets. Number of folds variable, increasing with age, at least 6, the second not smaller than the first and third. Stigmata longitudinal.

Two to many gonads on each side, those of the left side placed across the inner side of the intestinal loop (which is transverse to the long axis of the body). The two genital ducts open at the anterior end of each gonad. The gonads of each side are fused together posteriorly. The testicular lobes are grouped around the posterior ends of the ovaries.

Type species—*T. papillosum* Gunner.

Hartmeyer (Zool. Ann., Bd. III, 1908) has indicated *Ascidia rustica* L. and *A. quadridentata* L. as the types of *Tethyum* Bohadsch. He seems, however, not to have considered Art. 30 of the International Rules, in which we find the following:

"(*e*) The following species are excluded from consideration in selecting the types of genera.

(*a*) Species which were not included under the generic name at the time of its original publication."

It is possible that he may interpret this to mean only those species that have been named binominally. In that case he would neglect the four species of Bohadsch. Following Sherborn, he has accepted the species of Gunner as validly named. Gunner (Trond. Selsk. Skrift., III) names three species which are identical with three of the species described by Bohadsch. Hartmeyer states that Gunner's article appeared in the same year as the 12th edition of Linné's *Systema Naturae* (1767), and considers that Linné's work has the priority. He has evidently not seen the original article by Gunner, which (according to Sherborn and Hopkinson) appeared in 1765, but only the German translation (Dront. Gess. Schrift., III). That it antedates Linnæus is shown by a reference of the latter under *A. intestinalis*, viz. "Act. nidros. 3. p. 81, t.3. .3, 4. Tethyum." This refers to Gunner's description and figures of *Tethyum sociabile*.

As Hartmeyer has not indicated a type from among the species originally included in the genus—either practically (those of Bohadsch) or binominally (those of Gunner)—a type remains to be indicated. Of the species of Bohadsch, the one which we can identify to-day with the greatest degree of certainty is *Tethyum coriaceum*, the T. *papillosum* of Gunner and the *Ascidia papillosum* of Linné. This may be taken as the type of *Tethyum*.

Heller has indicated the same species as the type of *Cynthia* Savigny. *Halocynthia* Verrill and *Lais* Gistel were instituted to replace *Tethyum*. All three are therefore absolutely synonymous with *Tethyum*.

As defined above, this genus comprises a group of species, which differ from all other Tethyids in the position of their gonads. It includes *T. pyriforme* (Rathke), *T. aurantium* (Pallas), *T. roretzii* (Drasche), *T. hilgendorfii* (Traustedt), *T. igaboja* (Oka)and probably a number of others which have not yet been sufficiently described for one to be sure as to their position.

*T. aurantium* (Pallas).

Syn—.*Ascidia aurantium* Pallas, Nov. Act. Ac. Petr., vol. II, p. 240.
*Cynthia pyriformis* Dall, Amer. J. Conch., vol. VII, p. 157.
" " *alt. auct.* (Pacific).
" *superba et deani* Ritter, Ann. N.Y. Ac., vol. XII, p. 590.

A very few specimens from various points—Departure Bay, Ucluelet, Banks Island and between Cortez and Hernand Islands, in from 10 to 30 fathoms.

*T. pyriforme* from North Europe and the Arctic Ocean has, according to Hartmeyer (1903), 4 gonads on the left side and from 4 to 6 on the right.

All the Pacific specimens, that I have been able to examine, have 3 gonads on each side. They seem to be for that reason, quite distinct from *T. pyriforme*. From Traustedt's account (Vid. Meddel. Kbhvn., 1885, p. 34), I conclude that his Corean specimens had 3 gonads on each side. That would make the Asiatic and West American forms identical, Pallas' name, being the first one given, is the valid one for this group.

*T. igaboja* (Oka).

Syn.—*Halocynthia igaboja* Oka, Ann. Zool. Jap., vol. VI, Pt. 1, p. 45.
? " *okai* Ritter, Univ. Cal. Publ. Zool., vol.IV, p. 11.

A number of specimens from Departure Bay, Ucluelet, Lowe Inlet and Prince Rupert, in from 10 to 30 fathoms shelly or gravelly.

These specimens are in accord with Oka's description and differ from Ritter's only in regard to the inrolling of the horns of the dorsal tubercle. The gonads are quite variable, there being from 2 to 16 on the right side and from 5 to 14 on the left.

## NOTES ON THE SPECIES OF THE ATLANTIC COAST.

With the exception of the compound forms, which have been recently thoroughly treated by Dr. Van Name (Proc. Bost. Soc. N. H., vol. 34, No. 11, 1910), the species of the East Coast have for the most part been only imperfectly described. It will be necessary therefore to give an account of the anatomy of many of the species. It has been very difficult in many cases to refer, with much certainty, my specimens to the species that have been described from this coast, owing to the imperfect descriptions of the older authors. As many of the specimens have been obtained from or near the localities which gave the types of the species, the identifications should have a greater probability of being correct. Dr. Van Name, who is at present engaged in work on the simple Ascidians of this coast, has been most kind in giving me help in the identification of my specimens with Verrill's species. He has corrected some errors into which I had fallen and confirmed some of my surmises.

*Aplidium spitzbergense* Hartmeyer, Fauna Arctica, Bd. 3, Lf. 2, p. 341.

A single capitate colony was obtained in Long Island Bay, Grand Manan, in about 8 fathoms. This species has been previously reported only from Spitzbergen. The agreement with Hartmeyer's description seems, however, to be perfect.

The colony is 15 mm. by 10 mm., with a thick stalk 8 mm. long. The test contains very numerous sand-grains.

The zooids are about 2.5 mm. long. Oral aperture 6-lobed. Atrial aperture round, at the end of a short tubular siphon, placed opposite the interval between the first and second stigmatic rows. A long atrial languet is present a short distance in front of the siphon. Four stigmatic rows. Four gastric folds. Abdomen and postabdomen together are slightly longer than the pharynx. Ovary small and no embryos present.

Another colony, not capitate, 20 mm. long, 9 mm. wide and 6 mm. thick, seems to be referable to the same species. There are much longer and narrower zooids with the ovaries well developed, embryos in the peripharyngeal cavity, and the postabdomen nearly equal in length to the thorax and abdomen together. The colour of this colony, when living, was decidedly greenish.

This second colony was obtained off Long Island, Grand Manan, in about 35 fathoms shelly and muddy.

Of the characters which distinguish *Aplidium* from *Amaroucium* the only one possessed by this second colony is the small number of stigmatic rows. It might be best to place it in the genus *Amaroucium*, near *A. diaphanum* (v. Drasche).

*Amaroucium glabrum* Verrill.

Numerous colonies, apparently belonging to this species, were obtained at nearly all points at low tide and in the dredgings.

*Tetradidemnum albidum* (Verrill).

Both the white and salmon-coloured varieties of this species were found generally distributed at low tide and where dredgings were made.

*Didemnopsis tenerum* (Verrill).

Syn. *Lissoclinum tenerum* Verr.

Several colonies were dredged in the approaches to Passamaquoddy Bay and one off Swallow-tail Light, Grand Manan.

*Holozoa clavata* (Sars)?

Soft, light yellow, encrusting colonies of *Holozoa* were obtained at low water mark and practically throughout in the dredgings, though never in large numbers. Dr. Van Name has referred all the colonies from along this coast, that were examined by him, to Sars' species. None of the colonies in my collection show even an approximation to the clavate condition.

*Ciona intestinalis* (L.)

As only a single small specimen was obtained (off Grand Manan), no detailed study of it was made. It doubtless is identical with the European species.

*Ascidiopsis prunum* (Müller).

Syn.—*Ascidia callosa* Stimpson, Proc. Bost. Soc. N.H., vol. IV, p. 228.

*Ascidiopsis complanata* Verrill, Amer. J. Sc., ser. III, vol. 3, p. 289.

Characteristic of this species is the small number of longitudinal bars (from 15 to 19 on the left side and from 18 to 20 on the right), the presence of intermediate papillæ and the crossing (slightly) of the last bend of the intestine by the genital ducts. Eggs and larvae were found in the peripharyngeal cavities of some of the breeding individuals. The large individuals seemed to be uniform in having undeveloped reproductive organs.

Found in large masses at low tide mark. It is generally distributed as shown by the dredgings. At Grand Manan it seems to be largely replaced by the next species.

Genus *Phallusioides* nov.

This genus is formed for the reception of *Ascidia* (*seu Phallusia*) *obliqua*, which differs from *Phallusia* in that the pharynx and dorsal lamina do not extend beyond the œsophageal aperture, in this respect resembling *Ascidiella*. From the latter it differs in having papillæ on the bars and in not having renal vesicles. It is thus intermediate between *Phallusia* and *Ascidiella*. The ganglion is close to the dorsal tubercle and there are no intermediate papillæ. In the absence of renal vesicles, it resembles some *Phallusiæ*. As if to offset this lack of vesicles, there is a very great development of what appears to be the pyloric gland. This forms a thick layer of coarse branches, covering all parts of the intestinal canal

*P. obliqua* (Alder).

Syn. *Ascidia mollis* Verrill, Amer.J. Sc., ser. III, vol. 7, p. 409.

This can be distinguished from the preceding species by the thinner test (which is more collapsible), the more numerous (about 50) longitudinal bars, and the course of the genital ducts (not crossing last bend of intestine), as well as by the differing generic characters.

Large numbers were dredged at various points and depths near Grand Manan and occasional specimens were obtained in the approaches to Passamaquoddy Bay.

*Chelyosoma macleayanum* B. & S.

Syn. *Ascidia geometrica* Stimpson, Proc. Bost. Soc. N.H., vol. IV, p. 229.

A single specimen was obtained in the approaches. It is rather unusual in the asymmetry of the plates of the disk. Those of the left side are larger than those of the right and two additional plates are interposed between the middle and posterior marginal plates. In both these respects, it approaches *C. columbianum* of the West Coast.

*Caesira papillosa* (Verrill).

Syn. *Molgula papillosa* Verrill, Am. J. Sc., ser. 3, vol. 1, p. 57.

Surface with numerous radicoid filaments, those on the siphons being quite short. Siphons quite variable in length, frequently as long as the diameter of the body, nearly equal.

From 15 to 25 bipinnate tentacles. Aperture of dorsal tubercle horseshoe-shaped; opening between horns directed backwards. Dorsal lamina of medium width, not extending beyond œsophageal aperture; its margin is coarsely toothed. Six folds on each side of pharynx. Posterior end of each fold coarsely toothed along its free border. Bars on both sides of each fold, as many as 8 on a fold, the dorsal bars weak.

Intestine forming a double loop. Outer lip of anus with about a dozen rounded lobes. Gonads elongated, the right horizontal, the left oblique and filling the secondary loop of the intestine. Oviduct of medium length, projecting upward from posterior end of gonad and ending at base of atrial siphon. Each ovary with an upper and lower row of pouches. From the outer side it has the appearance of a double row of rounded lobes. Testicular lobes scattered along upper and lower margins of each ovary; usually on the right side the lobes are above anteriorly and below posteriorly, whereas on the left they are more variable, the majority being below. From 1 to 4 *vasa deferentia* on each side (usually 2) opening not far from the centre of the inner side of the ovary; the free part of each *vas deferens* is extremely short and can be seen only with difficulty.

Specimens obtained at the roots of eel-grass have very short siphons and seemed to fit Verrill's description of *Molgula manhattensis* better than that of *M. papillosa*. In internal anatomy they agree with specimens obtained beneath stones at low tide and in the dredgings, which correspond with the description of the latter species. Some of these specimens have siphons as long as those figured by Verrill for *Eugyra pilularis*. Specimens of *M. manhattensis* from Connecticut and Rhode Island, kindly sent me by Dr. Van Name, are distinctly different from all northern individuals. They have, as Dr. Van Name stated to the writer in a letter, a narrow dorsal lamina with smooth margin. Other differences are—a smaller, more rounded dorsal tubercle; the testicular lobes are not scattered but massed, being confined to the lower side of the ovary and the inner side of its anterior tip (on the left side, seen from without, the testicular mass appears to curl around the anterior end of the ovary, as figured in 1847 by Van Beneden for his *Ascidia ampulloides*, a related species); and the free portions of the *vasa deferentia* are much longer than in *C. papillosa*.

The nearest allies of the latter are *Molgula simplex* Ald. & Hanc. and *M. siphonata* Alder of the coasts of England. In both of these the testes are in the form of one or two large masses, confined to the inner side of the ovary. It is interesting to note that the English forms are short- and long-siphoned respectively, corresponding with the extreme individuals of the series of specimens of *C. papillosa* taken at St. Andrews.

This appears to be the *Caesira* that is most abundant and most generally distributed near St. Andrews.

*C. canadensis* sp. n.

This is the North American representative of the group to which Lacaze-Duthiers gave the name *Ctenicella*.

Body nearly spherical or flattened against the object of attachment. Attached usually by the right side. Up to about 1 cm. in diameter. Apertures fringed, each oral lobe with 3 teeth, each atrial with from 6 to 8. Exposed surface always more or less dirty. Along the margin of the attached area are numerous irregular radicoid filaments. If the animal is sand-covered, these are present over the entire surface, including that of siphons. If not sand-covered, the free surface has numerous minute adhesive tubercles.

From 15 to 25 tentacles, pinnate or slightly bipinnate. Aperture of dorsal tubercle varying from a simple slit to the shape of an imperfect S, which Hartmeyer suggests is characteristic of the genus *Ctenicella*. Dorsal lamina with tapering distant teeth. Seven folds on each side of pharynx. Bars on both sides of each fold, as many as 4 (or occasionally 5) on a fold. Stigmata in infundibula (divided once), each stigma usually representing ¼ of a circle and simulating the longitudinal stigmata of other groups.

Intestinal loop narrow, more or less bent. Anus with smooth margin. Gonads some distance above intestinal loop and renal organ respectively. Ovary short, bent with the concavity ventral; oviduct passing from its anteroventral angle; testicular lobes along the upper side of the posterior end of the ovary or in a semicircle around its posterior end; the single *vas deferens* projects from the centre of the inner side of the ovary.

The species to which this form is most nearly related, and the respects in which it differs from them are as follows:—

*Molgula complanata* Ald. & Hanc.—7 folds on left side instead of 6, smaller number of bars and larger infundibula with the stigmata in transverse rows.

*Ctenicella lanceplaini* Lac.–Duth.—more teeth on each atrial lobe, deeper infundibula, more regular transverse rows of stigmata, a larger number of bars.

*C. morgatae* Lac.-Duth.—the smaller number of bars, the toothing of the posterior ends of the folds and the position of the testicular lobes.

At first I referred this species to Verrill's *Molgula littoralis*, but Dr. Van Name has informed me by letter that the latter (from his preliminary study of Verrill's specimens) has the long bent oviduct of the next species. He also states that he has not yet found any *Ctenicellæ* among his material. He suggests that it is something new to the region. There is the probability that it has been introduced from Europe since the time that Verrill collected in the Bay of Fundy region. Its derivation from *C. tenax* (Traust.), a nearly related Arctic form (occurring in Greenland) with usually only 6 folds, and its subsequent extension down the coast is another possibility. It is possible that further study will make it necessary to unite this species with the three from Europe into a single species.

Hartmeyer has retained Lacaze-Duthier's *Ctenicella* with an alteration of the diagnosis. His group does not seem to be a more natural one than that of the latter author. Savigny's *Cynthia dione*, the type of the genus *Cæsira*, doubtless belongs to this same group. His description of the oral aperture as being 4-lobed and of the dorsal lamina as being smooth-margined was probably due to faulty observation. In that case *Ctenicella* will be synonymous with *Cæsira*.

*C. littoralis* (Verrill).

Syn.—*Molgula littoralis* Verrill, Amer. J. Sc., ser. 3, vol. I, p. 56.

Surface usually clean, at least in the neighbourhood of the apertures. Few radicoid filaments on surface. Siphons quite variable in length, usually rather short. Rows of papillæ on the outer surface of the siphons, corresponding with the apertural lobes. The papillæ are usually small and few in each row. Nearly globular in shape, somewhat laterally compressed. Siphons on dorsal edge, nearer anterior end.

From 20 to 30 bipinnate tentacles. Aperture of dorsal tubercle curved, the horns usually approximated so as to form a circle; opening between horns directed toward the right side. Dorsal lamina narrow, not continued behind œsophageal aperture, its margin smooth. Seven folds on each side, their posterior ends with smooth margins. Bars on both sides of each fold, as many as 10 on a fold. Stigmata in the usual infundibula (once branched), each stigma forming from ¼ to ½ a circle.

Intestinal loop rather narrow, bent with the concavity dorsal. Anus with smooth margin, Gonads in the usual positions close to intestine and renal organ. Ovary small, narrow; oviduct, which passes from its posteroventral angle, is long and bent so as to form a right angle, the terminal part passing up toward atrial siphon. Testicular lobes variously disposed, usually ranged along the upper and lower borders of ovary, sometimes forming a large mass covering the greater part of both inner and outer surfaces of the ovary; the free portion of the single *vas deferens* is of moderate length and projects from near the middle of the inner surface of the ovary.

A large number of specimens were obtained at low tide beneath rocks and in the dredgings from stony and shelly bottoms.

This form is very close to two European species, *Molgula citrina* Ald. & Hanc. and *M. echinosiphonica* Lac.-Duth. The former has fewer bars (6) and fewer tentacles (12 to 14). The latter has very conspicuous spines on the oral siphon whereas the atrial is smooth and the testicular lobes are placed at some distance from the ovary. It is doubtful whether these differences are important.

*C. pannosa* (Verrill).

Syn.—*Molgula pannosa* Verrill, Amer. J. Sc., ser. 3, vol. I, p. 55.

Surface, except that of siphons, with numerous fine, long filaments and entirely covered with shell-fragments, sand-grains &c. Siphons short, rather close together near anterior end; when retracted they occupy depressions, which are surrounded by projecting ridges or collars. Apertures with the usual lobes; the oral lobes occasionally have more than the single tooth or process and the atrial appear to have regularly 4 or 5 teeth, just as in Lacaze-Duthier's genus *Ctenicella*. Body elongated, laterally compressed, up to 2½ cm. in length.

About 20 (?) bipinnate tentacles. Aperture of dorsal tubercle horseshoe-shaped; opening between horns directed backwards. Dorsal lamina narrow, its margin smooth. Seven folds on each side. Bars on both sides of each fold, as many as 12 on a fold. Stigmata rather short, each forming only about 1/8 of a circle at base of infundibulum. Infundibula branched dichotomously once or twice.

Intestinal loop narrow, horizontal. Each gonad a large oblong mass, with ovary central and testicular lobes chiefly above and below ovary. Oviduct directed upward from posterodorsal angle. There are as many as 7 *vasa deferentia* projecting from the inner side of the ovary in an irregular row.

This species was obtained at most points where dredgings were made in gravel, but never in quantity.

It resembles *C. pacifica* in the structure of the gonads and pharynx (7 folds, bars on both sides of folds, smooth dorsal lamina), but differs from it in having the surface covered with radicoid filaments and the dorsal tubercle directed backwards. From *C. oculata* (Forbes) of Europe it differs in having a smaller number of bars on the folds and the horns of the dorsal tubercle not rolled in.

*C. retortiformis* (Verrill).

Syn.—*Molgula retortifromis* Verrill, Amer. J. Sc., ser. 3, vol. I, p. 56.

This species occurs sparingly at low tide beneath rocks near the station and was dredged at various points in the approaches to Passamaquoddy Bay on stony and shelly bottoms.

It is by far the largest Cæsirid occurring at St. Andrews, the majority of the specimens being about 3 cm. in diameter.

Characteristic of this form are—its thick test, long atrial siphon (when extended) and the separation of the testes from the ovary. The latter has the usual position—above the intestinal loop on the left and above the renal organ on the right. The testes are below the renal organ on the right side and rather extensively distributed below the ovary, on the inner side of the intestinal loop on the left side. The oviduct of each side is long, ending just beneath the atrial velum. The *vasa deferentia* are very numerous. In one specimen 12 were counted on the right side and 25 on the left. They are scattered over the inner surface of the testicular mass. Their free portions are extremely short.

*Eugyra* (*Bostrichobranchus*) *pilularis* Verrill.

Syn.—*Bostrichobranchus manhattensis* Traustedt, Vid. Meddel., ann. 1884, p. 22.

No specimens were found in the vicinity of Eastport (where Verrill obtained it). But in 10 fathoms sand at Grand Manan numerous specimens were obtained which seem to be referable to Verrill's species. The tubes are strongly retracted in all the specimens, but the 'collar' at the bases of the siphons is very distinct.

This is very evidently Traustedt's species as well. The only differences apparent are explicable as due to a difference in size. Traustedt having specimens with a diameter twice as great as that of the largest in my collection. There is one exception. He describes the margin of the anus as smooth. In two specimens examined, the margin is reflected, but distinctly lobed (about 16 lobes). Evidently he has overlooked this reflected margin.

In *E. glutinans* and *E. adriatica* the entire margin of the anus is lobed and free. In this species the inner margin or lip is fused with the pharyngeal wall and the line of fusion seems to be represented by an irregular row of about 16 papillæ, placed just in front of anus on the outside of the pharyngeal wall.

There are 15 tentacles, the largest bipinnate. The dorsal lamina is broad and continued back behind œsophageal aperture and downwards toward endostyle.

Infundibula as in typical *Eugyræ*, consisting each of two stigmata spirally coiled and not broken up into short stigmata. They are not in regular rows. In a very small specimen not more than one row can be made out between successive longitudinal bars. In one 8 mm. in diameter there are two irregular rows and Traustedt has figured a larger number for a much larger specimen.

The oviduct passes along the left side of the rectum and opens only a short distance from the anus. The testes are along the upper and lower margins of the ovary. The *vasa deferentia* are numerous (9 in one specimen) and their free portions short, opening at various points along the middle of the inner side of the ovary.

The irregularity in the arrangement of the infundibula is not of enough importance to warrant the formation of a genus for this species as Traustedt has done, especially when there are as many points of agreement between it and typical *Eugyræ* as the following:—

Musculature reduced to siphonal region, with the exception of short fibres arranged in one or two rows encircling the body in the median plane.

Dorsal tubercle horseshoe-shaped, opening between horns directed toward left side and slightly forwards.

Dorsal lamina with smooth margin, extending behind œsophageal aperture.

Pharyngeal folds represented by single longitudinal bars, which are very thin and broad. Infundibula as described above.

Margin of anus lobed.

Only one gonad and that placed on the inner side of intestinal loop; oviduct accompanying rectum; testes peripheral, their duct or ducts not accompanying oviduct.

It might be well to retain *Bostrichobranchus* as a subgenus, if there prove to be species more closely related to *E. pilularis* than to the typical members of the genus (*E. glutinans*, *E. translucida* and *E. adriatica*).

*Goniocarpa placenta* (Packard).

Syn.—*Cynthia placenta* Packard, Mem. Bost. Soc. N.H., vol. I, p. 277, part.

? " *pulchella* Verrill, Amer. J. Sc., ser. 3, vol. I, p. 99.

Easily recognized by the small, rounded, granular elevations that thickly cover the test. Near the apertures they are almost papilliform. I have not yet determined the differences (if any exist) between this form and the nearly related European and Pacific forms. It is as variable in shape as they.

Verrill states that Packard's specimens belonged to two different species and the one which he does not name but describes appears to be this species. Verrill himself probably confused this with *Dendrodoa carnea*, if the latter was as abundant and widely distributed in the Bay of Fundy when he made his collections as it is now. His *Cynthia pulchella* appears to have been a rounded form of one of these species, probably G. *placenta*.

*Cnemidocarpa mollis* (Stimpson).

Syn.—*Glandula mollis* Stimpson, Proc. Bost. Soc. N. H., vol. IV, p. 230.

" " Traustedt, Vid. Meddel., ann. 1880, p. 422.

" *arenicola* Verrill, Amer. J. Sc., ser. 3, vol. III, p. 288.

*Tethyum arenicolum* Hartmeyer, Zool. Anz., vol. 34, p. 147.

The two specimens obtained came from 10 fathoms sand not far from the locality from which Stimpson procured his specimens. They correspond with the descriptions given by the authors listed in the synonymy. I have placed this species in the genus *Cnemidocarpa*, as it agrees in the condition of the gonads and atrial tentacles with the type of the genus. It belongs to a group, consisting of forms with radicoid processes of the test to which sand-grains adhere, including *Styela vestita* Alder and *S. villosa* (Kupffer).

*Dendrodoa* (*Styelopsis*) *carnea* (Agassiz)?

Many specimens were obtained at low tide near the station and by the dredge at nearly every point, but never in large numbers. I have identified this with the *Ascidia carnea* of Agassiz with some hesitation. Hartmeyer, after examining specimens of this genus from Casco Bay, Maine, has considered Agassiz' species to be synonymous with *D. aggregata* (Rathke). I have not been able to find in my material any specimens that would correspond with Hartmeyer's description of the latter species. They are all more nearly related to *D.* (*Styelopsis*) *grossularia* (Beneden). They differ from it in having a very small number of longitudinal bars. This form shows, in fact, a much greater reduction in the number of bars than any other member of the genus. In nearly every case the formula is,

Right side. 0 (4) 0 (1) 0 (1) 0 (1) 0.
Left side. 0 (1) 0 (1) 0 (1) 0 (1) 0.

In one specimen the formula for the left side is

0 (2) 0 (1) 0 (1) 0 (1) 0.

In another specimen, which may belong to another species, the formula is—

Right side. 0 (4) 1 (3) 0 (2) 0 (1) 0.
Left side. 0 (2) 1 (2) 1 (2) 0 (2) 0.

This specimen differs from other individuals of the same size in having an immature gonad and no eggs in the brood-chamber.

The shape varies greatly—from scale-like to elongated oval, occasionally attached by a small base. Shallow-water specimens are a bright red. Those from deeper water are paler. As in *Cnemidocarpa joannæ*, the test in the living animal is transparent and the pigment is confined to the 'mantle.'

In a specimen 8 mm. in diameter there are 35 oral tentacles and 34 small tapering atrial tentacles. From 16 to 25 stigmata in each mesh.

The single gonad is similar to that of *D. grossularia*, the ovary forming the inner part and the testicular lobes a layer on the outer side. There are several *vasa deferentia*. The eggs are retained in a posterior brood-chamber into which the oviduct opens. There is a distinct pyloric cæcum. The anus is two-lipped, its margin indistinctly lobed.

*Pandocia fibrosa* (Stimpson).

Syn. *Glandula fibrosa* Stimpson, Proc. Bost. N.H., vol. IV, p. 230.

Specimens agreeing with Stimpson's description and obtained from the same locality as his specimens (the Hake Bay, off Grand Manan), prove to be closely related to the *Cynthia comata* of Alder. According to Hartmeyer, *Pandocia conchilega* Fleming the type of Fleming's genus *Pandocia*, is the same as *Cynthia comata*. Heller has specified *Glandula* *fibrosa* as the type of *Glandula*. The latter genus is consequently synonymous with *Pandocia*.

Two hauls of the dredge made at a point off Long Island in about 35 fathoms, mud, brought up numerous specimens of this species.

The shape is spherical, and there is a thick coating of mud, which adheres to long fibrous processes of the test. These cover the entire surface, with the exception of a small area near the siphons. They are of three kinds, which intergrade—(1) simple threads, most numerous ventrally, (2) numerous threads arising from small tubercles of the test and (3) long processes with threads arising from each at different levels in a verticillate manner. Siphons verrucose and rusty.

From 45 to 55 tentacles. Dorsal tubercle horseshoe-shaped, opening between horns directed backwards and slightly towards the left. Dorsal lamina narrow. Four folds on each side. From 9 to 15 bars on each fold and from 1 to 4 bars in a space. Intermediate transverse vessels. From 5 to 8 long narrow stigmata in each mesh.

Diameter of stomach scarcely greater than that of intestine. About 24 gastric folds. Intestinal loop narrow, horizontal. Margin of anus with about 20 rounded lobes. Gonads hermaphroditic, about 2 mm. in length and 1 mm. in width. The end of each, that bears the ducts, is directed in most cases toward the atrial siphon, but occasionally downwards. From 10 to 15 gonads on each side, more numerous on the right. Endocarps numerous, many with enlarged opaque summits.

Siphonal vela narrow, free from wall. Atrial tentacles small, filiform, irregular in size, placed in an irregular row near attached edge of velum.

This species differs from *P. comata* (Alder) in having larger, verticillate processes of the test, more numerous gonads and a habitat in mud instead of sand.

*Boltenia ovifera* (L.).

This well-known species occurs at nearly every point and frequently in large numbers.

*B. hirsuta* (Agassiz).

Syn.—*Ascidia hirsuta* Agassiz, Proc. Am. Assn., vol. 2, p. 157.
*Cynthia* (*seu Halocynthia*) *echinata auct. americ.*

Hartmeyer (Fauna Arctica, vol. 3) has queried whether or not the North American form that has gone by the name of *Cynthia* (*seu Halocynthia*) *echinata* is identical with the Arctic and European form for which the same name has been used. The study of a number of specimens from St. Andrews has shown that we have on this coast a distinct form which differs from European, Arctic and Pacific specimens in having rudimentary tentacles and very short gonads. The spines of the test are somewhat similar to those described by Hartmeyer for subarctic European specimens, but in this case we have large individuals with spines of this character.

*Ascidia hirsuta* Agassiz appears to be the only name that has been given primarily to Eastern North American specimens and is, therefore, the valid one for this species.

Specimens of large size were obtained at low tide near the station. It occurs generally distributed as shown by the dredgings.

*Tethyum pyriforme* (Rathke) subsp. *americanum* nov.

Syn.—*Cynthia* (*seu Halocynthia*) *pyriformis auct. americ.*

In contrast with the great constancy in the number of the gonads in the Mediterranean *T. papillosum* and in the Pacific *T. aurantium*, the number in *T. pyriforme* of Arctic and European seas is stated to vary from 4 to 6 on the right side and to be constantly 4 on the left. An examination of a series of individuals from St. Andrews, shows a variation of from 3 to 10 on the right side and from 5 to 14 on the left, the number on the left being usually greater than that on the right. It seems best to consider this as a subspecies of the Arctic *T. pyriforme*.

# THE CLIMATE OF NORTHERN ONTARIO.

BY R. F. STUPART, ESQ.

(*Read 29th March*, 1911.)

That portion of the Province of Ontario which lies north of and immediately south of the Canadian Pacific Railway has been the subject of much enquiry as to climate, but it is only within the past few years that reports from the Government Meteorological stations have made it possible to give any conclusive information as to the climatic conditions of this large section of the Province. The Territory in question comprises the districts of Nipissing and Algoma and extends northward from Lakes Superior and Huron and Lake Nipissing to James Bay and the Albany River. The stations from which data are available are Calvin near Lake Nipissing, Haileybury on the west shore of Lake Temiskaming, Lake Abitibi, White River, north of Lake Superior, Fort Hope on the Albany River and Moose Factory.

As the agricultural possibilities of a region depend chiefly on the length of the summer season and the intensity of the heat during that season, it is the period between May 1st, and September 15th, that is of primary importance.

A perusal of the accompanying tables will shew that even in the extreme north the summer is fairly warm. At Moose Factory and Fort Hope the average daily maxima temperatures for July and August are 74° and 70° as against 77° and 73° at Haileybury which latter temperatures are almost the same as those at Toronto in the same months. It will however be observed that in June the temperature is considerably lower in the north than at Haileybury and Toronto and that the nights are cooler all through the summer. Temperatures of over 80° are not infrequent in Northern Ontario and 90° and over usually occur one or more times in each summer.

All Meteorological records in the interior and in eastern Canada show that temperature differences resulting from difference in latitude are much greater in winter and spring than in the summer and early autumn, and this fact has a strong bearing on the character of the climate of the region under discussion. At midwinter the temperature is fully 12° lower on the mean at the northern boundary of Ontario than near Lake Nipissing. By May the difference has been diminished to 9° and in June, the southern district still averages 6.5° higher than the northern. In July and August however, the mean temperatures of the two districts only differ by 3° and it is October before there is any very marked divergence of the temperature curves. These facts go to shew that it is the late spring and the liability to June frost that will be the handicap to agriculture in the northern districts of Ontario, as late summer frosts do not appear to be much more frequent than in the Upper Ottawa Valley. There is some good ground for belief that the gradual clearing of the forests in the North will tend to a somewhat earlier spring.

From Lake Superior to the height of land the climate in summer is affected to a marked extent by the prevalent southwest wind from the cold water surface of Lake Superior and the mean temperature is lower than at Moose Factory or Abitibi. In winter extremely low temperatures occur in this district, the cold waves coming in from the interior of the continent with northwest winds, and are intensified by a comparatively high altitude.

The total annual precipitation near Lake Nipissing and Temiskaming is nearly the same as near Lake Ontario, but northward this diminishes somewhat, the rainfall becoming less and the snowfall greater. It would appear from the rather scant returns available that the number of rainy days during the summer in southern Nipissing corresponds very closely with the number in Muskoka and that northward the number diminishes, being less at Abitibi and Moose Factory than in the Peninsular of Southern Ontario. The winter snowfall of the whole district is heavy and there is usually a large accumulation in the early spring.

The average winter temperature at Lake Nipissing and Haileybury is several degrees lower than at Montreal; and at Abitibi and Moose Factory in the extreme north of the Province it is very nearly the same as in Manitoba.

TABLES showing the average mean highest, mean lowest, and the mean temperature; also the highest and lowest temperature on record, and the average precipitation.

HAILEYBURY.

| | Temperature | | | | Absolute | | No. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean High. | Mean Low. | Mean | Daily Range | Max. | Min. | days R or S | Rain-fall | Snow-fall | Total Precip |
| January..... | 17.7 | —4.3 | 6.7 | 22.0 | 48 | —40. | 16 | 0.32 | 17.2 | 2.04 |
| February.... | 19.8 | —2.9 | 8.5 | 22.7 | 47 | —38 | 12 | 0.24 | 17.4 | 1.98 |
| March....... | 32.1 | 8.3 | 11.9 | 23.8 | 71 | —34 | 13 | 0.51 | 17.2 | 2.23 |
| April........ | 48.3 | 26.3 | 37.3 | 22.0 | 79 | — 3 | 16 | 1.26 | 5.8 | 1.84 |
| May......... | 61.6 | 39.0 | 50.3 | 22.6 | 93 | 17 | 14 | 3.14 | 0.8 | 3.22 |
| June......... | 73.7 | 50.2 | 62.0 | 23.5 | 100 | 28 | 12 | 3.03 | | 3.03 |
| July......... | 76.7 | 55.4 | 66.0 | 21.3 | 99 | 36 | 14 | 3.91 | | 3.91 |
| August...... | 73.0 | 51.8 | 62.4 | 21.2 | 93 | 27 | 13 | 2.63 | | 2.63 |
| September .. | 65.1 | 44.4 | 54.7 | 20.7 | 91 | 24 | 15 | 3.52 | | 3.52 |
| October..... | 51.2 | 33.9 | 42.5 | 17.3 | 80 | 13 | 14 | 2.43 | 2.8 | 2.71 |
| November... | 35.3 | 20.9 | 28.1 | 14.4 | 63 | —25 | 15 | 0.94 | 13.1 | 2.25 |
| December... | 21.0 | 3.2 | 12.1 | 18.2 | 47 | —35 | 17 | 0.42 | 19.8 | 2.40 |
| | | | | | | | | 22.36 | 94.0 | 31.77 |

Av. date last frost, June 5th.
Av. date first frost, September 11th.

CALVIN, ONT.
1895-1908—14 years.

| | Temperature. | | | | Absolute. | | No. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean High. | Mean Low. | Mean | Daily Range | Max. | Min. | days R or S | Rain-fall. | Snow-fall. | Total Precip |
| January | 17.8 | —2.1 | 7.8 | 19.9 | 54 | —44 | 12 | 0.25 | 18.8 | 2.13 |
| February | 20.1 | —0.7 | 9.7 | 20.8 | 54 | —42 | 9 | 0.21 | 15.6 | 1.77 |
| March | 32.7 | 11.0 | 10.9 | 21.7 | 73 | —27 | 12 | 0.83 | 12.4 | 2.07 |
| April | 50.5 | 27.6 | 39.0 | 22.9 | 79 | 1 | 8 | 1.01 | 4.4 | 1.45 |
| May | 65.1 | 39.4 | 52.2 | 25.7 | 91 | 4 | 10 | 2.99 | 0.5 | 3.04 |
| June | 75.3 | 47.7 | 61.5 | 27.6 | 93 | 28 | 11 | 3.20 | | 3.20 |
| July | 78.1 | 53.0 | 65.6 | 25.0 | 96 | 31 | 11 | 3.47 | | 3.47 |
| August | 74.7 | 48.8 | 61.7 | 25.9 | 91 | 29 | 9 | 3.04 | | 3.04 |
| September | 66.9 | 44.0 | 55.4 | 22.9 | 88 | 18 | 10 | 3.25 | | 3.25 |
| October | 52.7 | 32.7 | 42.7 | 20.0 | 83 | 10 | 13 | 2.53 | 1.3 | 2.66 |
| November | 36.2 | 23.6 | 29.9 | 12.6 | 63 | —10 | 10 | 1.24 | 11.8 | 2.42 |
| December | 22.2 | 5.0 | 13.6 | 17.2 | 49 | —36 | 12 | 0.31 | 19.5 | 2.26 |
| | | | | | | | | 22.33 | 84.3 | 30.76 |

Light June frosts in nearly every year. In 3 years in 14, July frosts.

MOOSE FACTORY.
49 years.

| | Temperature. | | | | Absolute. | | No. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean High. | Mean Low. | Mean | Daily Range | Max. | Min. | days R or S | Rain-fall. | Snow-fall. | Total Precip |
| January | 8.1 | -15.3 | —3.6 | 23.4 | 43 | —48 | 10 | 0.02 | 19.1 | 1.93 |
| February | 10.5 | -14.8 | —2.2 | 25.3 | 45 | —48 | 7 | 0.01 | 10.0 | 1.01 |
| March | 25.1 | —3.0 | 11.0 | 28.1 | 57 | —45 | 9 | 0.21 | 7.3 | 0.94 |
| April | 38.8 | 16.3 | 27.6 | 22.5 | 72 | —29 | 9 | 0.42 | 9.1 | 1.33 |
| May | 53.1 | 31.8 | 42.4 | 21.3 | 95 | —11 | 11 | 1.86 | 4.7 | 2.33 |
| June | 67.0 | 42.4 | 54.7 | 24.6 | 94 | 23 | 9 | 2.34 | | 2.34 |
| July | 74.1 | 50.6 | 62.3 | 23.5 | 97 | 31 | 11 | 2.48 | | 2.48 |
| August | 70.3 | 48.3 | 59.3 | 22.0 | 96 | 32 | 12 | 3.24 | | 3.24 |
| September | 61.6 | 41.9 | 51.7 | 19.7 | 91 | 24 | 12 | 2.92 | | 2.92 |
| October | 48.3 | 32.3 | 39.7 | 16.0 | 84 | 8 | 12 | 1.45 | 4.3 | 1.88 |
| November | 30.5 | 16.4 | 23.5 | 14.1 | 63 | —27 | 10 | 0.37 | 8.2 | 1.19 |
| December | 13.9 | —4.8 | —4.5 | 18.7 | 43 | —41 | 11 | 0.04 | 14.3 | 1.47 |
| | | | | | | | | 15.36 | 77.0 | 23.06 |

No June without frost. White frost in August in every year.

FORT HOPE, ONT.

| | Temperature. | | | | Absolute. | | No. | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean High. | Mean Low. | Mean | Daily Range | Max. | Min. | days R or S | Rain-fall. | Snow-fall. | Total Precip |
| January | 3.8 | -17.8 | —7.0 | 21.6 | 37 | —54 | 7 | 0 | 8.7* | 0.87 |
| February | 7.5 | -16.3 | —4.4 | 23.8 | 42 | —52 | 3 | 0 | 4.5* | 0.45 |
| March | 22.2 | —4.3 | 9.0 | 26.5 | 55 | —49 | 4 | 0 | 7.9* | 0.79 |
| April | 41.1 | 16.6 | 28.8 | 24.5 | 71 | —27 | 2 | 0.02 | 3.0 | 0.32 |
| May | 54.4 | 30.7 | 42.5 | 23.7 | 87 | —7 | 4 | 1.21 | 2.4 | 1.45 |
| June | 68.2 | 43.5 | 55.8 | 24.7 | 92 | 24 | 6 | 2.41 | 0.1 | 2.42 |
| July | 73.7 | 50.1 | 61.9 | 23.6 | 93 | 30 | 8 | 2.31 | | 2.31 |
| August | 69.8 | 47.6 | 58.7 | 22.2 | 99 | 27 | 9 | 1.99 | | 1.99 |
| September | 58.7 | 38.5 | 48.6 | 20.2 | 89 | 16 | 8 | 2.19 | 0.6 | 2.25 |
| October | 44.7 | 28.2 | 36.4 | 16.5 | 83 | —4 | 6 | 0.96 | 3.2 | 1.28 |
| November | 26.4 | 12.1 | 19.2 | 14.3 | 56 | —38 | 6 | 0.09 | 9.3 | 1.02 |
| December | 9.0 | —9.6 | —0.3 | 18.6 | 40 | —47 | 5 | 0 | 8.9 | .89 |
| | | | | | | | | | 48.6 | 16.04 |

* No confidence in the Rain and Snow. Last frost, June 17th.
First frost, August 22nd.

WHITE RIVER.

| | Temperature. | | | | Absolute. | | No. days R or S | Rain-fall | Snow-fall. | Total Precip |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean High. | Mean Low. | Mean | Daily Range | Max. | Min. | | | | |
| January..... | 16.0 | -12.5 | 1.7 | 28.5 | 44 | —58 | 17 | | 16.9 | 1.73 |
| February.... | 17.0 | -13.5 | 1.7 | 30.5 | 47 | —55 | 14 | | 14.8 | 1.45 |
| March...... | 28.0 | —2.9 | 12.6 | 30.9 | 54 | —50 | 13 | | 15.1 | 1.70 |
| April....... | 48.0 | 20.2 | 34.1 | 27.8 | 79 | —23 | 12 | | 8.0 | 1.80 |
| May........ | 62.4 | 34.4 | 48.4 | 28.0 | 90 | —11 | 15 | | 3.8 | 2.45 |
| June........ | 70.8 | 41.8 | 56.3 | 29.0 | 95 | 23 | 11 | | | 2.39 |
| July........ | 74.6 | 47.2 | 60.9 | 27.4 | 97 | 28 | 13 | | | 2.67 |
| August..... | 70.2 | 44.4 | 57.3 | 25.8 | 87 | 26 | 14 | | | 3.03 |
| September. . | 61.2 | 38.5 | 49.9 | 22.7 | 91 | 14 | 16 | | 0.6 | 2.86 |
| October..... | 48.1 | 28.7 | 38.4 | 19.4 | 76 | —1 | 15 | | 3.4 | 2.50 |
| November... | 31.3 | 14.0 | 22.6 | 17.3 | 69 | —43 | 19 | | 14.0 | 2.34 |
| December... | 19.0 | —6.2 | 6.4 | 25.2 | 54 | —57 | 17 | | 15.6 | 1.79 |
| | | | 32.5 | | | | | | 92.2 | 26.71 |

Frost in every month of nearly every year.

ABITIBI, QUE.

1897 to 1910—Summer temp. 57.2°
" 3 mo. 61.1°.

| | Temperature. | | | | Absolute | | No. days R or S | Rain-fall. | Snow-fall. | Total Precip |
|---|---|---|---|---|---|---|---|---|---|---|
| | Mean High. | Mean Low. | Mean | Daily Range | Max. | Min. | | | | |
| January..... | 12.5 | -11.3 | 0.6 | 23.8 | 42 | —46 | 9 | 0.05 | 18.0 | 1.85 |
| February.... | 14.2 | -11.0 | 1.6 | 25.2 | 46 | —44 | 7 | 0.00 | 14.5 | 1.45 |
| March...... | 28.2 | 1.6 | 14.9 | 26.6 | 62 | —42 | 7 | 0.09 | 21.6 | 2.25 |
| April....... | 40.3 | 21.0 | 30.6 | 19.3 | 70 | —20 | 6 | 1.00 | 4.3 | 1.43 |
| May........ | 54.6 | 36.4 | 45.5 | 18.2 | 94 | 8 | 9 | 2.64 | 2.2 | 2.86 |
| June........ | 67.9 | 49.3 | 58.6 | 18.6 | 94 | 28 | 8 | 2.67 | | 2.67 |
| July........ | 72.6 | 55.5 | 64.0 | 17.1 | 94 | 35 | 10 | 2.77 | | 2.77 |
| August..... | 68.9 | 52.3 | 60.6 | 16.6 | 86 | 34 | 12 | 2.85 | | 2.85 |
| September .. | 60.2 | 44.7 | 52.5 | 15.5 | 87 | 26 | 12 | 2.60 | | 2.60 |
| October..... | 47.2 | 32.1 | 39.6 | 15.1 | 76 | 15 | 12 | 2.55 | 4.1 | 2.96 |
| November... | 31.1 | 18.2 | 24.6 | 12.9 | 68 | —16 | 11 | 0.77 | 12.8 | 2.05 |
| December... | 16.6 | —1.4 | 7.6 | 18.0 | 48 | —45 | 9 | 0.09 | 21.3 | 2.22 |
| | | | 33.4 | | | | | | 98.8 | 27.96 |

Average date of last frost, June 8th.
Average date of first frost, September 14th.

# ON THE SECONDARY RAYS EXCITED BY THE ALPHA RAYS FROM POLONIUM.—I.

BY V. E. POUND, M.A.*

(*Read 13th January, 1912*).

## I. Introduction.

RECENT researches have shewn that radioactive materials from which $\alpha$ rays are sent off also emit a radiation of negatively charged particles, which will not ionise a gas, and which have been called $\delta$ rays. The other characteristics of this radiation are that it is easily absorbed, it is easily deflected by a magnetic field and it is stopped by a small positive charge placed upon the radioactive substance emitting it. Still later researches by Logeman*[1] have shewn that when $\alpha$ rays fall on a polished piece of metal such as copper, this metal emits a secondary radiation with characteristics similar to those of the $\delta$ rays. Further, it has been found by Duane*[2] that the $\alpha$ rays lose their power to produce secondary rays at the same time that they lose their charge and their power to ionise a gas.

The present paper describes some experiments on these secondary rays produced by the $\alpha$ rays of polonium. The apparatus employed at first was somewhat similar to that used by Logeman when he proved the existence of this secondary radiation from metals bombarded by $\alpha$ rays. In the experiments to be described exhaustions were made with a Gaede pump and the pressures were measured with a McLeod gauge.

## II.—DESCRIPTION OF APPARATUS.

The apparatus used in the initial experiments is shewn in Fig. 1. It consisted of a brass cylinder about 4 cm. in diameter and 9 cm. in length which had an ebonite plug fitting into each end. Through one of these plugs was led a brass rod which carried a round brass electrode B, about 15 mm. in diameter. The electrode B was surrounded by a circular guard ring C. Through the other plug was led another brass rod and it carried the second electrode, A. A circular surface, *ab*, of this electrode A, about 15mm. in diameter was coated with a deposit of polonium.

*Presented by Prof. J. C. McLennan.

*[1] Logeman, Proc. Roy. Soc. Series A, Vol. 78, Sept. 6, 1907. E. Aschkinass, Ann. der Phys. No. 12, 1908.

*[2] Duane, Comptes Rendus, May 25, 1908.

The distance between the polonium deposit and the surface of the electrode B was 6 mm. The polonium and the surface of the electrode B were coaxial. The brass cylinder which was made air-tight with wax was connected to the McLeod gauge and the Gaede air-pump by a tube D. The polonium coated electrode, A, was connected to a battery, and the brass electrode, B, to a sensitive quadrant electrometer. The brass cylinder surrounding the two electrodes was connected to earth.

### III.—REPETITION OF LOGEMAN'S EXPERIMENT.

The experiment which Logeman made*[1] was first repeated, and the results obtained were similar to those obtained by him with identical electrical fields. The experiment was conducted in the following manner. By means of the Gaede pump the air was pumped out from the apparatus to as low a vacuum as possible. The pressure of the air was measured by means of the McLeod gauge, and when the pressure became so low that the McLeod gauge could not measure it, which was less than 1/1000 of a millimetre of mercury the polonium was connected to earth and the rate of charging of the brass electrode opposite was measured by means of the electrometer. Then the polonium was charged to a series of different potentials by means of a storage battery, and the corresponding rates of charging of the brass electrode were ascertained. Throughout the experiment the Gaede pump was kept going continuously in order to withdraw any gas which might come from the walls of the apparatus.

The results which were obtained are given in Table I.

TABLE I.

| Pressure less than .001 mm. | Distance between electrodes 6 mm. |
|---|---|
| Voltage on polonium. | Rate of charging. |
| 0. volts | −49 |
| .44 " | −16 |
| 2.1 " | 45.1 |
| 7 " | 81 |
| 19 " | 89.5 |
| 40 " | 88.5 |
| 76 " | 86 |
| 179 " | 82 |
| 258 " | 80 |
| 502 " | 75.5 |

In column I is given the voltage applied to the polonium, and in column II the charge gained per minute by the brass electrode opposite

*[1] Proc. Roy. Soc. Vol. 78, Sept. 6, 1907.

the polonium, as measured by the quadrant electrometer. A curve representing these results is shewn in Fig. 2.

It is evident from the results given in the Table, and from the curve, that when the polonium was at zero voltage the charge gained by the brass electrode was negative. It is also evident that as the voltage on the polonium was increased positively the charge gained by the electrode increased from a negative charge to a positive one, and that at a potential of about 20 volts the rate of charging became a maximum. This result agrees with the result published by Logeman. This can be seen from the numbers recorded in his paper, a few of which are given in the following table. The results can be readily compared because the distance between the polonium and the opposite electrode was about the same as that in Logeman's apparatus.

LOGEMAN'S RESULTS.

| Distance between electrodes 5 mm. | |
|---|---|
| Potential on Polonium. | Reading of current to electrode. |
| 0 volts | −58.0 |
| 2 " | 86 |
| 12 " | 182 |
| 14 " | 185 |

It will be seen however, from the curve, that as the potential on the polonium was increased beyond 20 volts, the rate of charging of the electrode gradually decreased. This effect does not appear to have been observed by Logeman. In searching for the explanation of it, further interesting properties of the secondary rays were found by the writer which have not as yet been noted by other experimenters.

Before seeking for an explanation of the results given in Table I, and shewn graphically in Fig. 2, it is necessary to enumerate the different currents which would give a charge to the brass electrode B. In the first place there would be a current due to the passage of the $\alpha$ rays from the polonium across the space separating the polonium from the electrode. Since the $\alpha$ rays are positively charged particles this current would charge the electrode positively. Then there would be a current of negatively charged particles from the polonium which would reach the electrode. This current is known as the $\delta$ radiation and always accompanies a discharge of $\alpha$ particles. The passage of this current would give a negative charge to the electrode. Again there would be a stream of negatively charged particles emitted by the electrode. The researches of Aschkinass and Logeman have proved this stream to exist whenever a substance is bombarded by $\alpha$ rays, and it has been called the secondary radiation. The emission of this stream of negatively charged particles would have the effect of charging the electrode positively. Finally, there would be a current through the air in the chamber, due to the ionisation of the air by the $\alpha$ rays. This last current would charge the electrode positively, since the polonium was positively charged. This current which we will call the ionisation current, would be, in all probability, very small, on account of the small quantity of gas in the chamber.

Let us now consider what would be the effect on these different currents of increasing the positive potential on the polonium from zero upwards. The number of $\alpha$ particles emitted per second by the polonium could not be changed by increasing the potential for it is found impossible to change the rate of emission of the $\alpha$, $\beta$ and $\gamma$ rays from the radioactive substances by any known agency. The increase of the potential on the polonium might, however, increase the speed with which the $\alpha$ particles passed from the polonium to the electrode. If this were the case, since it has been shewn by different experimenters, including Geiger and Marsden*[1] that $\alpha$ rays are reflected to some extent from the substances they strike this increase in velocity might cause a more profuse reflection of the $\alpha$ rays from the electrode. Hence as the potential was increased there would be fewer and fewer $\alpha$ particles which would remain attached to the electrode and this would cause the positive rate of charging of the electrode to decrease.

The effect of increasing the positive potential on the polonium could only tend to retard more and more of the $\delta$ rays which are negatively charged and of slow velocity. Hence, on account of the stopping of these rays, the rate of charging of the electrode positively must have increased. In fact the sharp rise in the first part of the curve shewn in Fig. 2 has been attributed by Logeman and others, and very probably correctly so, to the stoppage of the $\delta$ rays by the positive charge on the polonium.

Again the increase of the positive charge on the polonium must tend to produce a freer discharge of negative electricity from the electrode, since a positive charge on the polonium attracts negative from the electrode. The primary cause of this discharge would be, of course, the bombardment of the electrode by the $\alpha$ rays, and this is what we have called the secondary radiation. An increase in the amount of secondary radiation discharged from the electrode would increase the rate at which the electrode charged positively.

Finally, the increase of potential on the polonium would have the effect of increasing the ionisation current from the polonium to the electrode through the gas, and this would cause the positive rate of charg-

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*[1] Geiger and Marsden, Proc. Roy. Soc. Ser. A. 82, July 31, 1909.

ing of the electrode to increase since the charges on the polonium were positive. There is, however, one factor which may have influenced the experiment and which must be considered here, and that is that the Gaede pump was kept going continuously in order to keep the pressure low. The readings were not taken until the pressure was less than 1-1000 of a mm. of mercury but yet the pressure may have decreased still further while the readings were being taken and on account of the decrease in the pressure the ionisation current may have also decreased. It is evident that this would cause a decrease in the positive rate of charging of the electrode.

It is seen, therefore, that, according to the above explanations of the charging of the electrode by the different currents, there are only two things which might cause a decrease in the rate of charging of the electrode positively as the potential on the polonium was raised positively. Either there might be a more profuse reflection of $\alpha$ rays from the electrode, and so reduce its rate of charging or there might be a gradual decrease in the ionisation current due to the lowering of the pressure of the air in the apparatus.

Now it is evident from the curve given in Fig. 2 that there was a gradual decrease in the rate of charging of the electrode after the potential of the polonium was increased beyond 20 volts. In order to find out how much of this decrease or whether any at all was due to the withdrawal of more air from the apparatus after it was exhausted to a very low pressure the experiments described in the following section were performed.

## IV.—IONISATION EXPERIMENTS.

In the first experiment, the polonium was charged to a positive potential of 77 volts. It was found, that with the polonium at this potential the $\delta$ radiation was practically all stopped. The Gaede pump was started and the air which had stood in the apparatus for a week, at atmospheric pressure, was pumped out until the pressure as measured by the McLeod gauge was less than 1/1000 of a mm. of mercury. The time taken by the pump to do this was about 15 minutes. Then, while the pump was kept continuously going, readings were taken of the rate of charging of the electrode at different intervals of time. It was hoped in this way to get some idea of the effect of the withdrawal of the air on the ionisation current between the polonium and the electrode. In Table II the results obtained are given.

TABLE II.

Air in apparatus.

| Brass electrode B. | Voltage on polonium = 77 volts. |
|---|---|
| Time. | Current to electrode. |
| 0 minutes | 97 |
| 5 " | 81 |
| 10 " | 76 |
| 15 " | 67.5 |
| 25 " | 64 |
| 120 " | 59 |
| 130 " | 59 |

The first column states the time between any reading and the initial reading, while the second column gives the rate at which the electrode charged up.

As shown by the table the rate at which the electrode gained a charge decreased with the time and finally came to a constant value.

In this experiment the polonium was at the same voltage all the time, hence there could be no change in the rate of charging of the electrode due to a change in voltage. Therefore, according to the theory of the charging of the electrode as outlined in the previous section, the gradual drop in the rate of charging of the electrode as the time passed could only be due to a decrease in the ionisation current through the gas. This decrease could be attributed to a farther withdrawal of air from the apparatus by the pump after the pressure had been reduced to less than 1/1000 of a mm. of mercury. If this were the case this decrease in ionisation would continue until the pressure of the air in the vessel reached a constant value. Then the air withdrawn by the pump would be equal to the air which oozed out from the sides of the vessel. The final constant value for the rate of charging of the electrode would denote this equilibrium condition between the air taken away by the pump and the air which oozed out from the walls of the chamber.

If the above explanation is correct then if the apparatus were filled with another gas than air such as hydrogen, and the experiment were repeated as with the air there would again be a final pressure and also a final ionisation current through the hydrogen. But on account of the different nature of the two gases this final ionisation current would be different in the two cases and hence the final rate of charging of the electrode would also be different in the two cases.

In order to find out whether this was true the apparatus was filled with pure and dry hydrogen and left standing over night at atmospheric pressure. Previously the apparatus had been depleted as much as possible of air by keeping it at low pressure and pumping out the air which came from the walls. The polonium was charged to a positive potential of 77 volts, the hydrogen was pumped out to less than 1/1000 of a mm. of mercury, and then readings were taken as with the air of the rate of charging of the brass electrode and are given in the following table.

TABLE III.

Hydrogen in Apparatus.

Brass electrode — Voltage on polonium = 77 volts;

| Time. | Current to electrode. |
| --- | --- |
| 0 minutes | 86.6 |
| 6 " | 73.1 |
| 16 " | 65.1 |
| 31 " | 62.6 |
| 91 " | 59.5 |
| 95 " | 59.5 |
| 121 " | 59.0 |

It will be seen on looking at the Table that there was a decrease in the rate of charging of the electrode with the time as with the air. On comparing Table II and Table III it will also be seen that the initial rates of charging of the electrode were different with the two gases but the final rates were the same. The experimental results therefore, did not agree with the predicted results, for it was predicted that the final rates of charging of the electrode would be different using two different gases on account of the difference in the final ionisation currents through air and through hydrogen. The experimental results, go to show that the final ionisation currents were the same. This seemed hardly possible on account of the difference in density of the two gases. Another explanation of the reason why these two final rates of charging were the same was therefore looked for. The simplest one that suggested itself was that when the final rates of charging were the same, there was such a small quantity of either air or hydrogen in the apparatus that no ionisation current was possible.

The next question that naturally arose was whether all of the drop in the rate of charging of the electrode was due to a drop in the ionisation current through the air and through the hydrogen. In order to answer this question the following experiment was performed. It was found that if arc light carbon was used as the electrode instead of brass, there was a greater drop in its rate of charging than when brass was used under the same conditions. Accordingly the brass electrode was removed from the apparatus and a similar shaped piece of carbon was put in. The polonium was charged to a positive potential of 78 volts, and the pump was started exhausting the air which was initially at atmospheric pressure. Seven minutes after the pump was started readings were taken of the pressure of air in the vessel as measured by the McLeod gauge, and the rate of charging of the carbon electrode. Similar readings were made at different intervals of time after the initial readings. The pump was kept going continuously throughout all the readings. The results are given in the following table.

TABLE IV (*a*)

Air in Apparatus.

Carbon Electrode. Charge on Pol. = 78 volts.

| Pressure of air in vessel. | Time from initial reading. | Current to electrode. |
|---|---|---|
| .008 mm. | 0 minutes | 46 |
| .004 " | 1 " | 42 |
| .002 " | 5 " | 38 |
| < .001 " | 15 " | 34.5 |
| < .001 " | 30 " | 31.5 |
| < .001 " | 60 " | 29.0 |
| < .001 " | 120 " | 29. |

The pump was then stopped and while the pressure gradually increased as the air flowed out from the walls of the apparatus, the series of readings were continued and are given below.

TABLE IV (*b*).

| Pressure of air in vessel. | Time from initial reading. | Current to electrode. |
|---|---|---|
| < .001 mm. | 127 minutes. | 29 |
| .002 " | 126 " | 29 |
| .005 " | 129 " | 30.5 |
| .009 " | 134 " | 30.5 |
| .012 " | 139 " | 31 |
| .018 " | 146 " | 32.5 |
| .022 " | 153 " | 33 |
| .027 " | 161 " | 34 |
| .035 " | 171 " | 35.5 |

If the results that were obtained while the pressure of the air was decreasing are compared with the results obtained while the pressure was increasing as given in Table IV. and shewn graphically in Fig. 3, it will be seen that at any given pressure, the rate of charging of the electrode was greater as the pressure was decreasing than as it was increasing. It will also be seen that the rate of charging at a pressure of .035 mm. of mercury as the pressure was increasing was very much less than the rate of charging at much smaller pressures as the pressure was decreasing. These results shew clearly then, that the decrease in the rate of charging of the electrode as the air was pumped out of the apparatus was not all due to a decrease in the ionisation current through the gas. For, since the ionisation current is only dependent on the pressure of the air in the chamber, it should have the same value at like pressures whether the pressure was decreasing or increasing.

If the decrease in the rate of charging of the electrode with the time was not all due to a decrease in the ionisation current through the gas there must be some other reason for this decrease. As shewn in Section III there are three other currents which cause the electrode to charge up besides the ionisation current. These are, the $\alpha$ ray current from the polonium, the $\delta$ rays current from the polonium and the secondary ray current from the electrode. It has been shewn by an experiment in Section III that a positive potential of 20 volts is sufficient to stop practically all the $\delta$ ray current. Therefore, in this experiment, the only currents which charged up the electrode besides the ionisation current were the $\alpha$ ray current and the secondary radiation current. Either both, or one of these currents, then, must have had a decrease in intensity as well as the ionisation current in order to produce the total decrease in the rate of charging of the electrode as found by experiment. The decrease in intensity of the $\alpha$ rays from polonium with the time, has been studied by various experimenters and they have found the intensity falls to half value in 140 days. The time taken by the experiment was about three hours so that in this short interval of time the decrease in intensity of the $\alpha$ rays was practically nothing. Hence there must have been a considerable decrease in the intensity of the secondary radiation emitted by the carbon from the time when the first reading of the rate of charging of the electrode was taken.

The causes, then, of the decrease in the rate of charging of the electrode with the time as found in the above experiment was a small decrease in the ionisation current through the air as the pressure was reduced and a large decrease in the secondary rays sent off by the carbon. The same causes will account for the decrease in the rate of charging of the brass electrode used in the first two experiments of this section, and must also be considered when the results of the experiment described in Section III are explained. Before continuing experiments with the object of a further elucidation of the results described in Section III it was thought well first to make an extended study of the phenomenon of the decrease in the intensity of the secondary radiation as made evident by the foregoing experiments.

## V. Experiments on the "Fatigue" of Secondary Rays.

The experiments described in Section IV shew that there was a decrease in the secondary radiation sent off by carbon bombarded by $\alpha$ rays as the air was pumped out of the apparatus in which the carbon was placed. This decrease may be called a fatigue of the secondary rays for the effect is similar to that observed in the case of the photo-electric fatigue. The phenomenon of the photo-electric fatigue has been studied extensively, and various reasons have been suggested for it. One of the reasons which have been advanced is that the substance which emits the photo-electric radiation becomes impoverished of available negative corpuscles. If the fatigue in the present experiments were due to a decrease in the number of available negative corpuscles, this decrease must have been all at the surface since the exciting $\alpha$ rays have only a small penetrability. If the decrease were due to this cause, it is probable that if air were admitted into the apparatus again, the electrode would regain its normal condition. To test this the following set of experiments was performed.

A fresh piece of carbon was placed in the apparatus, a positive charge of 80 volts was put on the polonium, the Gaede pump was started, and at a definite interval of time after the starting of the pump, readings were taken of the rates of charging the carbon electrode, and of the corresponding pressures of air in the apparatus. These readings were continued until there was practically no further decrease in the rate of charging of the electrode.

The readings are given in the following table:

TABLE V.

| Fresh carbon electrode. | Air in apparatus. | Charge on Pol. = 80 volts. |
|---|---|---|
| Pressure of air in vessel | Time from initial reading taken seven minutes after starting pump. | Current to electrode. |
| .007 mm. | 0 minutes | 124.7 |
| .002 " | 5 " | 78.2 |
| .001 " | 15 " | 50.7 |
| < .001 " | 25 " | 41.2 |
| < .001 " | 41 " | 35.2 |
| < .001 " | 65 " | 31.2 |
| < .001 " | 87 " | 28.2 |
| < .001 " | 123 " | 26.2 |

The carbon was left in the evacuated apparatus, bombarded by $\alpha$ rays from the polonium for one week in order that it should get thoroughly fatigued to the production of secondary rays. Then the apparatus was filled with air at atmospheric pressure and again left standing for one week. At the end of this time the experiment described above was repeated and the readings are given below.

TABLE VI.

| Fatigued carbon electrode. | Air in Apparatus | Charge on Pol. = 80 volts. |
|---|---|---|
| Pressure of air in vessel | Time from initial reading taken seven minutesafter starting pump | Current to electrode |
| .008 mm. | 0 minutes | 32.7 |
| .003 " | 5 " | 30.2 |
| .002 " | 15 " | 29.2 |
| .001 " | 36 " | 24.7 |
| < .001 " | 60 " | 22.3 |

After this experiment was completed the apparatus was immediately filled with air at atmospheric pressure and left standing for 22 hours. Then the above experiment was again repeated with the following results.

TABLE VII.

| Fatigued carbon electrode | Air in Apparatus | Charge on pol. = 80 volts. |
|---|---|---|
| Pressure of air in vessel | Time from initial reading taken seven minutes after starting pump | Current to electrode. |
| .004 mm. | 0 minutes | 25.3 |
| .001 " | 5 " | 22.8 |
| < .001 " | 22 " | 21.8 |

The results given in the last two columns of Tables V-VII are represented by curves shewn in Fig 4. The upper curve is plotted from the results given in Table V. the middle curve from Table VI and the lower curve from Table VII.

It will be seen on looking at the curves that each has a gradual drop. This drop represents both the decrease as time went on in the rate at which the carbon electrode sent out secondary rays and the decrease in the ionisation current across the air gap between the polonium and the electrode beginning at a certain definite interval of time after the first air was taken from the apparatus. It will be seen also on comparing the curves that the initial point of the upper curve is much higher than the initial points of the lower curves. Also the upper curve decreases much more quickly than the lower curves, until finally the three curves all come together. Now the decrease in the ionisation current through the air space with the time would be the same in all three experiments because this decrease is dependent on the air pressure and, as the pump was kept going regularly the air pressure in all three cases would be the same at equal intervals of time after the pump was started. Hence since the upper curve shews a much greater drop than the two lower curves, there must have been a much greater decrease in the secondary radiation in the first experiment than in the two latter experiments. Therefore there must have been a much more copious emission of secondary rays at the beginning of the first experiment than at the beginning of the other two experiments. This is indicated by the height of the initial point of the upper curve above the initial points of the other two curves.

The above experiments therefore shew that when fresh carbon is used as an electrode and subjected to bombardment by $\alpha$ rays and the air withdrawn from around the carbon, there is a great decrease in the secondary rays as time goes on until finally the secondary rays emitted reach a constant value. Then, if the carbon is kept *in vacuo* for some time (one week) it will not regain its primary power of emitting secondary rays by being again surrounded by air while still under bombardment by $\alpha$ rays even for periods of time extending up to 22 hours.

The next experiments that were performed were for the purpose of finding out whether this same carbon would send out secondary rays with their initial intensity if it were placed in an atmosphere of hydrogen instead of air. The apparatus was first filled with dry hydrogen, produced from zinc and acidulated water and left at atmospheric pressure for four hours. Then as before a positive charge of 80 volts was put on the polonium, the pump was started, and at a definite interval of time after starting the pump, a series of readings was taken of the rate at which the carbon electrode charged up, and the pressure of the hydrogen in the apparatus. The readings are given in the following table.

TABLE VIII.

Fatigued carbon electrode. Hydrogen in Apparatus. Charge on pol. = 80 volts.

| Pressure of hydrogen in vessel | Time from initial reading taken four minutes after starting pump | Current to electrode. |
|---|---|---|
| .006 mm. | 0 minutes | 24.5 |
| .003 " | 6 " | 23.0 |
| < .001 " | 15 " | 22 |
| < .001 " | 31 " | 22 |
| < .001 " | 56 " | 22 |

Next the apparatus was filled with hydrogen at atmospheric pressure and left standing for eighteen hours. A series of readings was taken as before and is given below.

TABLE IX.

Fatigued carbon electrode Hydrogen in apparatus Charge on polonium = 80 volts.

| Pressure of hydrogen in vessel | Time from initial reading taken four minutes after starting pump | Current to electrode |
|---|---|---|
| .005 mm. | 0 minutes | 25.7 |
| .002 " | 5 " | 24.7 |
| < .001 " | 15 " | 24 |
| < .001 " | 30 " | 23.5 |
| < .001 " | 62 " | 23.5 |

It will be noticed that in these two last experiments with the hydrogen the first reading was taken four minutes after the pump was started while in the three experiments with the air the first reading was taken seven minutes after the pump was started. The reason for this was that the pump reduced the pressure of the hydrogen much quicker than the air and it was desired to take the first readings for both hydrogen and air at approximately the same pressure.

From the results given in the last two columns of Tables VIII and IX the two lower curves of Fig. 5 are plotted, while the upper curve of Fig. 5 is plotted from the results given in the last two columns of Table V. The latter curve pictures the way in which the rate of charging of the fresh carbon electrode decreased with the time, while the former curves shew how the rate of charging of the fatigued carbon electrode, which had been left in hydrogen at atmospheric pressure, decreased with the time.

It will be noticed that there is hardly any drop in the lower curves and a great drop in the upper curve. It will also be seen that the rate of charging of the fatigued electrode as indicated by the lower curves is nearly the same as the final value of the rate of charging of the fresh electrode as indicated by the upper curve. Hence the above experiments indicate that the carbon electrode did not regain any of its primary power of producing secondary rays by being surrounded by hydrogen at atmospheric pressure.

The above experiments therefore shew that a carbon electrode which has been fatigued to the production of secondary rays and left *in vacuo* for a long time will not regain its primary power of producing secondary rays, by simply being placed in an atmosphere of either air or hydrogen. Hence the fatigue of the carbon is not due to a temporary loss of negative corpuscles which can readily be regained from air or hydrogen when these gases are allowed to surround the carbon.

The next experiments that were tried were to find out whether a piece of carbon would regain its power of producing secondary rays if it were fatigued for a very short time only. A fresh piece of carbon was placed in the apparatus and a set of experiments similar to the ones described above was performed, except that instead of leaving the carbon in the evacuated chamber after the current to the carbon had gained a steady value, it was left for a week with the air at atmospheric pressure. The readings taken with the fresh carbon are given in Table X and the readings taken after the fatigued carbon had been left for a week surrounded by air at atmospheric pressure are given in Table XI.

TABLE X.

Fresh carbon electrode.
Air in apparatus — Charge on polonium = 82 volts.

| Pressure of air in vessel | Time from initial reading taken seven minutes after starting pump | Current to electrode |
|---|---|---|
| .008 mm. | 0 minutes | 123.5 |
| .003 " | 5 " | 82.5 |
| .001 " | 15 " | 44.5 |
| .001 " | 30 " | 29 |
| < .001 " | 60 " | 22 |
| < .001 " | 90 " | 19.5 |
| < .001 " | 120 " | 18 |
| < .001 " | 142 " | 17.5 |

TABLE XI.

| Fatigued carbon electrode | Air in Apparatus | Charge on polonium = 84 volts |
|---|---|---|
| Pressure of air in vessel | Time from initial reading taken seven minutes after starting pump | Current to electrode. |
| .006 mm. | 0 minutes | 66.3 mm. |
| .004 " | 1 " | 45.3 |
| .002 " | 5 " | 29.3 |
| .002 " | 15 " | 21.3 |
| .001 " | 30 " | 17.3 |

The results given in these two tables are graphically illustrated by the curves shewn in Fig. 6. The upper curve refers to the results in Table X while the lower curve refers to Table XI. A comparison of these curves with the curves shewn in Fig. 4 makes it plain that there was a much greater recovery of the carbon fatigue when it was left *in vacuo* a very short time and then surrounded by air than when it was left for a long time before being surrounded with air.

This pointed to the probability that the gas occluded in the carbon was the cause of the large decrease with the time in the secondary radiation. For if the gas occluded in the carbon, as well as the carbon itself, produced secondary radiation, then, as the exhaustion proceeded gas would ooze out of the carbon and the secondary radiation would decrease until all the gas which could leave had disappeared entirely from the surface of the carbon. Also, the longer the carbon was left *in vacuo* the more occluded gas would come out and the more difficult it would be for the same amount of gas to enter the carbon again. Hence this would cause the fatigue to be more permanent when the carbon was left in a vacuum a long time than when left a short time. This conclusion, it will be seen, has been amply confirmed by the experiment described above.

In order to decide definitely whether the release of the gas occluded in the carbon had to do with the decrease in the secondary rays which has been called a fatigue, a special piece of apparatus was designed and experiments were performed which will be described in the following section.

## VI. EXPERIMENTS SHEWING THE INFLUENCE OF OCCLUDED GAS ON THE SECONDARY RADIATION.

The essential parts of the apparatus (Fig. 7) were two parallel electrodes B and C, in an air tight vessel, separated a distance of about 6 mm.

The polonium which was carried by the electrode B could be made to face in any direction by turning the axial rod A. This rod passed through and was sealed to a glass tube D which fitted over another glass tube E so arranged that the joint could be covered with mercury and so made air tight. The electrode C which was made of carbon, was connected with the quadrant of an electrometer, the connecting rod passing through an ebonite plug fitted into the side of a vessel by a side tube F. Another side tube G connected the vessel to the McLeod Gauge and the Gaede pump. The vessel itself, which was a cylindrical brass tube about 5 cm. in diameter and 8 cm. in length was connected to earth. All joints were made air-tight by means of wax and solder.

The first experiment was conducted as follows. A fresh carbon electrode was placed in the apparatus, the polonium was turned away from the electrode and the air was pumped from the vessel for over an hour with the pump going continuously. Then the polonium was charged to a positive potential of 80 volts and turned so that it faced the carbon electrode. A reading was at once taken of the rate at which the carbon electrode charged up, and similar readings were made at different intervals of time afterwards. The results obtained are given in Table XII.

TABLE XII.

Fresh carbon in apparatus.
Turned polonium to face carbon 1 hour, 20 minutes after pump was started.
Voltage on polonium = 80 volts.

| Pressure of air in vessel | Time from initial reading taken 1 hr, 20 min. after starting pump. | Current to electrode. |
|---|---|---|
| < .001 mm. | 0 minutes | 122 |
| < .001 " | 5 " | 123 |
| < .001 " | 15 " | 124 |
| < .001 " | 30 " | 122 |
| < .001 " | 60 " | 123 |

These results shew that there was no sign of a "fatigue" in the rate at which the carbon electrode charged up with the time, for the rate was practically constant throughout all the readings.

We have seen therefore that it is possible to get rid of the fatigue effect altogether by withdrawing the gas from the surface of the carbon before beginning the bombardment by $\alpha$ rays. The "fatigue" then which has been described in the previous sections must be due to a decrease in the secondary radiation from the gas occluded at the surface of the brass or carbon electrode used.

In view of the effect which the presence of gas has on the secondary radiation it was thought well to repeat the experiment described in Section III and first performed by W. H. Logeman. Instead of using a brass electrode a carbon electrode was used, also the carbon was left in the vessel at low pressure for two days in order that the gas occluded in the carbon should disappear or reach a value which would be constant for the low pressure used. Then readings were taken of the rate at which the carbon electrode charged up as the positive potential on the polonium was varied from 0 volts to about 1700. The results are given in Table XIII below, and a curve drawn from these results is shewn in Fig. 8.

TABLE XIII.

| Voltage on polonium. | Pressure of air in vessel. | Time from initial reading. | Current to electrode. |
|---|---|---|---|
| 0 volts | < .001 mm. | 0 minutes | −447 |
| 1.6 " | " | 12 " | −191 |
| 7 " | " | 16 " | − 4.7 |
| 18 " | " | 28 " | 54 |
| 39 " | " | 31 " | 89 |
| 168 " | " | 38 " | 131 |
| 251 " | " | 44 " | 141 |
| 334 " | " | 48 " | 144 |
| 401 " | " | 62 " | 150 |
| 538 " | " | 72 " | 160 |
| 788 " | " | 95 " | 165 |
| 1095 " | " | 105 " | 172 |
| 1337 " | " | 121 " | 175 |
| 1708 " | " | 137 " | 181 |

The curve shewn in Fig. 8 rises very rapidly from -447 to about 90, as the potential on the polonium was increased from 0 to 40 volts and then more slowly as the potential is increased beyond 40 volts. This is somewhat different from the results obtained in Section III with the brass electrode and shewn graphically in Fig. 2, for the curve in Fig. 2, it will be seen, rises rapidly while the potential on the polonium is raised from 0 to 40 and then falls again as the potential is further increased. The cause of this fall in the rate of charging of the brass electrode as the potential on the polonium was raised above 40 volts in a measure may be attributed, as has been suggested, either to a more profuse reflection of $\alpha$ rays from the electrode as the potential of the polonium was raised or to a gradual decrease in the ionisation current due to a lowering of the pressure of the air in the apparatus. But as a result of the later experiments performed with the carbon electrode it is clear we must add another and more important cause for the fall, namely, the decrease in the secondary radiation throughout the experiment as the gas layer on the electrode became less and less dense.

The experiment just described with the carbon electrode shews that when the gas layer was removed, there was no fall in the rate of charging of the carbon electrode, as the potential on the polonium was increased, but instead a gradual increase was obtained.

The question arose, then, whether the brass electrode would act in the same manner as the carbon electrode if the gas layer was first removed from it. To answer this question the brass electrode was kept *in vacuo* a long time and the experiment with it was repeated. Contrary to expectation it was found that there was still a very slight decrease in the rate of charging of the electrode after the potential of the polonium was raised above 40 volts but this decrease was not nearly as great as before.

The reason for the final slight difference between the behaviour of a carbon and of a brass electrode appears then to be due to a difference between the $\alpha$ ray reflecting power of carbon and brass at different voltages, the brass reflecting more $\alpha$ rays than the carbon as the voltage was increased.

If the work done by Geiger and Marsden*[1] on the reflection of $\alpha$ rays is taken to be applicable to the present experiments, it would seem that $\alpha$ particles can not be reflected in sufficient numbers to account for this difference. However, the experiments described above point definitely to the reflection of $\alpha$ rays as the cause of the slight difference in the behaviour of the carbon and the brass plates under the bombardment by $\alpha$ rays. Moreover, it can easily be shewn that with the fields used variations in the speed of the $\alpha$ rays amounting to 1.7% must ensue. It is just possible that this variation might be sufficient to cause such a change in the amount of $\alpha$ radiation reflected from the carbon and brass electrodes as to contribute, in part at least, to the above effect. It would appear, therefore, that additional experiments should be made on the reflection of $\alpha$ rays of different velocities at surfaces subjected to low gas pressures before the explanation offered above of the effect observed is set aside.

## VII. SUMMARY OF RESULTS.

1. It has been shewn that there is a secondary radiation produced when alpha rays fall on a brass or a carbon plate.

*[1] Geiger and Marsden, Proc. Roy. Soc. Ser. A, 82 July 31, 1909.

2. This secondary radiation has been proved to be in part due to the presence of gas occluded in or at the surface of the brass or carbon.

3. When this gas is being removed from the brass or carbon it is found that the secondary radiation decreases and gives rise to an effect similar to a "fatigue" of the secondary rays.

4. This fatigue effect is found to be greater for carbon than for brass. This last result was to be expected when the fatigue effect was traced to the presence of occluded gases since carbon is known to possess a greater capacity for occluding gases than a metal such as brass.

5. From the experiments which have been described it will be seen that the secondary radiation emitted by a substance like carbon under bombardment by $\alpha$ rays furnishes a new means of investigating the process by which gases are occluded in carbon and probably also in other substances.

In conclusion I wish to express my gratitude to Professor McLennan for his suggestions and help throughout the course of this investigation.

Physical Laboratory,
University of Toronto.

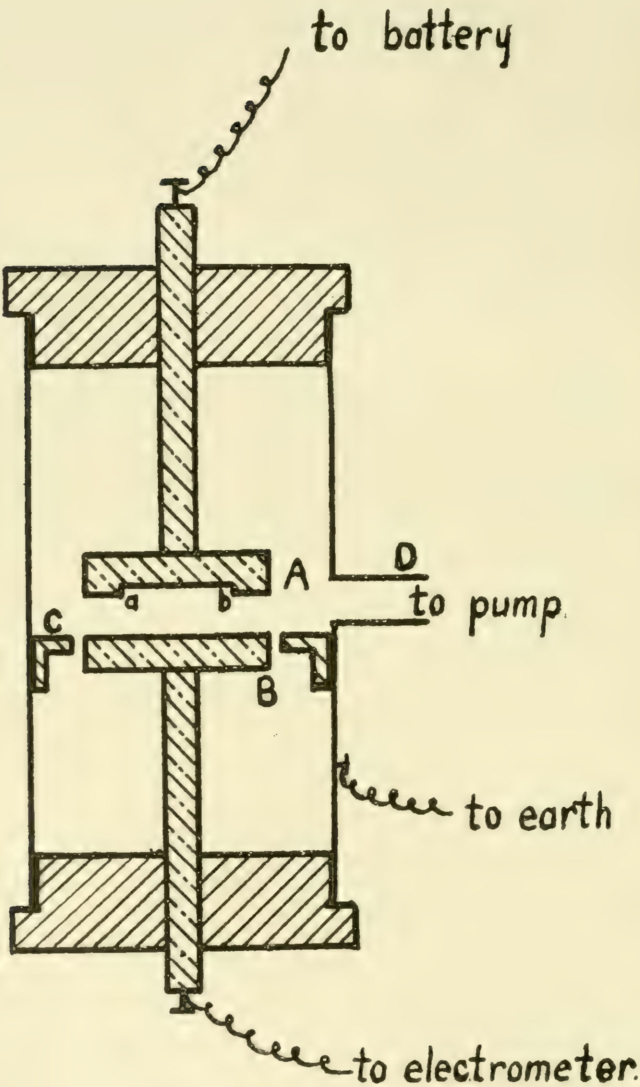



FIGURE 1.

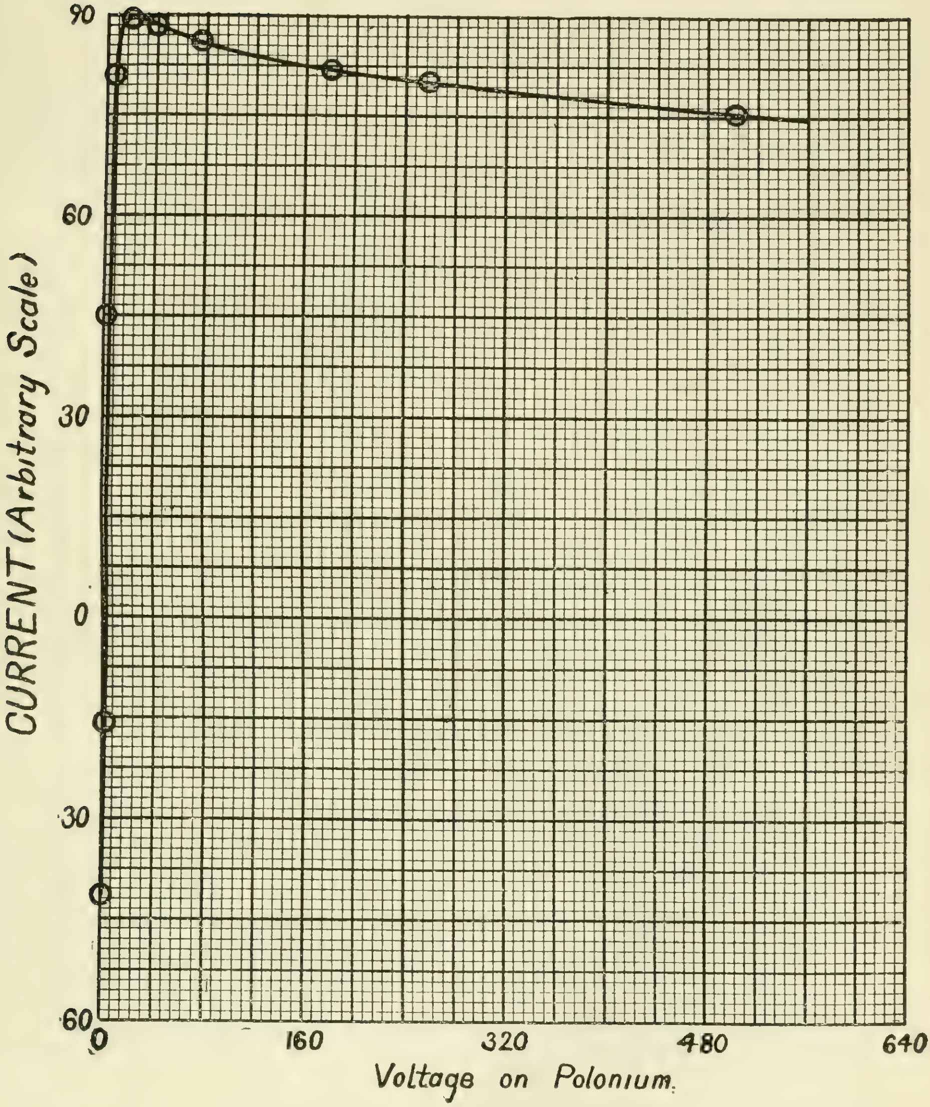

90
60
30
0
30
60
0
160
320
480
640
CURRENT (Arbitrary Scale)
Voltage on Polonium.

FIGURE 2.

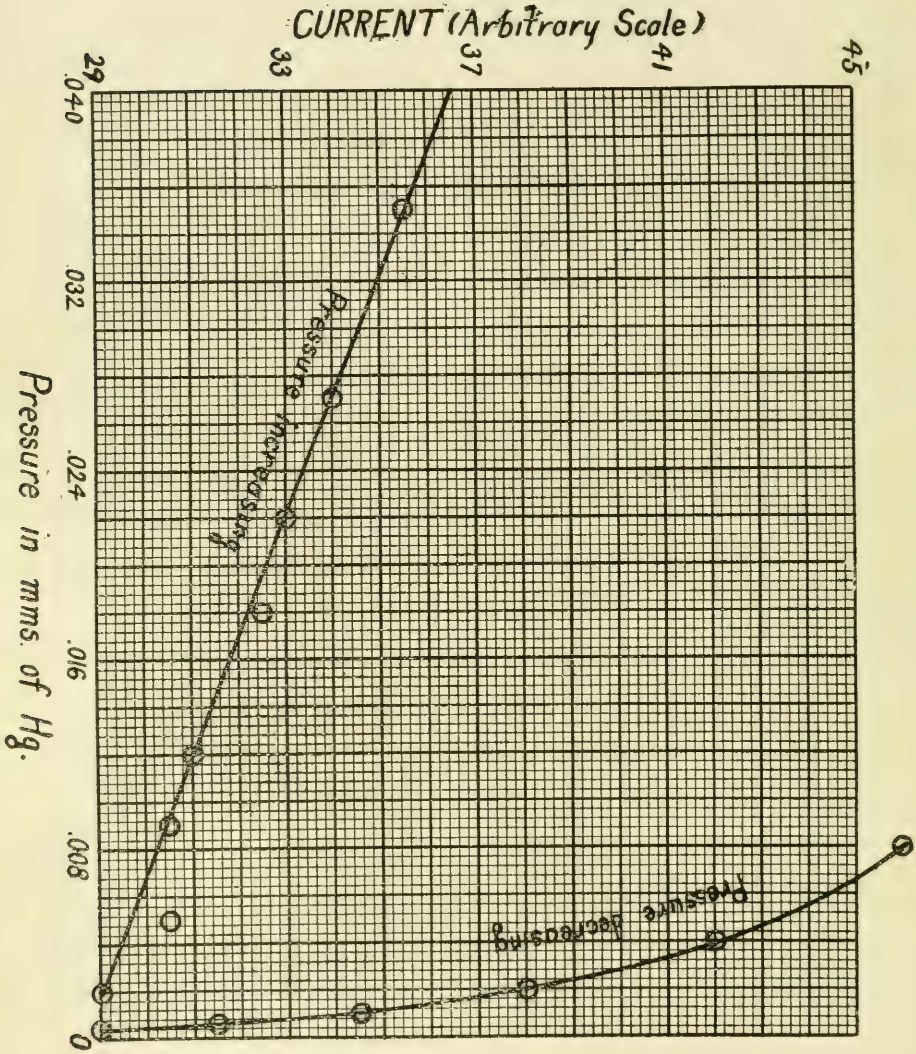

CURRENT (Arbitrary Scale)
29
33
37
41
45
.040
.032
.024
.016
.008
0
Pressure in mms. of Hg.
Pressure increasing
Pressure decreasing

FIGURE 3.

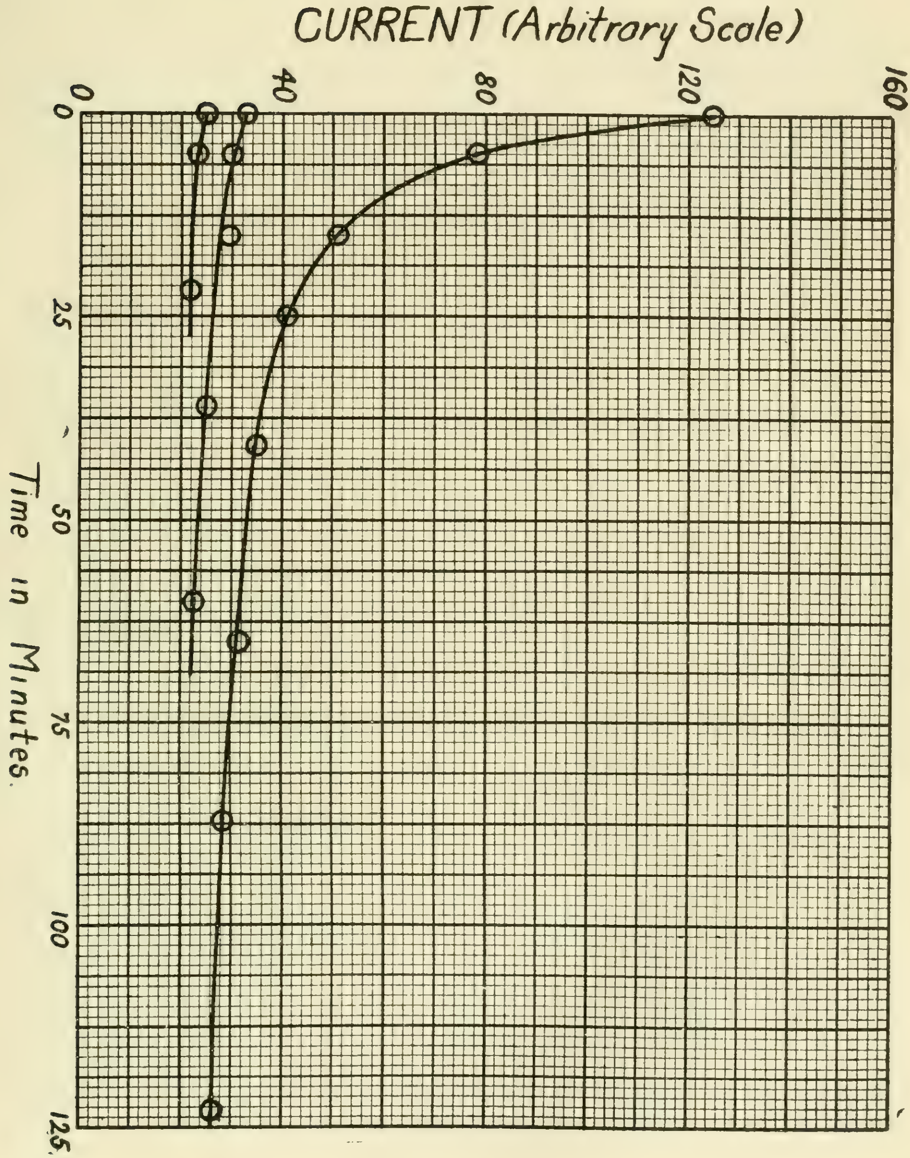

CURRENT (Arbitrary Scale)
0
40
80
120
160
0
25
50
75
100
125
Time in Minutes.

FIGURE 4.

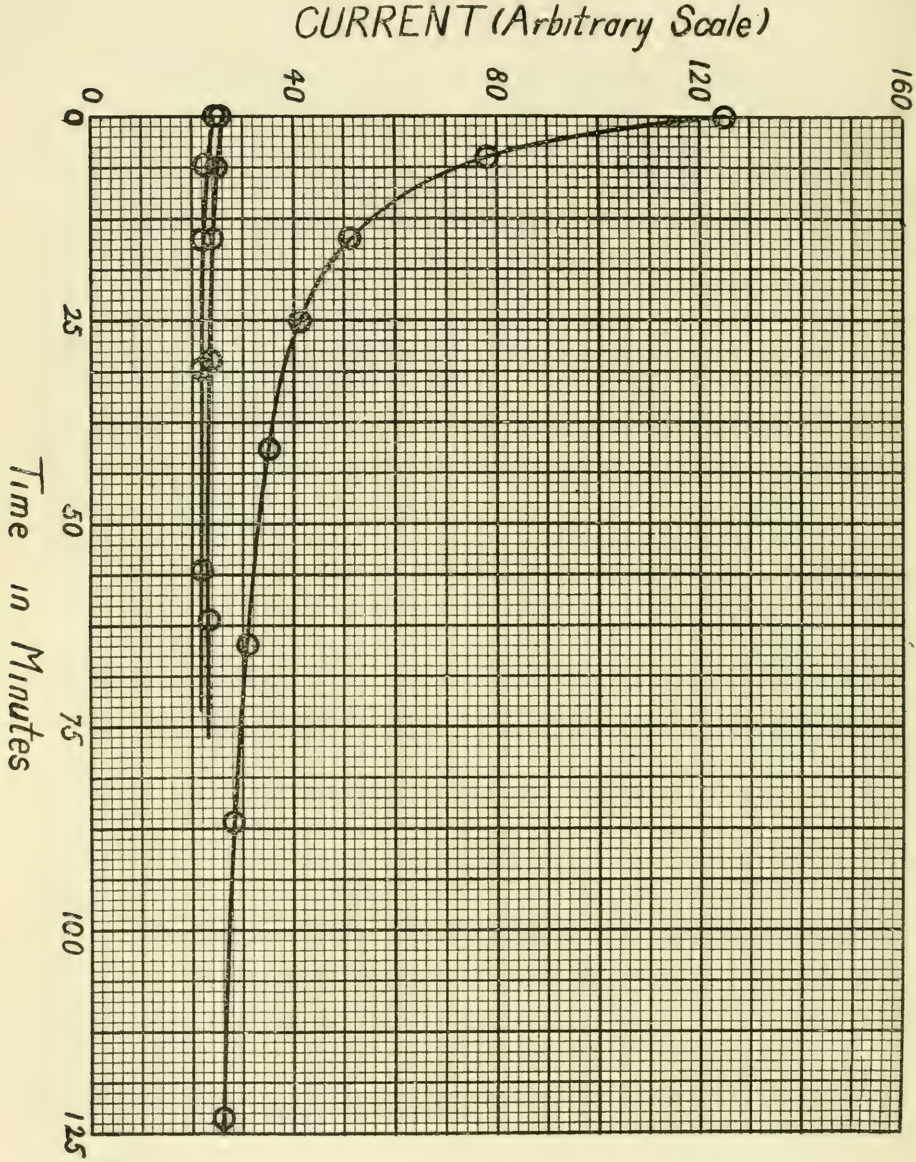

CURRENT (Arbitrary Scale)
0
40
80
120
160
0
25
50
75
100
125
Time in Minutes

FIGURE 5.

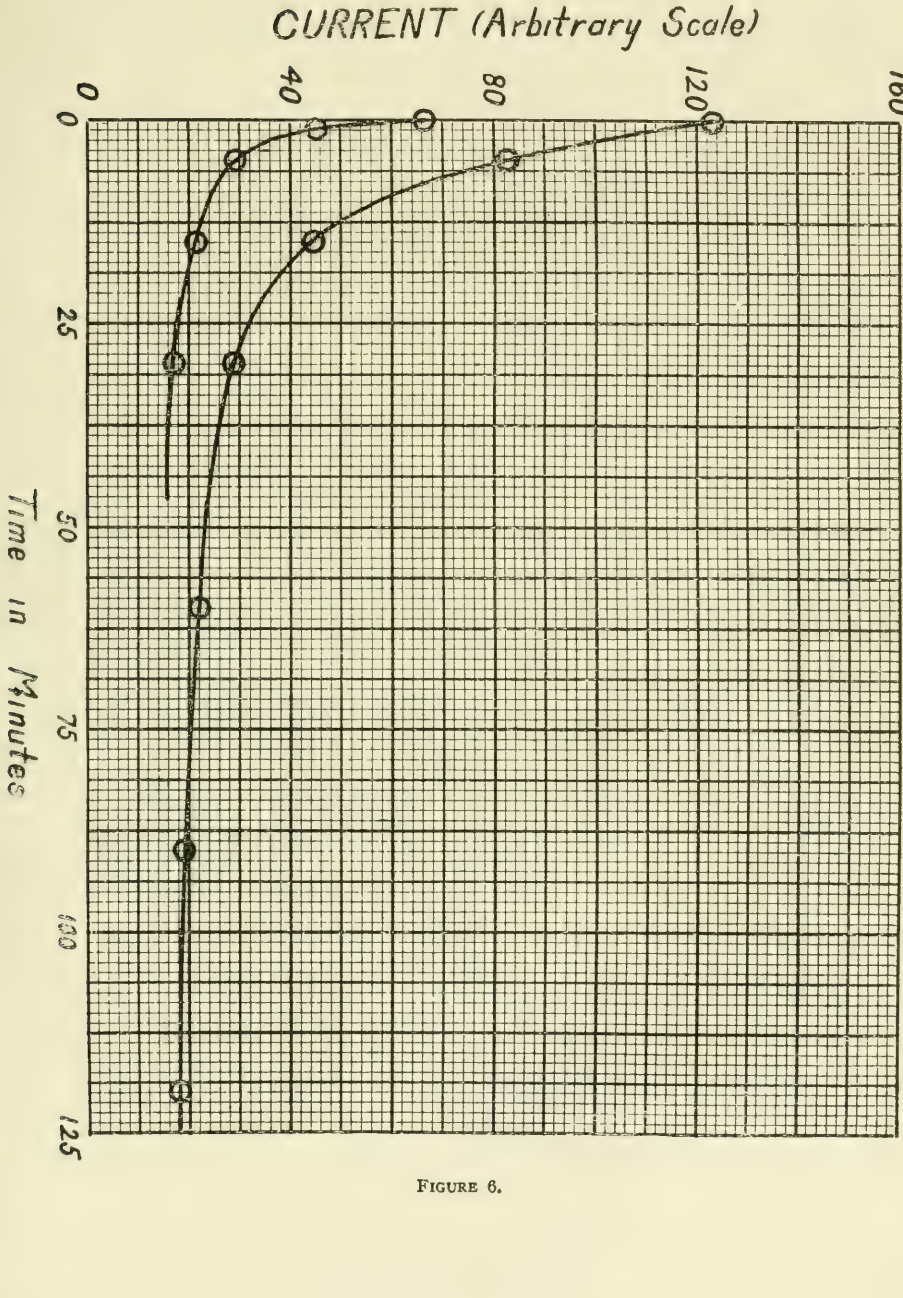

CURRENT (Arbitrary Scale)
0
40
80
120
160
0
25
50
75
100
125
Time in Minutes

FIGURE 6.

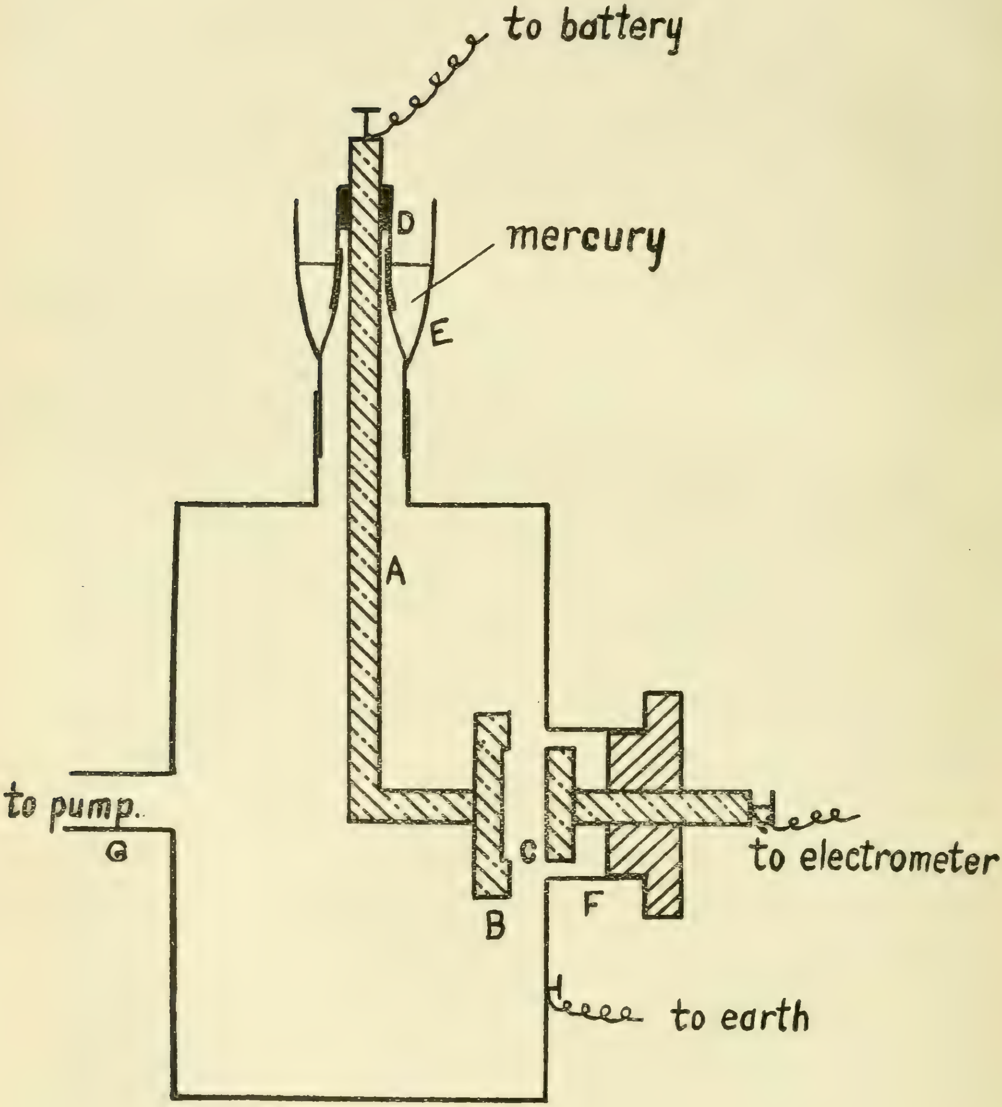

to battery
D
mercury
E
A
to pump.
G
C
B
F
to electrometer
to earth

FIGURE 7.

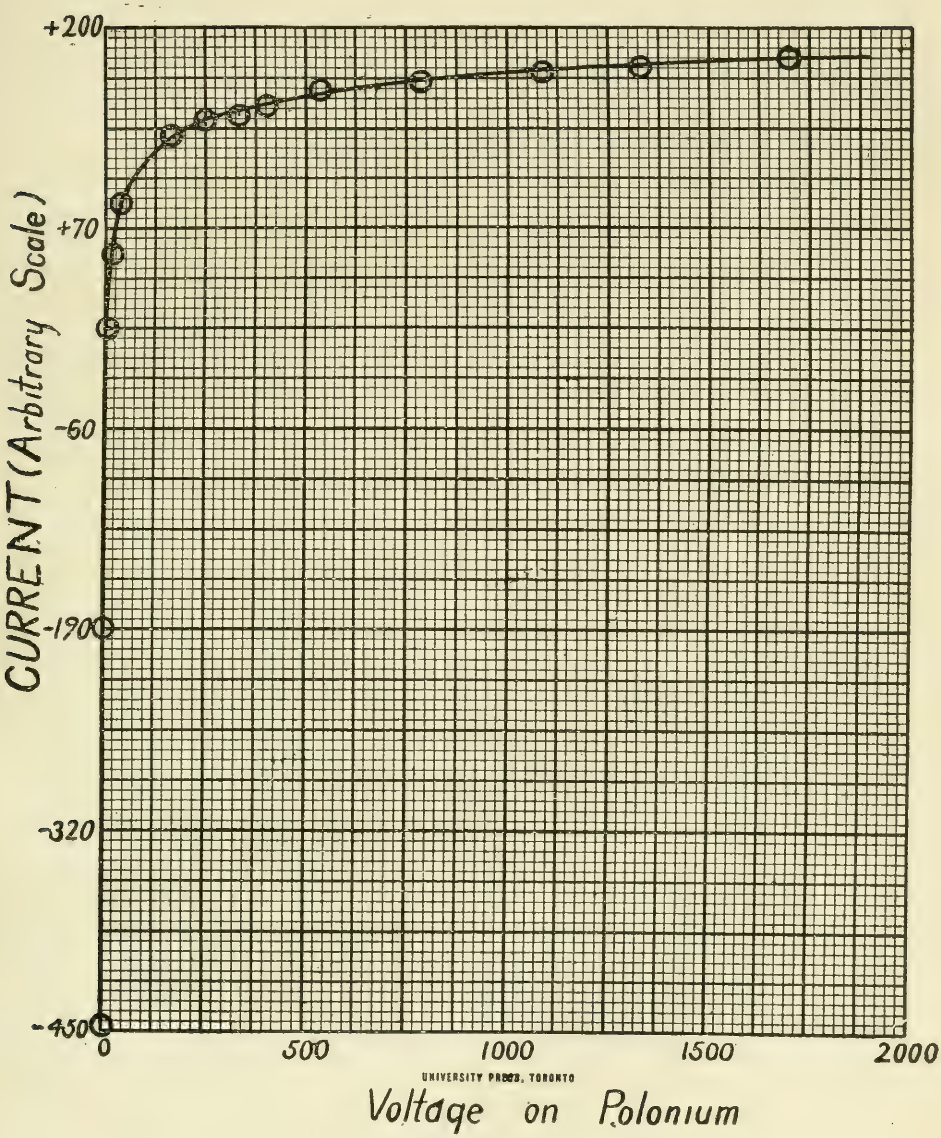

+200
+70
-60
-190
-320
-450
0
500
1000
1500
2000
CURRENT (Arbitrary Scale)
UNIVERSITY PRESS, TORONTO
Voltage on Polonium

Figure 8.

# ON THE SECONDARY RAYS EXCITED BY THE ALPHA RAYS FROM POLONIUM—II.

(*Read 13th January, 1912*).

BY V. E. POUND, M.A.*

## I.—INTRODUCTION.

In a previous paper by the writer*[1] it has been shewn that when the $\alpha$ rays of polonium strike a carbon or a brass plate, secondary rays are produced which are similar to the $\delta$ rays of polonium. It has been shewn, too, that a very considerable part of this secondary radiation is due to the presence of gas occluded at or deposited on the surface of the brass or carbon plate. The present paper describes some further experiments on the influence of this gaseous layer on the secondary radiation excited in different substances when these are subjected to bombardment by the $\alpha$ rays of polonium.

## II.—DESCRIPTION OF APPARATUS.

The apparatus used for the investigation was composed of a brass tube A about 3 cm. in diameter and 18 cm. long, one end of which was closed air tight by an ebonite plug sealed in with wax. Centrally through this plug was led a brass rod, B, carrying a brass plate C upon which a thin circular piece of polonium coated brass about 1.5 cm. in diameter was fixed. A brass ring D passed through the ebonite and connected to earth served as a guard ring. At the other end of the tube A, a smaller tube E, 1.5 cm. in diameter was inserted and soldered in position at the top so as to be co-axial with the former. In this way the space between the tubes A and E was made air tight. The lower end of the tube E was closed by means of a very thin brass sheet and a flat circular plate K of carbon or metal was held against this thin brass sheet by means of a flanged collar F provided with a screw. The distance between the polonium and the lower face of the carbon or brass plate was .6 cm. The whole apparatus was connected by a tube G to a Gaede pump and a McLeod gauge. The apparatus was insulated by mica and supported in such a way that the polonium and the circular plate

*Presented by Prof. J. C. McLennan.
*[1]Trans. Canadian Institute, 1912.
Phil. Mag. 1912.

opposite the polonium were symmetrically placed between the poles of a powerful electromagnet. The circular plate held at F could be altered in temperature by liquid air or some other liquid of constant temperature in the tube E. The polonium was connected by means of the brass rod B and a screened connecting wire to an electrometer of moderate sensibility.

## III.—EXPERIMENTS WITH CARBON AT DIFFERENT TEMPERATURES.

The method of conducting the experiments was as follows. The carbon plate K was charged to a negative potential of about 80 volts by connecting the outer part of the apparatus to a battery. This high negative potential on the carbon was sufficient to prevent any $\delta$ rays from leaving the polonium. The Gaede pump was set exhausting the gas from the apparatus and seven minutes after the pump was started the pressure of the gas was read by a McLeod Gauge and the rate of charging of the polonium was measured by the electrometer. The charge which came to the polonium was negative and consisted of a current of $\alpha$ rays leaving the polonium, a current of secondary rays coming from the carbon to the polonium excited by the $\alpha$ ray bombardment on the carbon, and an ionisation current through the remaining gas in the chamber. Readings of the charge which accrued on the polonium plate were made at definite intervals of time afterwards until the rate of charging of the plate became fairly constant. This constant value as shewn in the previous paper* was reached when the density of the layer of gas occluded in the surface of the carbon was in equilibrium with the pressure of gas in the vessel, that is, when there was no readjustment going on in the gaseous layer. After the rate of charging of the polonium had become fairly constant a weak magnetic field was established by passing a small current through the electromagnet, and the rate of charging of the polonium was again found. Then larger and larger currents were sent through the electromagnet and readings were taken until the rate of charging of the polonium became constant. This last constant charge which came to the polonium was composed of the $\alpha$ ray current leaving the polonium and the ionisation current through the gas. The magnetic field was used to deflect the slow moving secondary rays coming from the carbon and the constant rate of charging of the polonium denoted that the magnetic field had deflected them all. The influence of the magnetic field in deflecting the $\alpha$ rays or the ionisation current through the gas was probably very small. Accordingly the difference between the first constant value of the rate of charging of the polonium and the last constant value was a

*Trans. Canadian Institute, 1912.
Phil. Mag. 1912.

measure of the magnitude of the secondary ray current from the carbon excited by the $\alpha$ ray bombardment.

In the following tables the results obtained with air filled carbon, first at a temperature of 110° C, second at room temperature, third at a temperature given by a mixture of solid carbonic acid gas and ether, namely, −78° C, and lastly at liquid air temperature, −192° C are given. After each experiment air was allowed to remain in the apparatus at atmospheric pressure until the next experiment. Before beginning the set of experiments a piece of carbon, the surface of which was freshly cut and which had never before been exposed to $\alpha$ rays was placed in the apparatus. For comparison all the readings were reduced to the same date by the use of the standard equation,

$$I = I_0 e^{-\lambda t}$$

the half decay period of the polonium being taken as 140 days.*

TABLE I.—AIR IN APPARATUS.

Carbon electrode at temperature 110°C. Charge on carbon = −83 volts.

| Pressure of air in vessel. | Time from initial reading taken 7 min. after starting pump. | Current through magnet. | Current to Polonium. |
|---|---|---|---|
| .02 mm. | 0 min. | 0 amp. | −203 |
| .007 " | 5 " | 0 " | −185 |
| .007 " | 15 " | 0 " | −173 |
| .004 " | 30 " | 0 " | −169 |
| .003 " | 45 " | 0 " | −162 |
| .006 " | 60 " | 0 " | −166 |
| .003 " | 68 " | 0 " | −162.5 |
| .005 " | 90 " | 0 " | −162 |
| .004 " | .. | 1 " | − 98 |
| .002 " | .. | 6 " | − 41 |
| .002 " | .. | 15 " | − 39.2 |
| .002 " | .. | 23.5 " | − 37.8 |

*See Physical and Chemical Constants by Kaye and Laby, page 107.

TABLE II.—AIR IN APPARATUS.

Carbon electrode at temp. 23° C. Charge on Carbon = –83 volts.

| Pressure of air in vessel. | Time from initial reading taken 7 mins. after starting pump. | Current through magnet | Current to polonium |
|---|---|---|---|
| .02 mm. | 0 min. | 0 amp. | –254 |
| .006 " | 5 " | 0 " | –209.5 |
| .003 " | 15 " | 0 " | –180 |
| .003 " | 30 " | 0 " | –165 |
| .002 " | 45 " | 0 " | –158 |
| .002 " | 60 " | 0 " | –158 |
| .002 " | .. | 1 " | – 57.8 |
| .002 " | .. | 5.5 " | – 38 |
| .002 " | .. | 12 " | – 37.4 |
| .002 " | .. | 18.5 " | – 37.4 |
| .002 " | .. | 26 " | – 37.4 |

TABLE III.—AIR IN APPARATUS.

Carbon electrode at temp. –78° C. Charge on carbon = –84 volts.

| Pressure of air in vessel. | Time from initial reading taken 7 mins. after starting pump. | Current through magnet | Current to polonium. |
|---|---|---|---|
| .02 mm. | 0 min. | 0 amp. | –161.5 |
| .004 " | 5 " | 0 " | –157.7 |
| .003 " | 15 " | 0 " | –159.2 |
| .001 " | 30 " | 0 " | –161.5 |
| .001 " | 45 " | 0 " | –165 |
| .001 " | 70 " | 0 " | –172 |
| .001 " | 90 " | 0 " | –176 |
| less than .001 " | 105 " | 0 " | –178 |
| " .001 " | 140 " | 0 " | –182 |
| " .001 " | 155 " | 0 " | –184 |
| " .001 " | ... | 1 " | – 36.5 |
| " .001 " | ... | 6 " | – 35 |
| " .001 " | ... | 11 " | – 35 |
| " .001 " | ... | 17.5 " | – 33 |
| " .001 " | ... | 24 " | – 35 |

TABLE IV.—AIR IN APPARATUS.

Carbon electrode at temp. −192° C. Charge on Carbon = −84 volts.

| Pressure of air in vessel. | Time from initial reading taken 7 mins. after starting pump. | Current through magnet. | Current to polonium. |
|---|---|---|---|
| .03 mm. | 0 min. | 0 amp. | −269 |
| .009 " | 5 " | 0 " | −245 |
| .004 " | 15 " | 0 " | −246 |
| .004 " | 25 " | 0 " | −245 |
| .002 " | 40 " | 0 " | −249 |
| .002 " | 55 " | 0 " | −252 |
| .002 " | 70 " | 0 " | −253.8 |
| .001 " | 85 " | 0 " | −256 |
| .001 " | 100 " | 0 " | −262 |
| .001 " | 118 " | 0 " | −262 |
| .001 " | ... | 1 " | − 37 |
| .001 " | ... | 5.5 " | − 35 |
| .001 " | ... | 11 " | − 34 |
| .001 " | ... | 16.5 " | − 34 |
| .001 " | ... | 24.5 " | − 34.4 |

The results given in these tables are plotted in Figures (1), (2), (3) and (4). The curve drawn on the first half of each figure shews the way the rate of charging of the polonium decreased or increased with the time until it became approximately constant. The curve drawn on the remaining half of the figure shews the way the rate of charging of the polonium decreased to a constant value as the magnetic field was gradually increased from zero upwards. The curves drawn on the first half of Fig. (3) and of Fig. (4) shew a remarkable difference from the corresponding curves in Figures (1) and (2). The curves of Figures (1) and (2) drop gradually with the time and come to a constant value while the curves of Figures (3) and (4) first decrease and then increase to an approximately constant value. The only difference in the conditions under which the experiments were made was a difference in the temperature of the carbon. When the carbon was at room temperature or at a temperature of 110° C, the rate of charging of the polonium decreased with the time before becoming constant while when the carbon was at −78° C or at -192° C the rate of charging decreased slightly and then increased. The cause of this difference is readily seen when it is remembered that carbon occludes more air at a low temperature than at a high and that the α rays excite secondary in the air layer on the surface of the carbon as well as in the carbon itself.* When the temperature of the carbon is high the air readily comes away from the surface of the carbon and hence the secondary radiation decreases. When the temperature of the carbon is low the air does not come away but becomes denser and denser at the surface of the carbon as it oozes out of the interior and also as it comes out of the cooled brass walls of the apparatus. (It will be shewn later that air is expelled from brass as it is cooled.) Therefore instead of a decrease there is set up a gradual increase in the secondary radiation as the air layer becomes denser.

The final value of the secondary radiation from the carbon and the air layer at its surface was obtained in each case by taking the difference between the constant rates of charging of the polonium without and with the applied magnetic field. In the following table the values of the secondary radiation with the carbon at the several different temperatures are set down.

TABLE V.—FRESH CARBON IN AIR.
Secondary radiation from Carbon and Air Layer.

| Temperature of Carbon... | 110°C | 23°C | −78°C | −192°C |
|---|---|---|---|---|
| Secondary Radiation..... | −124.5 | −120.6 | −151 | −228 |

It will be seen from the table that when the carbon was at the temperature of 23° C the secondary radiation excited by the α rays was -120.6 and when the carbon was at 110° C the secondary radiation was -124.5. These numbers are very nearly the same and accounting for their difference by experimental error, they shew that the amount of α ray excited secondary radiation from carbon was the same when the carbon was at 23° C as when it was at 110° C. Since this secondary radiation most probably comes from both the carbon and its air layer, the coincident values of the secondary radiation from carbon at the two temperatures would indicate that the density of the gaseous layer at the surface of the carbon was the same at the two temperatures. When the carbon was at −78° C however, the secondary radiation from it amounted to -151 i.e., an increase of about 24% over the value of the secondary radiation when the carbon was at room temperature. Again when the carbon was at −192° C the secondary radiation was −228 or an increase of 87% above the value at room temperature. These large

*V. E. Pound, Trans. Canadian Institute, 1912.
Phil. Mag. 1912.

increases in the secondary radiation when the carbon was at the lower temperatures are readily accounted for by the increase in the secondary radiation from the gaseous air layer at the surface of the carbon which increases in density as the temperature is lowered.

In order to find out whether this same effect would occur when the carbon was in other gases than air, experiments were also tried with oxygen and hydrogen. A fresh piece of carbon was used for each gas. The air which was occluded in the fresh piece of carbon on account of its being in an atmosphere of air was got rid of by putting the carbon in the apparatus and exhausting and leaving it for a long time. The apparatus was then filled with the gas which was to be experimented upon and left for some time in order that the carbon might take up the new gas as much as possible. After this the carbon was cooled or heated to the desired temperature, the gas was pumped from the apparatus and a series of readings was taken, in the manner indicated above, of the rate of charging of the polonium both with and without the magnetic field. The same characteristic results were obtained with these gases at the different temperatures as with the air. The readings taken with the carbon at temperatures 115° C, 23° C, -78° C and -192° C in an atmosphere of oxygen are given in Tables VI, VII, VIII and IX below and the readings taken with the carbon at temperatures 24° C and -192° C in an atmosphere of hydrogen are given in Tables X and XI.

TABLE VI.—OXYGEN IN APPARATUS,

Carbon electrode at temp. 115° C. Charge on carbon = –84 volts

| | Pressure of air in vessel | Time from initial reading 7 mins. after starting pump | Current through magnet | Current to polonium |
|---|---|---|---|---|
| | .05 mm. | 0 min. | 0 amp. | –219.5 |
| | .012 " | 5 " | 0 " | –199.5 |
| | .008 " | 15 " | 0 " | –189.5 |
| | .005 " | 25 " | 0 " | –182 |
| | .003 " | 102 " | 0 " | –157 |
| | .001 " | 114 " | 0 " | –157 |
| less than | .001 " | 130 " | 0 " | –158 |
| " | .001 " | 133 " | 0 " | –158 |
| " | .001 " | ... | 1 " | – 42 |
| " | .001 " | ... | 9 " | – 34.5 |
| " | .001 " | ... | 15 " | – 32.8 |
| " | .001 " | ... | 23.5 " | – 32.8 |

TABLE VII.— OXYGEN IN APPARATUS.

Carbon Electrode at Temp. 23° C. Charge on Carbon = –84 volts.

| Pressure of air in vessel | Time from initial reading 7 min. after starting pump | Current through magnet | Current to polonium |
|---|---|---|---|
| .06 mm. | 0 min. | 0 amp. | –184 |
| .015 " | 5 " | 0 " | –175 |
| .006 " | 15 " | 0 " | –159 |
| .003 " | 30 " | 0 " | –156 |
| .003 " | 40 " | 0 " | –156 |
| .001 " | 55 " | 0 " | –155 |
| .001 " | 70 " | 0 " | –155 |
| .001 " | 86 " | 0 " | –155 |
| .001 " | .. | 1 " | – 38 |
| .001 " | .. | 5.5 " | – 34 |
| .001 " | .. | 12 " | – 34 |
| .001 " | .. | 20 " | – 32 |
| .001 " | .. | 25 " | – 34 |

TABLE VIII.—OXYGEN IN APPARATUS.

Carbon electrode at Temp. –78° C. Charge on carbon = –83 volts.

| Pressure of air in apparatus | Time from initial reading 7 minutes after starting pump | Current through magnet | Current to polonium |
|---|---|---|---|
| .045 mm. | 0 min. | 0 amp. | –206.5 |
| .011 " | 5 " | 0 " | –190 |
| .005 " | 15 " | 0 " | –187 |
| .003 " | 30 " | 0 " | –185.5 |
| .003 " | 45 " | 0 " | –188 |
| .003 " | 60 " | 0 " | –187 |
| .002 " | 75 " | 0 " | –188 |
| .002 " | 90 " | 0 " | –190 |
| .002 " | 128 " | 0 " | –193.5 |
| .002 " | 132 " | 0 " | –193.5 |
| .002 " | ... | 1 " | – 36.2 |
| .002 " | ... | 12 " | – 34.2 |
| .002 " | ... | 18 " | – 34.2 |
| .002 " | ... | 25 " | – 33.4 |

TABLE IX.—OXYGEN IN APPARATUS.

Carbon electrode at Temp. -192° C. Charge on carbon = -84 volts.

| Pressure of air in apparatus | Time from initial reading 7 minutes after starting pump | Current through magnet | Current to polonium |
|---|---|---|---|
| .08 mm. | 0 min. | 0 amp. | -277 |
| .012 " | 5 " | 0 " | -237 |
| .006 " | 15 " | 0 " | -224.5 |
| .004 " | 30 " | 0 " | -224.5 |
| .004 " | 45 " | 0 " | -229 |
| .003 " | 60 " | 0 " | -224.5 |
| .003 " | 75 " | 0 " | -227.5 |
| .003 " | 90 " | 0 " | -225 |
| .003 " | .. | 1 " | - 35.5 |
| .003 " | .. | 5 " | - 33.4 |
| .002 " | .. | 13 " | - 32.6 |
| .003 " | .. | 19 " | - 33.4 |
| .002 " | .. | 24.5 " | - 33.4 |

TABLE X.—HYDROGEN IN APPARATUS.

Carbon Electrode at Temp. 24° C. Charge on Carbon = -84 volts.

| Pressure of air in apparatus | Time from initial reading 7 minutes after starting pump | Current through magnet | Current to polonium |
|---|---|---|---|
| .006 mm. | 0 min. | 0 amp. | -429.5 |
| .002 " | 10 " | 0 " | -230.5 |
| .001 " | 20 " | 0 " | -205 |
| less than .001 " | 40 " | 0 " | -202 |
| " .001 " | 60 " | 0 " | -196 |
| " .001 " | 90 " | 0 " | -194 |
| " .001 " | .. | 1.5 " | - 66 |
| " .001 " | .. | 4.5 " | - 47.5 |
| " .001 " | .. | 9 " | - 48.5 |
| " .001 " | .. | 18 " | - 49 |
| " .001 " | .. | 24.5 " | - 47 |

TABLE XI.—HYDROGEN IN APPARATUS.

Carbon electrode at Temp. −192° C. Charge on carbon = −84 volts.

| Pressure of air in apparatus | Time from initial reading 7 minutes after starting pump | Current through magnet | Current to polonium |
|---|---|---|---|
| .015 mm. | 0 min. | 0 amp. | −256 |
| .004 " | 5 " | 0 " | −212 |
| .002 " | 22 " | 0 " | −213 |
| .001 " | 29 " | 0 " | −227.5 |
| .001 " | 39 " | 0 " | −238 |
| less than .001 " | 52 " | 0 " | −242 |
| " .001 " | 65 " | 0 " | −254 |
| " .001 " | 80 " | 0 " | −249 |
| " .001 " | 95 " | 0 " | −266 |
| " .001 " | 115 " | 0 " | −272 |
| " .001 " | 130 " | 0 " | −273 |
| " .001 " | ... | 1.5 " | − 39.6 |
| " .001 " | ... | 4 " | − 37.5 |
| " .001 " | ... | 9.5 " | − 36.8 |
| " .001 " | ... | 15.5 " | − 36.8 |
| " .001 " | ... | 25 " | − 36.2 |

From these results the values of the secondary radiation from the carbon at different temperatures in oxygen and in hydrogen were deduced as with the air, by taking the difference between the final rates of charging of the polonium without and with the magnetic field applied. These are given in Tables XII. and XIII.

TABLE XII.—FRESH CARBON IN OXYGEN

Secondary Radiation from Carbon and Oxygen Layer.

| Temperature of Carbon... | 115° | 23° | −78° | −192° |
|---|---|---|---|---|
| Secondary Radiation..... | −124.7 | −121.5 | −160 | −193 |

TABLE XIII.—FRESH CARBON IN HYDROGEN.

Secondary Radiation from Carbon and Hydrogen Layer.

| Temperature of Carbon... | 24° C | −192° C |
|---|---|---|
| Secondary Radiation..... | −147 | −236 |

Here again we find that both with oxygen and with hydrogen the results shew that the secondary radiation was much greater when the carbon was at a low temperature than when it was maintained at a higher temperature.

From the foregoing it is clear that this modification of the intensity of the secondary radiation is attributable as in the case of air to an increase in the amount of gaseous oxygen and hydrogen occluded in the surface of the carbon by a reduction of the temperature.

From the experiments just described it follows that the amount of secondary radiation obtained from an electrode under bombardment by $\alpha$ rays may be taken as a measure of the density of the gaseous layer at the surface of the electrode when the latter is placed in a gas at a very low pressure. If there were no difference in the secondary radiation from a substance at different temperatures under the conditions mentioned it would indicate either that there was no gaseous layer at the surface of the substance bombarded, or else that the density of the gaseous layer adhering to it was the same at all temperatures. In the following section an experiment is described which makes use of this conclusion.

## IV.—EXPERIMENTS WITH BRASS.

A peculiar effect was observed during the course of all the experiments, namely, that it took a longer time to reduce the pressure of the gas in the apparatus to a low value when the walls of the vessel were cooled with liquid air, than when the walls were at ordinary room temperature. At first this effect was supposed to be due to some leak in the apparatus and the vessel was removed and carefully tested under pressure for small holes or porous places in the brass. But invariably it was found that no such holes or porous places could be discovered. It was also found that when the apparatus was put back and exhausted at ordinary temperatures the pressure was reduced with the same speed as before the apparatus was cooled with liquid air. There seemed, therefore, to be no leak of air through the walls of the apparatus and the only other explanation that could be offered was that a gas came from the walls of the brass vessel at liquid air temperature which did not come at room temperature. If this were the case there would be less gas in the brass at low temperature than at high, and the method indicated in the previous section of studying the gaseous layer at the surface of a substance by the quantity of secondary rays coming from it could be used to test the above explanation. Accordingly a brass plate was placed at K instead of a carbon one and the amount of $\alpha$ ray excited secondary radiation from the brass plate was determined when it was at room temperature, and when it was at the temperature of liquid air. The series of readings taken are given in Tables XIV and XV. In order that the brass when at room temperature might be as free of air as possible the pump was made to exhaust the air from the apparatus for three hours continuously before a reading was taken of the rate of charging of the polonium.

TABLE XIV.—AIR IN APPARATUS.

Brass electrode at Temp. 20° C. Charge on brass = −81 volts.

| Pressure of air in apparatus | Time from initial reading 3 hours after starting pump | Current through magnet | Current to polonium |
|---|---|---|---|
| less than .001 mm. | 0 min. | 0 amp. | −238.5 |
| " .001 " | 5 " | 0 " | −237 |
| " .001 " | 15 " | 0 " | −238.5 |
| " .001 " | .. | 1 " | − 40.5 |
| " .001 " | .. | 10 " | − 34.5 |
| " .001 " | .. | 17 " | − 34 |
| " .001 " | .. | 22 " | − 34.5 |

It will be seen from the above table that at the end of three hours constant pumping by the Gaede pump the pressure of the air in the apparatus had fallen very low and that the rate of charging of the polonium had become constant before the magnetic field was applied.

Immediately after the readings on the rate of charging of the polonium with increasing magnetic fields were taken, another reading was taken of the rate of charging of the polonium without the magnetic field. After this the brass plate was cooled by pouring liquid air in the tube E, and the readings on the rate of charging of the polonium were continued once more.

TABLE XV.—AIR IN APPARATUS.

Brass Electrode. Charge on Brass = −81 volts.

| Pressure of air in apparatus | Time from initial reading of Table XIV | Current through magnet | Current to polonium |
|---|---|---|---|
| Less than .001 mm. | 28 min. | 0 amp. | −238.5 |
| COOLED BRASS WITH LIQUID AIR. | | | |
| .003 mm. | 35 min. | 0 amp. | −235.5 |
| .005 " | 40 " | 0 " | −227 |
| .005 " | 50 " | 0 " | −217 |
| .005 " | 65 " | 0 " | −214 |
| .004 " | 80 " | 0 " | −210.5 |
| .004 " | 95 " | 0 " | −210.5 |
| .004 " | 110 " | 0 " | −210.5 |
| .003 " | 140 " | 0 " | −209 |
| .003 " | 170 " | 0 " | −210.5 |
| .003 " | ... | 1 " | − 42.5 |
| .003 " | ... | 9.5 " | − 35.6 |
| .003 " | ... | 16 " | − 35.6 |
| .003 " | ... | 21.5 " | − 36.5 |

From the numbers given in the table it will be seen that immediately after the brass began to cool down to the temperature of the liquid air the pressure in the apparatus rose slightly and then fell again as the pumping was continued. The rate at which the polonium charged up, however, steadily decreased as the brass plate cooled down. As the effect of a rise in pressure would be to increase the ionisation current in the chamber it follows from the occurrence of this decrease in the rate of charging of the polonium that the secondary radiation from the brass plate must have dropped off as its temperature lowered.

The values of the $\alpha$ ray excited secondary radiation from the brass plate at temperatures 20° C and -192° C as deduced from Tables XIV and XV are given in Table XVI.

TABLE XVI.—BRASS IN AIR.

Secondary Radiation from Brass and Air Layer.

| | | |
|---|---|---|
| Temperature of Brass.... | 20° C | –192° C |
| Secondary Radiation..... | –215 | –173 |

From these numbers it is evident that the secondary radiation from the brass at a temperature of 20° C was about 25% higher than it was under the same $\alpha$ ray bombardment at the temperature of liquid air.

If differences in $\alpha$ ray excited secondary radiation at low pressures be taken to connote differences in the quantities of gas occluded at the surface of the substance bombarded, the meaning of this smaller secondary radiation from the brass at liquid air temperature is that the brass held less gas in its surface at liquid air temperature than at the temperature of the room. This experiment therefore, strongly supports the explanation given above of the greater difficulty experienced in pumping the air from the brass chamber at -192° C than in making the same exhaustion when the apparatus was maintained at the temperature of the room.

## V.—SUMMARY OF RESULTS.

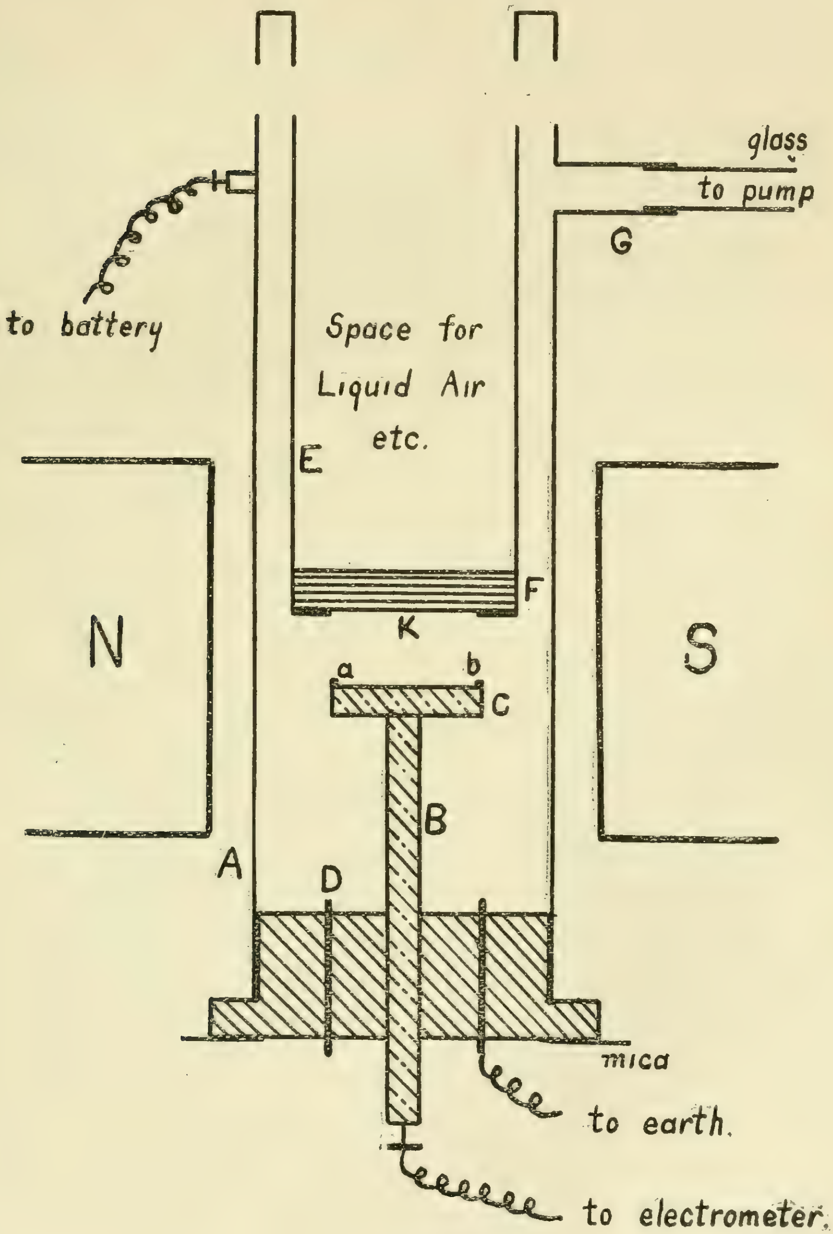
I. The secondary radiation excited by the $\alpha$ rays of polonium in carbon was found to increase in intensity as the temperature of the carbon was lowered from room temperature to the temperature of liquid air.

II. This increase in the secondary radiation from carbon as its temperature was lowered has been shewn to be due to an increase in the amount of gas occluded in the surface of the carbon.

III. Since it has been shewn that gases occluded in such substances as carbon contribute to the secondary radiation excited at the surface of these substances by $\alpha$ rays, it follows that the procedure adopted in this investigation constitutes a new method of studying the phenomena of occlusion.

IV. The results of the experiments described in this paper also go to shew that with a metal like brass the amount of a gas retained in its surface when it is placed in a vacuum is less at the temperature of liquid air than at ordinary room temperature.

In conclusion, I desire to thank Professor McLennan for the kindly interest he has shewn throughout the course of this research.



glass
to pump
G
to battery
Space for
Liquid Air
etc.
E
N
S
F
K
a
b
C
B
A
D
mica
to earth.
to electrometer.


FIGURE 1.

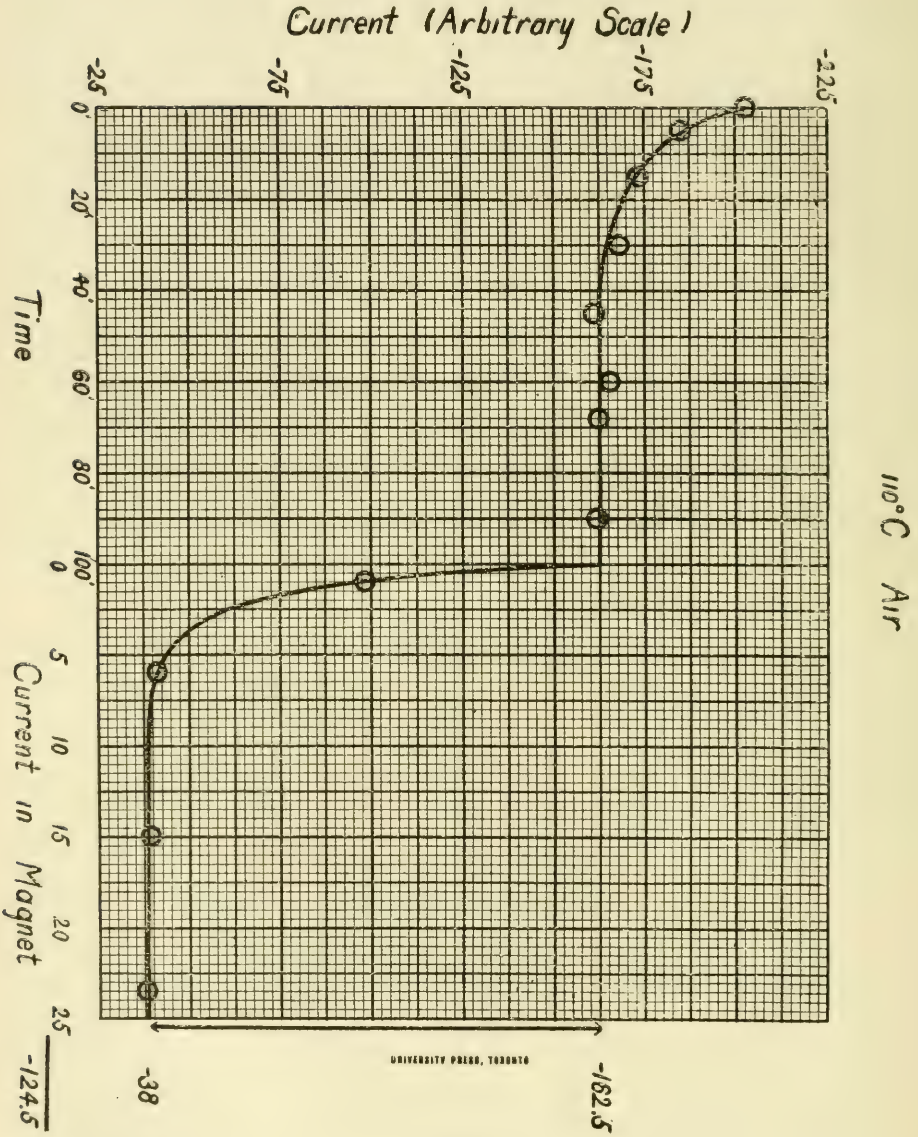
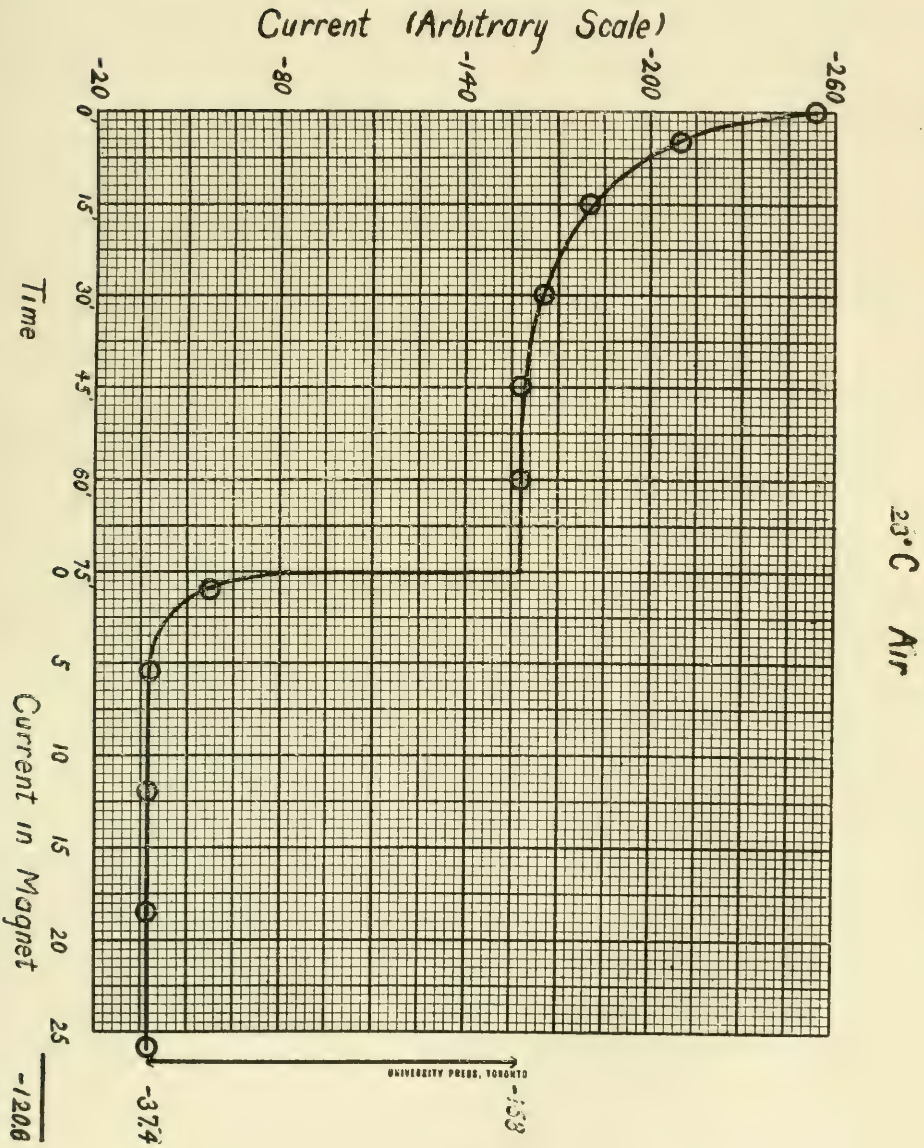

Current (Arbitrary Scale)
-25
-75
-125
-175
-225
0'
20'
40'
60'
80'
100'
Time
0
5
10
15
20
25
Current in Magnet
110°C Air
-38
-162.5
-124.5
UNIVERSITY PRESS, TORONTO

FIGURE 2.



Current (Arbitrary Scale)
-20
-80
-140
-200
-260
Time
0'
15'
30'
45'
60'
75'
0
5
10
15
20
25
Current in Magnet
-37.4
-153
-120.8
23°C Air
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FIGURE 3.

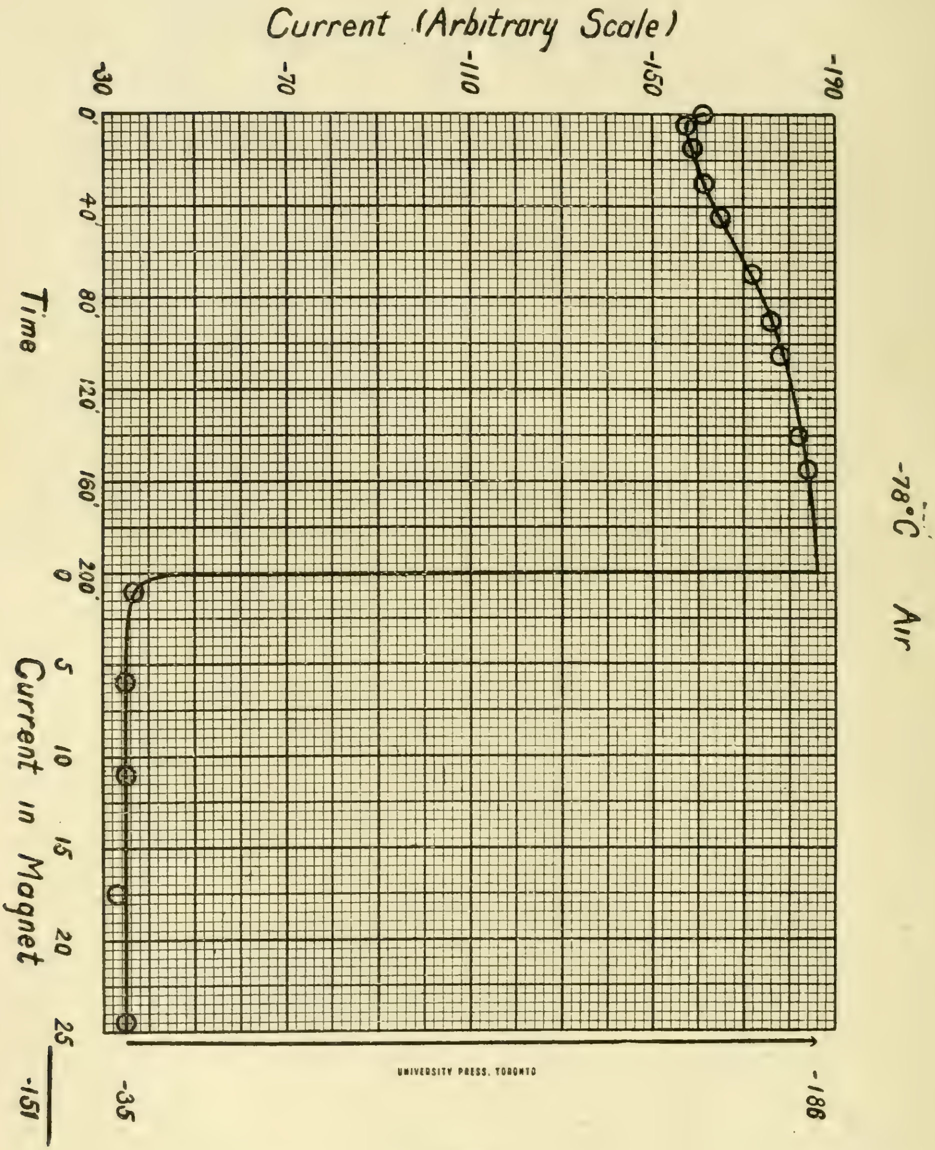
Current (Arbitrary Scale)
-30
-70
-110
-150
-190
Time
0'
40'
80'
120'
160'
200'
Current in Magnet
0
5
10
15
20
25
-151
-35
-186
-78°C
Air
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FIGURE 4.

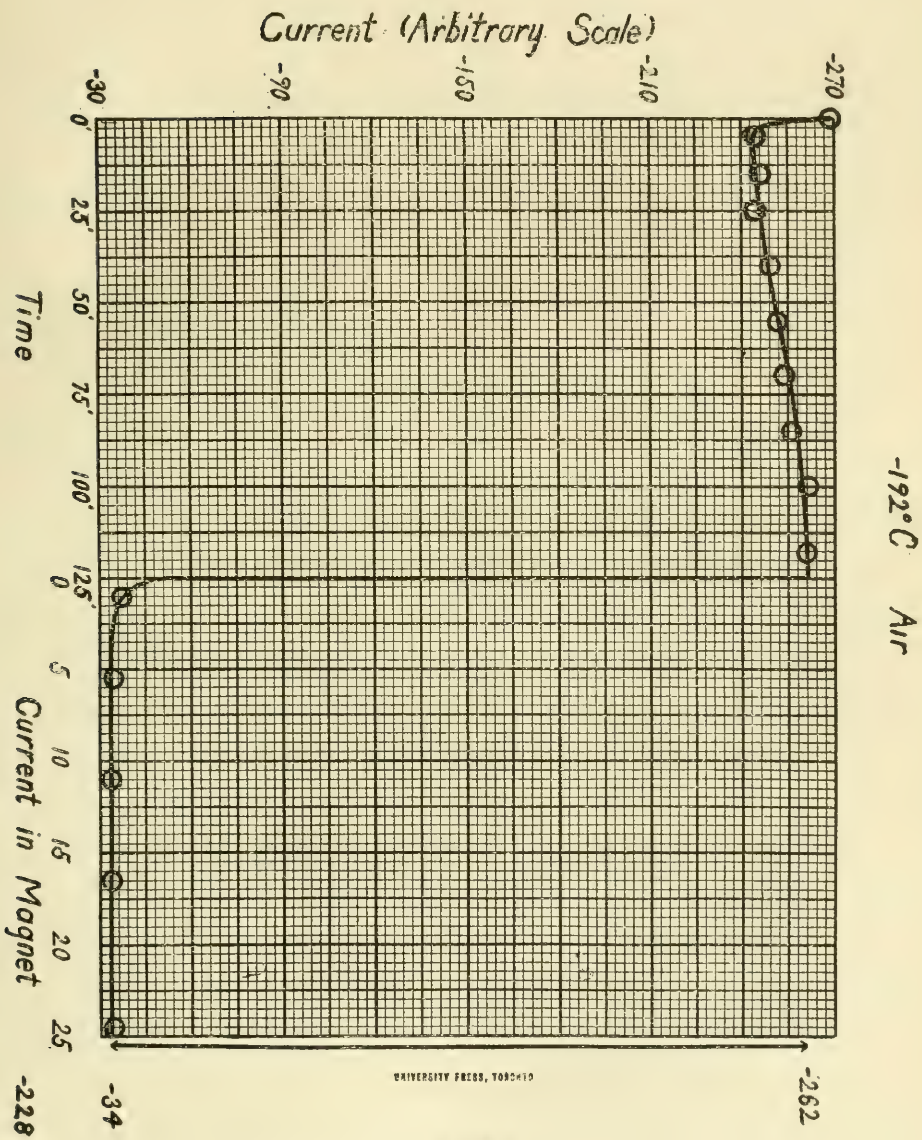
Current (Arbitrary Scale)
-30
-90
-150
-210
-270
Time
0'
25'
50'
75'
100'
125'
Current in Magnet
0
5
10
15
20
25
-192°C Air
-228
-34
-262
UNIVERSITY PRESS, TORONTO

FIGURE 5.

# THE COPPERMINE COUNTRY.

BY J. B. TYRRELL, M.A., F.G.S., F.R.S.C.

(*Read 4th November, 1911.*)

The Coppermine country is situated about the centre of the northern coast of North America, just south of the Arctic Ocean, the shores of which are low, shallow and covered with ice nearly all summer.

Whaling ships now regularly navigate the Arctic Ocean from Behring Strait as far eastward as the mouth of the Mackenzie River, but from this point eastward navigation becomes more difficult and more impeded with ice, so that it has rarely been possible for such vessels to reach the mouth of the Coppermine River.

The country here considered is of unknown area, but speaking generally, it lies near the mouth of the Coppermine River and would appear to extend one hundred miles or more westward from it along the Arctic Coast and about two hundred miles eastward from it. Taking its centre as a point on the Coppermine River about thirty miles above its mouth, this centre lies nine hundred miles northwest of Fort Churchill on Hudson Bay, five hundred and fifty miles west-northwest from the head of Chesterfield Inlet on Hudson Bay, three hundred miles north of Fort Rae on the north arm of Great Slave Lake, and fifty miles east of Great Bear Lake.

At the present time the easiest method of reaching it is to descend the Mackenzie and Athabasca Rivers from Athabasca Landing to the mouth of Great Bear Lake River, to ascend this river to Great Bear Lake, cross Great Bear Lake, and thence strike across the country eastward from Great Bear Lake to the Coppermine, but the main difficulty in this route is caused by the fact that Great Bear Lake, which is very large, having an area of 11,800 square miles, is only open throughout its whole extent for about two months of each year, from the first of August to the first of October.

A canoe route leads north from Great Slave Lake (area 10,700 square miles) to the East end of Great Bear Lake, and thence to the Coppermine River. It is available for a little longer time than the other, in fact from the time when Great Slave Lake opens on the first of July until it freezes again on the first of November.

A party travelling through, or stopping in, that country can add largely to its supply of provisions by catching the fish which are so abundant in the rivers and lakes, and by shooting the Caribou which roam in vast herds over the open plains, but it is never safe to depend on these sources of supply, for both may fail at critical times, or if they do not entirely fail they may become so scanty as to tax the strength and energy of the party in order to obtain sufficient food to support existence, while that very strength and energy should be devoted to prospecting and exploration. It would therefore be advisable for any party entering the country to take with it provisions sufficient to supply at least two-thirds of the normal rations, chiefly in the form of cereals, sugar and fat, while the region itself might be depended on to supply a fair quantity of lean meat.

The Coppermine River itself, which flows through the middle of the Coppermine country, is a stream from four to five hundred miles long. It rises somewhere to the east or northeast of Point Lake, (Indian Ekka tua,) and flows from that lake northward to north latitude 67° 48′ where it empties into Coronation Gulf, one of the great bays of the Arctic Ocean, five hundred miles east of the mouth of the Mackenzie River. The stream is swift but rather shallow, and is broken by numerous rapids, though most of these can be descended in canoes under the guidance of good canoemen. The ice on it breaks up annually about the first of June and does not form again until about the first of October. Its Indian name is Tzan deze, meaning Metal River.

The Coppermine country lies within what are known as the Barren Grounds, or, to use the proper translation of the Indian name, the Treeless Region, where all the uplands are devoid of trees and almost devoid of shrubs, and bear but a stunted growth of grasses, sedges, and low Arctic annuals. Near the head of the river some trees, chiefly spruce, tamarac and poplar, grow around the shores of Point Lake and groves of smaller trees extend northward along its banks to within twenty miles of its mouth.

For more than two hundred years native copper has been known to exist on the banks of the Coppermine River, and over large areas in its vicinity. Writing about 1714 M. Jeremie, who had been in charge of York factory or Fort Bourbon, then the most northerly trading post on the west side of Hudson Bay, between 1708 and 1714, while it was in the hands of the French, says of the Dogribbed Indians: "They have in their country a Mine of Red Copper so abundant and so pure that without putting it through the forge, just as they obtain it at the Mine, they pound it between two stones and make anything that they wish with it. I have often seen it, since our Indians constantly bring it from there when they go in war parties."

Thus the French traders, who travelled so far through the northern country and have told us so much about it, were the first to give us information about this region which still seems so remote and difficult of access.

After York Factory and the other trading posts on Hudson Bay were handed back by the French to the English and to the Hudson's Bay Company, those in control of this latter company immediately began to look for the great mine of copper, from which the Esquimaux and Indians derived their supply of the metal, and as early as July 1717 they sent out Richard Norton, a boy about seventeen years of age, who had shown a great aptitude for learning the Chippewyan Indian language, with two of these Indians. No account of Norton's journey has ever been published, but from the remarks of Captain Middleton and Arthur Dobbs it would appear that he spent about a year travelling with the Indians, and there is a possibility that he went as far north as the Coppermine River itself. At all events, judging from the reports brought back by him and from the reports of the northern Indians, Captain Christopher Middleton, F.R.S., writing in 1743, makes the following remarks:—

"All the Indians I have ever conversed with, who were at the Coppermine, agree in this; that they were two Summers going thither, pointing towards the north-west and Sun-setting, when at Churchill; and that where this mine is, the sun, at a certain season of the year, keeps running round the Horizon several times together, without setting. Now we know from the Principles of Cosmography, that this cannot be true of any place, whose latitude is less than 67 or 68 degrees, even allowing for the effects of refraction; and if the credibility of the testimony of these simple Indians be called in question, I can mention that of Mr. Norton, who was Governor at Churchill above twenty years, and had travelled almost a year north-westward by land with this country Indians. This gentleman has often affirmed the same thing of the sun; and that in his whole journey he met with no Salt River, nor tree, nor shrub, but only moss; and that he and his retinue were reduced to such extremity as to eat moss several days; having nothing else that could serve them for sustenance but their leather breeches, which they eat up also. Now it will appear, from a just trigonometrical computation, that Churchill being in latitude 59°, and the mine in latitude 67°, and the bearing N.W., the difference of longitude between Churchill and the mine is 17° 45′ (actually 11° 30′). But Wager River's entrance being in latitude 65° 20′, and 10 degrees of longitude east of Churchill, the difference of longitude between the mouth of the river and the mine is 27° 45′, and their distance in the arc of a great circle, or their nearest distance, no less than 700 miles. (Actual distance 900 miles.) From what

I have here made out concerning this mine, and the way to it, upon the report of the Indians and of Governor Norton, it follows, even to demonstration:

"1st. That neither Wager River nor any other river or sea does extend so far westward, from any part of Hudson's Bay in less than latitude 65°, as to cross the Route that lies between Wager River and the mine. And,

"2dly, That if there be any passage at all, it must run up so high northward, as to cross the parallel of 67° on the east side of the mine, and consequently must be frozen up, and absolutely unnavigable the whole Year."*

A brief reference to the map of Canada will indicate to you how nearly correct Captain Middleton was able to judge of the position of the Coppermine country, and at the same time it is difficult to avoid the conclusion that Richard Norton, his informant, had either visited the country himself or had gained a very just idea of its position through his intimate knowledge of the Indian language and character.

In 1719 the directors of the Hudson's Bay Company ordered Mr. Norton, upon application of his mother on his behalf, a gratuity of £15 on account of having "endured great hardships in travelling with the Indians," *1 doubtless on this journey to or towards the Coppermine country. With reference to this journey a Captain Carruthers, who was in the employ of the Hudson's Bay Company states in the Parliamentary Report of 1749 that he "himself carried Mr. Norton, who was afterwards Governor, and two Northern Indians, to Churchill, where he put them in a canoe; and the purpose of this voyage was to make discoveries, and encourage the Indians to come down to trade, and bring Copper Ore."*2

In the same Parliamentary Report, Alexander Brown, a surgeon who had been for six years in the Company's service, testified that the Indians "brought down the ore at the request of Governor Norton," and also "that he had heard the late Mr. Norton say that he had been at this Mine, and that a considerable quantity of Copper might be brought down."*3

During this same time Captain Knight, who had been in charge of a number of the Company's posts on Hudson Bay, and who was himself the founder of Churchill, had also seen some of this copper ore and had

* A Vindication of the Conduct of Captain Christopher Middleton in a late voyage on board His Majesty's Ship Furnace, by Capt. C. Middleton. London, 1743. P. 41.

*1 Report from the Committee Appointed to inquire into the state and condition of the Countries adjoining to Hudson's Bay. London. Govt. 1749, p. 276.

*2 Report from the Committee, 1749, p. 231,

*3 Report 1749, p. 226.

become greatly interested in it, though there is also reason to suppose that he considered that it was associated with gold, or that gold occurred in the country. Arthur Dobbs says of him, that he had a great share in the Company's stock and that he pressed the Company to go upon the discovery and trade, and had strong chests made to hold the gold he was to bring home.

In the spring of 1719 Captain Knight and his associates sailed from England in two ships named the "Albany" and the "Discovery". Unfortunately, the expedition was wrecked on Marble Island and all the officers and crew were lost, although their fate was not definitely known until the year 1767, when their remains were discovered by Mr. Joseph Stephens of the Hudson's Bay Company, who was in charge of a small vessel called the "Success" engaged in the whale fishery.

The account of the finding of the remains of Captain Knight and his men is given in very pathetic terms by Samuel Hearne*; how they lived on the Island for a couple of years and used to go up to the top of the rock looking for some one to come and rescue them, and how, at last, only two remained and of these two one fell down and died and the other died in attempting to bury him.

After the unsuccessful and tragic voyage of Knight and Barlow no serious attempt was made to find the Coppermine country for some time, but the following references to it in Arthur Dobbs' "Account of the Countries adjoining to Hudson's Bay," 1744, pp. 47, 48, 59 and 80, will show that it was not forgotten·

"Mr. Frost, who has been many years employed by the company in the bay, both at Churchill and Moose River factory, who was their interpreter with the Natives, and travelled a considerable way into the country, both north-westward of Churchill,—

"He says, when he was at Churchill he travelled a considerable way in the country north-westward of the river of Seals; that near the rivers and sea-coast, there was small shrubby woods, but for many miles, at least 60 farther into the country, they had nothing but a barren white moss upon which the reindeer feed, and also the Moose, Buffalos and other Deer; and the natives told him, further westward beyond that barren country, there were large woods. He was acquainted, when there about fifteen years ago, with an Indian chief, who traded at Churchill, who had often been at a fine copper mine, which they struck off from the rocks with sharp stones; he said it was upon islands at the mouth of a river, and lay to the northward of that country where they had no night in summer.

* Hearne's Journey. New Edition. Toronto, 1911. With Introduction by J. B. Tyrrell. Pp. 45-49.

"The Company avoid all they can making Discoveries to northward of Churchill,—

"But tho' they are fully informed of a fine copper mine on a navigable arm of the sea north-westward of Whale Cove, and the Indians have offered to carry their Sloops to it, yet their fear of discovering the passage puts bounds to their avarice, and prevents their going to the mine, which by all accounts is very rich; yet those who have been at Whale Cove own, that from thence northwards is all broken land, and that after passing some islands, they from the hills see the sea open, leading to the westward;—

"Churchill River, in Lat. 59° a noble river, navigable for 150 leagues, and after passing the falls, navigable again to far distant countries, abounding in mines of Copper."

"Scroggs, in his journey northward in 1722 had two Northern Indians with him, who had wintered at Churchill, and told him of a rich copper mine somewhere in that country, upon the shore, near the surface of the earth, and they could direct the sloop so near it, as to lay her side to it, and be soon loaden with it; they had brought some pieces of copper from it to Churchill, that made it evident there was a mine thereabouts."

About the same time an acrid discussion was carried on between Arthur Dobbs, and Captain Christopher Middleton, Captain of the "Furnace" as to the honesty of the latter in endeavouring to find a north-west passage in 1741-2, and while the main points in the discussion are of little interest, the disputants published four books which contain some useful information about Hudson's Bay and the adjoining country. The quotation from Captain Middleton published on p. 203 is from one of these books. The following references to the Coppermine River also occur in them.

Edward Thompson, Surgeon (of the Furnace) is quoted as stating:

*"Likewise, the two Indians gave us an Account of a river or straits, salt-water and deep, a great number of large black fish, spouting up the water, and that they were five days in crossing it, and that there was a copper mine upon the side of this river or strait, and by the best accounts I could gather from them, it was somewhere hereabouts; and when we left Brook Cobham, and sailed to the north-eastward, they told us, that that was not the way to the copper mine, but were going from it."

And also:

*[1]"These two Indians left their wives and families, and came on board entirely to show us the copper mine before mentioned."

* A Vindication, 1743, p. 186.
*[1] Op. cit. p. 189.

With regard to Richard Norton's journey, Arthur Dobbs makes the following statement:—

*"For there are several persons, now living, who know the exact time of Norton's setting out upon his travels, and the time of his return, who all agree, that Norton was a poor boy, taken an apprentice by the Hudson's Bay Company, and sent over to one of their factories in Hudson's Bay. After he had served three Years of his Time, he became a tolerable Linguist for the languages of those nations that traded with the Hudson's Bay Company's Factors. When Norton was about seventeen Years of Age, a factory was first begun to be settled near Churchill River, in order to enlarge the Company's Trade; and Norton was pitched upon, though a youth, to go in quest of a nation of northern Indians, (he speaking their language) to acquaint them there was a factory settled at Churchill, for promoting a commerce between that Nation and the Company. Norton set out in his canoe, with a northern indian, the middle of July 1717, and went no farther to the northward than the latitude of 60 degrees. He there left his canoe, and travelled inland in quest of this Northern Nation, took a great sweep to the southward of the west, and found them returning to their winter quarters. He engaged some of those people to travel with him to Churchill, where they all arrived about Christmas the same year, after having endured a great many hardships. How does this relation which is well known to be a matter of fact, tally with Captain Middleton's Story of the Indians' and Norton's travelling by land to 68°, their seeing the sun running round the horizon for several days together, especially Norton, who must have inverted the order of Nature, by seeing the sun above the horizon for several days together in winter-time, when in 68°."

In the same book Dobbs quotes Edward Thompson and John Wigate, the Surgeon and Clerk of the "Furnace" as follows:—

*[1]"Whereas it hath been reported by Capt. Middleton, that Mr. Norton, late Governor of Churchill, travelled from Whale Cove, in the Latitude of 62°. off to 65° odd inland, without Interruption of any Lakes, Rivers or Straits, and could perceive no such Things as any Inlet or Opening to the South Sea, &c.

"To confute this, it has been several Times reported by the said Norton, that so far as he travelled he saw nothing but broken lands and Islands, from 60°. to the Extent of his Journey; and that the native Indians he had then with him gave him a very good Account of a Copper Mine upon the Side or Bank of a large River or Strait; and that a Person might easily go with a Ship or Sloop, and lie close to the side thereof, and fill their Vessel with the aforesaid Metal at Pleasure.

* Remarks upon Middleton's Defence, by Arthur Dobbs, 1744, pp. 24-25.
*[1]Remarks, &c., pp. 146-7.

"Likewise the two Northern Indians that we took in at Churchill, the one named Nabiana, the other Iazana (tho' upon the Ship's Books they are called Clayhulla and Cloydiddy) gave me a particular and more affirmative Account than Mr. Norton's. They marked out upon my Table the Tract of Land or Confines of their Country, as far as they knew together with the Course of some remarkable fresh Water Rivers in their Country; but in particular they gave a very good and clear Account of a Copper Mine, which they generally used to go to once in two Years; and at this Copper Mine there is a large River or Strait, salt Water and strong Tides, Plenty of a large kind of black Fish, which by their description I imagine to be Whales; and that they were five days in crossing that salt Water in their Canoes; and that this River or Strait was so deep, that they could find no Bottom with a Deer Skin cut into very fine Thongs, and at least was an hundred Fathoms long; that the Course of this River run towards the Sun at Noonday, and this River appeared to me to be about the Latitude of 63°. or thereabouts; for they seemed, in our Voyage, to have more Knowledge of the Land near that Latitude than in any other Part of our Discovery; and when we sailed to the North-eastward of that latitude, they told us we were going from the Copper Mine, and the River they spoke of.

"The Country these Nations inhabit in Summer, upon account of their killing Deer, they told me was all barren, high and rocky, and that they go inland in the winter to the Southward to catch Beaver and other Furs. I had frequent Conference with these two Indians, who seemed to be well affected towards me, and were never better pleased than when I was writing a Vocabulary of their language; by which I might be enabled to discourse with them more familiarly, and they were very eager of learning English.—

Given under our Hands this 9th Day of April, 1743.

EDWARD THOMPSON.
JOHN WIGATE."

Writing of Norton's trip northward, Captain Middleton again says:

"But this I aver, that he has very often told me, and not long since, that he went from the Factory in the Fall of the Year, which was sometime in August, and paddled along the shore in a canoe, with a Northern Indian man, and a girl, for the space of fourteen days, before they quitted the canoe; and travelled afterwards inland to the northward of the west, about ten or twelve days, and then met with the Northern Indians or some of them. Now could they be fourteen days in paddling but twenty leagues, from Churchill the Latitude of 60°, which is but one degree? Twenty miles a day in a canoe, is esteemed but easy labour for him who paddles. Let us suppose they went but fifteen miles in twenty-four hours, one day with another; this gives two hundred and ten miles in the space of time mentioned, which are 3° 30′, and makes the latitude 62° 30′;—

"From all the Accounts I could get, and I have made the strictest Enquiry, the Northern Indian Nations live between the Lat. of 63° and 64°. The most particular account I ever had, was after I came home from my last voyage, and this was from the Indian Linguist, whom I had then with me, and at my lodgings after my return, till about Christmas, 1742, when he died. He had been several winters and summers among them, and said they were never less than three weeks or 21 nights, which is their way of reckoning, in coming to the factory ; but were much longer in going back, (The reason of this difference of time, is that in coming to the factory, the way is frozen, but the ice broken up when they return). As near as he could make it out, their country lies in a straight line with the sun setting in summer (from Churchill) which must be about N.W. Now admit these Indians travelled but 20 miles in 24 hours, which to them is nothing when the ground is frozen, this would make 421 miles, and that distance N.W. will give near 5° of Lat. which added to that of Churchill, places these Northern Indians in Lat. 64° north; this agrees with all the accounts I have heard, and with what Scroggs' Indian said. See his Account in Whalebone Bay; from whence they desired him to let them return home, as then being not above three or four day's journey from their own country. (Vid. Mr. Dobbs' Remarks, p. 115.)

"I all along understood, and do yet believe, that Mr. Norton continued that winter and one summer with these northern Indians, and returned the winter following, after having travelled throughout their country, to engage as many as possibly he could, to come down and trade; and if this was the case, he might very well have observed the sun's going round several days together, and the imputed blunder falls to the Ground."*

A few years later, in 1748, at the request of Arthur Dobbs, a Parliamentary Investigation was held into the conduct of the Hudson's Bay Company, and the following references to the Coppermine Country, in addition to those already cited, appear in the Report of the Committee and in the evidence submitted.

Edward Thompson, who had been three years at Moose River in the Company's service as surgeon, said:

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* A Reply to the Remarks of Arthur Dobbs, by Captain C. Middleton. London, 1744, p. 26.

*"That he has heard the natives talk of a sea to the westward, which, by their accounts, is not far distant; and of a copper mine, which lay on the side of a Strait which takes them five days in crossing; that they describe the water of this strait to be very deep, and that they could not reach the Bottom with two deer-skins, cut into thongs; and if a sloop could be brought along-side this copper mine, they say they could fill it in a little time. And, by their account, this strait has a communication both with the bay and the south Sea.

"The witness could not learn at what distance this was from the factory, nor did he inquire which way the tide sat; but the Indians said, that the water was deep and salt, and there were great fish spouting up in it."

*[1] "Christopher Bannister, who had been Armourer and Gunsmith to the Hudson's Bay Company, and had resided in the bay about 22 years, informed your committee:

"That he had seen Copper frequently brought down by the Northern Indians, a piece of which he produced to your committee; and said, he had seen great quantities of it there; and was informed by a young man, who is now at Hudson's Bay, that the Indians told him, that it was brought from a mine, in search of which the young man would gladly have gone."

"Mr. Alexander Browne, who has been six years in the Company's service at Hudson's Bay as Surgeon, informed your committee, that he has seen both copper and copper ore at Prince of Wales's Fort in Churchill River, which the Northern Indians informed the witness they brought from an Isthmus of land, which lies by a lake at the farthest extent of their country: that 'tis hard to ascertain the distance from the accounts of the Indians, by that 'tis judged to be about three or four hundred miles. That he never heard the Indians say whether there was a passage to this place from the Bay by water, but they informed him their river ran by it.

"That they bring down the copper for ornaments, and that they brought down the ore at the request of Governor Norton. But that the witness does not know whether any of it was sent to England, or whether any trial was made of it there. That he has seen about four or five pounds of it, both before it was smelted, and after; and he takes it to be a rich Ore, but does not understand metals. That he has heard of Lead Ore at Hudson's Bay, but never saw any.

"That he never saw the Indians smelt it; but they informed him, that the earth was washed from the ore by showers, and that they smelt it on a fire till it runs, and then beat it, it being very malleable. That he

* Report from the Committee appointed to inquire into the State and Condition of the Countries adjoining to Hudson's Bay. London. Govt. 1749, p. 223.

*[1] Report &c., 1749, p. 225.

never heard of a copper mine on the large arm of the sea, but the ore is brought down by canoes to the open sea; and that the rivulet which washes the said copper is not known to have any communication with Hudson's Bay, the mine being about fifteen miles from the open sea, by the accounts of the Indians.

"That they might bring the Ore in their canoes to Churchill River. But the witness can't say whether the company's sloops could go within fifteen or sixteen miles of the mine, since there are frequent shoals in those seas. But canoes may come down to meet the vessels, for the ice makes the water so smooth, that a canoe can live thirty leagues from shore; that he apprehends the Indians come a little to the northward of Whale Cove, which bears a point or two to the west of the north from Churchill.

"That if the Indians were encouraged, they would bring great quantities of ore, as well as smelted copper, to Whale Cove; and that a pound and a half of ore would, in the opinion of the witness, produce a pound of pure metal. That if persons were sent up to the mine, they might smelt the ore there; but they would labour under a difficulty for want of fuel, the country producing no wood; and what the Indians smelt, they do in small quantities with moss.

"That the country about the mine is only inhabited in the fishing season; and that he apprehends it produces furs; and that he never heard the Company offer to trade with the Indians for copper; That the Rivulet which runs by the mine runs into the sea; and that he apprehends there is a communication betwixt this sea and Whale Cove; that he has heard the late Mr. Norton (who was the first that brought the Northern Indians to trade, being sent among them for that purpose by the then Governor) say, that he had been at this mine, and that a considerable quantity of copper might be brought down; that the Indians will carry their canoes, as the witness believes, about four or five miles over land, but they often leave their canoes and go within land. That on Mr. Norton's being sent to the Northern Indians, a small trade was carried on, which has been improved of late years, but nothing to what it might be by giving the encouragement of a greater price. But Mr. Norton never told the witness why the copper trade was not carried on."*

*[1] "Captain Carruthers, being examined, informed your Committee, that he had formerly been in the service of the Hudson's Bay Company, which he quitted thirty-five years ago.

"That he has heard a good deal of a copper mine to the northward of Churchill River, the Indians speaking of it to the interpreter while

* Report 1749, p. 226.
*[1] Op. cit., p. 231.

the witness was by; but he understood no more than that it lay to the northward of Churchill, and that the Governor was mighty fond of the discovery, and made great inquiries about it.

"That the Interpreter reported the answers of the Indians to the Governor and Council, of which the witness was one; and they described the mine somet mes as a gold mine, sometimes as a copper mine; and that the witness has seen copper which was said to be brought from thence, but he does not know whether it was so or not; that the Governor was very earnest in this discovery, which was always his topic, and he took all opportunities of making presents to the natives ; and the witness himself carried Mr. Norton, who was afterwards Governor, and two northern Indians, to Churchill, where he put them in a canoe; and the purpose of their voyage was to make discoveries, and encourage the Indians to come down to trade, and bring copper ore ; that he can't recollect, that he ever heard how far it was to this copper mine; nor does he know whether there is an easy passage to it by land, having never travelled by land himself, nor heard of any expedition of that kind, except that undertaken by Norton and the two Indians aforesaid."

In 1768 Richard Norton was dead, but his half-breed son Moses Norton had been appointed Governor of Fort Churchill in his place, and during that year some Indians brought in beautiful specimens of copper from that fabled copper country. Norton was so interested in these new specimens from a country of which he had already doubtless heard much from his father and others, that he took passage on the annual ship to England and laid before the Governors of the Company a project for what he believed to be the complete exploration of the country and a definite settlement of the question of whether there was available copper within reach of the shores of Hudson Bay or not. It is interesting to note that the same ship which took Governor Norton to England had brought out William Wales and Joseph Dymond to observe the transit of Venus at Churchill.

In the following year Mr. Norton returned from England with authority to send out one of his clerks named Samuel Hearne to explore the Coppermine country. The following is an extract from the instructions of the Company as given by Hearne himself.*

"From the good opinion we enterta n of you, and Mr. Norton's recommendation, we have agreed to raise your wages to £130 per annum for two years, and have placed you in our Council at Prince of Wales's Fort."

* Hearne's Journey (New Edition). Toronto, 1911. With Introduction, &c., by J. B. Tyrrell. P. 50.

"Mr. Norton had proposed an inland journey, far to the North of Churchill, to promote an extension of our trade, as well as for the discovery of a north-west passage, copper mines, &c.; and as an undertaking of this nature requires the attention of a person capable of taking an observation for determining the longitude and latitude, and also distances, and the course of rivers and their depths, we have fixed upon you (especially as it is represented to us to be your own inclination) to conduct this journey, with proper assistants.

"We therefore hope you will second our expectations in readily performing this service, and upon your return we shall willingly make you any acknowledgment suitable to your trouble therein."

Hearne was then a young man, 24 years of age, and as soon as possible after Norton's arrival home he made preparations for the journey inland. On the 6th of November he left Churchill, or rather Fort Prince of Wales, at the mouth of Churchill River, in company with a few Chippewyan Indians and started north-westward on foot for the copper mine, but he only got a short distance when the Indians left him and he was obliged to return.

After a couple of months at home he again started out in the middle of winter and wandered over the Barren Grounds until the following autumn, when, being again abandoned by his Indians, he was obliged to return to his old home on Hudson Bay; but on the way home he had met an Indian chief named Matonabbee, who offered to take him to the Coppermine River, and who afterwards showed that he was able to substantiate his offer by accomplishment; so, on the 7th of December, 1770, after having been home for only twelve days, he again started out on foot for the Coppermine River, and this time, thanks to the leadership of the great Indian whom he accompanied, he was able to reach the country that he was in search of.

Hearne knew nothing of mines or minerals, but, like many a man similarly equipped since his day, he was sent to report on a great mining property. Naturally, his report on the mine of copper is of little value, but in his book he has given an exceedingly interesting account of life among the Indians on the Barren Grounds in his day. What he has to say, however, is interesting, as it is the first account of the occurrence of the copper by an eye-witness. His remarks are as follows.—*

"We arrived at one of the copper mines, which lies, from the river's mouth about south southeast, distant about twenty-nine or thirty miles.

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* A Journey from Prince of Wales Fort on Hudson's Bay to the Northern Ocean. By Samuel Hearne. New Edition. Toronto, 1911. With Introduction and notes by J. B. Tyrrell. Pp. 194 et seq.

"This mine, if it deserves that appellation, is no more than an entire jumble of rocks and gravel, which has been rent many ways by an earthquake. Through these ruins there runs a small river; but no part of it, at the time I was there, was more than knee-deep.

"The Indians who were the occasion of my undertaking this journey represented this mine to be so rich and valuable, that if a factory were built at the river, a ship might be ballasted with the ore, instead of stone; and that with the same ease and dispatch as is done with stones at Churchill River. By their account the hills were entirely composed of that metal, all in handy lumps, like a heap of pebbles. But their account differed so much from the truth, that I and almost all my companions expended near four hours in search of some of this metal, with such poor success, that among us all, only one piece of any size could be found. This, however, was remarkably good, and weighed above four pounds. I believe the copper has formerly been in much greater plenty; for in many places, both on the surface and in the cavities and crevices of the rocks, the stones are much tinged with verdigrise.

"It may not be unworthy the notice of the curious, or undeserving a place in my Journal, to remark, that the Indians imagine that every bit of copper they find resembles some object in nature; but by what I saw of the large piece, and some smaller ones which were found by my companions, it requires a great share of invention to make this out. I found that different people had different ideas on the subject, for the large piece of copper above mentioned had not been found long before it had twenty different names. One saying that it resembled this animal, and another that it represented a particular part of another; at last it was generally allowed to resemble an Alpine hare couchant; for my part, I must confess that I could not see it had the least resemblance to anything to which they compared it. It would be endless to enumerate the different parts of a deer, and other animals, which the Indians say the best pieces of copper resemble : it may therefore be sufficient to say, that the larger pieces, with the fewest branches and the least dross, are the best for their use, as by the help of fire, and two stones, they can beat it out to any shape they wish.

"Before Churchill River was settled by the Hudson's Bay Company, which was not more than fifty years previous to this journey being undertaken, the Northern Indians had no other metal but copper among them, except a small quantity of iron-work, which a party of them who visited York Fort about the year one thousand seven hundred and thirteen, or one thousand seven hundred and fourteen, purchased; and a few pieces of old iron found at Churchill River, which had undoubtedly been left there by Captain Monk. This being the case, numbers of them from all quarters used every summer to resort to these hills in search of copper; of which they made hatchets, ice-chisels, bayonets, knives, awls, arrow-heads, &c. The many paths that had been beaten by the Indians on these occasions, and which are yet, in many places, very perfect, especially on the dry ridges and hills, is surprising; in the valleys and marshy grounds, however, they are mostly grown over with herbage, so as not to be discerned.

"The Copper Indians set a great value on their native metal even to this day; and prefer it to iron, for almost every use except that of a hatchet, a knife, and an awl; for these three necessary implements, copper makes but a very poor substitute. When they exchange copper for iron-work with our trading Northern Indians, which is but seldom, the standard is an ice-chisel of copper for an ice-chisel of iron, or an ice-chisel and a few arrow-heads of copper, for a half-worn hatchet; but when they barter furs with our Indians the established rule is to give ten times the price for everything they purchase that is given for them at the Company's Factory."

After Hearne's visit in 1771 no white man visited the country for 50 years, until Sir John Franklin arrived at the head waters of the river, and then descended and made a survey of it from Point Lake to the Arctic Ocean. Franklin's account of the country may be interesting, and I will accordingly read it to you:—

"We rejoined our hunters at the foot of the Copper Mountains, and found they had killed three musk-oxen. This circumstance determined us on encamping to dry the meat, as there was wood at the spot. We availed ourselves of this delay to visit the Copper Mountains in search of specimens of the ore, agreeably to my instructions; and a party of twenty-one persons, consisting of the officers, some of the voyagers, and all the Indians, set off on that excursion. We travelled for nine hours over a considerable space of ground, but found only a few small pieces of native copper. The range we ascended was on the west side of the river, extending W.N.W. and E.S.E. The mountains varied in height from twelve to fifteen hundred feet. The uniformity of the mountains is interrupted by narrow valleys, traversed by small streams. The best specimens of metal we procured were among the stones in these valleys, and it was in such situations that our guides desired us to search most carefully. It would appear, that when the Indians see any sparry substance projecting above the surface, they dig there; but they have no other rule to direct them, and have never found the metal in its original repository. Our guides reported that they found copper in large pieces in every part of this range, for two days' walk to the north-west, and that the Esquimaux come hither to search for it. The annual visits which the Copper Indians were accustomed to make to these mountains, when most of their weapons and utensils were made of copper, have been discontinued since they have been enabled to obtain a supply of ice-chisels and other instruments of iron by the establishment of trading posts near their hunting grounds. That none of those who accompanied us had visited them for many years was evident, from their ignorance of the spots most abundant in metal.

"The impracticability of navigating the river upwards from the sea, and the want of wood for forming an establishment, would prove insuperable objections to rendering the collection of copper at this part worthy of mercantile speculation."*

Among the members of Franklin's party was Sir John Richardson, the great Naturalist, and the account which he gives of it is much more detailed than that given by his Chief, and therefore you may be interested in hearing it.

"The Copper Mountains appear to form a range running S.E. and N.W. The great mass of rock in the mountains seems to consist of felspar in various conditions; sometimes in the form of felspar rock or claystone, sometimes coloured by hornblende, and approaching to greenstone, but most generally in the form of dark reddish-brown amygdaloid. The amygdaloidal masses, contained in the amygdaloid, are either entirely pistacite (epidote), or pistacite enclosing calc-spar. Scales of native copper are very generally disseminated through this rock, through a species of trap tuff which nearly resembled it, and also through a reddish sand-stone on which it appears to rest. When the felspar assumed the appearance of a slaty claystone, which it did towards the base of the mountains on the banks of the river, we observed no copper in it. The rough and in general rounded and more elevated parts of the mountain, are composed of the amygdaloid; but between the eminences there occur many narrow and deep valleys, which are bounded by perpendicular mural precipices of greenstone. It is in these valleys, amongst the loose soil, that the Indians search for copper. Amongst the specimens we picked up in these valleys, were plates of native copper; masses of pistacite containing native copper; of trap rock with associated native copper, green malachite, copper glance or variegated copper ore and ironshot copper green; and of greenish grey prehnite in trap (the trap is felspar, deeply coloured with hornblende), with disseminated native copper; the copper, in some specimens, was crystallized in rhomboidal dodecahedrons. We also found some large tabular fragments, evidently portions of a vein consisting of prehnite, associated with calcareous spar, and

* Narrative of a Journey to the Shores of the Polar Sea in the Years 1819, 20, 21, and 22. By John Franklin. London, 1823. 4to, pp. 340-1.

native copper. The Indians dig wherever they observe the prehnite lying on the soil, experience having taught them that the largest pieces of copper are found associated with it. We did not observe the vein in its original repository, nor does it appear that the Indians have found it, but judging from the specimens just mentioned, it most probably traverses felspathose trap. We also picked up some fragments of a greenish-grey coloured rock, apparently sandstone, with disseminated variegated copper ore and copper glance; likewise rhomboidal fragments of white calcareous spar, and some rock crystals. The Indians report that they have found copper in every part of this range, which they have examined for thirty or forty miles to the N.W., and that the Esquimaux come hither to search for that metal. We afterwards found some ice-chisels in possession of the latter people twelve or fourteen inches long, and half an inch in diameter, formed of pure copper.

"To the northward of the Copper Mountains, at the distance of ten miles in a direct line, a similar range of trap hills occurs, having, however, less altitude. The intermediate country is uneven, but not hilly, and consists of a deep sandy soil, which, when cut through by the rivulets, discloses extensive beds of light-brownish red sandstone, which appears to belong to the new red sandstone formation. The same rock having a thin slaty structure, and dipping to the northward, forms perpendicular walls to the river, whose bed lies a hundred and fifty feet below the level of the plain. The eminences in the plain are well clothed with grass, and free from the large loose stones so common on the Barren Grounds, but the ridges of trap are nearly destitute of vegetation.

"Beyond the last-mentioned trap range, which is about twenty miles from the sea, the country becomes still more level, the same kind of sandstone continuing as a subsoil. The plains nourish only a coarse short grass, and the trees which had latterly dwindled to small clumps, growing only on low points on the edge of the river under shelter of the high bank, entirely disappear. A few ranges of trap hills intersect this plain also, but they have much less elevation than those we passed higher up the stream.

"The river in its section of the plain, as far as Bloody Fall, presents alternately cliffs of reddish sandstone, and red-coloured slaty indurated clay or marl, and shelving white clay banks. At Bloody Fall, the stream cuts through a thick bed of dark, purplish-red felspar rock, similar to that observed at the Rocky Defile, and associated, as at that place, with a rock composed principally of light red felspar and quartz, but which is probably a species of red secondary granite. At the Bloody Fall, the felspar rock is covered to the depth of six or seven hundred feet with a bed of greyish white, and rather tenacious clay, which being deeply intersected with ravines, forms steep hills. Nearer the sea, the river is bounded by very steep cliffs of yellowish-white sand; and on the sea-coast, the above mentioned red granite reappears on the west bank of the river, forming a rugged ridge about two hundred and fifty feet high."*

In this same year, 1821, Franklin and Richardson found trap-rocks of the copper-bearing series eastward along the Arctic Coast for nearly two hundred miles, or as far as the east side of Bathurst Inlet, nearly two hundred miles, though no copper or copper-ore seems to have been found in them.

On Franklin's Second Journey in 1826 Richardson recognized the existence of rocks of similar character at a number of points along the Arctic Coast for 200 miles west of the Coppermine River.

With regard to the character and age of some of these rocks Sir John Richardson says:

"The quartz rock beds acquire occasionally a pistachio-green colour, as if from the presence of epidote. A similar stone occurs at Pigeon River on the north shore of Lake Superior; and the limestones and sandstones of the latter district with their associated trap rocks, as at Thunder Mountain, correspond in most respects with those between Cape Parry and the Coppermine River; and consequently, if we can rely on lithological characters, they may be considered as the oldest members of the Silurian series, or as the rocks on which that series is deposited, to which epoch the Lake Superior formation has been assigned."*[1]

From the description quoted above it would appear that the rocks on the Coppermine River are similar to the Copper-bearing rocks on Lake Superior, and that the conditions under which the copper occurs are also similar to those under which it occurs on Keewenaw Point on the south shore of Lake Superior. Speaking broadly, these rocks would appear to indicate a repetition to the north of the great Archean protaxis of the conditions which have prevailed on Lake Superior to the south of it.

Since Franklin and Richardson visited, mapped and described this region, very little attention has been paid to it, though Thomas Simpson and John Rae both crossed the Coppermine River, and make mention of it in their Journals.

The traps and associated rocks may cover a very much larger area than we have any knowledge of at present. In 1903 I found them on the north shore of Doobaunt Lake and on the Doobaunt River below the Lake. As late as 1902 the late David Hanbury ascended Coppermine

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* Narrative of a Journey to the Shores of the Polar Sea in the years 1819, 20, 21, and 22. By John Franklin. London, 1823. 4to, pp. 528-30.

*[1] Arctic Searching Expedition. By Sir John Richardson. London, 2 Vols., 1851. Vol I, p. 283.

River as far as the portage to Great Bear Lake in his journey from Hudson Bay to the Mackenzie River, and he has mentioned in his account that one of his men named Sandy, while tracking up the river, "was nearly tripped up by a chunk of native copper on the shore. It weighed about twelve pounds."*

Though Hanbury gives us little or no information about the copper-bearing rocks in the immediate vicinity of the Coppermine River, he gives us very positive information about these rocks and the occurrence of the metal in them, in and around Bathurst Inlet and Melville Sound, 175 miles east of the Coppermine River, substantiating Richardson's description of the country, and adding to it evidence of the presence of native copper.

The following is his description of the rocks and the occurrence of copper:—

"On the 16th (of June 1902) we reached Barry Island, which one of my Eskimo had described as the best place for copper. He now said copper was more plentiful on an island six or eight miles north of Fowler Bay. However, two pieces of native copper were found in the evening.

"The next day we searched for copper on the north-west shore of the island.

"The main rock of the island is a fine-grained basalt which Dr. Flett described as granular, holocrystalline, and non-porphyritic, and a good deal decomposed. The rock, although hard, is easily broken in all directions by a tap of the hammer. The summit of the island is, however, formed of a rock of the character of No. 6, which is described as coarse-grained ophitic dolerite with plagioclase and augite, and perhaps a few grains of olivine. The ophitic structure is very perfect.

"The underlying basalt dips west at an angle of about 25°, and it is in this rock that the native copper occurs. The copper is plentiful, for the quantity we obtained was found after but a brief search, and on a neighbouring island, Kun-nu-yuk, a mass of copper had just been found, so large that a man could hardly lift it. There also copper is often found in the tide-way. The whole of the lower levels on Barry Island are covered with debris from the basalt, and where the rock has been disintegrated by weathering, copper has fallen out, so that flakes of the metal may be found along the sea-shore. In many places, too, green patches indicate that nuggets or flakes of copper have recently fallen out from their matrix.

* Sport and Travel in the Northland of Canada, by David Hanbury, 1904, p. 206.

"The copper-bearing rock also contains crystalline quartz, some of which forms beautiful amethystine veins, of which some specimens were taken.

"This island, Barry Island or Iglor-yu-ullig, is several miles in length, and perhaps three or four miles across. The island to the south-south-east, Kun-nu-yuk, is still larger, besides which there is an island to the south-west which has given much copper, and there are copper-yielding islands to the north. The copper-bearing formation holds good everywhere except on the summit cappings of the islands.

"On the 23rd, on our way across Bathurst Inlet, we approached a flat-topped precipitous island very much resembling a kopje.

"About five miles beyond this limestone island we passed a small basaltic island on which two pieces of copper ore were picked up. It seems as if copper is to be found wherever this basalt occurs.

"With the exception of some precipitously-cut rocks near our camp, this island is formed of the same partly-decomposed basalt as Barry Island. It is described as fine-grained, granular crystall ne, decomposed basalt.

"Although we did not find so much copper here, the green marks on the rocks were more numerous, but we did not spend an hour altogether in the search. One of our Eskimo knew of a large mass of copper on the south-west shore of the island, which he stated to be as much as five feet in length and three inches thick. It protruded from the rocks under the water, it was said, but there was too much ice for us to find the copper. A piece of quartz with copper ore and native copper was picked up on the seashore. Another specimen of the copper-bearing rock here is a decomposed basalt, fine-grained, and not unlike No. 15, but vesicular.

"On the 27th we rested at the north-west point of Lewis Island, where we again found the copper-bearing basalt, and accordingly we commenced a search that resulted in our collecting about 2 pound weight of copper. The metal appeared to be very persistent in its occurrence in the partly decomposed basalt of which all the islands we passed that day consisted. The flakes of copper seemed to be always vertical when in their rock matrix. The rocks of this island, where they are not disintegrated, are well smoothed by glacial action, and the striae are numerous and distinctly trend south and south-east."*

An important addition to our knowledge of the copper-bearing rocks of the northern coast of America has just been brought to my attention by Doctor James Douglas of New York, and I am permitted to publish it through the kindness of the Secretary of the American Museum of Natural History. The information is contained in a letter

* Sport and Travel. Pp. 264-6.

from Mr. V. Stefansson, dated Langton Bay, July 1st, 1911, and addressed to Doctor H. C. Bumpus, Director American Museum of Natural History, New York City. Mr. Stefansson writes as follows:—

"That copper was to be found on the Coppermine River has been generally known for more than a century; we found, however, that even the Eskimos nearest the river, while they pick up some copper on the banks occasionally, depend chiefly on the richer deposits north of Dismal Lake. Neither of these regions is rich in native copper, however, compared with the mountains northeast of Prince Albert Sound." (on Victoria Land).

This is the first record of the occurrence of native copper or the copper-bearing rocks on any of the large Islands in the Arctic Ocean, and as Prince Albert Sound is probably accessible to ocean-going ships by way of Behring Sea, the locality might be much easier to explore, and mines might be much more readily developed, than in the districts on the main land in the vicinity of the Coppermine River.

Judging from the evidence here presented, the existence of a great copper-bearing area on the Arctic Coast of America near the Coppermine River is certain, and it is also reasonably certain that that area is very much more extensive than the copper-bearing area south of Lake Superior, extending, as it does, from Victoria Land and the hills west of the Coppermine River to the shores of Bathurst Inlet far to the east, but whether native copper will be found anywhere as plentifully distributed or in such rich segregations as on Keewenaw Point, is yet quite uncertain. As the area is larger it is quite possible that the mineral deposits may be similarly larger, and it is worth while for the Canadian people to find out whether they have in this far northern country a great reserve of copper ore for the use of themselves and the world when the mines that are now being worked become depleted. It may seem foolish for us to spend money at the present time to determine the existence of bodies of ore which we cannot use, but copper is one of the most useful metals in the world to-day, and it behoves a nation like an individual to study its ore reserves in order that it may deal with them wisely, and have them developed in such a way that they will afford the greatest benefit to the people. Therefore I say that we Canadians, knowing that we possess an area of potential wealth in copper in that far northern country, should examine it carefully and find out whether we have a natural asset, that, if intelligently used, will add greatly to the wealth of the nation, or whether we are prepared to hand over that possible asset without knowing whether it is valuable or not, to private individuals, probably aliens, who, by the expenditure of a little capital and energy, may make enormous fortunes as a result of our negligence.

On the table you will see a few specimens of native copper which have been brought by Esquimaux from the Coppermine River. Some of the implements are the property of my brother, J. W. Tyrrell of Hamilton, who obtained them in 1900 on his trip across the Barren Lands from Great Slave Lake to Hudson Bay; while others were obtained by Mr. Alston at Churchill from Esquimaux who resorted there to trade.

# THE CRYING NEED OF INDUSTRIAL RESEARCH IN CANADA

BY REV. GEO. BRYCE, M.A., D.D., LL.D., F.R.S.C.

Member of Royal Commission on Industrial Training and Technical Education.

(*Read 3rd February, 1912.*)

CANADIANS, I fear, Mr. President, are disposed to be a self-satisfied people. We have not yet reached our jubilee as a Nation of the Empire, but we are inclined to think that we have done pretty well. It may be that the contrast between our condition before Confederation and our status at the present time is so great that we are apt to think more highly of ourselves than we ought to think. The student who fears the result of his examination is hilarious if he should make a bare "pass," the workman who has been receiving a low wage regards himself as rich if he is given a slight increase, and the Government which has had a deficit or a falling revenue is highly pleased if expenditure does not go beyond receipts. But excellence in each case means more than that. So, when we recall the homespun garb and the impassable roads, and the unsettled markets, and the poor school facilities whlch some of us knew some forty or fifty years ago, we are inclined to self-congratulation over our present circumstances and achievements. No doubt to-day Canada is the land of opportunity, but that is just because it is still far from what it may become.

I am a patriotic, and, in some respects, a proud Canadian, but tonight I cannot be a prophet of smooth things.

After a survey of many countries, in the last year or two, I feel it to be appropriate to choose as a subject for this evening's address, "The Crying Need for Industrial Research in Canada."

I have been in the cities and towns of England and Scotland, in many of the centres of Germany and Holland, and in several of the States of the American Union, and all these places, I find, are earnestly taken up with enforcing laws of compulsory education and in organizing Continuation Schools, so that a general elementary education may be secured for virtually the whole population.

What have we seen in Canada? Several provinces with no compulsory educational requirement; except in a few places no real insistence on general education, and the adjuncts of a sympathetic and persuasive education entirely lacking. When we think of the hundreds of small groups of children in Canada in the so-called little red school-houses, when there are uncertificated and incompetent teachers by hundreds in many provinces, and when there are thousands of boys and men unable to read or sign their names to a pay-roll, we may well be ashamed to see in Belgium or Switzerland greatly higher general school opportunities; indeed we may see enough to give us pause as self-confident Canadians.

It is surely with pain that we contrast the thorough preparation secured from the Gymnasium in Germany and the High Schools of Edinburgh, Glasgow or London, with what those of us who have been Educationalists for years have seen of hundreds of our poorly prepared matriculants, who present themselves for a University course.

An investigation into our factories, machine shops and business places all through Canada tells the same story, that the working lads coming from our schools have been very poorly instructed. We used to think the three Rs a very modest measure of acquirement for a lad leaving the public schools, but now we are quite familiar with his having not even that acquisition.

We cannot disguise the fact from ourselves, that, though Governments seem to make liberal donations to education, though many municipalities take pride in their public schools, though the inspectorates are well manned, yet there is in almost every province of the Dominion growing up a very considerable percentage of the young who are practically illiterate.

Now, this very lamentable state of things, which in the last forty or fifty years of our experience has been forming the standards of hundreds of our communities in all the provinces from the Atlantic to the Pacific, has produced a public opinion none too favorable to higher culture and the acquisition of a good sound education. The Mechanics in many cases do not value the reputation for efficiency. Men, as we have seen them—"handymen"—undertake to do work which they cannot do and "turn their hand" to anything that may present itself. A member of the Royal Commission had a stock question for carpenters:—"Could you build a winding staircase or a complicated house-roof?" Not one quarter of the witnesses could answer "Yes."

Teachers on permits without knowledge or facility make teaching a farce. Doctors have entered their profession who did not adorn it, and even, I am afraid, ministers innocent even of "Scant Latin and less Greek" were none too strong either in philosophy or general erudition.

I state these things because I fear that they indicate a serious imperfection of training, a carelessness about standards, and an unwillingness to surrender some of our fallacies, that may interfere with any effort to rouse our educational boards, our civic authorities, our cabinets and parliaments, to look on thoroughness and efficiency in education, labour and professional life, as absolutely essential to our Industrial success.

Complaints are made all through Canada that our schools do not fit the scholars for the factory, that apprentices are changeable and unreliable, that the apprenticeship system has broken down, that art as applied to Industry is not properly taught, and that writing in the schools is very bad. These are all marks of imperfection and poor training. What are the consequences of these things in the Industries? They are these:—The Employer and foreman are poor judges and poor purchasers of the material needed; the management of the offices and shops is careless; the quality of the labour is poor; the business as a whole is badly managed, and the waste is enormous.

These are the things which the people who know have been telling us all through Canada; and we are bound to say that in older countries, where custom is strong and communities are better established, the efficiency in industry is greater. An observing writer has said: "The Manufacturers have not been men educated in the knowledge of the schools, but are men who know practically nothing of applied science and who in consequence forced their way to success through sheer fighting manhood and through the application of principles which they did not understand."

Many of the manufacturers think it sufficient to have a so-called "practical man," one not instructed, but simply an expert mechanic, who serves as "guide, philosopher and friend."

1. Thus the Manufacturer does not value true expert advice.
2. He shuts his eyes to the waste.
3. He settles down to a career of non-progressiveness.
4. He agitates for a higher duty on his products.
5. Dissatisfied, he turns his thoughts to making a Combination or combine—which is illegal.

The real remedy for many of his difficulties is Scientific Research.

This is the solution of his difficulties, used by the German manufacturer. The following are the figures as to the employment of experts in Germany in 1897. They would be still more startling in 1912.

GERMAN MANUFACTURERS.

| Description of Chemical Works. | Trained Chemists Employed |
|---|---|
| Artificial Manures | 90 |
| Explosives | 50 |
| Petroleum, Lampblack | 50 |
| Inorganic Compounds | 250 |
| Organic Compounds | 1000 |
| Various works | 610 |

| Description of Chemical Works. | Trained Chemists Employed. |
|---|---|
| Sugar Works and Refineries | 300 |
| Starch, Dextrine, etc | 50 |
| Oil, fat, tanning, and dye works | 100 |
| Smelting works | 400 |
| Laboratories and Agricultural Stations | 700 |
| Government works | 100 |
| Apothecaries (Qualified) | 100 |
| Various Chemists | 100 |
| | 4000 |

The total number of chemists who had been trained in Germany in 1897 was:—

| | |
|---|---|
| Technical Chemists in Works in Germany | 4000 |
| Technical Chemists in foreign countries | 1000 |
| Professors, lecturers, etc. of Chemistry: | |
| In Universities | 150 |
| In Technical Schools | 250 |
| Mining, Veterinary and Agricultural Schools | 100 |
| Building, Engineering and Industrical Schools | 200 |
| Chemists employed by the States | 100 |
| Private Chemists | 400 |
| Apothecaries (qualified) | 300 |
| Various Chemists | 500 |
| | 7000 |

Thus thinking men are saying to-day—we need better elementary education, better High School training, more practical University Science, more men who know the principles and reasons of things. Especially do we need more Science in our Industries. Look at the wasted opportunities. Out of many letters, relating to from fifty to a hundred fields of Industry which I have received from keen sighted and intelligent scientific men in Canada, I may give examples of the tremendous waste of valuable things, and of unused opportunities. Nature has given us great resources in Canada and we do not know how to use them. All these problems are suggested to us by experts:

1. In our Silver Ore regions the great heaps of metallic Cobalt and Cobalt Oxide for which we have found no use.
2. We need a plan to separate out nickel from low-grade ores.
3. Investigation as to qualities of Illuminating Gas.
4. Investigation of Anhydrite.
5. Remedy for Sulphur in Coal.
6. To find cause of explosibility of Coal Dust.

7. How to utilize Straw.
8. How to utilize wood waste.
9. How to utilize smoke.
10. How to utilize hardwoods.
11. How to utilize sewage.
12. How to utilize tar as a by-product.
13. How to utilize waste in Wood pulp (50 per cent).
14. How to utilize Peat.
15. How to utilize by-products of shales.
16. How to treat pulp of various kinds.
17. How to obtain a safe bleaching agent.
18. How to improve paper making.
19. How to acclimatize corn.
20. How to acclimatize Alfalfa.
21. How to acclimatize Wheat.
22. Investigation of water-lifting in the soil.
23. Methods of meeting hurtful insects.
24. Improvement in Leather.
25. Improvement in Glass.
26. Improvement in Glue.
27. Improvement in Enamel.
28. Improvement in Gas producers.
29. Treatment of British Columbia ores by electricity.
30. Methods of Utilizing fish waste; and so on.

But in Canada, though we may be far behind the Industrial Nations of Europe, we have the future before us. How are we to meet these and hundreds of other problems? We are to follow men who observe and men of experience, who know.

Our late King Edward, inherited from his father, the wise Prince Albert, the true spirit of a forward Industry. This is what King Edward said:—"The prosperity, even the very safety and existence of our country, depends on the quality of the scientific and technical training of those who are to guide and control our industries." And not less decided and far-seeing are the words of our late King's nephew, the present Kaiser, Wilhelm of Germany. In opening a new University in Breslau in 1910, the German Emperor said: "The close connection between Technical Science and Industry becomes year by year more manifest, and it is not only by chance that the immense advance made by our industrial work is contemporaneous with the progressive development of our Technical University system in Germany. The times are past in which a school of practice sufficed for the engineer. Whoever wishes to be equal to the demands made by technics in our time must go into the battle of life equipped with a solid scientific education."

Surely when Emperors, Professors, Manufacturers, foremen and even halting apprentices, say there is need for improvement, we must grapple with the question and master it. It is useless, however, to think that there are no difficulties, and serious difficulties, in the way of Research.

Almost all the principles dealt with in our search are included in Chemistry and Physics—with, in some special departments, the principles of Biology. These sciences deal with the most intricate problems and the most recondite principles of the world in which we live. Nature presents the most complicated of her puzzles to us in the commonest things of life. The seemingly simple problem of the sustenance of the growing plant in the soil involves the deepest processes of Chemistry, Physics and Bacteriology.

The questions of Animal Husbandry include deep problems of life and of physiological chemistry. The common health of the people brings us face to face with the unseen agencies that threaten our very existence, while the foundry, the mine and the blast furnace present processes which so often go wrong and baffle the most competent of experts. Every science is simply the attempt to know some phase of nature presenting its most perplexing complications in the ordinary course of life, progress, and Industry. Now, if this be a true view of our environment, it is plain that we are in a world full of mysteries, some of which we may to some extent penetrate, others that will remain unsolved. This being so, it will appear that not alone splendid laboratories, not high-sounding titles, not alone institutions posing as practical centres, can guarantee successful research, for a very observant American Scientist has said "a great deal of unimportant work masquerades under the name of Research." In a letter written to me by Dr. McLaurin, the distinguished President of the Massachusetts School of Technology, there occurs the following sentence: "I need hardly say to you that almost the only equipment that really counts for much in scientific research is the equipment in MEN."

We may say of the true man of Research—in a more earnest sense than old Lucian used the expression: "outos ekeinos"—that is the man!

While of course every system may be faulty, and while even the best system may not always supply the inventive, penetrating, persevering and intense qualities needed by the man of research, yet, as a general requirement such a man, following the best models, should have:

1. A thorough Primary and Secondary Education.

2. Training in a modern University, where the Science Option has been fully followed, or in a Technical College of University rank, in either case among students under competent science professors and where the aspirant has completed satisfactorily a practical science course.

3. A post-graduate course of several years absolutely devoted to the Department in which the candidate is to specialize, and this under a professor who has a "fine frenzy" and devotion to his subject.

4. Certificates of competence, of skilfulness and of success in solving a prescribed problem.

Even under all the power and pressure of a great guiding intellect, the aspirant may at times fail. But that there is a certainty of a general average of fair results is seen when we but name over, and recall the work achieved and the impulse imparted by the

### DEANS OF RESEARCH IN ENGLAND.

Lord Lister, London, in Preventive Medicine.
Sir H. H. Roscoe, London, in Chemistry.
Sir J. J. Thomson, Cambridge, Physics.
Sir Oliver Lodge, Birmingham, Physics.
Sir William Ramsay, London, Chemistry.
Sir William Slich, Oxford, Forestry.
Dr. Silvanus Thompson, London (Guilds School), Physics.
Dr. Ernest Rutherford, Manchester, Physics.
Sir James Dewar, Cambridge, Chemistry.

What then is Research?

1. *It is a great National Asset.* Think of what it would be to have a hundred men of high attainments and practical skill working under favorable conditions in Canada upon the hundred problems to which we have referred. Yes, we have had them, but we did not set them to work on our National Science problems. Our Commission met Canadians highly educated and occupying places of scientific distinction in twos and threes in New York, Cornell (Ithaca), Johns Hopkins (Baltimore), Washington, Pittsburgh, Buffalo, Madison, Wis., Minneapolis, Kansas, Missouri, California, Washington State—our brightest minds.—From Toronto University alone there have gone to high educational positions in the United States hundreds of Canadians, and I have a list of graduates of the Guelph Agricultural College who have left Canada to hold high educational and research positions in 30 agricultural colleges and experiment stations, from the Atlantic to the Pacific in the United States. I am informed that in Institutions of Higher Learning and Scientific occupations in the United States there are no fewer than 600 graduates of Toronto University, and I know that McGill and Queen's are similarly represented.

One of the most brilliant of these wanderers said to me lately: "I am a Canadian; my wife is a Canadian; we are bringing up our little girl here as a Canadian. When I was in a Canadian University the only outlook I could see for myself at that time was as teacher of a High School. For that I did not care. I came here to be a Research professor." In harmony with this complaint one of my own students in Science, now a dean of Faculty in one of the most prominent Universities in the United States, lamented to me lately the few positions in Canada open to Canadians of higher grade. Even to Oxford, Manchester, Edinburgh, London, have our men of scientific mark been taken from us. These bright minds of ours are a national asset. We need them. We have no right to let them leave us. They are the Creator's gift to us for our higher development. Our Governments, our Universities, our private citizens of means, and our manufacturers should take hold of them, open positions for them, not specially for their own sakes, but because the field of profitable research requires them.

2. *Research is a spirit or a passion.* The brilliancy, the inventiveness and the aptitudes of the true disciples of Research seem to carry with them a certain unsettledness and variability from rule, that some would call genius. It is the power of keen mental vision, which reaches its object by a species of intuition. It involves a sensitive intellect which can be in touch with the deep fundamental principles of the Universe. The bird sings because it cannot but sing. Wordsworth saw visions because he was in responsive touch with Nature. Kelvin saw the practical application of principles by a sort of instinct, and Edison simply imagines the line of search which experiment ensures to him.

3. *Research is a concentrated piece of Intellectual work.* The essence of the process of Research is experiment, and continued trial. It means to some extent isolation from the world. It means long nights and watching and laborious days to him who would succeed. The laboratory has to be to a certain extent to the seeker his curling rink, golf links, his cricket field, and his hunting ground. He should be provided with all the resources of a high and scientific civilization. He must, however, know what is going on in the world about him, what his fellow workers are doing, what mistakes they have made, and what results they have achieved. And if he is all this, just as when we call for soldiers in time of war and give our best to the volunteer, so we should see that our best of support, of respect, and consideration, is given to the men who will seclude themselves in the Laboratory and will give up the pleasures of gaiety or even of general culture. To secure the safety of the country, the soldier is honored on his return from the war, so the experimenter who overcomes ignorance and inefficiency should be crowned with laurels by his country.

4. "Laborare est orare" is an old motto, and so, when we see the high ideals of a Newton, a Kepler, a Clerk Maxwell or an Agassiz, worked out into discovery we regard their research as high work—a moral exploit. In short, the persistent, honest, self-denying work of the earnest seeker after truth is surely a high virtue.

### THE MEANS.

If then Research is all this, how are we to secure it to our Country?

1. If it is a national asset and a benefit to all the people, then it is a fit subject for Government assistance. Probably the hundreds of brilliant Canadians who have gone abroad and are in the service of foreign nations could all have been saved to Canadian education and Canadian Manufacture by judicious Government action. If during our rising entrance upon manufacturing in Canada which has been very remarkable in the last forty years, the Government had understood and taken action, the result would be very different.

The total for additional Government grants to Universities and other high-class institutions (chiefly for Science) in the British Empire for 1910 was about six and a half millions of dollars. All that I find included in this from the Dominion Government is for Experimental Farms, $87,500. Of large sums voted for the Universities and Technical Schools in Germany for general purposes, it is well known that a great portion of this is voted by the States in order that advanced Technical Education may be given. Even little Switzerland, among the clouds, is so practical that a Swiss professor remarked to me:—"When we want a new professor in our Universities and Technical Schools we choose him first on the basis of his being able to carry on Research, and after that on account of his power to teach." The Federal Government of Switzerland, while allowing the Cantons to carry on and pay entirely for the Universities and subordinate schools, keeps up at its own expense the only Technical School of University rank in Switzerland, and it does this in a most generous way. In Holland, while the Universities are left to manage general culture, in the old town of Delft the most magnificent of Technical Schools is found. It carries on every variety of Industrial Research and is maintained entirely by the General Government.

In Denmark, which we have not been accustomed to look upon as a rich country, the General Government gave last year to Agricultural Societies for Research and Experiment:

| | |
|---|---|
| Experiments in Agriculture and Veterinary High School........ | $ 2,530. |
| Royal Society for Research in Plant Culture................ | 29,500. |
| Bacteriological Investigation of Serums, Vaccine, &c.......... | 78,000. |
| Total for Research................................ | $144,580. |

## PRIVATE BENEFICENCE.

The subject of Research has a peculiar attraction for men of large means. First, Research takes a great deal of money to be effective. Then, it has a very definite aim which appeals to men of large fortunes and business habits. In 1910 in the British Empire—none of them, I am sorry to say, in Canada—thirteen men of large means gave or bequeathed for Research no less than $3,441,500, the largest one sum of this being for the Otto Beit Scholarships for scientific students, the capital amounting to $1,075,000. The two great American capitalists, Messrs. Carnegie and Rockefeller, have shown great interest in Research and have been very liberal towards it. A purely Research Institution —the Carnegie Institute of Washington, during the past year, 1911, gave to ten different departments of Research the sum of $450,160. Rockefeller's Foundation for Medical Research, which had received from him for the Institute and the Hospital in former years $3,820,000 had from him in 1911 the princely gift of $3,520,000. It was also interesting to note that a bequest for Research—unique in being left by Alexander Agassiz, one of the professorial class, which does not as a profession usually possess a plethora of wealth, was given last year, amounting to $225,000.

## UNITED SUPPORT OF RESEARCH.

One of the strong features of German advance in Research is the union of all classes of the people in supporting it. Kings and Grand Dukes find their highest pleasure in being patrons and liberal supporters of learning.

The latest example of this is seen in Germany. The Emperor has become head of an organization called "The Kaiser Wilhelm Society for the Promotion of Science." Individuals or firms pay $5,000 for entrance, or may make an annual contribution of $250, commutable by a lump sum of $10,000. The Emperor announced in 1910 that the Society already had a capital of $2,500,000. The object of this society is to subsidize from this fund men of distinction in Science and thus reward and stimulate Research.

## CO-OPERATIVE RESEARCH WORK.

Several of the United States Universities, imitating somewhat the German Universities and the Modern Science Universities of England in obtaining the co-operation of Manufacturers have accomplished a great work in Research. A few examples of these are well worth our attention.

1. THE MASSACHUSETTS SCHOOL OF TECHNOLOGY.

This remarkable Institution, of University rank, has a world-wide fame. In 1911 it celebrated the jubilee of its founder, Dr. Rogers. It does a great work in Research. While in this field individual members of its staff have gained fame, the Institution aims rather at developing "Departmental Research," i.e. Research carried on by the joint work of individuals of the Department. Dozens of intricate problems, and this frequently at the expense of large manufacturers, have been dealt with by its departments. Problems in 1, Naval construction and architecture; 2, in Electrical Engineering, have been solved. Perhaps most remarkable as showing its policy of taking up practical questions as they arise has been. 3. The problem of Public Health. Seven volumes of past researches have been printed as Contributions from the Sanitary Research Laboratory and Sewage Experiment Station. 4. Most notable is the work of the Physical Chemistry Laboratories. Ten members make up the staff. The Research staff is organized as made up of professors, associate professors, and assistant professors. The Associates and Assistants do not teach, but deal only with practical work. Research Conferences are held by the whole staff every week of the Session A vast amount of work is done, and the enormous sums saved by manufacturers stand to the credit of the faculty.

2. CINCINNATI & PITTSBURGH UNIVERSITIES CO-OPERATIVE PLAN.

In these two Universities the Engineering Departments are carried on by a close co-operation of the Faculty with certain manufacturers in their several cities. The students for Engineering are carefully selected as to their ability and attainments. In the first of these Universities there is a waiting list of several hundred applicants for entrance. The students for Engineering are divided into two shifts; and each shift takes week about in shop and classroom. For their shop work the student apprentices receive the fixed pay of the mechanics of similar status beside them. Each alternate week the student confers with his professor and on his efficiency receives his credits. The connecting link between the shop and the classroom is the Shop Co-ordinator, who is a highly paid College graduate acquainted with shop practice. He spends every morning in the University classroom and every afternoon in the shops, giving advice and direction to the students. The Yearly course extends over ten months and the remaining two months are employed in doing remunerative work on railways or in factories. The Course lasts over four or five years and the plan is said to be popular with the manufacturers.

### 3. THE FOREST PRODUCTS LABORATORY, MADISON, WISCONSIN.

One of the most remarkable examples of co-operation in Research is that between the Forestry Department of the United States and the University of Wisconsin at Madison. The University erected a $50,000 building on its own site, and agreed to supply water, light, and heat to the Department. The Department of Forestry have complete control, appoint and pay the staff, of whom there are sixty and more than one third of them experts of high standing. The staff is bound to supply a certain limited number of lecturers to University students who desire them. The Laboratory is organized under nine sections:—

1. Maintenance.
2. Engineering.
3. Timber Tests.
4. Wood Preservation.
5. Wood Technology.
6. Wood Distillation.
7. Pulp and Paper.
8. Chemistry.
9. Pathology.

The building consists entirely of Laboratories and offices. Every phase of wood investigation is carried on. Daily reports are made. The high-class of experimenters, thorough men of Research—the practical work for Railway companies, lumbermen, and all the wood-using industries, suggest a suitable institution for Canada with its forests. The Forest Products Laboratory staff is supported entirely by the Federal Government—the local expense by the University.

## COMMERCIAL CHEMICAL RESEARCH.

This is carried on in Kansas and Pittsburgh Universities under a distinguished Scientist and author, who is a graduate of Toronto University—Prof. R. K. Duncan. His plan, to quote his own words, "is a mutually advantageous arrangement between manufacturing companies on the one hand and the University on the other for the adequate solution of important manufacturing problems." Professor Duncan is a University professor, formerly of Kansas University, and still has supervision of his scheme there, but now resides in Pittsburgh, Pennsylvania, and is entirely paid by his University. His Laboratory in Pittsburgh is a temporary building with accommodation for twenty two experts—all of the highest class of experienced Research men. His annual pay roll of these men is $40,000, individual salaries varying from $700 to $3,500. These amounts are paid entirely by manufacturing interests. The scheme in Pittsburgh promises to be one of great importance. In Kansas there are twenty fellowships paid by manufacturers and in Pittsburgh nineteen. Professor Duncan deals with the manufacturer as to his problem and what he is willing to pay for investigation for two or three years. The professor has sole choice of his experts. As a matter of fact three of the Pittsburgh experts are from Toronto University, and the remainder are graduates of various Universities. If a discovery is made it is the sole property for three years of the manufacturer contributing to it. At the end of three years it is the property of the public. The experimenter has a share in the profit, but Professor Duncan has none. The most important questions taken up in Pittsburgh Laboratory are Baking, Smoke Nuisance, Glass perfection, Soap making, Glue, Orange Culls, Crude Petroleum, ($10,000 a year for two years and bonus), Cement, Natural gas, etc.

The advantages of this system as stated by Professor Duncan are:

1. A great advantage to the Industrialist.

2. The general elevation of Industry by introducing experts into factories (much after the fashion in Germany.)

3. The co-operation of a large expert staff in which personal integrity is the sine qua non to election to these fellowships. Thus is constituted a fraternity of mutual helpfulness.

4. A remarkable effect upon the Industrialists, interested in elevating and widening their aims and projects.

5. A most important effect on the University concerned, in their relation to the Industrial communities.

Gentlemen of the Canadian Institute, Research is a practical subject. It is no dream or visionary fad. I have endeavored to describe it in its different phases. If Canadian Manufacturers are to succeed, this cannot be done by artificial bolstering up, or sleight of hand, or industrial cornering, or anything else except plain, intelligent hard work. I have pointed out how success may be obtained. It can only be done by Governments—Dominion, Local, and Municipal co-operating heartily in advancing Technical Education, by the co-operative association of Universities and Technical Schools, and it can be greatly assisted by the shrewd but interested support in co-operative plans of the Canadian Manufacturers. Besides, all these may be mightily stimulated by the gifts of rich and generous Canadians—and I am further sure that the Local Governments will pardon us if we should advise the wealthy men to take steps to escape the Legacy Tax by giving hundreds of thousands of dollars while they are still living, that they may see the fruit of their labours.

# HISTORY OF CANADIAN METALLIC CURRENCY.

BY PROFESSOR ADAM SHORTT.

*(Read 22nd April, 1911.)*

Canadian metallic currency as we have it to-day has not been the result of any definite or conscious choice on the part of the Canadian people or their Government. In fact, if the earlier Governments could have settled the matter according to their own convictions and wishes, our currency would be quite other than what it is. However, circumstances are stronger than policy and popular usage than Government enactments.

At the time of the Conquest Canada passed into the hands of the British with practically no metallic money in sight. It was submerged in a flood of depreciated paper currency, the result of extravagance and corruption on the part of the last French colonial Government. When confidence was restored the trade of Quebec and Montreal began to revive through the activities of the immigrant British merchants from the southern colonies. Metallic currency re-appeared, but it was of a very varied character, coming as it did from the old stockings of the more fortunate French-Canadians, the traders from the English colonies and the payments of the British Government.

The long and intimate trade connection between the American colonies and the West Indies resulted in the introduction of Spanish and Portuguese coins. The Spanish dollar was the chief medium of exchange and consequently the practical standard of value. The sterling currency of Britain was the legal standard of the colonies, but there were few British coins in circulation. Metallic currency in a new country whose manufactured goods must be obtained from abroad is apt to be scarce. Popularly the most reasonable manner of protecting and retaining currency is the simple method of over-rating it. This however led to competition in over-rating among the British colonies in America. The Legislature of Massachusetts fixed the value of the Spanish dollar or "Piece of eight" (meaning eight Reals) at six shillings. This was confirmed by the Royal proclamation of Queen Anne, under advice from the Board of Trade, in 1704. In this Proclamation the same rating was extended to the other colonies, and the other silver coins were rated in like proportion. As the Proclamation was only indifferently observed by some of the other colonies, in order to have it legally enforced its terms were embodied in an Act of the Imperial Parliament in 1707.

To evade the conditions of the Act the West Indies passed to the gold standard, with the Portuguese Johannes or "Joe" as the usual medium. Some of the northern colonies took refuge in paper currency, and fluctuations were more common than ever. Remedies were attempted in 1740-41. In 1750 an Imperial Act prohibited the issue of paper currency in several colonies, and in 1764 this was extended to them all.

At the time of the Conquest then, the rating for silver coins, as established by the Proclamation of Queen Anne in 1704, was still in force, the unit was the Spanish dollar, the sterling value of which was 4s. 6d, but rated in the colonies at 6s. Gold coins had received no special rating. At the time of the Conquest the dollar was accepted in Massachusetts and Nova Scotia at 5s. whereas in New York it was accepted at 7s.6d., shortly after at 8s. Now both these standards were introduced by the merchants going to Canada, the Eastern merchants coming from Massachusetts to Nova Scotia, and the Western merchants to Montreal from New York by way of the Lake Champlain route. From Quebec east the customary standard was 5s. the rating being known as Halifax currency. From Quebec west, and centring at Montreal, the customary standard was 8s. known as New York, or more commonly York currency. There were varied ratings for the French and other coins, gold and silver. In order to furnish a standard for legal purposes, Governor Murray passed an Ordinance in 1764 fixing the legal rating of the chief coins in the country, which rating was as follows:—

| Coins. | Weight dwt. | grs. | Rating L | s | d. |
|---|---|---|---|---|---|
| Gold: | | | | | |
| Johannes of Portugal | 18 | 6 | 4 | 16 | 0 |
| Moydore | 6 | 18 | 1 | 16 | 0 |
| Carolin of Germany | 5 | 17 | 1 | 10 | 0 |
| Guinea | 5 | 44 | 1 | 8 | 0 |
| Louis D'Or | 5 | 3 | 1 | 8 | 0 |
| Spanish or French Pistole | 4 | 4 | 1 | 1 | 0 |
| Silver: | | | | | |
| Seville, Mexican and Pillar Dollar | 17 | 12 | | 6 | 0 |
| French Crown, or six Livre piece | 19 | 4 | | 6 | 8 |
| French piece passing at present for 4s. 6d. Halifax currency | 15 | 16 | | 5 | 6 |
| British shilling | | | | 1 | 4 |
| Pistareen | | | | 1 | 2 |
| French nine-penny piece | | | | 1 | 0 |
| Twenty British coppers | | | | 1 | 0 |

Following the legal rating in the Proclamation of Queen Anne it fixes the dollar at 6s. In contracts already made the French Livre was to be rated at one shilling, thus making an easy transition from the French to the English system. There was no coin however, representing the shilling in this Ordinance. It was simply a money of account, the English shilling being rated at 1s.4d.

Though the ratings given in this Ordinance continued to be the legal basis for settlement in disputed accounts, yet in actual practice the merchants of Canada, like those of the other colonies, paid just as much deference to the Ordinance as suited their convenience. Murray, however, took steps the following year, in 1765, by passing a further Ordinance to enforce his ruling. This constituted one of the grievances of the merchants against him and assisted towards his recall and the repeal of his second Ordinance. The Ordinance of 1764 was not very satisfactory in several respects, but there were numerous difficulties in the way of amending it, not the least of which was the difference of opinion and practice between the merchants of Quebec and Montreal. The troubles incident to the passing of the Quebec Act and the American Revolution prevented any local action being taken untill 1777 when the colony of New York being in rebellion and its sympathisers in Montreal in disfavour, the Quebec influence carried the day and Halifax currency became the new official currency, the rating of the dollar being changed from 6s. to 5s. The Ordinance is as follows:—

| Coins. | Weight dwt. | grs. | Rate. L | s | d. |
|---|---|---|---|---|---|
| Gold: | | | | | |
| The Johannes of Portugal | 18 | 6 | 4 | 0 | 0 |
| The Moidore | 6 | 28 | 1 | 10 | 0 |
| The Doubloon, or four Pistole piece | 17 | 0 | 3 | 12 | 0 |
| The Guinea | 5 | 8 | 1 | 3 | 4 |
| The Louis D'Or | 5 | 3 | 1 | 2 | 6 |
| Paying two pence one farthing for every grain of gold under weight. | | | | | |
| Silver: | | | | | |
| The Spanish Dollar | | | | 5 | 0 |
| The British Crown | | | | 5 | 6 |
| The French Crown, or piece of six Livres tournois | | | | 5 | 6 |
| The French piece of four livres ten sols tournois | | | | 4 | 2 |
| The British shilling | | | | 1 | 1 |
| The French piece of twenty-four sols tournois | | | | 1 | 1 |
| The Pistareen | | | | 1 | 0 |
| The French piece of thirty-six sols tournois | | | | 1 | 8 |

According to the intrinsic value of the silver in these respective coins, the Spanish dollar being rated at 5s., the British Crown at 5s.6d. was underrated to the extent of 4d. and was therefore driven out of circulation. The French Crown when rated at 5s. 6d. was over-rated and remained in the Colony. The Pistareen, however, at one shilling was more highly overvalued than any of the silver coins. The agitation for a further revision of the rating began immediately after the effects of the Ordinance were realized. But owing to the old difference of opinion between Quebec and Montreal merchants, nothing was done until 1795, after representative Government had been introduced into the Canadas and the two Provinces separated. Then a new act making some slight changes was passed in Lower Canada and a somewhat similar act in Upper Canada. In these the American dollar was rated for the first time and at the same rate as the Spanish dollar, namely 5s. but no other changes were made in the ratings of the silver coins.

The practice of the Montreal merchants in following the York currency naturally extended to Upper Canada where most of the Loyalist settlers were from New York State. Thus though the Halifax standard of 5s. to the dollar was the official rate, the customary rate was 8s. to the dollar, the basis of which was the Mexican Real eight of which made up a dollar, whence the old name "piece of eight." In time this came to be identified with the English 6d. which was sometimes called a York shilling.

As the new American currency of dollars and their fractions gradually took the place of all other coins in the United States, the light and defaced coinage of other mints took refuge in Canada and added to the piebald character of its currency. Only the scarcity of any medium of exchange enabled much of this to circulate. In 1808 the rate of the gold coins was further amended as affecting the foreign exchanges of the colony.

During the whole of this period the Imperial authorities in Canada continued to keep their books in sterling and made payments to the troops on the same basis, rating the dollar at 4s. 6d. It was not, however British coinage which was brought to Canada to supply the Military Chest, but simply Spanish dollars. When these were issued to the troops at 4s. 6d. it simply meant that the soldiers were paid a bonus of 6d. on each dollar as the legal rate was 5s. In 1808 to partially overcome this advantage to the troops the dollars were issued at the rate of 4s.8d. sterling, which in practice meant the reduction of 2d. on the dollar from the soldier's pay.

In 1812 to guard against replacement of the metallic currency of the Canadas by the army bills which were then being issued, it was provided in the Army Bill Act that no metallic currency or gold or silver bullion should be exported from Canada in any shape on pain of forfeiture if discovered. This last law continued in force until 1817.

After 1792 the old French coins circulating in Canada were no longer minted, though the French Canadians held to these coins as among the symbols of their nationality. Much as they disliked the new French coinage after the Revolution, yet they preferred it to anything British, and in 1819 by an act of the Lower Canadian Legislature the new French coinage was created legal tender at fixed rates; in Upper Canada, however they received no official standing.

In the upper Province the conflict between the older form of York currency and the newer form of Halifax currency gave rise to no little difficulty, especially in the settlement of cases brought to court. To definitely settle these differences, an Act was passed in 1821 providing that no interest should be collected on notes, bonds, or other contracts in which the sums were expressed in York currency. No rendering of accounts and no presentation of books in court were to be deemed legal where they were presented in York currency. Thus was York currency finally displaced by Halifax currency. Yet so strong is custom that for nearly half a century afterwards in the older sections of Upper Canada prices continued to be quoted and farm produce bought and sold in York currency.

In 1825 the British Government undertook to correct all the anomalies of colonial currency by introducing the British sterling currency as a standard of value and medium of exchange throughout the Empire. As already observed, among the French Canadians the old French coins, so far as available, constituted the favorite currency, while in the English settlements, in the city of Montreal and throughout western Canada, the Spanish and American dollars, with a miscellaneous fringe of other gold and silver coins, constituted the general medium of exchange.

In 1816 Britain herself had adopted gold as a standard and silver became a token money, its face value being above its intrinsic value, while its legal tender was limited to 40s. In 1821 the Bank of England resumed specie payment. At this time also the Spanish colonies were achieving their independence, the silver mines passed out of the hands of Spain and the supply of Spanish dollars was checked, leaving henceforth the American dollar in command of the field. In view of these conditions and especially of the successes which attended the re-adjustment of the British coinage, it was perhaps natural for the Government to suppose that they could re-construct the currency system of all parts of the Empire. It was resolved to make use of the extensive payments in the colonies through the Military Chests for the purpose of effecting the desired change. The Lords of the Treasury, in a minute dated February 11th, 1825, set forth their scheme for re-organization and the arguments in support of it. They acknowledged that in most of the colonies the Spanish dollar was at once the prevailing coin in circulation and the standard by which all other coins were measured. But the Spanish dollar was greatly over-rated, it was paid out by the Military Chests at 4s 8d. when as a matter of intrinsic value it was scarcely above 4s. and at the rate of British silver coinage it would be 4s. 4d.

Under the circumstances the Lords of the Treasury had reached the conclusion that the best medium, alike for the payment of the British troops quartered in the colonies, and for colonial exchange, was the British silver and copper currency. This currency, however, must be capable of conversion into the standard gold coinage of Great Britain. This could be accomplished by issuing for it in the colonies, bills of exchange on Britain at a standard rate. The rate suggested was 3% premium, or £103 in the colonies for £100 in London. British silver coinage being issued at a higher rate than its intrinsic value, was expected to remain in circulation in the colonies, because it would not pay to melt it down for export as bullion, and the issue of bills of exchange on London would prevent its being returned there. Steps were to be taken at once to have the British silver coins sent to the colonies, in the meantime the dollar to be rated at 4s. 4d. and other coins in proportion.

The very natural object of this comprehensive scheme was to establish one currency language for all exchange operations throughout the Empire. Wherever the British flag waved the British shilling was to circulate, to the advantage of imperial trade and commerce. Looked at from the point of view of London, the plan was faultless, but from the colonial point of view it was much less simple or attractive. Most unexpected obstacles to its realization cropped up. In Canada the proposition provided for the rating of the dollar at 4s. 4d. sterling, instead of 5s.2d. as in the existing act. This however would mean the infringement of the Canadian law by a British order in Council. Such a proposal stirred the constitutional bile of the Canadian Legislature, and though Lord Dalhousie endeavoured to get the Canadian Act changed by the Assembly, that body simply referred the matter to a committee from which it never emerged. The Legislative Council, on the other hand, though a strong pro-British body, gave numerous reasons why the Canadian system in operation at the time could not be disturbed. Their chief objection was that as the British silver was over-rated and not subject to free coinage, nor legal tender for more than 40s. it would be very unwise to adopt it as a standard in Canada. In other respects it would involve too many changes in Canadian contracts and general business. The British Treasury, being informed of the difficulties in the way of their imperial scheme gracefully abandoned it in formal shape, trusting to the payment of the troops in British silver to alter the usage in Canadian business.

In Upper Canada though declining to alter the basis of the currency, or change the rating of the dollar, the Legislature raised the rating of the British coins. The Crown was rated at 5s.9d. instead of 5s.6d. and the shilling at 1s.2d. instead of 1s.1d. This had the secondary consequence of putting the two Canadian Provinces out of touch with each other in the official rating of their coinage.

The British military authorities sent out £30,000 in British silver for the payment of the troops. Contracts for military supplies were to be sent in in sterling at the specified rate of 4s. 4d. for the dollar. Bills of exchange might be issued at the rate of 103 for 100 payable in London. But the very fact that the British silver when paid out in the colonies could be used to purchase exchange on Britain resulted in its being immediately returned to the Military Chest, or the vaults of the banks, while the actual currency of the colonies remained paper bank notes and the over-rated Pistareens and French silver, together with the American and Mexican silver dollars. But the chief currency used to buy up the British silver were the local Canadian Bank notes and these were all expressed in dollars. The very efforts therefore of the Imperial authorities to put British coinage in circulation, proved to be the most effective method of excluding it from circulation, and of insuring the use of the American medium of exchange. The fact was that though the dollar was the nominal standard the metallic currency in circulation consisted of the odds and ends of the coinage of all commercial nations, most of it too highly over-rated or too much worn and defaced to be profitably exported.

For fractional currency the Spanish Pistareen became the most common silver coin in the English sections of Canada. It was being discarded in the United States owing to the reformation of their currency, and passed over to Canada where it was accepted as a shilling piece, i.e. 20 cents, while in the United States it was worth only 17c. or 18c. As a matter of fact the Pistareens and their halves were among the most worn and defaced coins in circulation.

Copper coinage in the early days was also very scarce though considerably over-rated. About 1825 it consisted of discarded and worn British half-pence, farthings, various private tokens, native and foreign, and even brass buttons hammered smooth, As indicating the manner in which the Canadian copper currency was regarded, we may take the following extract from a letter of one of the Dorking immigrants. "Tell John to bring as many farthings as he can get, and old halfpence, as they go for as much as a penny piece; they call them coppers." In Upper Canada the enterprising firm of Ed. Leslie and Sons imported a considerable number of tokens for their own use, and the demand for them became so great that in 1831 they applied to the Government to either furnish a supply itself or sanction importations to meet the public need.

There was an increasing demand on the part of the mercantile element in the country for a Canadian silver and gold coinage, on the basis of the decimal system of dollars and cents. But in 1830, under Sir James Kemp, another effort was made to have the British standard adopted. A Bill was introduced providing for the sterling standard and the rating of the dollar at 4s. 4d. It provided also for calling in the

Pistareens and French silver, and for excluding all gold coins but the British sovereign and half sovereign. It failed to pass, however, its changes being regarded as too radical.

In both Provinces temporary measures were passed making some slight adjustments. The Lower Canadian measure rated the Pistareen at 10d. instead of a shilling and the half Pistareen at 5d. The Upper Canadian act merely excluded from legal tender the worn and defaced coinage then forming a large part of the circulation, such as worn British coins, the Pistareens, and French crowns and half crowns. But as no new coinage was provided to take the place of that which had been disfranchised the situation was not much improved. Matters were simply left to be dealt with by practical agreements among the merchants and others.

Meantime the miscellaneous trash, constantly imported into Canada and circulating under the name of coppers, became an intolerable nuisance. The banks of Lower Canada undertook to remedy matters by issuing a series of copper bank tokens of definite standard which were accepted at their face value. The first issue was dated 1837 but did not pass into circulation until the spring of 1838. The banks providing them were the Bank of Montreal, the City Bank, the Quebec Bank, and the Banque du Peuple. Later the Bank of Upper Canada also obtained and exercised the right to issue copper bank tokens. This movement only partly remedied matters. As a further condition of relief the Bank of Montreal imported $10,000 worth of 5 and 10 cent pieces from the United States Mint. This certainly improved the situation, but in doing so further determined the country in the direction of the American and not the English standard.

For some time the changing ratio of silver to gold had caused the American rate of 15 to 1, by undervaluing gold, to drive it out of the country. Hence in 1832 the new ratio of 16 to 1 was adopted. This however had the opposite effect, and as gold increased faster than silver, the latter passed to a premium and disappeared from circulation. American silver disappeared from Canada also, increasing the difficulties of the Canadian situation. Once more therefore the rating of the coinage had to be changed in Upper Canada. This was accomplished by the act of 1836. The British crown was rated at 6s. and the British shilling at 1s. 3d.

British coinage continued to act as an exchange on England and was therefore rated at its exchange value, not at either its currency value or its bullion value. Thus instead of the pound Halifax currency being equivalent to 17s. 4d. sterling, as formerly under the Act of 1836, it became equivalent to 16s. 8d. or, in the shape of the British shilling, to 16s.

These changes very materially affected all military and other contracts. The British shilling now being the cheapest legal tender in Upper Canada, soon displaced practically all other coins.

Though the Home Government did not disallow the Act of 1836, which had only four years to run, it had so little confidence in the Canadian views on money matters that the Governor was required to reserve any further measures dealing with the currency.

The general situation brought to the attention of the better informed Canadians the fact that Canada, being dependent upon foreign coins for its medium of exchange, was liable at any time to lose its currency through an adverse balance of exchange with England or the United States. To over-rate the coins proved only a very temporary expedient as prices rapidly adjusted themselves to the new rates, and the coinage flowed off once more. It was proposed by the more intelligent business men to have a regular Canadian currency which would not be admissible in other countries at its face value, and would therefore serve no other purposes than that of a medium of exchange. This was of course the ultimate remedy and was eventually realized in the present Canadian silver and copper coinage. Still it is surprising to find how long it took to get this simple and obvious remedy into operation.

Upper and Lower Canada had drifted further apart with every change in their currency laws. The dollar alone remained common to both, at the rating of 5s. but no one was compelled to pay in dollars. In Lower Canada payments were made as far as possible in French coins, and in Upper Canada in English shillings. As a result exchanges between the provinces were at varying ratios of discount, and in both exchange on New York was always at a premium. The business of the Canadian provinces was certainly suffering from the unfortunate condition of the currency.

Amid all the conflicting arguments and proposals of the period, on two points the leading financial men were agreed, namely, that there should be a special coinage for the British North American colonies, and that the basis and denomination of that coinage should be the same as in the case of the new American gold and silver coinage. These views were endorsed by the Governor-General, Sir John Colborne, and Sir George Arthur, Lieut.-Governor of Upper Canada.

An Act was passed by the Legislature of Upper Canada with the object of bringing the currency of the provinces into closer relation with that of the United States. The special Council of Lower Canada also passed an Ordinance to improve the currency situation in that province, but both measures were disallowed by the Home Government. The reasons given were sound enough from a British point of view, and several of them from any point of view, inasmuch as too many coins were made unlimited legal tender by tale and the ratings were in several cases inconsistent with each other. But to make the ratings accurate would have required the use of awkward fractions. Thus the shilling instead of being rated at 1s.3d. would have to be rated at 1s. $2\frac{6}{10}$d., and similarly with the others.

The British Government, or at least the Treasury Board, still hoped to enforce the British standard in Canada and to prevent the adoption of the American system, as they were convinced that the use of a common currency must of necessity lead to annexation. In consequence, the Lords of the Treasury suggested that the regulation of Canadian currency should be left to the Home Government to be dealt with by Orders in Council and Royal Proclamations, as in the case of the West Indies, and that the ratings should be determined with reference to British sterling. The Canadian Provinces strongly protested against any such arrangement as quite ignoring vital local conditions.

Before anything further was done the Union of the Provinces had been effected, responsible government was introduced, and further changes depended for good or evil upon the wishes of the Canadian people. For one thing union involved a uniform currency throughout the Canadas. When the Union Parliament opened in 1841, one of the first matters brought up was the condition of the currency. The mercantile community, especially at Montreal, strongly recommended one system of currency for the whole of British North America. But, strange to say, the Montreal people were now in favour of the British and not the American standard. This change of heart was due to the silver famine in the United States, as the result of the 16 to 1 law. However a more popular recommendation throughout the country was that the silver dollar be taken as the standard of currency and that gold be treated only as bullion. Mr. Francis Hincks was the advocate of this system and he was chairman of the Committee of the Legislature to consider the currency question. A census of financial opinion was taken and it was found that the larger number favored the dollar for practical reasons though on sentimental grounds a number seem to have preferred the sterling standard.

One remarkable change of view was that of Commissary-General Routh, who, while the British Government was attempting to establish a uniform currency throughout the Empire, was a strong advocate of the sterling standard; but now that the military question had lost its influence, had given up this policy and came out as a strong advocate of the American decimal system. This he did on purely practical grounds. "It is," he said, "the system most familiar to the Canadian people, and it is most convenient for their business, while the United States is the only available source for large and immediate supplies of metallic currency. On the other hand the British standard cannot be maintained in Canada because it will be subject to constant fluctuations following the conditions of exchange and the currency will be liable to be exported in lieu of Bills of Exchange."

With Canadian opinion in a divided condition the Currency Bill was necessarily a compromise. It corrected, however, many of the existing anomalies and reduced the range of unlimited legal tender. The Halifax standard was retained, though there were still no coins corresponding to it. The gold coins allowed as legal tender were the American eagle and the British sovereign. Other gold coins might be used as legal tender at specified rates per ounce. The silver coins admitted as unlimited legal tender were the American dollar and half dollar and the new French 5 franc piece. The other rated coins were limited as legal tender to £2.10s. The dollar was rated at 5s. 1d. and the 5 franc piece at 4s.8d. The old French silver coins of Lower Canada were not given any rating and therefore became mere bullion, much to the disgust of the banks and the people of Lower Canada. The French Canadians of course saw in this another blow dealt at their nationality. There was a rather amusing scramble among the banks to unload on each other before the Act came into force the now homeless old French coins. The exclusion of British silver from the privilege of unlimited legal tender caused quite an outburst of sentiment on the part of the pocket Loyalists, as they were likely to lose a little in consequence. But, as Mr. Hincks pointed out, British silver was now treated in Canada exactly as it was treated in England. It was merely a token currency of limited legal tender. The general effect of the new measure was decidedly beneficial, and certainly prepared the way for further changes in the same direction.

After the passing of the Metcalfe ministry, Mr. Hincks once more became Finance Minister in the Reform ministry of 1847 under Lord Elgin, and resumed the task of developing a permanent currency for Canada. Under the Act of 1841, at the instance of the Council, but much to the dislike of the Assembly, the dollar had been rated at 5s. 1d. and the English crown at 6s. 1d. In 1850 the older ratings were restored, namely 5s. for the dollar and 6s. for the crown. This was done with the express object of equalizing the American and Canadian standards. The same Act gave authority to the Governor in Council to cause silver coins to be struck for circulation in Canada, the coins to be of the following values, 5s., 2s. 6d., 1s. 3d., 1s., 6d., and 3d. These were of course merely currency ratings corresponding to the dollar, half and quarter dollar, 20c., 10c., and 5c. pieces. These coins were to be legal tender to the extent of $10. This act therefore laid the foundation for our present system of coins. The Government was also authorized to obtain a supply of gold coins of the value of £1.5s. or $5, £1, or $4 and the halves of these. They were to be of the same standard of fineness as the British sovereign and of unlimited legal tender. When this act, to which Lord Elgin had assented, reached the Home Government it was submitted to the Treasury Board who declared that the section relating to the special coinage for the province required the immediate disallowance of the Act. They declared that it "involves an uncalled for and most objectionable interference with the prerogative of the Crown." When this information was transmitted to Canada, Mr. Hincks made one of those lucid, convincing, vigorous and yet temperate replies for which he was noted. This brought out an elaborate justification on the part of the Treasury Board to which Mr. Hincks made a still more effective reply, which was eulogized even by his political opponents, and to which no reply was attempted on the part of the Treasury Board. The Act was disallowed, but the discussion over it considerably cleared the air and advanced matters a long way towards the ultimate adoption of the decimal system in Canada.

Mr. Hincks entered into communication with the Governments of Nova Scotia and New Brunswick with reference to a uniform currency for British North America. In a series of resolutions in 1851 he laid down certain principles on which he hoped the general currency question might be settled. There should be a definite currency for Canada, which might become common to the British North American colonies, and which would facilitate commerce with all parts of the continent. It should be simple and convenient and therefore the decimal system based on the dollar as the unit of account. It should be mono-metallic with gold as the standard and with silver and copper coins of limited legal tender, which might be over-rated to the same extent as the British silver and copper to prevent their being exported. The dollar of the United States should be accepted at one dollar or 5s. currency. An Act based on these resolutions was duly passed and provided that as soon as practicable the public accounts of the province should be kept in dollars, cents and mills, and all moneys and accounts might be legally stated whether in dollars and cents or in the existing Halifax currency. In authorizing the introduction of gold and silver coins, the standard of the sovereign was adopted rated at $4.86 2/3 or £1.4s.4d. currency. The Provincial gold coins were to be unlimited legal tender under the same conditions of loss by wear and payment by weight as applied to British gold; the silver coins to be legal tender to $10 only, and the copper coins to 20c. Unfortunately, with the exception of the changes here made, the other parts of the Currency Act of 1841 were to remain in force, which involved the continuing of the American dollar as unlimited legal tender. This oversight caused the Act to be sent back to Canada for revision.

Together with it the British Treasury Board sent an exhaustive memorandum on the North American colonial currency, and suggested a basis for common agreement among the provinces. The British authorities no longer objected to the decimal system but wished the unit to be the pound currency, and not the American dollar. It was now proposed that the pound should be represented by an actual gold coin to be called a "Royal," with subsidiary gold and copper coins in decimal ratio.

Seeing that the Home Government had conceded so much, Mr. Hincks was inclined to accept the suggestions of the Treasury Board, But the more the members of the Canadian Parliament and the bankers and business men considered the practical effects of the proposal, the more they reverted to the system of dollars and cents. The new measure was proposed in the session of 1852-3. As first presented it provided for a special Canadian decimal currency with a gold coin of the value of one half pound currency to be called a Royal, equivalent to $2, and with a silver coin 1/10 of that or 20c., to be called a shilling, and another copper coin 1/10 of the shilling or 2c. to be called a "mark." In the discussion in the House the majority favoured the system of dollars and cents, though leaning towards the sterling standard on sentimental grounds. Among these was John A. Macdonald. Mr. Hincks readily adopted the views of the majority, which were also his own at heart. The new Act legalized transactions in dollars and cents, making them the new legal money of account, though the Halifax or provincial denomination currency was not excluded. The gold coins of Britain were to be legal tender to any amount at $4.86 2/3 or £1. 4s. 6d. currency; the American eagle to be legal tender at $10 or £2. 10s. currency. Her Majesty was empowered to direct the issue from the Royal Mint of special silver coins for circulation in Canada, these to be legal tender up to $10; special copper coins might also be struck. Until the new coins were issued British silver was to be accepted at rates specified.

In this Act the American silver dollar and its fractions disappeared from the list of rated coins. This was because the dollar had disappeared in the United States itself, owing to its being overrated. In 1853 the American Government had provided a subsidiary silver coinage from 50c. downwards. This was accomplished by diminishing the quantity of silver in these coins, thus making them a token currency with legal tender to $5 only. From 1853 to 1878, when the Bland Act was passed, the United States had a monometallic currency with gold as the standard but with subsidiary silver currency as in Britain. This will explain the disappearance of the American silver from the Canadian Act.

Mr. Hincks went out of power in 1854, just after the new Currency Act was approved, and there was much delay in putting the new measure into practice. Finally in 1857 a further Act was passed requiring the Government accounts to be kept in dollars and cents without the option of using Halifax currency; and requiring all accounts presented to the Government to be rendered in the new denomination, as indeed had been largely the practice. The Act was to come into force on January 1, 1858. From that day dates the actual official adoption of the decimal system of dollars and cents in Canada. Following the Government the merchants and banks quite generally adopted the new system, and steps were immediately taken to have the new silver and copper currency provided. About the middle of 1858 the first shipment was received from the Royal Mint. It consisted of $100,000 in 20c. pieces, $75,000 in 10 cent pieces, $75,000 in 5 cent pieces, and $50,000 in 1 cent pieces. Some surprise was expressed that there were no 25 cent pieces, which many regarded as the most necessary of all. But the British shilling had been provided for in the Act of 1853 as legal tender to the extent of $10. Its proper rating should have been 24⅓ cents but it was commonly accepted at 25 cents, hence the omission of the Canadian 25 cent coin. The shilling being over-rated soon appeared in large numbers and gave considerable trouble. The new American token currency also flowed into the country under the influence of the Reciprocity Treaty, but more especially during the period of the Civil War. The banks did not favour the Canadian gold coinage nor have they to this day, because it was not necessary in commerce and it would be no use in exchange except as bullion. Various attempts were made to extend the legal tender range of the silver coinage, but fortunately without success.

No further changes in the currency were made until after Confederation. But Confederation being accomplished, and the American Civil War ended, the Canadian Government found it necessary to set the currency in order for the whole Dominion. Canada was flooded with American silver which had been sent over to purchase supplies. At this stage Sir Francis Hincks once more became Finance Minister of Canada, and in 1870 undertook to dispose of the Yankee silver and to supply its place with Canadian coins. By employing the banks in general to gather it in, and the Bank of Montreal in particular to dispose of it in New York, upwards of $5,000,000 in American fractional silver was exported at a cost to the Government of $118,000. While this process was going on, Sir Francis Hincks temporarily supplied its place with fractional Dominion notes, the well-known "shin-plasters." When the process was completed he substituted a new Dominion coinage including Canadian coins of the denomination of 50 cents and 25 cents which were added to the Canadian coinage for the first time thus bringing it to the condition in which we know it to-day, the shin-plasters and 20 cent pieces having gradually disappeared. This also brought the Provinces of Nova Scotia and New Brunswick into line with the Canadian decimal currency.

Such is in outline the history of our Canadian metallic currency up to the establishment of the Canadian branch of the Royal Mint. Incidentally there are connected with it a good many picturesque episodes, political contests, inter-imperial discussion and domestic wild-eyed proposals which furnish both entertainment and instruction for those specially interested in such matters, but they could not be introduced in the course of a single paper.

# THE SAXBY GALE.

By D. L. Hutchinson.

(*Read 18th November, 1911.*)

On the fourth of October, 1869, New Brunswick and its western border was visited by an unusually destructive and violent storm, accompanied by a tide which rose to an extraordinary height.

This great storm was called the "Saxby gale" for the reason that Lieut. Saxby, R.N. made a prediction (subsequently described) nearly a year before, that at 7 a.m. of the 5th of October the earth would be visited by a storm of marked severity, attended by an exceptionally high tide. From old records and various reliable sources the following account of the storm has been procured.

On the day preceding the storm the weather in St. John was foggy in the morning followed by partly cloudy in afternoon becoming overcast at night.

On the day of the storm (Monday, Oct. 4th) the early morning was foggy, then part clouded and by 7 a.m. fine and warm, in the afternoon the heat was particularly oppressive, while to the southward the sky assumed a dull leaden colour becoming completely clouded by 5 p.m. As the afternoon advanced the wind blew in fitful angry squalls and the rising tide was noticed to be coming in unusually early. At 5 p.m. the wind had increased to a gale and rain began falling at 6 p.m. The gale continued to increase, about 8.30 p,m. it was blowing with hurricane force from S. by E. reaching its maximum velocity about 9 p.m. when the rain almost ceased. About 10 p.m. the wind began to subside shifting to S.W.

The night is said to have been exceptionally dark with shingles, slates and other debris blown about in a most dangerous manner. When the gale was at its height (about 9 p.m.) the tide was much above any preceding mark, was rising rapidly and had an hour and a half to come, In St. John harbour and along the water front the waves were coming in from the Bay of Fundy to a tremendous height dashing over every wharf along the whole harbour line, while the vessels moored at them seemed as if they must be rolled over upon the wharves by the next swell. Vessels broke away from moorings, some were driven ashore and many badly damaged.

Buildings near the water front were flooded in lower floors, warehouses were destroyed, everywhere signs of destruction met the eye, slips, coves and beaches were filled with debris from the wreckage.

On the west side shipyards and valuable weirs were destroyed. At Sand Point, now the terminus of the C.P.R. some wooden houses were badly wrecked, the inmates barely escaping to safety. All along the west shore of Courtenay Bay, wharves, abutments and fish houses were washed away and one side of a foundry blown in by force of the gale. A little outside of the city unstable wooden buildings were unroofed and blown down.

In Charlotte County and the adjacent United States Coast the gale was most severe. One hundred and twenty-one vessels were beached near St. Andrews, N.B., Calais, Machias and Eastport, Me. Near Point Lepreaux the Barque Genii was wrecked and eleven lives lost.

St. Andrews and St. George suffered to a great extent, houses were unroofed, completely demolished and streets blocked with debris of the gale. At the latter place the roof of a volunteer armoury was carried to a distance of 100 yards. Spire of Episcopal Church at St. Stephen was blown over and the building badly wrecked. A church at Milltown destroyed and the railway bridge blown into the falls.

On the islands of this county, Grand Manan, Deer and Campobello, wind and tide was the cause of much damage; on the latter island alone some eighty buildings composed of sheds, barns and fish houses were destroyed.

In York County there was some unroofing and wreckage to buildings. In this as well as Charlotte County whole acres of forest trees were uprooted and in the woods of these counties traces may yet be seen of the great storm.

The high tide at St. John backed up the river to such an extent that it rose upwards of three feet at Fredericton. On the St. John River near Gagetown in Sunbury County a river steamer had her upper work carried away by the gale.

In Albert County the damage from wind and tide was excessive and at that time estimated at nearly a quarter of a million dollars.

Westmorland had a terrific gale and the highest tide ever known, tons of hay destroyed on the marshes, cattle drowned in great numbers, whole barns and their contents carried away, telegraph line destroyed and the roads made impassable. From "Tide Levels and Datum Planes in Eastern Canada" by Dr. W. Bell Dawson, it may be seen that the water level at Moncton was nearly six and a half feet above former or subsequent records.

At Moncton the tempest and tide was most disastrous, while at Shediac, and Point Du Chene on the gulf not eighteen miles distant, no damage of any description was done.

In the Bay of Chaleur the water was much above the normal and at Dalhousie, Restigouche County, bordering on the bay, the lower portion of the town was inundated and boats used to remove property and people from the lower levels.

At the head of the Bay of Fundy, in the Basin of Minas, in and about Cumberland, Hants, Kings and Colchester Counties, N.S., the gale was not severe, but rain fell heavily. The chief damage was caused by the tide, dykes were broken away in all directions, in some places the water was two feet above the second floor of dwelling houses, many hundreds of cattle, sheep, etc., drowned, large quantities of hay destroyed, great stretches of the railroad carried away and travel made impracticable in any direction. The wind itself did not do much injury, except to the fruit crop. At Windsor, N.S. wharves were damaged and churches, dwellings and business places flooded.

In Cornwallis and Annapolis Counties similar conditions obtained.

At Bridgetown, Annapolis County, N.S. a gale from the south set in during the afternoon and continued some hours accompanied towards night by heavy rain. At Annapolis, early on Monday evening, the water stood knee-deep in the streets and flooded the stores, carried away lumber from the wharves and caused great devastation. No marine disasters were reported.

Yarmouth, N.S. reported the following weather conditions. The wind was strong from southeast in the morning, gradually increased during the day, until late in the afternoon it blew with great violence, accompanied with heavy rain. The gale continued to rage furiously until towards midnight, when it gradually subsided. The tide rose to a great height, in some places causing serious damage. A number of buildings were unroofed or blown down in several parts of the County.

The steamer plying between St. John and Digby, N.S. anchored in Digby Basin and by keeping full steam ahead, managed to weather the gale. Some damage to wharf and vessel property at Weymouth was reported. At Westport, Brier Island N.S. much damage was done to the wharves and ten vessels were driven ashore.

The storm was not severe at Halifax, the night was dark and rainy, but the blow was not an unusual one nor the tide extraordinarily high

The following meteorological conditions were obtained from the records kept by the late Gilbert Murdoch, at St. John—

| | | Barometer. | Temperature |
|---|---|---|---|
| October 3, | 8 a.m. | 30.120 | 57 |
| " | 2 p.m. | 30.010 | 61 |
| " | 10 p.m | 30.005 | 59 |
| October 4, | 8 a.m. | 29.923 | 63 |
| " | 10 a.m | ——— | 70 |
| " | 2 p.m. | 29.780 | 70 |
| " | 6 p.m | 29.527 | — |
| " | 10 p.m | 29.332 | 62 |
| October 5, | 8 a.m. | 29.450 | 55 |
| " | 2 p.m | 29.456 | 55 |
| " | 10 p.m. | 29.665 | 46 |

Excepting on the 1st of October wind has been southwest since the 29th ult. The wind was from south in morning but backed to east, then veered to south, and at 10 p.m. to southwest. The 5th was raw and blustery, wind going to northwest between 5 and 6 p.m. The total rainfall on the 4th. was 0.530 inch. The barometer reading at 10 p.m. of the 4th was the lowest during storm.

When violent storms occur near the New Brunswick coast comparison is sometimes made with the great storm above described, known as the "Saxby gale" because Lieut. Saxby of the British Navy wrote the London press in November 1868 predicting the Earth would be visited by a storm of unusual violence attended by an extraordinary rise of tide at 7 o'clock on the morning of October 5th, 1869. Saxby concluded his letter as follows:

"I now beg to state with regard to 1869 at 7 a.m. October 5th, the moon will be at the part of her orbit which is nearest the Earth. Her attraction will be therefore at its maximum force. At noon of the same day the moon will be on the Earth's equator, a circumstance which never occurs without marked atmospheric disturbance, and at 2 p.m. of the same day lines drawn from the Earth's centre would cut the Sun and Moon in the same arc of right ascension (the Moon's attraction and the Sun's attraction will therefore be acting in the same direction) in other words the new moon will be on the Earth's equator when in perigee, and nothing more threatening can, I say, occur without miracle. The earth it is true will not be in perihelion by some 16 or 17 seconds of semi-diameter.

With your permission I will during September next (1869) for the safety of mariners briefly remind your readers of this warning. In the meantime there will be time for the repair of unsafe sea walls, and for the circulation of this notice throughout the world."

It appears evident that Saxby had at least on one other occasion made a somewhat similar prediction as he further adds—

"At the period referred to in 1863, the moon happened to be in extreme south declination, and accordingly the greater devastations occurred in the southern hemisphere."

Not to be outdone by Saxby Mr. Frederick Allison of Halifax, N.S. gave the following prediction to a Halifax newspaper—

"I believe that a heavy gale will be encountered here on Tuesday next 5th October beginning perhaps on Monday night or possibly deferred as late as Tuesday night, but between these two periods it seems inevitable, At its greatest force the direction of the wind should be southwest, having commenced at or near south.

"Should Monday the 4th be a warm day for the season an additional guarantee of the coming storm will be given. Roughly speaking the warmer it may be on the 4th, the more violent will be the succeeding storm. Apart from the theory of the Moon's attraction, as applied to Meteorology—which is disbelieved by many, the experience of any careful observer teaches him to look for a storm at next new moon, and the state of the atmosphere, and consequent weather lately appears to be leading directly not only to this blow next week, but to a succession of gales during next month."

Referring to the above predictions the Halifax Citizen published the following—

"Great preparations were made about the wharves yesterday, to meet the storm which had been announced to take place to-day. Nearly all the small craft, and several large vessels, including the Roseneath, ran out in the stream and anchored, while those who remained had fasts out in all directions, making it almost impossible to get down on a wharf after dark, without danger of breaking one's neck. In consequence of the expected high tide, many of the owners of warehouses and stores near the water, had the lower floors cleared of goods, and everything possible to prevent damage, was done. After all these preparations, many were disappointed at the result. The performance did not come up to the programme, and was not at all what was expected. Yesterday was fine in the morning, but in the afternoon the sky began to cloud over, and signs of a storm were numerous. About six o'clock p.m. the tide had risen to within two or three feet of the tops of the wharves, but was then full and began to recede. Prognostications were freely made, however, by the weather wise, that this morning 'we would see,' and 'we did see'—nothing very remarkable, being only a repetition of last evening's tide. A pretty stiff breeze commenced about five o'clock last evening, and gradually increased until about twelve, when it blew a moderate gale. It continued blowing more or less strong until about four o'clock, when it attained a very respectable force, but not sufficient to do any damage. About five it began to die away, and at eight there was hardly a breath of wind to be felt, and beyond two or three old fences in the North end and a few shingles off some houses in Water street, we have heard of no damage. Torrents of rain fell during most of the night. Altogether, though Capt. Saxby and Mr. F. Allison deserve all credit for warning the public of the approaching storm, the general feeling is one of disappointment."

Commenting on the Saxby prediction the London, England, Standard said—

"Saxby claims to have been successful in some of his predictions, and he may prove either lucky or clever on the present occasion. As the astronomical effect will operate over the entire globe, it is exceedingly likely there will be a gale of wind and a flood somewhere."

The chances of a hit in Saxby's case were greatly in his favour. He had the whole world to range over, for he expressly stated the two hemispheres would be affected alike. If then in any locality, on the surface of the earth a violent storm occurred on the day named Saxby could claim a fulfilment of his prediction. In these latitudes during the month of October we are fairly certain to have gales, and that one of these should occur about the time indicated is nothing very remarkable.

The prediction of the weather prophets was published in Newfoundland and the fifth said to have been a day of quaking terror, but both Monday and Tuesday were perfectly fine, not a trace of the storm being recorded there.

The S.S. Acadia of the Anchor Line from Glasgow arrived at St. John on the ninth, but did not experience heavy gales on the passage out.

So far as I have been able to trace the storm it was in the vicinity of the Southern States on the second.

Washington, D.C. had an excessive rainfall on the third and fourth, The Tiber overflowed and some small buildings were carried away. Storm subsided about 3 a.m. of the fourth followed by sunshine in forenoon. Maryland had an excessive rainfall. At Fort Washington 5.68 inches fell between third and fourth. Baltimore had heavy rain on third but no gale was reported. Pennsylvania was flooded in many parts of the State and at Philadelphia the river was full of floating wrecks, in this as well as New York State traffic was held up in all directions by the flood. In Connecticut, New Hampshire, Massachusetts, Rhode Island and Maine, great freshets and floods were everywhere reported, rivers were swollen by the run off from torrential rainfall, and in some cases backed up by the abnormally high tide. Railroads were submerged and bridges and culverts carried away by the flood.

In Concord, New Hampshire, the rain storm was pronounced without parallel in that section. Rain began Saturday night and continued till 4 o'clock in afternoon of Monday the fourth. Up to daylight of the fourth two inches of rain fell, between that and four o'clock in the afternoon six inches fell making a total of eight inches. Great damage was occasioned to railroads and highways. In Maine an immense amount of damage was done, the freshet and flood being greatest ever known.

New York had a heavy gale in early morning of the fourth. Boston had a heavy rain storm and the wind did some minor damage, but no shipping disasters. Tide did not rise above level of wharves though unusually high in forenoon.

At Portland, Maine, the gale was not severe, but is said to have been much heavier inland.

In all probability the storm was one of tropical or semi-tropical origin characterized to the southwest by extremely heavy precipitation and greatly increasing in energy as it moved towards Eastern Maine and the western portion of New Brunswick.

Since the inception of the forecast branch of our Canadian Meteorological Service, not one of these storms has reached the Maritime Provinces without ample warning and display of storm signals. Had the present system of warning to Mariners been in force, the gale of Oct. 4th, 1869 would not have left the record of loss of life and shipping enumerated. Take the instance of the Barque Genii, with a display of storm signals, which certainly would have been made well in advance of the gale, this vessel would have undoubtedly remained in port and the appalling disaster averted.

# RURAL DEPOPULATION IN SOUTHERN ONTARIO.

By S. A. Cudmore,
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(*Read 27th April, 1912.*)

Among European peoples and societies of European extraction the decline of rural population—relative in some cases, absolute in others—has been one of the most remarkable phenomena of the last half-century. It has taken place in such densely populated regions as Great Britain, France, Germany and Belgium, and also in such comparatively thinly settled countries as the United States, Canada and Australia. It is on the whole most noticeable in what we should consider the most progressive countries, and least evident in such economically backward societies as those of Russia and the Balkan States. This great displacement of population has naturally excited the keenest interest, and in many cases the greatest alarm. It has, during the past decade, been widely discussed in Europe, the United States and Canada, and in the discussion the advantage of numbers, if not of argument, has been with those who hold that the movement is an evil, pregnant with danger for the future of the entire white race, and particularly of the English-speaking nations.

The results of the Canadian census of 1911 show that in the past decade the rural population of the Dominion has increased 17.16 per cent. while urban population has increased 62.25 per cent. or more than three times as fast. Four of our nine provinces—Ontario, Nova Scotia, New Brunswick, Prince Edward Island—show an actual decrease of rural population; nowhere in the Dominion has rural population increased at the same rate as urban.

Our subject, however, confines us to our own Province of Ontario. Here we find that in spite of the activity of a progressive Department of Agriculture and considerable immigration of agricultural labourers, the rural population of the Province has declined during the decade by 52,811, while the urban population has increased by 392,511. A decline of 52,811 may not at first seem a very serious matter in a large and populous province, but one must remember that this has occurred in spite of a considerable extension of settlement in New Ontario, and further that this decline has been going on in some parts of the Province for about fifty years.

## MOVEMENT OF POPULATION IN TYPICAL MUNICIPALITIES.

The best way of measuring the movement of rural population is to take the distinctively rural municipalities, the townships, with their populations at respective enumerations. It is, of course, essential that our typical townships shall not have been changed by the creation of new urban municipalities during the period under consideration. This is the course which I propose to follow, and as a County of Peel "old boy" I shall take my first examples of this decline from the county with which I am best acquainted.

The township of Chinguacousy, just outside the county town, Brampton, has a generally excellent soil, is well watered, and close to the Toronto market. It is well adapted to grain-growing and stock-raising, and is a good example of the ordinary Ontario agricultural township. This township had in 1861 a population of 6,897, which has since that time been steadily declining. The figures for the five succeeding decennial censuses, taken in order, are 6,129, 5,476, 4,794, 4,177, 3,913. For every 100 people in the township in 1861, there were only 56 in 1911—a loss of 44 per cent. In the same period of fifty years, the population of the small adjoining township of Toronto Gore declined from 1830 to 1032—a loss of 43 per cent.

Fruit-growing and market-gardening townships have of late had a different story to tell. If we go back again to Peel County, we find that the population of the lakeside township of Toronto, lying just south of Chinguacousy, was in 1861, 6,592, and in 1901 only 5,208—a loss of 21 per cent. During the past decade, however, the growth of fruit farms and market gardens has occasioned a substantial increase in the population, which in 1911 stood at 6,208—only 384 less than the maximum. The continued growth of the Toronto market for its products and the growing practice of "commuting" will probably make the 1921 population the greatest that has been.

The same phenomenon which we have already noticed in the case of Chinguacousy and Toronto townships is also perceptible in other pairs of adjoining townships so situated that one is naturally a fruit-growing, the other a grain-growing and stock-raising district. When we consider the lakeside township of Saltfleet and the inland township of Binbrook, in the County of Wentworth, we notice that Saltfleet's population has increased from 2,740 to 4,458 between 1861 and 1911, while that of Binbrook has decreased from 2,100 to 1,254. In other words, Binbrook in 1861 had three-quarters of Saltfleet's population; in 1911, two-sevenths. Once more, considering North and South Grimsby, the former a lakeside, fruit-growing township, the latter agricultural, we find that in the last twenty years the population of the former has increased from 1,095 to 1,758, while that of the latter—the inland township—has declined from 1,610 to 1,389. Everywhere then, we notice that the influence of the increase of fruit-growing and market-gardening has been to increase the rural population, while the inland townships have shared the common depopulation of the ordinary Ontario agricultural community.

So far our illustrations have been drawn from a comparatively small area. In order to show that the decline is not merely a local phenomenon, we shall take cases from different parts of the Province.

The township of Oro in Simcoe reached its maximum population, 4,566, in 1881; in 1911 its population was only 3,485, a decline of 26 per cent. in thirty years.

The population of the township of Bosanquet in Lambton declined from 4,425 in 1871 to 2,491 in 1911, or forty-three per cent. in forty years.

East Nissouri in Oxford declined from 3,668 in 1871 to 2,623 in 1911—a loss of twenty-eight per cent. in forty years.

Otonabee in Peterborough declined from 4,261 in 1861 to 3,287 in 1911—a decrease of twenty-two per cent. in fifty years.

Osnabruck in Stormont declined from a maximum of 5,796 in 1881 to 4,170 in 1911—twenty-eight per cent. in thirty years.

Numerous other examples can be given, but the foregoing are sufficient to establish our general conclusion—that the population of the ordinary agricultural Ontario township to-day has declined from 20 to 45 per cent. from its maximum. This decline is, however, partially offset by the very considerable increase of late years in the population of fruit-growing and market-gardening districts. This latter increase is itself largely due to the rise of our cities, which provide a market for their products.

## PRESENT DENSITY OF RURAL POPULATION.

It will now be worth our while to consider the present density of rural population in order to see what is the complement of human labour per square mile in the ordinary Ontario township. What is the average number of people living and labouring on and maintained by the products of the average square mile in an ordinary agricultural district? My general conclusion on this point is that the Ontario agricultural township averages about thirty persons to the square mile. This figure necessarily includes the population of small unincorporated villages—probably from one-fourth to one-third of the whole—so that only about twenty to twenty-three persons actually reside in the average square mile of agricultural land in a grain-growing and stock-raising township.

This conclusion was reached by taking various agricultural communities and dividing the aggregate population of the rural municipalities of a county by the area. Thus I found that the average density of population in Prince Edward County was 31.54 to the square mile; in East Huron, 28.4; in Wellington, 28.5; in Dufferin 24.45; in Simcoe (excluding the non-agricultural and partly settled township of Matchedash), 31.26; in Norfolk, 31.9; in North York, 35.9. For purposes of comparison I calculated the density of rural population in Prince Edward Island, the only province which is all settled, and found it to be 36 persons to the square mile. It should be noted that all the communities under discussion are overwhelmingly English-speaking.

In French-speaking districts the density is quite noticeably greater than in English-speaking. For example, the density of rural population in Prescott is 40.87 and in Russell 41.6 to the square mile. Also in the Province of Quebec the density in Bagot is 41.6 per square mile, and in Chambly and Vercheres, 43.6. From these and other examples I conclude that the average density in an ordinary French-speaking agricultural community is in the neighbourhood of 40 to the square mile. The significance of this greater density we shall see later.

So far I have dealt only with facts. I shall now attempt to give an explanation of the causes of this great decline in rural population and to show why these causes have not operated with the same intensity in French-speaking as in English-speaking districts.

## CAUSES OF THE DECLINE.

Various causes of this decline—the alleged contempt in which the farmer's profession is sometimes held, the tendency to city life inculcated in our schools, the glittering financial lures held out by the city, the electric lights and shop-windows and the gregarious instinct of mankind have no doubt had more or less effect upon our young people in the choice of a vocation. These have been discussed almost *ad nauseam* in our press, while the main cause is left in comparative obscurity. That cause is not social but economic.

The decline of rural populat on in our province, as in other provinces and other countries, is mainly due, I believe, to the introduction of labour-saving, agricultural machinery and to the increasing operation of the great economic principle enunciated by Adam Smith—the division of labour, which has transferred to the cities and towns various branches of production which half a century ago were carried on almost exclusively on the farms. Further, the decline of rural population has been to the economic advantage of the people of the North American continent as a whole.

I shall best make clear my point by going back to my first example, that of the township of Chinguacousy, Why has its population declined from roughly 7,000 persons to less than 4,000 in the half-century, when, at a low rate of natural increase and making no allowance for immigration, that population should now be 11,000? Where are the missing 7,000 people? The answer is easy enough: either in the country districts of Western Canada and the United States, or in Canadian and American cities.

In the settlement of the North American continent, the young men of each community have as they grew up become the founders, the pioneers of still other communities further West, even as far as San Francisco, Vancouver, and Prince Rupert. The great North American continent, with its unrivalled transportation system; inhabited by men of one race who spoke one language and lived under similar institutions, has become what I should call a single labour market of area unparalleled in the history of the world. Labour has been more mobile here than elsewhere, and it is one of the first principles of political economy that, other things being equal, the greatest production takes place where labour is most mobile—moves most freely to those localities where it is most needed and is best rewarded. The West needs these labourers worse than does Chinguacousy; it rewards them better. Their per capita production of wealth is greater in the West than in their home township. They could not have produced so much nor earned so much in Chinguacousy as they produce and earn in the West. Therefore they go West.

This mobility of labour on the North American continent is mainly due to the predominance of a single language. The English-speaking labourer finds himself at home wherever he goes, and is consequently ready to go anywhere. This, however, is not the case with the French-Canadians. The barriers of language and religion, the distaste for migration into an alien community and the ignorance of the economic conditions and opportunities of that community—make them cling to their native place. This fact at least partially explains the greater density of the French-speaking rural population. It also explains why the growing French population floods the Eastern Townships and the Ottawa River counties of Ontario in preference to going West.

The great mobility of labour and the "call of the West"—which is really the call of the economic opportunities there—will account for Chinguacousy's loss of her natural increase of the past fifty years, which we have estimated at 4,000 persons. But they are hardly sufficient to account for the loss of nearly half the population resident in the township in 1861. To explain this absolute decrease of population we must compare the methods of production in use at the two periods.

### DECLINE OF AGRICULTURAL EMPLOYMENT DUE TO MACHINERY.

The agricultural methods of to-day are very widely different from those of 1861, especially in the matter of the use of labour-saving machinery, which has revolutionized agriculture. How great the change has been may be shown from statistics of the United States Department of Labour, published some years ago. Here we find that the nine principal crops of the United States required 120,000,000 days of human labour in 1895, with the methods then in use, while they would have required 570,000,000 days of human labour with the methods of 1850. In other words, 400,000 agricultural labourers, working 300 days a year, could do in 1895 work which it would have taken 1,900,000 labourers working 300 days a year, to perform in 1850. It is entirely probable, to say the least, that the 4,000 people in Chinguacousy to-day can cultivate the soil of that township quite as efficiently and thoroughly as the 7,000 could in 1861. Under the new conditions thirty persons to the square mile are able to perform the work which once required fifty, and still demands forty in the French-speaking districts, where agricultural methods are backward and unprogressive.

Labour has thus been displaced in agriculture, just as in the manufacturing industries, by the introduction of labour-saving machinery. The displaced farm-labourers of the past generation have very wisely migrated to "fresh fields and pastures new" instead of remaining at home and attempting to secure employment by the hopeless method of underbidding the machine. They and their descendants are now, as a result, using labour-saving agricultural implements on their own Western farms, and their position in life is vastly higher than it could otherwise have been. The labour-saving machine, which would have crushed them by its competition had they remained at home, has helped them to raise themselves altogether out of the class of manual labourers, and the total agricultural product of the country is vastly greater than if they had remained in the East.

### TRANSFER OF OTHER EMPLOYMENTS TO THE CITIES.

Not all the labourers who have left the farms of Southern Ontario have migrated to the West. Thousands have gone to the stores and factories of Canadian and American cities. But what of that? In 1861 these people who worked on the farm were yet by no means exclusively agricultural in their occupation. The farm household of 1861 produced all its own food, nearly all its own clothing, was quite capable of building its own house, and often did so. Thus the three primary needs of mankind—food, clothes, shelter—were satisfied within the household, and the average household had few others. Some of the members of the household specialised, for instance, in spinning and the production of clothes. When the factory system of weaving and garment-making superseded the old domestic system, what wonder that such persons left the farm and betook themselves to the cities and towns, where alone the power was available to run the machinery of the new factories? Who would expect them to remain at home and compete with the machines—a method of procedure which would have been both uneconomic for the country and hopeless for themselves? And if still others who were better at house-building than at grain-growing left the farm and devoted themselves to the occupation for which they were best suited, is there not an economic gain here also? Here again we have Adam Smith's principle of the division of labour: "Let every man do only that which he can do best, and the total product of the community will be the greatest possible." The whole displacement of Ontario's rural population during the past half-century is due to this law of the division of labour which has taken people who are not fitted for farm work away from it, or to the invention of labour-saving machinery which has freed agricultural labourers for the opening up of the West. Both of these causes are productive of economic gain, and help to produce a greater quantity of wealth in the country.

Has this not been the case? Is not the average farmer to-day ever so much better off than he was fifty years ago, and is not the production of a given number of people engaged in agricultural pursuits much greater than it has ever been in the past? The average annual product on the Ontario farm of to-day, according to the Department of Agriculture, is worth about $2000. Even in the last decade there has been a striking increase in rural wealth, as far as we can see from the assessment rolls. The Ontario Bureau of Industries shows that in 1900, 1,094,241 persons resident in the townships of the Province were assessed for $453,917,203, or a trifle under $415 per head, while in 1909, 1,049,240 persons were assessed for $607,173,285, or over $578 per head.

The case then seems quite clear that the decline of our rural population is due to causes predominantly economic, and that on the whole it has been productive of great economic benefits to society. Critics and sentimental *laudatores temporis acti* who believe that it implies a weakening of the fibre of the younger generation are absolutely in the wrong. Both the westward movement and the movement from the country to the cities are simply due to the desire for the economic betterment of the individual, which generally coincides with the best interests of society. Since this desire is the strongest motive of mankind, it is as vain for the critics to combat it with the ordinary superficial "back to the farm" address as to drive back the Atlantic with a mop.

# THE CHEMICAL INTERPRETATION OF VITAL PHENOMENA.

By J. B. Leathes, M.A., F.R.S.
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*(Read 20th April, 1912.)*

There are many natural phenomena which everyone recognizes as falling within the legitimate province of chemical interpretation, but it is only within the last hundred years or so that anyone but the alchemists have included among them phenomena of life, and even now the cliam of chemists to interpret these is conceded grudgingly by those who are in sympathy with the aspirations of Science, and by the rest of the world is looked upon with something of the horror and the suspicion in which the chemists of the Middle Ages practised their arts.

There are perhaps three moments in the history of modern chemistry at which we may recognize this claim clearly pronounced for ears that hear through the clamour of scientific pretensions: and the first is at the very hour of its birth. In the ten years preceding the outbreak of the French Revolution a number of experiments were designed and carried out by the Baptist of this science, Lavoisier, in some of which he had the assistance of another French genius of the day, Laplace. These experiments were the prototypes of investigations that have ever since been carried on along essentially the lines marked out by Lavoisier himself. A sparrow enclosed in a bottle was found to die in less than an hour; while animals in a similarly confined space, if provision was made for the absorption of carbonic acid by potash and a sufficient supply of oxygen was given, lived comfortably. In another set of experiments a stream of air was passed through a vessel in which an animal was placed, the escaping air collected and the amount of water and carbonic acid that it contained determined. And similar determinations were carried out in experiments on man, a mask being used with valves arranged so that the air inspired came from the free air of the room, but that which was expired was delivered into a vessel where it could be measured and analyzed.

Experiments of these three types have been repeated with more elaborate apparatus almost continuously since that time. The first method was that employed in the important work of Regnault and Reiset in the middle of the last century; and as recently as twenty years ago a large apparatus on this principle was constructed by Hoppe Seyler at Strassburg for the study of respiratory exchange in man. The second method was the one that Pettenkofer and Voit employed in their classical experiments and which is at this day perfected in the apparatus of Benedict, for which the Carnegie nutrition laboratories at Boston have been built. The third, as developed in the apparatus of Zuntz, has been used by him and others for the study of the same phenomena in man under the most diverse conditions, on balloon voyages or climbing expeditions in the Alps, and in the wards of hospitals for the sick. And the outstanding result of all this has been to establish abundantly and completely the fundamental fact which Lavoisier's intuition led him to search after, though he could not formulate it, that the sum total of the material changes in living organisms is in as good accord with the laws of conservation of energy and matter as any group of phenomena with which life has nothing to do. A living organism takes in food as a furnace takes in fuel; the energy of chemical structure contained in this food is transformed into heat and work within the organism and can be shown quantitatively to be the source of all the activities which the organism exhibits, no less than the fuel is the source of the heat that generates power in the boilers for the working of an engine. The balance sheet of the living organism can be made out in the same terms as that of the engine, and the chemical changes underlying the transformation of energy are in their broad outlines the same: oxidation in both gives rise to the same end products—water, carbonic acid and sulphuric acid.

The physiology that has followed this trail on which Lavoisier was the first great pioneer, and that is still actively engaged upon it, has established this great principle which lies at the root of all the chemical interpretations of vital phenomena. But this principle established, it has seemed to many that the further working out of details is not likely to answer the questions that urge themselves upon the notice of all questioning men. The elaboration of balance sheets based on the analysis of all that enters and of all that is given off from a living organism becomes a *tour de force* and, interesting as it may be as such, especially to those who have the joy of overcoming technical difficulties, it is sterile and tantalizing to the hungry enquirer who wishes to see into the meaning of the actual manifestations of living activity, the movements, the correlation of working parts and the processes by which a living thing is distinguished from inert matter. Those who have pursued this trail have distinguished between the different kinds of material in which the phenomena of life are made manifest, in many cases only because the proteins give rise in the body of animals to substances that cannot be exhaled from the lungs and must leave the body in solution, carrying with them some of the energy that was originally contained in the protein molecules: and for such minds the one noteworthy difference between fats and carbohydrates was that the former contain more than twice as much energy as the same weight of the latter.

Another and entirely different train of thought has been prominent in the history of physiology. Fats and carbohydrates have laid bare the secrets of their constitution; the atoms that compose them are not only present in different proportions but in different groupings which confer upon them different chemical characters. They behave differently, and the relation of chemical structure to physiological function is the problem that has engaged the attention of perhaps the largest number of physiologists in the last generation or two. For these the appreciation of chemical character and subtle differences in constitution is the guiding light.

The impulse to this study, which is obviously but one part of the great activity of organic chemistry in the last century, is commonly dated from the discovery of Wöhler, more than eighty years ago, that urea, the principal nitrogenous substance of those which are produced in the life of the higher animals and man, could be synthesized in the laboratory. We have in our days become so familiar with the synthetic achievements of organic chemistry that it is difficult for our generation to realize how the synthesis of so comparatively simple a substance as urea could come to be a landmark in the history of physiology. We are apt nowadays to be a little impatient that the chemists cannot yet synthesize proteins for us; it is high time with eggs at 75 cents a dozen that synthetic eggs should be upon the market. What are the chemists about? They make hosts of unfamiliar substances the only interest of which, for any but chemists, consists in their unintelligible, labyrinthine complexity. But in the thirties of the last century this was not so. Life was life, and all that came from living things shared in its mystery. There was in those days something uncanny, almost sacrilegious, in the idea that anything produced by living organisms should be capable of being produced by the hand of man. It was as if the wild dreams and fancies of the alchemists should become an actuality.

This impulse has been strong right down to the present time. It has actuated the work which is associated first and foremost at the present time with the name of Emil Fischer, who has given to Biochemistry more that is solid and substantial than probably anyone that has given anything. It is only with the more exact knowledge as to the constitution of sugars and the complex substances built up out of them, with the concrete conceptions that we have begun to have as to the structure of proteins and of the essential groups associated with them in the nucleus of all cells, so much of which is due to him, that the imagination can begin to move with any freedom among the chemical problems of life. Only a year or two ago such was the wonder that these achievements aroused that it seemed to some as if it was perhaps but the matter of a few years and we should really have synthetic proteins with the highest credentials in our hands. And it may indeed be that it is only faint-hearted, common mortals that stand aghast and incredulous before the notion that the sort of means hitherto at the disposal of synthetic chemists should be adequate for such a feat as this.

And yet it is a fact that there have been others who felt, however dazzling these marvels might be, that even this supreme achievement must leave us pretty much where we were with regard to the real problems of the chemistry of life. Indispensable as it necessarily is that we should know what we have to deal with as we creep up to the last defences of material truth, the real thing when it comes, and if it comes, must be something different from these reconnoitring essays. If life is all a manifestation of chemical laws, these laws have another quality from that which they have as they have been observed in the laboratory. It is a commonplace of physiological philosophy that points out that the behaviour of substances in living organisms is entirely different from that which the same substances appear to exhibit where there is no life. The burning of alcohol or the carbohydrates of which wood is composed, as commonly made use of for the generation of heat and the performance of work in the arts, bears no kind of sensible resemblance to the burning of similar substances in our bodies. The fierce heat evolved and the pungent, poisonous by-products make it inconceivable to the uninitiated that there should be anything of the kind going on where there is life. The end products in the main may be the same, but in the living process the end products are turned out clean and quantitatively and all in the quiet orderly way which well regulated life requires. And on the other hand at one moment the activities that result from this burning may be passionately strong, as when a horse gallops past the winning post, and the next be tranquil, placid, almost imperceptible, as the movements in the sleep of a child. Fats and oils again are familiar as substances that burn fiercely, it is true, but under the sort of physical conditions which our senses would tell us must obtain in the bodies of animals, they are among the most stable of natural products. Substances of this nature have been found in the caves of Egypt practically unchanged, though it is thousands of years since they were put there for the sustenance of the departed soul. And yet an animal that is kept without food lives for days, and its heart and muscles and kidneys do their work as smoothly and uninterruptedly as ever, when it can be shown that nine-tenths of this work is the outcome of the quiet oxidation of fat. The same commonplace points out that the changes which the foodstuffs undergo in assimilation are such as in the laboratory involve the use of the strongest boiling acids: that if the syntheses effected in living organisms can be accomplished at all *in vitro*, it is only by a succession of countless laborious operations that it would be impertinent to compare with the operations of life.

The only clue that we seem to have at present to give us confidence in the future of science revealing to us further chemical interpretations of the phenomena of life is one that had its origin about the same time as Wöhler's synthesis of urea, in the first observations of Berzelius on what he called catalysis. Certain substances, platinum, silver and organic substances such as fibrin, have the power of decomposing hydrogen peroxide into oxygen and water without themselves undergoing any change. He compared this process to what takes place when sugar is fermented by an insoluble body known as a ferment and converted into alcohol and carbonic acid, a change which could not be explained as a double decomposition between the sugar and the ferment. We have reasons, he said, well founded on fact for making the assertion that in living plants and animals there take place thousands of catalytic processes between tissues and fluids. Twenty years later the first physiologist of the day, Carl Ludwig, prophesied that some day perhaps physiological chemistry might prove to be but a chapter in the chemistry of catalytic action. And there are reasons for thinking that that prophecy is coming true in our own days.

It is especially since 1897 that the grounds for this belief have grown wider. In that year Buchner showed that a substance could be obtained from the living yeast plant, solutions of which, though entirely free from living organisms of any kind, cause sugar to be resolved into alcohol and carbonic acid, just as the living yeast plants do. The inference is that since this subtance is found in the plant, when the plant ferments sugar it does so because it contains this substance, and not because it is alive.

Now the difficulty, to which I have alluded, in tracing any similarity between the conditions under which chemical changes are effected in the laboratory and those under which the same changes are brought about where life is manifest, led to the assumption that life was a cause of chemical change. Vital activity, the action of some property of living things, some property not to be defined in any other way and not shared by anything that is not alive, was the only explanation forthcoming for the time to meet this difficulty. The explanation was merely a verbal one, but there was no other. And up to the time of Buchner's discovery, the fermentation of sugar by yeast was the typical instance always cited of fermentation due to the vital activity of an organism or an organized ferment, as it was called. And this kind of fermentation was kept always strictly distinct from fermentations brought about by unorganized ferments, or enzymes as they were called by Kühne, chemical substances, that is, that are active as ferments where there is no life. Two totally distinct causes of fermentation were recognized: life and enzymes. When therefore what had always been regarded as the crucial instance of the fermentative action of life was found to be nothing of the kind, there was a movement about the foundations of physiological belief.

Enzymes were before this known as substances excreted by certain cells that brought about certain changes in other substances in the environment of the cells, changes which were in some way necessary for facilitating the assimilation of food. The digestive enzymes of the gastric or pancreatic juice or of the saliva might serve an important function contributing to the life of an organism, but it was an ancillary function, little more than a culinary operation. But here was an enzyme normally operating within the organism, the cause of the most striking manifestation of its life, suddenly proved to be removable from the organism, though it is true only by special measures, and capable of operating after all other signs of life had ceased.

The surrender of this point need not involve, and has not involved, the surrender of the whole position. Alcoholic fermentation is only one among myriads of changes that we have been in the habit of attributing to vital activity. But it has made obvious, what was often overlooked before, that in regarding life as the cause of the chemical reactions underlying the phenomena of life we are indulging ourselves in a verbal illusion.

There is a convenient term in common use among physiologists—first introduced into the language by Sir Michael Foster thirty years ago or more—metabolism, a general name under which he intended to include all the chemical transformations which go to make the life of an organism. These changes may be constructive or anabolic, or they may be destructive or catabolic; growth, assimilation, repair are effected by anabolic change: the evolution of energy as heat or work, decay and death by catabolic. At all moments of the life of an organism both phases of its chemical life are in operation side by side, and every manifestation of its life is accompanied by, or an expression of some chemical change. Food is taken in, digested, assimilated and so altered as to become part of the living body and of the material in which its life is exhibited. Every activity of the body involves some chemical change in the living substance, and a certain proportion of this substance is at each moment so far changed as to be incapable of further participation in its life, and is then expelled and returned to the condition of inanimate matter. Each step is a chemical reaction or a complex system of reactions. And these reactions, as we have seen, are in the main such as cannot under the conditions obtaining in living organisms occur where there is no life. But now since the time of Buchner's discovery of the enzyme that causes alcoholic fermentation, partly, it may be, as the result of the stimulus it gave, more and more of these reactions of metabolism have been found to be due to the action of enzymes. A large number of other enzymes have been shown to exist within the cells like the zymase of yeast, and our conception of the use made of enzymes in nature has had to be considerably extended.

The position into which we are thus brought is this: in so far as the chemical changes underlying the phenomena of life are the result of the action of enzymes, these reactions are due to the presence of chemical substances in no sense alive, and are not therefore caused by life, or by the activities of living matter.

The question then that at once arises is this: how far would the operation of enzymes account for those differences that make it at first sight inconceivable that the laws which govern the reactions of metabolism are the same as the laws of chemical change that we learn of in inanimate nature?

To answer this we have first to consider what we understand by an enzyme. We have seen that Berzelius compared fermentation to the catalytic action of certain substances which could bring about chemical changes, that otherwise were not observed, without themselves participating in those changes. Berzelius of course did not know that yeast was a living organism, and the significance of his comparison was lost sight of when this came to be understood. But when the fermentative activity of yeast was found to be due to an enzyme, the analogy drawn by Berzelius between fermentation and catalytic action was realized, and acquired for common mortals the luminous import that it had had for the prophet.

At the same time the nature of catalytic action had been further studied and more closely defined. In many cases at any rate it can be shown that in catalysis chemical reactions are not initiated but merely accelerated. This holds, for instance, in the case of the decomposition of hydrogen peroxide, the original instance given by Berzelius. At the ordinary temperature a solution of hydrogen peroxide is converted into water and oxygen very slowly, but in the presence of a catalytic agent the change is very greatly accelerated. And the acceleration effected may be so great that the reaction that results may appear as one that does not otherwise take place. Hydrogen and oxygen can exist side by side at the ordinary temperature without appearing to unite, though the union takes place rapidly in the presence of finely divided platinum. But the formation of water from oxygen and hydrogen probably does take place at the ordinary temperature only so slowly that it is not detectable by the means at our disposal. Changes in the rate of chemical reactions of such a degree as this are familiar as the result of changes in temperature. It is in fact the rule that a change of temperature amounting to 10° C. increases the rate of chemical reactions, other things being equal, between two and three fold. If a reaction takes place at 10° C. with twice the velocity that it has at 0°, it will at 20° C. take place with 4 times, at 30° C. with 8 times, at 100° C. with 1024 times, and at 200° C. with more than a million times that velocity. Now the formation of water from hydrogen and oxygen is known to occur at 500° C. with a measurable velocity: if this reaction is subject to such a change in velocity due to changes in temperature as this, it is obvious that at the ordinary temperature of the air, though the reaction still went on, it would be at a rate that could never be detected. When therefore hydrogen and oxygen are made to unite by means of platinum black, the platinum does not create a reaction, though the change in the rate at which this reaction occurs is so great that that is how it must appear to our senses. There are many cases in which the reactions that we attribute to the action of enzymes can be shown to be effected at high temperatures, in proportion to the temperatures, without the assistance of enzymes, so that we may justly infer that enzymes do not create chemical change but merely affect the rate at which it occurs.

If we accept this as true then in so far as the chemical changes in living organisms are due to the action of enzymes, these changes which appear to us as manifestations of the hidden forces of life, may become merely reactions that are going on everywhere but at a different rate. And the chemistry of life may in respect of them cease to be different in kind from the chemistry of inanimate nature. Let us then see exactly how we stand: where the labours of a hundred years have brought us in the quest of biological truth. We have in the quantitative measurements that Lavoisier first showed men how to attempt, the proof that life is a chemical phenomenon as capable of being expressed in mathematical terms as the movements of the heavenly bodies. We have been shown that the structure and chemical constitution, if not of living matter itself, at least of almost all the material in which the phenomena of life are exhibited, can be exactly determined, and we are heirs to a lively and reasonable faith that the constitution of what remains may still be determined. And now we think we have been given a clue by which we may come to see that there is no essential difference between the chemistry of animate and inanimate nature however great the apparent difference is. We can substitute for the metaphysical conception of vital activity, as the cause of the chemical transformations of living matter, the idea that these transformations are manifested in virtue of the catalytic properties of definite substances that come together when living things grow, properties that are of the same nature as those exhibited by common substances that may be shown to operate wherever there is matter.

How far this clue may really lead, it is impossible of course to say. But it stands the first test of scientific hypothesis. It has set the world at work upon experiments that certainly shed light, confident that these will be followed by those that bear fruit. The catalytic action of metals, such as platinum, iron, manganese, the power they have of bringing into evidence changes that otherwise appear not to take place, is made manifest in chemical changes similar to those that we know are effected in plants and animals but which cannot be detected without the intervention of catalytic agents. What are the properties of these metals that confer on them this power? In the case of platinum and also of some other catalysts it seems clear that the action is one that takes place on the surface of the metal. The action varies not with the mass of the platinum but with the amount of surface it presents, so that exceedingly minute weights of platinum in the finest state of division that can be attained, in the form of what is called a collodial solution of the metal, may act very strongly. This reminds us of what is one of the most striking characteristics of enzymes. Their activity in producing chemical change is all the evidence we have of their existence. No one has ever weighed an enzyme because no one has ever separated one out in a pure state. But we know that the amount of active substance must in some cases be less than a hundred thousandth part at any rate, probably less than a millionth of the weight of substance that it can transform. And we know too that the amount of substance transformed is not determined by the amount of enzyme. Small quantities of enzyme, if they are given time enough, can effect as much change as larger quantities. There are even reasons for thinking that the explanation of these properties of enzymes is the same as that in the case of a colloidal solution of platinum—that it may be, on the surface of minute particles suspended in a colloidal state, that the influence on the velocity of the reaction is felt. Enzymes are colloidal substances, their solutions are not like the solutions of the common salts; the ultimate particles in solution are apparently units of a different nature from molecules, and it is possible that the surface presented by such units as in the case of the particles in a colloidal solution of platinum should be regarded as the seat of changes in the physical distribution of other substances present in the solvent about them. That at any rate is one of the ideas that underlie much of the work at present being done with the object of learning more about the nature of the action of enzymes. The chemists have reached a point at which they need the assistance of physicists, and physical chemistry is busy endeavouring to understand the nature and properties of colloidal solutions and the forces exhibited at the surface of substances suspended in fluids because it is felt that in this way light may be thrown upon the catalytic phenomena of the chemistry of life.

But there are other catalytic phenomena, other instances of profound modification of the course or velocity of chemical change, which are familiar in the study of the chemistry of inanimate nature, which it would be premature at the present time to coerce into conformity with this conception of catalysis, with the conception, that is, that catalysis is due to surface condensation. Chemists speak of induced reactions when a reaction which does not otherwise make itself manifest is caused to become manifest by the simultaneous occurrence of another reaction. Sodium arsenite dissolved in water and shaken with air undergoes no detectable change. A solution of sodium sulphite, on the other hand, is readily oxidized in this way. If a solution of both salts together is treated thus, both salts are oxidized. There are indications that some of the changes that occur in the body of men and animals, that make the course of metabolism so hard to unravel, are instances of such induced reactions. A very well-known and very remarkable fact in animal metabolism appears to require some such explanation. A man's food ordinarily consists of three principal classes of chemical compounds, proteins, fats and carbohydrates. Of these, proteins are indispensable because they alone supply nitrogen and sulphur which are constantly being given off and must be replaced. But though the carbohydrates contain no elements that are not supplied by either fats or proteins they are also indispensable. It is not very difficult to devise a diet for a man that would contain no carbohydrate, but so far as its elementary composition and the energy it is capable of developing in the body is concerned be theoretically sufficient. But no such diet can be taken for more than two or three days without serious illness and signs that the chemical utilization of the food given is not being perfectly carried out. Organic substances leave the body unburnt that are never allowed to leave it in health when the diet contains even a small amount of carbohydrate. And as soon as a little starch or sugar is added to the experimental diet the symptoms disappear and the complete oxidation of fats and proteins is normally and easily effected again. One of the principal dangers in the disease diabetes, in which the body has lost the power of properly oxidizing sugar, consists in the tendency for the same abnormality in the course of the oxidation of fats and proteins to occur, which is so easily induced in any normal man by excluding carbohydrates from his diet. The diabetic patient, partly because he can make but imperfect use of carbohydrates and partly because the common treatment of his disease is to reduce his carbohydrate intake as much as possible, is liable as a result to lose his power of oxidizing completely and normally even the fats and proteins of his food, and in such cases it is the physician's duty to treat the condition by supplying more carbohydrate in his patient's diet than his first instinct would allow. It is difficult to account for this remarkable phenomenon otherwise than by regarding it as an instance of an induced reaction. The oxidation of fats and proteins leads to the formation of certain organic substances the complete oxidation of which normally occurs as a reaction induced by the simultaneous oxidation of carbohydrates or of some substance found in the course of the breakdown of carbohydrates in the body. When the normal course of the breakdown of carbohydrates is interfered with as in diabetes, or when no carbohydrates are supplied with the food, then the reaction by which certain products of the breakdown of fats and proteins are finally and completely disposed of is not induced, and these products leave the body unburnt or accumulate in it causing certain definite and, it may be, serious symptoms.

It would not be difficult to multiply instances in which the facts of the chemistry of the body in health and disease, which till recently seemed to involve the assumption of vital activities inaccessible to the methods of physical science, can now be regarded as intelligible manifestations of catalysis such as we know it and can study in the chemistry of inanimate nature.

The laws of chemical change are not yet so clearly understood that it should be imperative that those who would study the chemistry of life must fold their hands in despair and say these things are not for men to understand.

# A REVISION OF MY "NORDAMERIKANISCHE HYDRACHNIDEN"[1]

BY F. KOENIKE, BREMEN.

Translated by E. M. Walker, Biological Department, University of Toronto.*

A fuller knowledge of the Hydracarine genera *Eylais* and *Lebertia* has necessitated a fresh diagnosis of the Canadian material on which my paper was based. As regards *Eylais* I recognized while working over the collection of water-mites made by Professor Voeltzkow in Madagascar, Aldabra, etc.,[2] that species were present that were readily distinguishable from *E. extendens* (O. F. Müll.). The recognition of this fact led me some years ago to work over the Canadian *Eylais* material, and as a result three new species (*E. falcata*, *E. desecta* and *E. triangulifera*) were established and briefly described.[3] In the present paper these species are more fully characterized and figured. A fourth new species of *Eylais* has also recently come to light, which I have dedicated to the American naturalist, Miss Ruth Marshall, in recognition of her admirable work on her native representatives of the genus *Arrhenurus*.

What has been said of the genus *Eylais* applies also to the genus *Lebertia*, for our knowledge of which great credit is due to Dr. Sig. Thor. Under the material formerly referred to *Lebertia tau-insignita* (Leb.) I can now distinguish three species, one of which I have named after the eminent North American Hydracarinologist, Prof. Robert H. Wolcott, and a second after Dr. J. B. Tyrrell, who collected the Canadian water-mite material which formed the basis of my paper of 1895. I am also specially indebted to Dr. Tyrrell for his kindness in placing at my disposal his collection of preparations of the Hydracarine material here treated of.

*The translator wishes to express publicly his thanks to Prof. Robert H. Wolcott, for many helpful suggestions in the translation of Herr Koenike's paper.

[1] F. Koenike, Nordamerikanische Hydrachniden. Abh. Nat. Ver. Bremen, 1895, XLII Bd., S. 167-266, Taf. I-III.

[2] F. Koenike, Hydrachnidenfauna von Madagaskar und Nossibé. Abh. Senckenl. naturf. Ges., 1898, XXI Bd., S. 297-435, Taf. XX-XXIX.

[3] F. Koenike, Zur Systematik der Gattung Eylais Latr. Abh. Nat. Ver. Bremen, 1897, XIV Bd., S. 279-295. With 6 fig.

*Eylais falcata* Koen.

Syn. *Eylais extendens* Koenike, Abh. Nat. Ver. Bremen, 1895, XIII Bd., S. 171.

*Eylais falcata* Koenike, Abh. Nat. Ver. Bremen, 1897, XIV Bd., S. 288.

*Female.*

The eye-capsule is 180μ long and 125-150μ broad, the breadth of the eye-plate 300-330μ. The anterior margin of the capsule runs more or less obliquely inwards and backwards and occasionally presents a slight emargination (Figs. 1 and 2). This species appears to vary strikingly, particularly in the form of the eye-plate. The antero-internal angle of the front margin of the capsule projects more or less distinctly and bears here a moderately long bristle. The bridge lies a little behind the level of the front margin of the capsule and is rather narrow. On the front margin there is always a more or less distinct median excavation. The opening on the under side of the capsule is usually triangular though it occasionally has a rounded form; it presents a stout marginal thickening, which, beginning in front upon, or just laterad of, the side of the bridge, projects behind, in some cases, over the margin of the capsule (Fig. 1). The anterior eye-lens is moderately large and mushroom-shaped. The posterior lens has the usual ellipsoid form, measures 83μ in length and occupies its usual position.

The capitulum including the projecting tracheal plates is 600-700μ long and 330-415μ broad in front. The oral area is almost circular but somewhat narrowed behind, i.e., short ovate; its longitudinal and transverse axes measure 166μ. Behind the oral area the maxillary shield is only about 165-200μ long and is here greatly narrowed (180-215μ) on account of the deep rounded excavation of its lateral margins. This excavation appears the more pronounced, as the posterior pair of processes of the maxillary shield, owing to their considerable length, project conspicuously on each side. The processes appear of slenderer form in lateral than in ventral view. Their free end is enlarged and bent inwards. The posterior processes of the upper wall are 215μ long, gradually and moderately enlarged distad to the rounded free extremity, and project strongly on each side. The anterior half of that portion of the maxillary shield situated behind the oral area is coarsely porous, while scattered pores are distributed from the middle almost to the hind margin of the shield.

The pharynx is only a little broader behind than in front and extends to a distance of 265μ beyond the hind margin of the maxillary shield. It measures 450μ in length and its greatest breadth (behind) reaches 250μ. As the breadth in front is not much less, its outline as seen from above has a very long oval form. The lack of a distinct chitinous arch in the posterior part of the pharynx is noteworthy.

The tracheal plates are 500-530$\mu$ long. In dorsal view they present a thickened anterior and an expanded, shovel-shaped posterior extremity. In lateral view they appear very stout, the posterior end with a long and strongly falciform upward curve.

The mandible is 250-340$\mu$ long and attains a breadth of 200$\mu$. It is markedly narrowed caudad. The flexor side presents a marked shortening. The angle of the hind margin of the extensor side projects somewhat. On the strongly receding opposite angle is the stigmatal papilla which is quite broad at base. The claw of the mandible is strongly bent, thickened at its distal extremity and very densely chitinized.

The maxillary palpus measures fully 1000$\mu$ in length, and its segments, taken in series from the first to the fifth, measure as follows: 99, 199, 166, 381 and 182$\mu$. The second segment, whose cuticle is soft on the flexor surface, has a series of 6 to 8 short, closely pectinate bristles. On the stout rounded prominence on the flexor side of the third segment is a group of numerous short spinous bristles, on the middle of the inner anterior margin a moderately long, fine hair, and in the corresponding situation on the outer anterior margin a short, strong, pectinate bristle, whose branches become gradually longer and stouter from the tip proximad. The outer side of this segment shows near the margin of the flexor surface an opening of obovate form. On the inner side the penultimate segment bears a longitudinal row of four short ensiform bristles and a group of stouter pectinate bristles on the distal margin; one of the ensiform bristles is, as a rule, shifted from the row towards the extensor side of the palpus. On the outer side of the same joint is a row of four stout ensiform bristles, of which the three posterior arise near the margin of the flexor surface, while the most anterior, on the other hand, is shifted perceptibly away from the latter margin forward. Close to the second bristle of this row between the two longitudinal rows of bristles is another stiff, moderately long bristle, strongly bent forward. At the tip of the terminal segment is a number of very short spines (Fig. 3).

The egg has a globular form and a diameter of 116$\mu$.

Locality, Rideau, from a pond.

*Eylais desecta* Koen.

Syn. *Eylais extendens* Koenike, Abh. Nat. Ver. Bremen, 1895, S. 171.
*Eylais desecta* Koenike, Abh. Nat. Ver. Bremen, 1897, S. 288.

*Female.*

The eye capsule measures 158$\mu$ in length, 249$\mu$ in breadth. The anterior and posterior ends of the capsule are rounded off, though the outer angle of the latter forms a slight prominence. The outer side of each capsule is strongly excavated. The front margin of the bridge lies but little behind the anterior end of the capsule and has an undulate form, owing to the presence of two rounded prominences. The two bristles on the bridge are moderately long and separated from one another by 49$\mu$. Breadth of bridge 66$\mu$. The opening on the under side of the capsule is of considerable size, extending laterad almost to the outer margin of the capsule; its outer end presents an angular form. A distinct marginal thickening reduces the size of the opening. The anterior eye-lens is not stalked and is short ovate in form; its two axes measure 37 and 32$\mu$. The posterior eye lens occupies the usual position and is ellipsoid in form (Fig. 4). It measures 64$\mu$ in length and 27$\mu$ in breadth.

The capitulum including the pharynx has a length of about 450$\mu$. Its front edge is not emarginate but appears as though cut across, as does also the antero-lateral margin next to the socket for the articulation of the palpus; and the structure has thus a markedly angular form when viewed ventrad (Fig. 5). The outer margin of the oral area is almost circular though flattened in front, its diameter measuring about 150$\mu$. The circular oral aperture is comparatively large, being 27$\mu$ in diameter. The oral fringe (Mundkrause) has a transversely elliptical form. The coarsely porous area of the maxillary shield extends almost to the hind margin of the latter, while marginal areas of considerable width, extending almost to the oral area, are finely porous. The processes of the upper maxillary wall are unusually stout, especially at the outer end; they extend caudad about as far as the hind margin of the maxillary shield and are rather strongly divergent posteriorly. The processes of the lower wall are directed upwards and backwards; their free ends bent and slightly thickened.

The tracheal plates extend back to the posterior margin of the pharynx; they are stout and their posterior extremities are strongly thickened and slightly curved upwards.

The pharynx has a comparatively moderate breadth behind (182$\mu$), and is narrowed anteriorly to a slight extent. The transverse arch which is not far from the posterior end is but slightly chitinized. In the region of its outer end the lateral walls of the pharynx are slightly tumid.

The mandible is about 158$\mu$ long and 140$\mu$ broad; its basal segment is narrowed proximad to 108$\mu$ at its posterior end. On the extensor side of the two mandibles two small openings are distinguishable, one behind the other. Of these the one that is immediately behind the terminal segment is quadrate and equally broad at each end. The posterior extremity of the pair of mandibles, viewed from the extensor side appears broadly rounded off. At the angle of the hind margin of the flexor side the basal segment bears a somewhat pointed stigmatal papilla. The mandibular claw is 43$\mu$ long, strongly hooked and gradually thickened towards its free extremity.

The egg has a globular form and a diameter of 90$\mu$.

In the undulate front margin of the bridge of the eye-plate this species strikingly recalls *E. undulosa* Koen., though the latter species is distinguished by the much greater dimensions of the eye-plate (eye capsule 232$\mu$ long, breadth of bridge 398$\mu$); and the anterior eye-lens also differs in having a long stalk. The pharynx of this latter species is very considerably narrowed cephalad, owing to the greater breadth at the posterior end (250$\mu$), thus giving the lateral margins a strongly convex form.

Locality—Pond in the vicinity of Dechenes.

*Eylais triangulifera* Koen.

Syn. *Eylais extendens* Koenike: Abh. Nat. Ver. Bremen, 1895, XIII Bd., S. 171.

*Eylais triangulifera* Koenike: Abh. Nat. Ver. Bremen, 1897, XIV Bd., S. 289.

*Male.*

The eye capsule is about 200$\mu$ long and 140$\mu$ broad; the eye-plate about 315$\mu$ broad. Behind the bridge, which is about 35$\mu$ long and 60$\mu$ broad at the middle, the capsules are nearer together than in front of this structure. On the front margin of the bridge, on each side, is a stout, rounded prominence, on which are situated the minute plates that bear the bristles of the bridge. Of the bristles themselves I can give no particulars as they are broken off on both sides in the single specimen before me. The middle part of the front margin of the bridge forms a rounded projection (Fig. 6). On the under side each capsule presents a triangular opening of moderate size, whose marginal thickening has a considerable breadth though but little elevated. The anterior eye-lens including the short stalk has a length of 50$\mu$ and in its outer globular part a diameter of 43$\mu$.

The capitulum including the pharynx is about 600$\mu$ long and 300$\mu$ broad behind the oral aperture. The oral area, which is almost circular in its outer ring, has a diameter of 116$\mu$. The oral fringe (Mundkrause) forms a transverse ellipse. The capitulum is deeply and angularly excavated in front and has an angular form in this part, when viewed from the ventral side, the antero-lateral margins of the sockets for the articulation of the palpi being truncated, as in the same structure in *E. desecta*. Behind the oral area the maxillary shield has a length of 166$\mu$. Its lateral margins are straight, converging to the bases of their posterior processes. Only about the oral area is the maxillary shield coarsely porous, the breadth of the porous area behind the latter being about 50μ. The large processes do not extend backwards beyond the hind margin of the maxillary shield and are moderately thickened at their free extremities.

The tracheal plates extend beyond the pharynx; they are of considerable breadth and moderate height and are perfectly straight except at their free extremities which are slightly curved upwards.

The pharynx, which is only about 50μ broad at the anterior end, widens caudad to 175μ at the slightly-developed, transverse, chitinous arch; its lateral margins are convex. The posterior end including the chitinous arch appears triangular in ventral view. The mandible is 232μ long, the basal segment about 150μ broad in front. The posterior angle of the flexor side is very obtuse, so that the flexor and posterior sides present a regularly curved margin and the basal segment appears to run out behind into a point (angle of the hind margin of the extensor side). The antero-lateral margin of the flexor side is straight.

The maxillary palpus has on the whole a slender form. It is 762μ long and the individual segments, taken in series from the first to the fifth, are 66, 116, 149, 265 and 166μ long respectively. The second joint, whose cuticle is thin on the flexor side, bears on its inner anterior margin only three bristles, two near together towards the flexor surface and one on the extensor surface. The third palpal segment is quite slender at base, but at the opposite end extremely thick, owing to the unusually stout prominence on the flexor side; the latter bears a group of short spines. On the outer side the same segment has an oval opening 85μ long, whose margins are not sharply defined. On both outer and inner sides of the penultimate segment, near the flexor side, is a longitudinal row of sabre-shaped or ensiform bristles of medium length. On the inner distal margin of the same segment are also seen several finely pectinate bristles. The terminal segment is noticeable for its considerable length and comparatively stout form; its tip is beset with five slender spines (Fig. 7).

The genital aperture is bounded on each side by an arcuate, chitinous ridge 225μ long, which is closely beset with bristles about 135μ long. The penis-skeleton (Penisgerüst) is about 415μ long and consists in the main of two long chitinous arms, which meet together at their arcuate, anterior ends, from which a common process is given off forwards. The free end of this arm is markedly thickened.

Locality:—Pond near Dechenes.

*Eylais marshallæ* Koen., n. sp.

Syn. *Eylais extendens* Koenike: Abh. Nat. Ver. Bremen, 1895, XIII Bd., S. 171.

The body-length of the single example before one is 1600$\mu$.

The breadth of the eye-plate in front is about 300$\mu$, the length of the capsule 200$\mu$, length of the bridge 45$\mu$, breadth 40 . The front margin of the capsule has internally a slight rounded prominence; on each side of these two prominences is a distinct hair-plate with a fine short bristle. The eye-capsule is produced posteriorly into a blunt point (Fig. 8). Its opening on the under side is comparatively small, triangular in outline and without well developed marginal thickenings (Fig. 9). The anterior eye-lens has, on the whole, an oval form, and is somewhat shifted away from the capsule-margin; the posterior lens is elongate-elliptical.

The length of the capitulum on its lower wall, without the processes, is about 350$\mu$; the breadth (in the region of the oral aperture) 230$\mu$. The oral area is almost circular in its outer ring; its two axes measure 182 and 166$\mu$. The oral fringe (Mundkrause) forms a somewhat smaller ring. The oral aperture is not surrounded by a leaf-like pattern (Fig. 10), such as, e.g., occurs in *E. desecta* (Fig. 5). The area about the oral margin is coarsely porous, the posterior part of the maxillary shield, on the other hand, finely porous. Otherwise no reliable particulars concerning the capitulum can be given, as it was much injured by its removal.

The tracheal plates are 332$\mu$ long and strongly curved upwards at their posterior ends.

The mandible is 265$\mu$ long and 166$\mu$ broad. The flexor side is not shortened, as compared with the extensor side; the former bears a rounded prominence at the posterior angle; the latter, behind the sheath of the mandibular class, is without an excavation.

The maxillary palpus is, on the whole, of slender form, the terminal segment much more than half as long at the penultimate segment; the distal end of the latter is stouter than the proximal end. This joint bears an inner series of fine, widely separated, smooth bristles, and at the distal end some pectinate bristles arranged in tufts (Fig. 11); four smooth bristles are present in the outer row. The third segment of the palpus is without an opening on any side. Its process is provided with numerous, moderately long, non-pectinate bristles.

In *E. triangulifera* Koen., the most nearly related species, the eye-capsules differ in that they are not angularly produced behind, but are rounded off, the lateral prominences at the front margin of the bridge more distinct and the opening on the under side of the eye-capsule surrounded by stouter marginal thickenings. The capitulum of *E. triangulifera*, which is rounded off and considerably narrowed in front, is broadest, not in the direction of the oral aperture, but farther back, about the base of the large process, which forms laterally an angular projection in this situation.

Locality:—Pond in the vicinity of Hog's Back, on the Rideau.

*Thyas stolli* Koen.

Syn. *Thyas stolli* Koenike: Abh. Nat. Ver. Bremen, 1895, XIII Bd., S. 194-196, Taf. II, Fig. 29-32.

In 1895 I described the imago of this species that was collected in Canada, but I was at that time not in a position to state the points of difference between the sexes. Recently I have been able to make known the male through the discovery of the penis-skeleton (Penisgerüst) in a Canadian imago. It may be briefly characterized as follows:—

*Male.*

The following statements pertain to a specimen about $1000\mu$ in length.

Including the first and last acetabula, the external genitalia measure about $200\mu$ in length, the genital valve $150\mu$. The latter exhibits at both anterior and posterior ends a marginal obliquity, of such a form that the inner side is considerably shortened. The posterior obliquity is more or less emarginate, according to the position of the valves. Near this oblique margin is a row of strong bristles, which increase in length from before backwards (Fig. 12). The inner margin of the valve is provided with a number of somewhat widely separated and very short hairs. The acetabulum anterior to the valve is approximately circular and has a diameter of $27\mu$. The posterior acetabula are borne upon a strong chitinous appendage, which passes backwards from the under side of each valve. The hindmost acetabulum is borne upon, and partly sunk into the end of a very prominent process of the chitinous appendage, which is directed backwards and outwards. It has a transversely elliptical form and a longitudinal axis of $27\mu$. The inner of the two acetabula lying posterior to each valve is borne at the end of a special process of the appendage of the valve, though not at the same level, but deeper. Its breadth is somewhat greater than that of the outer acetabulum, its length about the same. Upon the inner angle of the valvular appendage is a group of strong bristles.

Behind the genital organ is seen a roundish chitinous thickening in the skin (Fig. 12) which, however, is not a porous cuticular plate, such as occurs e.g., in *Th. barbigera* Viets, but a subdermal structure, probably a small chitinous body serving for muscular attachment. Such porous cuticular plates as K. Viets has shown to be present in large numbers in his species are entirely absent in *Th. stolli.*[1]

[1] I have recently succeeded in preparing a perfect chitinous skeleton of *Thyas stolli* from an alcoholic male example, collected by Dr. J. B. Tyrrell in 1883. I softened this specimen by heating it in a 10 per cent. solution of caustic potash over a spirit-lamp, then allowing it to swell for a short time in cold water. I then boiled it 1 to 2 minutes in concentrated glycerine, after which it was transferred to glycerine and acetic acid. After separating the capitulum, the internal parts were entirely removed through the camerostome by pressure.

*Panisus cataphractus* Koen.

Syn. *Thyas cataphracta* Koenike; Abh. Nat. Ver. Bremen, 1895, XIII Bd., S. 196-198, Taf. II, Fig. 33-35.

Repeated efforts to confirm the presence of a fifth unpaired eye in this Hydracarine were unsuccessful, so that I must now regard the absence of such an organ in this species as an established fact. It is thus, of course, incorrectly placed in the genus Thyas, belonging much more properly to the genus Panisus.

*Megapus crassipalpis* Koen.

Syn. *Atractides ovalis* Koenike: Abh. Nat. Ver. Bremen, 1895, XIII Bd. S. 211, Taf. III, Fig. 58 and 59.

*Megapus crassipalpis* Koenike: Abh. Nat. Ver. Bremen, 1908, XIX Bd., S. 246.

*Megapus ovalis* (Koen.)

Length of body 500$\mu$.

Capitulum 99$\mu$ long, with distinctly projecting rostrum.

Maxillary palpus 265$\mu$ long.

Fourth segment of palpus dorsoventrally 25$\mu$ thick.

Spine on the internal part of the flexor side of the 4tn palpal segment 25$\mu$ from the distal end of the segment, rather slender, 15$\mu$ long, straight and not pectinate.

*Epimeral region, 249$\mu$ long.*

The first pair of epimera fused with one another behind the maxillary emargination, 149$\mu$ long.

The outer margin of the last epimera in front of the articular fossa of the last pair of legs distinctly excavated.

The anterior leg 630$\mu$ long; its terminal segment strongly bent and 20$\mu$ thick.

The penultimate segment of the anterior leg 166$\mu$ long, 45$\mu$ thick at the distal end, which bears on its flexor side two unequally broad ensiform bristles.

*Megapus crassipalpis* (Koen.).

Length of body 500$\mu$.

Capitulum 116$\mu$ long, without projecting rostrum.

Maxillary palpus 215$\mu$ long.

Fourth segment of palpus dorsoventrally 37$\mu$ thick.

Spine on the internal part of the flexor side of the 4th palpal segment 35$\mu$ from the distal end of the segment, of considerable thickness, 25$\mu$ long, markedly bent and finely pectinate on both sides in the outer half.

*Epimeral region 315$\mu$ long.*

The first pair of epimera fused with one another behind the maxillary emargination, 249$\mu$ long.

The outer margin of the last epimera slightly convexly bent throughout its length.

The anterior leg 630$\mu$ long; its terminal segment strongly bent and 25$\mu$ thick.

The penultimate segment of the anterior leg 182$\mu$ long, 50$\mu$ thick at the distal end, which bears on its flexor side two unequally broad ensiform bristles.

The hind leg almost twice as long as the body.

The external genitalia 99$\mu$ long; and 116$\mu$ broad at the middle, narrower in front than behind.

The three genital acetabula on each side arranged in an arcuate series, the last acetabulum 30$\mu$ long.

The hind leg 1½ times as long as the body.

The external genitalia 116$\mu$ long and 149$\mu$ broad in the middle, broader in front than behind.

The last genital acetabulum shifted forward to the inner side of the second one, and 55$\mu$ long.

*Lebertia tyrrelli* Koen., n. sp.

Syn. *Lebertia tau-insignita* Koenike: Abh. Nat. Ver. Bremen, 1895, XIII Bd., S. 201.

The length of the body without the projecting epimera is 581$\mu$, with the latter 630$\mu$.

The outline of the body is obovate, the front between the antenniform bristles, which are separated from one another by 100$\mu$, somewhat produced. The margin of the body is nowhere excavated (Fig. 13). The cuticle is apparently without any special structure; no striation or punctuation (porosity) could be perceived even with the aid of an oil-immersion lens. The hypodermal glandular areas are small but stand out sharply.

The two pairs of eyes are separated from one another by 100$\mu$ and from the body-margin by 33$\mu$. The length of a double eye measures 33$\mu$. The eye-pigment is black and of slight extent.

The capitulum with the projecting pharynx measures 150$\mu$ in length, 52$\mu$ in breadth and 83$\mu$ in height. The buccal part of the organ forms a broad stout projection (Fig. 14). The lateral walls are bent far inwards above and in lateral view give the appearance of a stout protuberance at the base of the upper processes. These processes are long, not spreading, rounded laterally behind, terminating dorso-ventrad in an acute apex. The processes of the lower maxillary wall are directed strongly laterad and dorsad. The pharynx lies in the concavity of the maxilla and is 40$\mu$ broad and 35$\mu$ thick through the marginal thickenings at its posterior end.

The mandible is 130$\mu$ long. Its basal segment is dorso-ventrally strikingly deep and the slender posterior end comparatively short and without a hook-like curve (Fig. 15).

The maxillary palpus measures 33$\mu$ laterally at the second joint and is distinctly slenderer than the front leg; in height this segment measures 45$\mu$. The flexor side of the same segment is concavely, the extensor side strongly convexly, bent. The penultimate segment is on the whole slightly curved and presents a tumid enlargement on the flexor side not far from the proximal end. In the vicinity of this spot are two small marginal hairs (Fig. 16). The third segment, which is 50$\mu$ long, is shorter than the second (length 65$\mu$); the length of the whole palpus is 240$\mu$. The bristle on the flexor side of the second segment is stout, straight, not pectinate, and shorter than the segment. The inner surface of the third segment bears six fine bristles, of which three are borne upon the distal margin, one upon the proximal margin, and two approximately on the middle of the extensor surface, close to each other. On the outer end of the penultimate segment internally is a spine-like, chitinous process.

The epimeral region, which is about 500$\mu$ in length, extends 50$\mu$ beyond the frontal margin of the body and leaves the ventral abdominal surface uncovered only to the extent of a space 132$\mu$ long; its breadth is not less than that of the body.

The genital emargination, the length of which is 166$\mu$, is considerably longer than the maxillary emargination, which is only 116$\mu$ long. The common posterior end of the second pair of epimera is 33$\mu$ broad. The median suture of this pair of plates is a little shorter than half the distance between the maxillary and genital emarginations. The last plate has a considerable size and is narrower externally than internally, terminating behind in an irregular curve; its postero-internal angle projects considerably toward the genital organ, though not to the same extent as obtains in *L. complexa* Koen. The articular fossa of the posterior leg is situated far from the outer margin of the epimeron (Fig. 13).

The lengths of the legs measured in series from first to last are as follows: 464, 531, 614, 180$\mu$. The legs are all of the same thickness, on the whole moderately stout, becoming only slightly slenderer towards the distal extremities. The tarsi of the three posterior pairs are slightly enlarged at the distal extremity, the ungues correspondingly larger than those of the anterior legs; those of the latter are 20, of the remaining legs 30-35$\mu$ long. The ungual plate (Krallenblatt) is 15$\mu$ broad, the accessory tooth considerably shorter than the principal one. The leg bristles consist on the whole of spines of different lengths, mostly arranged in circlets at the outer ends of the segments; the largest and stoutest occur on the second pair of legs; fine hairs are sparingly present on the front pairs. Swimming hairs, even vestigial ones, are entirely absent.

The genital area is 140$\mu$ long, 83$\mu$ broad behind and completely withdrawn into the genital emargination. The elliptical acetabula differ but little from one another in size (Fig. 13). The sex of the imago here described was not recognized.

The anal aperture is near the posterior margin of the body, from which it is distant by about its own posterior breadth. It lies a little behind the level of the anal glands. There is no distinct anal area.

Among the species of Lebertia with 6 bristles on the inner side of the third palpal segment *L. tyrrelli* comes nearest to *L. complexa* Koen., from which, besides the structureless cuticle, it is most clearly distinguished by the relatively longer genital emargination and the less prominent postero-internal angle of the last epimeral plate.

Locality: Flathead River, August 1883.

*Lebertia wolcotti* Koen., n. sp.

Syn. *Lebertia tau-insignita* Koenike : Abh. Nat. Ver. Bremen, 1895, XIII Bd., S. 201.

The following description is based upon a single poorly preserved specimen.

The length of the body is about 1200$\mu$. The firm cuticle of the body is very finely and somewhat densely and irregularly punctate, a feature which could only be determined under strong magnification and the use of an oil-immersion lens.

The hypodermal gland-areas are inconspicuous. By maceration of the mite in a 10 per cent. solution of caustic potash the glands become dark brown in colour and are most easily seen through the skin. The antenniform bristle is 66$\mu$ long, of moderate thickness and bent backwards. On the outer side of the antenniform bristle is a very fine forwardly directed hair. On the antero-lateral margin is seen a short projecting bristle, bent strongly backwards.

The capitulum is 265$\mu$ long and 91$\mu$ broad. Its buccal part projects but little forward. Laterally at the base of the process of the upper wall is a small prominence (Fig. 17). The pharynx is conspicuously broad in front, thus giving the posterior end the appearance of being less widened.

The anterior end of the mandible, which is about 300$\mu$ long, is strikingly shortened to the knee; the slender posterior end, on the other hand, unusually long and curved towards the extensor side. The broad hyaline process (Mandibularhäutchen) is about equal in length to that of the short mandibular claw.

The maxillary palpus, like that of the following new species (*L. setosa*), is remarkable for the elongated third segment, which is not shorter than the penultimate segment (Fig. 18). The second palpal segment has, on the extensor side, a moderately convex curvature. The penultimate segment is almost straight and its distal end is dorsoventrally thicker than its proximal end. On the former there are present on the inner side, besides several small hairs, a sharp-pointed chitinous spine. The bristle of the flexor side of the second segment is probably very stout; nothing more definite can be said of it as it is broken off at the base from both palpi. The extensor side of this palpal segment has in its anterior half three stout curved bristles, the most anterior of which is densely and finely pectinate on both sides; on the inner side, close to the latter is a somewhat longer, likewise pectinate bristle. On the inner side of the third segment are six peculiarly arranged and very long bristles; these are densely or loosely pectinate, some on one side, some on both sides (Fig. 18). On the flexor side of the penultimate segment, near the middle, is a short, projecting, strongly-bent bristle.

The epimeral region, which is 747$\mu$ in length, apparently does not project beyond the frontal margin of the body and covers not quite two-thirds of the ventral surface; laterally it fails to reach the body-margin; its greatest breadth is 664$\mu$. The genital emargination is 166$\mu$ long and is a trifle longer than the maxillary emargination (150$\mu$). The common posterior end of the second pair of plates has a very slight breadth (33$\mu$). The median suture of these epimera is longer than half the distance between the maxillary and genital emarginations. The suture between the third and fourth plates extends distinctly as far as the genital emargination. The last epimeron is of little breadth and terminates behind in a regular curve. The position of the basal articulation of the hind legs is in the middle between the suture mentioned and the posterior margin of the last epimeron (Fig. 19). At the end of the epimeral process beside the maxillary emargination is a membranous appendage, which apparently represents the base of attachment of a bristle. The lengths of the legs measured from first to last are: 713, 913, 913 and 1245$\mu$. The segments are all rather stout, recalling, on the whole, the legs of *Thyas;* towards the distal end they taper but little; the tarsus of the third last pair of legs is slightly thickened and its ungues enlarged; its length is 45-65$\mu$; the basal part of the same segment has but a slight breadth (10-15$\mu$) and thus, as in *L. angulata* Sig. Thor., has no leaf-like expansion. The leg bristles resemble those of the species of *Thyas*, in consisting chiefly of stout spines; they occur most abundantly on the extensor side of the middle segments of the legs and in circles at the ends of the segments. Except a few very short and fine hairs scattered here and there, swimming hairs are entirely wanting.

The genitalia, measured from the valves, are 166$\mu$ long and 149$\mu$ broad posteriorly; they extend beyond the epimeral emargination to a distance of about one-third of their length. The inner margin of each valve is densely clothed with hairs; the anterior hairs are short, posteriorly they become gradually longer. The most anterior acetabulum has an elongate-elliptical form, the two succeeding ones are roundish (Fig. 19). The sex of the specimen here described was not recognized.

The anal opening is situated about the middle between the genitalia and the hind margin of the body.

Among the species of *Lebertia* with six bristles on the inner side of the third palpal joint *L. wolcotti* occupies an isolated position, on account of the marked elongation of this segment.

Locality: Canada (without further data).

*Lebertia setosa* Koen., n. sp.

Syn. *Lebertia tau-insignita* Koenike, Abh. Nat. Ver. Bremen, 1895, XII Bd., S. 201.

*Female.*

The body without the projecting epimera measures 1675$\mu$ in length, 1245$\mu$ in breadth and 1112$\mu$ in height at the middle.

Its outline is elliptical in dorsal view, the frontal end between the antenniform bristles truncate. A short distance behind the marginally placed eyes is a minute marginal tubercle with a short backwardly-directed bristle. In lateral view the outline of the body, including the epimeral shield, is oval; the dorsum appears longitudinally strongly arched; the venter, on the other hand, flat. These statements are merely tentative, their correctness depending upon whether the natural form is reproduced after treatment with caustic potash. The skin is thin, the cuticle smooth, appearing structureless even under an oil-immersion lens. The antenniform bristles are 83$\mu$ long, stout, blunt and borne upon low tubercles, separated by a distance of 282$\mu$ and bent backwards.

The two pairs of eyes are situated behind the antenniform bristles, just at the body-margin, and are separated from one another by a distance of 481$\mu$.

The capitulum including the pharynx is 282$\mu$ long, the maxillary shield strongly tumid, the posterior superficial process of the same strongly directed upwards and deeply sulcate. The posterior angles of the latter are provided with a slender acute process. The posterior processes of the maxillary wall are of considerable length and are not divergent. Their posterior end is bent inwards. The pharynx does not lie as usual in the cavum pharyngis but extends far up out of it at its posterior end. The pharyngeal canal is unusually broad; its posterior end is distinctly constricted on each side, not bell-shaped and only slightly expanded.

The mandible measures 365$\mu$ in length, the claw 66$\mu$. The hyaline process is only slightly shorter than the latter. The posterior end of the basal segment is strongly bent.

The maxillary palpus is strongly chitinized; all five segments are distinctly porous. The length of the palpus is 400$\mu$. The third segment exceeds the fourth in length to an abnormal extent. The bristle of the flexor side of the second is very stout; it is curved towards the basal segment and is densely pectinate on the convex side towards the tip (Fig. 21). The same segment shows on the extensor surface two short, stout, bipectinate bristles. All the other palpal bristles are unbranched. On the third segment, particularly upon the extensor surface is a number of extremely stout, long and bent bristles, upon which the specific name *setosa* is founded. The fourth segment is thickened at the outer end and is provided, on the inner side, with a long, acute, chitinous spine. The extremity of the palpus bears two or three larger claws, lying close to one another, and at the base of the dorsal claw is another considerably smaller one, which is noticeably bent.

The epimeral region is 863$\mu$ long and leaves the ventral abdominal surface uncovered to a distance of 581$\mu$. The maxillary emargination is 240$\mu$ long, the genital emargination 215$\mu$ long, the posterior end of the second pair of epimera 41$\mu$ broad, the median suture of this pair of plates 200$\mu$ long. The posterior dividing furrow between the second and third plate is strongly bent inwards. The last epimeron is noticeable for its narrowness and is bordered by a broad poreless margin; this is continued forward on the outer side of the third plate as a still broader marginal zone.

The legs are robust, porous and strongly chitinized. The three posterior pairs are remarkably expanded at the distal extremity. The ungues of the posterior pair are 80$\mu$ long, the ungual plate (Krallenblatt) of little breadth, the accessory tooth not long but stout. The front leg is as long as the epimeral shield; the hind leg has a length of 1543$\mu$ and is thus shorter than the body. With the exception of the first pair the legs are richly supplied with bristles and, in fact, chiefly with stout spinous ones, especially at the outer end of the femur and the patella of the three posterior pairs of segments. A few of the bristles are leaf-like, attaining a breadth of 12$\mu$. Swimming hairs are wanting.

The valves of the external genitalia measure 232$\mu$. The latter extend a considerable distance back out of the epimeral emargination which, in consequence of the marked narrowing of the last epimera, is noticeably shortened. The inner margin of the valves bears a number of stiff and crooked bristles. The two posterior pairs of acetabula are shorter and broader than the most anterior (Fig. 20).

The anal opening lies somewhat near the hind margin of the body, separated by 415$\mu$ from the genital area (Fig. 20).

Locality:—Canada (without further data).

## EXPLANATION OF PLATES.

### Plate I.

Fig. 1. *Eylais falcata* Koen. Eye-plate, viewed from beneath. From preparation 115. Obj. 3×oc. 4×20 cm. tub. (×135).

Fig. 3. *Eylais falcata* Koen. Right maxillary palpus. From preparation 115. Obj. 3×oc. 2×18 cm. tub. (×81).

Fig. 4. *Eylais desecta* Koen. Eye-plate. From preparation 656. Obj. 3×oc. 5×18 cm. tub. (×177).

Fig. 6. *Eylais triangulifera* Koen. Eye-plate viewed from beneath. From preparation 661. Obj. 3×oc. 4×20 cm. tub.

Fig. 7. *Eylais triangulifera* Koen. Right palpus. From preparation 661. Obj. 5×oc. 0×14 cm. tub. (×114).

Fig. 8. *Eylais marshallæ* Koen. From the type preparation in Ottawa (Museum of the Geological Survey). (×121.)

Fig. 9. *Eylais marshallæ* Koen. From the type preparation in Ottawa (Museum of the Geological Survey). (×121.)

Fig. 11. *Eylais marshallæ* Koen. From the type preparation in Ottawa (Museum of the Geological Survey). (×106.)

Fig. 16. *Lebertia tyrrelli* Koen., n. sp. From the type preparation in Ottawa (Museum of the Geological Survey). (×460.)

Fig. 17. *Lebertia wolcotti* Koen., n. sp. From preparation 1123. Length of the organ 0.265 mm.

Fig. 18. *Lebertia wolcotti* Koen., n. sp. Left palpus. From preparation 1123. (×270.)

## Plate II.

Fig. 2. *Eylais falcata* Koen. Eye-plate, viewed from beneath. From preparation 1331. Obj. 3×oc. 4×20 cm. tub. (×135).

Fig. 5. *Eylais desecta* Koen. Capitulum, viewed from beneath. From preparation 656. Obj. 3×oc. 4×20 cm. tub. (×145).

Fig. 10. *Eylais marshallæ* Koen. From the type preparation in Ottawa (Museum of the Geological Survey). (×106.)

Fig. 12. *Thyas stolli* Koen. From preparation 1323. Obj. 5× oc. 4×14 cm. tub.

Fig. 13. *Lebertia tyrrelli* Koen., n. sp. From the type preparation in Ottawa (Museum of the Geological Survey). (×92.)

Fig. 14. *Lebertia tyrrelli* Koen., n. sp. From the type preparation in Ottawa (Museum of the Geological Survey). (×325.)

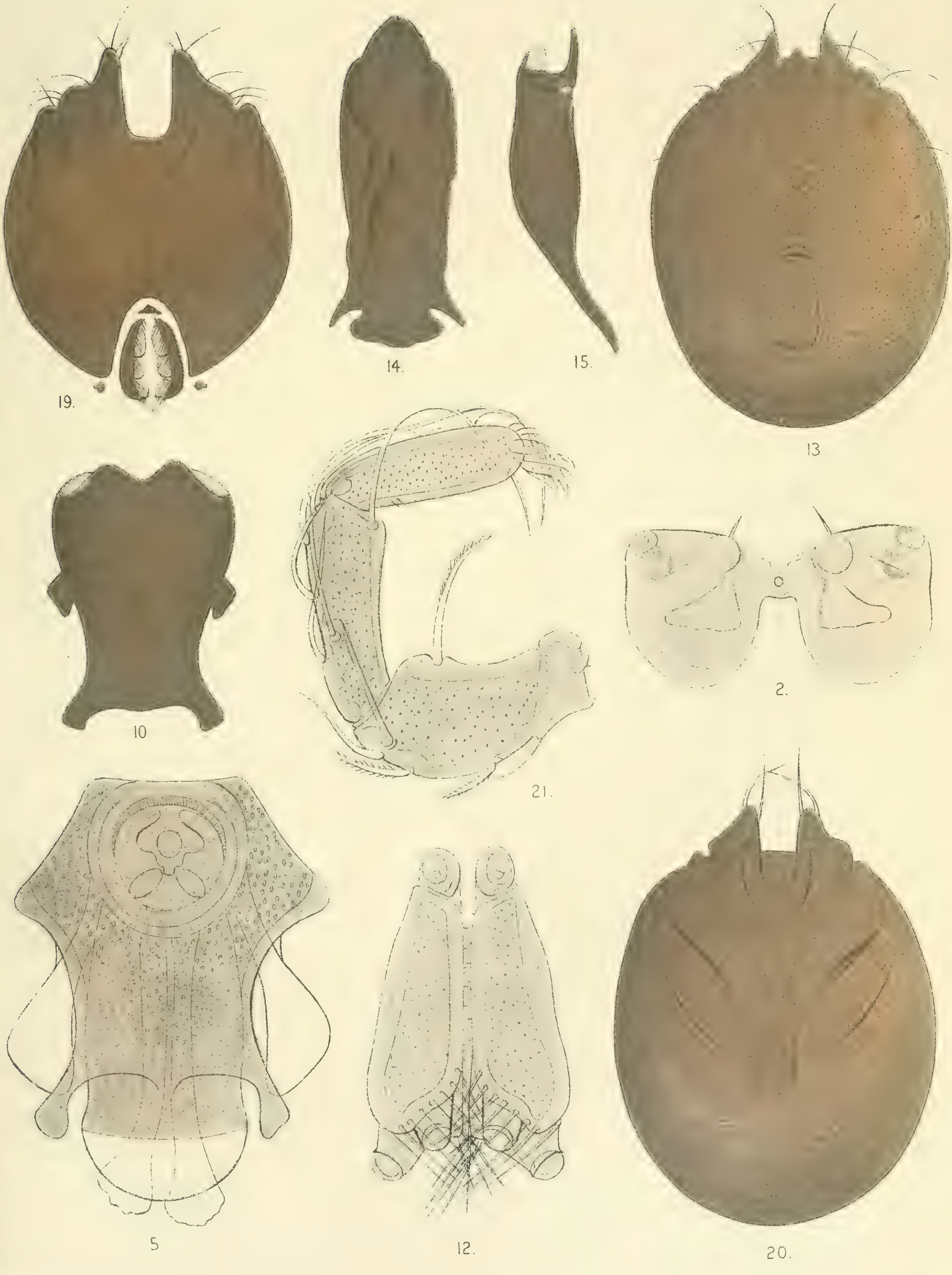
Fig. 15. *Lebertia tyrrelli* Koen., n. sp. From the type preparation in Ottawa (Museum of the Geological Survey). (×380.)

Fig. 19. *Lebertia wolcotti* Koen., n. sp. From preparation 1123. Length of epimeral shield 0.747 mm. (×64.)

Fig. 20. *Lebertia setosa* Koen. From preparation 52. (×43.)


F. Koenike. del

B. Meisel lith. Boston.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# A CONTRIBUTION TO THE MORPHOLOGY AND BIOLOGY OF INSECT GALLS.

BY A. COSENS, M.A.

The earliest explanations offered to account for the origin of galls are more or less fanciful, as must needs be, since nothing was known concerning the reciprocal relations of host and parasite involved in their life histories. Some of these theories dating from a less scientific age are crystallized in the popular names attached to certain classes of these structures. Thus the bristling masses of twigs, produced on several species of trees by the stimulation of plant or animal parasites, are known by some as "thunder bushes," a term that implies the expenditure of electrical energy in their origin. Also the more common name, "witches' brooms," indicates an equally imaginative explanation.

With the gradual advances of science much of the mystery surrounding galls has been dispelled, but they still present many interesting problems. Among these are two standing out so prominently that they seem to include all others. The first of these concerns the causes that are operative in producing the gall. It is now generally recognized that its origin is directly ascribable to the stimulation of a parasi e, but the problem still remains concerning the nature of the stimulus and the principle governing the response. Concerning the nature of the stimulus, Fockeu and his school ascribe it to mechanical means, while Küster, Küstenmacher and others believe it to be referable to a chemical action. With regard to the response by the host, the conventional view endows the stimulated protoplasm with power to originate something foreign and without a prototype in the normal host. But a view is developed in this paper proposing an entirely different explanation, namely, that the supposedly new types of organs, tissues, etc., are due to the awakening of dormant characteristics in the protoplasm.

The second problem deals with the apparent philanthropy that characterizes the host plant in its care for the parasite. Concerning this, several explanations have been offered. The parasite may be simply taking advantage of structures thrown out by the plant in its own defence, or as Adler[1] figuratively expresses it, the besieger is making use of the water in the moat in pushing forward the attack on the fortifications. Perchance, even what Darwin regarded as impossible has taken place, and the plant is producing the gall entirely for the welfare of the parasite. In opposition to this the theory is proposed by some investigators that in reality the host does derive benefit from the abnormal swelling since it has been the means of restricting the ravages of the parasite to a limited area.

I have confined the subject-matter of this research to the Zoocecidia including the Insecta and Arachnida. In the Insecta the following orders are dealt with—Hemiptera, Lepidoptera, Diptera and Hymenoptera. No attempt has been made to treat any one order exhaustively, but the work was restricted to the living gall material at hand. As a preliminary to the botanical work, several seasons were spent in rearing the producers in order that unquestioned identification could be assured of the various forms studied.

Concerning the anatomy of our American galls, the only work done previous to this is that by Cook,[22] who must be considered the pioneer in this branch of the subject. The anatomical studies pursued are considered important as forming a foundation for deductions.

The recent investigations of Weidel[45] on the early developmental stages of Neuroterus have added valuable data to the ontogenetic work. It is exceedingly necessary that some of the American species should be worked out in the same manner, but before this can be done with assurance of success, an American Adler must settle the questions concerning the alternate generations of our native forms.

Special attention has been paid to the Sawfly and Lepidopterous galls, since the anatomy of the former has hitherto not been dealt with at all and the ontogeny only very inadequately. The latter have also been neglected to nearly the same extent. The order Diptera and the family Cynipidæ have presented the most interesting biological phenomena, notably concerning the feeding habits and the nature of the gall-producing stimulus, two factors that are closely parallel if not indeed identical in these two sections of the gall producers.

With the exception of *Pachypsylla celtidis-mamma* Riley all the material was collected in the vicinity of Toronto. It was fixed in picrosublimate or Flemming's weaker fluid and cut in series in paraffin or celloidin. A double stain of safranin and hæmatoxylin was invariably used.

The investigations described in this paper were carried on in the Botanical Laboratories of the University of Toronto under the supervision of Prof. J. H. Faull, who suggested the subject and to whom I wish to acknowledge my indebtedness for invaluable criticism and assistance throughout. To Dr. C. D. Howe I wish to express my obligations for direction in the physiological experiments. My thanks are also due to Mr. W. A. McCubbin, M.A., for valuable assistance in the photography and to Mr. J. H. White, M.A., for normal material.

## ORDER ACARINA.

The following species are described in this section:—

Order Acarina.

Fam. Eriophyidae.

*Eriophyes Sp.* (*Fagus grandifolia* Ehrh.)
*Eriophyes querci.* (*Quercus macrocarpa* Michx.)
*Eriophyes Sp.* (*Acer negundo* L.)
*Eriophyes Sp.* (*Populus grandidentata* Michx.)
*Eriophyes Sp.* (*Populus tremuloides* Michx.)
*Eriophyes Sp.* (*Prunus nigra* Ait.)
*Eriophyes abnormis.* (*Tilia americana* L.)
*Eriophyes serotinae* Beut. (*Prunus serotina* Ehrh.)

The numbers referred to are from "A Catalogue of the Phytoptid Galls of North America," by George H. Chadwick, 23rd Report of the State Entomologist, New York State Museum, 1907.

### *Eriophyes Sp.*
Chadwick's No. 65
Host *Fagus grandifolia* Ehrh.

This gall occurs on the under side of the leaves of the host plant. It is an erineum, white and frost-like at first, turning to a brown colour at a later stage.

The anatomical structure of the interior of the leaf remains perfectly normal, the effect of the stimulation being confined to the epidermis. This produces a large number of unicellular, capitate hairs, resembling miniature mushrooms, the resemblance to which is the more striking since the stalks of the hairs are bulbous at the base, as shown in Fig. 3. The hairs on the normal leaf are long, acicular and unicellular. As this gall is produced with no increase in the number of cells in the leaf, anatomically it stands as a simple type of "hypertrophy", the remaining forms all exhibit the more advanced phenomenon of cell proliferation.

### *Eriophyes querci* (Garman).
Chadwick's No. 112
Host *Quercus macrocarpa* Michx.

In this gall, which is of the "dimple" type, the depression is on the under and the elevation on the upper side of the leaf. The hollow is filled with a dense mass of brown pubescence. In rare cases the elevation is on the under side of the leaf, when the pubescence then covers it.

The leaf blade in this case has become of nearly twice the normal thickness. This has resulted from cell division which has occurred in the tissues of both the palisade and the spongy parenchyma, producing a compact mass of undifferentiated cells, entirely without intervening air spaces. This tissue is shown in Fig. 6.

The epidermis has responded to the stimulation by producing many long, acicular, unicellular hairs, which are narrowed at the base. The hairs are stellate on the normal leaf of the host, but are simple, unicellular and acicular on its reproductive axis. The same feature is true of *Quercus robur var. pedunculata*, and in all probability of the other oaks. This appears to be a clear case, not of the production of a new type of trichome, but of a reversion.

*Eriophyes Sp.*
Chadwick's No. 2
Host *Acer negundo* L.

A shallow dimple on the under side of the leaf, filled with a white pubescence.

In this gall as in the preceding species, the leaf blade has been very much thickened by proliferation in the mesophyll. The cells produced are circular in outline and of about the same size as those of the normal spongy parenchyma. The hairs produced in this case not infrequently consist of from 2 to 3 cells which are very much convoluted. They are well shown in Fig. 4. The hairs on the normal leaf of the host are straight or only very slightly curved, but the glandular, convoluted type of hair is found on the inflorescence. Both the normal and abnormal hairs are composed of the same number of cells.

*Eriophyes Sp.*
Chadwick's No. 84
Host *Populus grandidentata* Michx.

A deep dimple gall with the convex part on the upper surface of the leaf. The gall is light green above, with the contents of the depression dark red.

The cells produced by the palisade parenchyma can be distinguished in this case from those arising from the spongy parenchyma. The former are almost square in outline and placed in two very regular rows immediately below the upper epidermis, and parallel with it. This tissue can be seen in Fig. 2. The latter constitute a tissue made up of cells which are circular to elliptical in outline. These cells are much smaller than those produced by the palisade layer. The outgrowths from the lower epidermis described in various ways as trichomes, granules, etc., are in reality produced by a complicated folding, in which only the lower epidermis and the spongy parenchyma participate, as shown in Fig. 2.

A cross section of the gall shows a number of vascular strands, but in my opinion the gall-producing stimulus only enlarges the veins that are already present in the normal leaf; it does not originate a special vascular system for the gall.

*Eriophyes Sp.*

Chadwick's No. 88.

Chadwick considers this form, first described by Jarvis,[28] the same as his No. 87. But the latter is characterized by a depression on the under side of the leaf, the former by an elevation, so that the two are constantly distinct.

Host *Populus tremuloides* Michx.

A dimple gall with the elevation on the under surface of the leaf. The elevation is a lighter green than the surrounding normal leaf and the folds that occupy the concavity are greenish-yellow or reddish in colour.

In dealing with the anatomical structure it is to be noted that the spongy parenchyma has in this case remained normal. The folds are produced in the same manner as in the preceding species, except that in this form it is the upper epidermis that undergoes the folding process. The nature of this folding can be seen in Fig. 1.

*Eriophyes Sp.*

Chadwick's No. 93.

Host *Prunus nigra* Ait.

A very much elongated pouch gall, greenish or whitish in colour, found on the upper side of the leaf with the opening on the under side.

All the characteristics of the normal mesophyll have been completely altered in the affected part of the leaf. Its cells, which, with the epidermis, constitute the wall of the gall, are larger than the normal and are elongated parallel to the long axis of the outgrowth. The upper epidermis which forms the epidermis of the gall has not been affected, but the cells of the lower epidermis which line the gall cavity have become much enlarged and in addition have produced a large number of closely set trichomes which project into the gall cavity. The nature of these is shown in the upper part of Fig. 5. These structures are often from 2 to 3 cells in length. Around the opening of the gall a circle of closely set acicular hairs occurs. The hairs on the outside of the gall and on the normal leaf are also of the acicular type. The vascular strands are much larger than those of the normal leaf but appear to be simply the stimulated normal veins.

*Eriophyes abnormis* (Garman).

Chadwick's No. 144

Host *Tilia americana* L.

A very much lobed pouch-gall, usually on the upper side of the leaf, found rarely on the under side. The opening which is on the opposite side of the leaf to the pouch is surrounded by a dense growth of acicular trichomes.

The anatomical structure of this gall shows it to combine the characteristics of a pouch-gall with a type in which the epidermis lining the larval cavity is thrown into folds, as described in the case of the galls on Populus. The foldings of the lining of the gall cavity often coalesce, and practically divide the cavity into a number of compartments. Morphologically this is one of the most highly differentiated of our Phytoptocecidia. The lining epidermis has produced a large number of acicular, unicellular trichomes; these in some cases almost fill the cavities. The hairs surrounding the gall aperture are of the same type, as are also the normal hairs of the leaf. Glandular cells are much more abundant in the gall tissues than in those of the normal leaf.

*Eriophyes serotinæ* Beut.
Chadwick's No. 100
Host *Prunus serotina* Ehrh.

This is a club-shaped gall, produced on the upper side of the leaf of the host. The aperture of exit, which is on the lower side, is surrounded by fine white hairs. It varies in length from 5 to 8 mm. and at a distance from the apex of about two-thirds the total length, it is narrowed into a stalk with an average diameter of 1 mm. In color it varies from green to a distinct red.

The stimulation has not produced very marked changes in the structure of the leaf near the origin of the gall. Apart from the fact that the spongy parenchyma has divided more actively, the mesophyll is normal. The upper epidermis of the leaf that forms the outer covering of the gall, has its cell walls abnormally thickened. The lower epidermis that lines the gall cavity has larger cells than the unstimulated epidermis, and from these cells originate elongated, unicellular trichomes with bulbous bases. The hairs on the normal leaf are acicular and unicellular. While the cells in the neck of the gall are arranged in rows parallel to its length, the larger cells that form the main body of the gall are not regularly placed. The vascular strands pass up from the leaf at a distance of about three cell layers from the gall cavity.

*Summary.*

In some forms the effect of the stimulation does not extend beyond the epidermis, on which the producers are located, but in other species it is transmitted throughout the mesophyll of the leaf.

The abnormal activity of the epidermis is expressed in the curving and folding of the tissue as well as in the production by it of various forms of trichomes.

In general, when the effect of the stimulation extends to the mesophyll the distinction between the palisade and the spongy parenchyma is lost. In place of these tissues a compact mass of uniform cells is produced.

The types of the galls constitute a clear phylogenetic series from the simple erineum to the well developed pouch-gall. The distinction between the different members of this series is largely a difference in degree rather than in kind, and seems to be explainable on the assumption of a gradually increasing intensity of stimulus from the lowest to the highest member of the series.

The literature of this group of galls contains a number of statements, to the effect that the host plant under the influence of the gall stimulus can originate entirely new types of hairs. While it is true, as a general rule, that hairs produced by an organ under such a stimulus differ from those originated by that organ under normal conditions, yet in such cases I have found that the abnormal type of hair is being produced on another part of the host plant. Thus the curiously convoluted, glandular hairs, originating in the dimple galls on the leaves of *Acer negundo* L., are duplicated exactly in the hairs occurring on the reproductive axis of the same plant, and the long acicular hairs composing the brown pubescence that fills the concavities on the leaves of *Quercus macrocarpa* Michx have their exact counterparts in those produced on the flowering axis of that plant. In the former example the normal hairs on the leaves of the host are straight and acicular, in the latter they are of the stellate type.

### ORDER HEMIPTERA.

The following Hemipterous galls have been studied:—

Fam. Aphididæ.

- Gall on *Populus balsamifera* L. (Unclass.).
- *Hormaphis hamamelidis* Fitch.
- *Hamamelistes spinosus* Shimer.
- Aphid Corrugations on Birch.
- *Pemphigus vagabundus* Walsh.
- *Pemphigus rhois* Fitch.
- *Chermes abietis* Chol.
- *Chermes floccus* Patch.

Fam. Psyllidæ.

- *Pachypsylla celtidis-mamma* Riley.

#### Aphid Gall (Unclassified).
#### Host *Populus balsamifera* L.

A pouch-like gall on the under surface of the leaf, produced by a fold in the blade near the base of the midrib. One edge of the fold is attached along this midrib. The slit-like opening, which is on the upper surface of the leaf, extends the full length of the gall. This species resembles very closely the gall produced by *Cecidomyia majalis* Bass. The general structure is shown in Fig. 7.

Dimensions:—Length along line of attachment to midrib, 10-12 mm.; Width, 4-5 mm.

In the part of the leaf blade that forms the gall all resemblance to the normal mesophyll has disappeared. A compact mass of tissue has taken its place, the cells of which are much larger than normal mesophyll cells. Towards the interior of the gall the cells become smaller and richer in protoplasmic contents. The upper epidermis forming the interior of the gall remains practically normal, except that it produces longer and more abundant trichomes than when unstimulated. These trichomes are usually three cells in length. A cross section of this gall shows two small groups of cells with porous laminated sclerenchymatous walls, one of which is situated near the midrib and the other exactly opposite on the other side of the gall opening. Thus each side of the gall aperture is bordered by a band of sclerified cells, as shown in the transverse section of Fig. 8.

*Hormaphis hamamelidis* Fitch.
Host *Hamamelis virginiana* L.

The gall formed by this species is found on the upper side of the leaf of the host, but the larvæ escape from an opening on the under side. The mature gall is conoidal in shape with the apex usually slightly bent over. General structure is illustrated in Fig. 12. A circular ring of tissue covered with pubescence surrounds the gall opening which is shown in Fig. 12.

Dimensions:—Average length of gall 10.5 mm.; diameter at base 4 mm.

The gall is composed of small cells placed close together, forming a compact and very uniform tissue. The cells are arranged with their longer diameters pointing in the direction of the gall apex. In a longitudinal section the vascular strands are seen to pass up each side at a depth of about three cells from the gall cavity. The beaks of the larvæ, often found imbedded in the wall of the gall, were inserted far enough to almost reach these vascular strands. The hairs that surround the gall aperture are acicular and unicellular.

*Hamamelistes spinosus* Shimer.
Host *Hamamelis virginiana* L.

The galls in this species are modified flower buds. These are somewhat elliptical in outline with gradually tapering stalks. They are covered with spines, which are usually curved. The opening is situated at the union of the stalk and the gall proper. This opening is funnel-shaped and is surrounded by a circular ring of tissue as in the preceding species on the same host. The pubescence is absent in this case.

Dimensions:—Average length including stalk 21 mm.; average width 10 mm.

This gall is covered by an unusually small-celled epidermis. The spines that are so noticeable a feature are found to consist of projections of the epidermis, filled with cells in continuity with the mesophyll. The cells of the gall are almost perfectly circular in outline and packed together very closely. This tissue is very uniform except in the four or five layers adjoining the gall cavity. In that zone the cells are smaller and richer in protoplasmic contents, constituting a fairly well marked nutritive layer.

In cross section of the gall about thirty main fibro-vascular bundles are cut; these are comparatively large and situated near the larval cavity. Two of these have been cut in the section shown in Fig. 10. Other smaller strands are cut further out. The gall receives all the fibro-vascular strands that, under normal conditions, would have passed up into the flower. The interior of both this and the preceding species is almost perfectly glabrous.

Aphid Corrugations on Birch.

Hosts {*Betula lenta* L.
*Betula alba var. papyrifera* (Marsh) Spach.

The primary folds in the leaf that form this gall run parallel to the main veins, with the latter as boundaries between them. Their crests are on the upper side of the leaf, while the hollows which form the larval chambers are on the under side. The primary folds are divided into secondary folds, and these again into depressions resembling minute Acarina dimple-galls. This complex arrangement is conditioned entirely by the veining of the leaf, since each fold, primary or secondary, is supported along its edges by veins. The folding can be seen in Fig. 9.

The anatomical characteristics of these galls show that the folding of the leaf has not entirely changed the structure of its normal mesophyll. Around the gall cavities the spongy parenchyma is nearly normal throughout and the palisade layer is recognizable in different places. The cells, however, are considerably larger than the cells of the normal mesophyll. The cells of the lower epidermis, that form the lining of the gall cavities, are well filled with food materials for the larvæ. The supporting veins on each side of the fold send out branches that supply the gall with an adequate vascular system.

*Hormaphis hamamelidis* Fitch and *Hamamelistes spinosus* Shimer, as worked out by Pergande,[40] show that they inhabit alternately *Betula nigra* L. and *Hamamelis virginiana* L.

The galls on the birch leaves are produced by the fourth generation of *Hamamelistes spinosus* Shimer. Pergande described them as "pseudo-galls or corrugations".

The witch-hazel galls produced by the stem-mother of this species are plentiful in this locality, but *Betula nigra* L. is not found here. The Aphids have consequently been compelled to extend their list of food plants to include *B. lenta* L. and *B. alba var. papyrifera* Spach.

*Pemphigus vagabundus* Walsh.
Host *Populus deltoides*, Marsh.

All the leaf rudiments of the terminal bud appear to be concerned in the production of this gall. Yet it is in reality a large pouch-gall with its wall thrown into smaller secondary folds. The apex of the stem, from which the gall originates, is usually swollen to nearly twice its normal diameter. These galls often remain on the host plant until the next season's galls begin to appear.

The cells composing this gall form a compact and fairly uniform tissue and a nutritive layer is not clearly differentiated. About one-third of the thickness of the gall wall, on the side next the larval chamber, however, is composed of cells that are somewhat larger than the remaining cells. The epidermal cells, lining the gall cavity, are elongated into short trichome-like structures. The phyllome origin of this gall is revealed by the presence of well defined stomata on its epidermis. These structures are numerous and appear to be quite normal. Glandular cells are plentifully distributed. Vascular strands pass irregularly throughout the wall of the gall.

*Pemphigus rhois*, Fitch.
Host *Rhus typhina* L.

A balloon-shaped gall with the regularity of its outline destroyed by the elongated lobes that cover its surface. A gall is shown in Fig. 14. The epidermis is slightly pubescent and coloured red, shading into yellow and green. It originates from the under side of the leaf, and the point of attachment on the upper side is indicated by a small papilla covered with a dense pubescence. These galls vary in size from very short types less than 1 cm. to those that are 4 to 5 cm. in length.

In the part of the leaf blade folded to form the gall, the mesophyll has been entirely changed. The effect of the stimulation has even destroyed the normal characters in the mesophyll for some distance from the point of attachment of the gall. The gall consists of a compact tissue composed of cells considerably larger than the normal cells of the mesophyll. The cells of this tissue are arranged in layers parallel to the epidermis of the gall. The vascular strands are situated about four cell layers in from the gall cavity. In all pouch-galls the tracheary tissue is composed of the ordinary vascular elements of the normal leaf that have been stimulated to increased activity. There is not a special tracheary system originated for the gall. In the galls the strands occupy a definite position, since in the normal leaf they occupy a definite place in relation to the spongy and the palisade parenchyma. Large glands are present in the gall tissue, as shown in Fig. 14. A gland is found invariably associated with a fibro-vascular strand and seems to have its counterpart in the very small gland that runs through each vein of the normal leaf. In some cases the abnormal glands have acicular trichomes projecting into their cavities.

*Chermes abietis* Chol.

Hosts { *Picea abies* (L) Karst.
*Picea mariana* (Mill) B.S.P.

A polythalamous gall produced by the swelling of the base of the young shoots. Since the twigs are not usually killed the galls are surmounted by a variable length of normal stem. The galls in general vary from conoidal to nearly spherical in shape, but in some cases, owing to the stimulation not having affected the entire circumference of the stem, the gall does not extend completely around it and is consequently less regular in outline. The surface of the gall is covered with the enlarged bases of the aborted needles. These give a faceted appearance to the gall and produce a likeness to a miniature pineapple.

Dimensions:—Longer diameter 2-3 cm.; shorter diameter 1-2 cm.

The gall in this case is a joint production of the cortex of the stem and the bases of the leaves of the host. The cells of the epidermis, lining the gall cavities, in some cases have been prolonged to form very short trichome-like structures. The hairs at the aperture of exit, as seen in Fig. 11, are composed of one or two cells.

The resin ducts that occur in the normal cortex are found considerably enlarged in the gall. In addition to these, there are out near the gall periphery numerous smaller resin ducts, as shown near the margin of Fig. 11, that do not have corresponding structures in the unstimulated tissues. These additional ducts pass in from the swollen bases of the aborted leaves. A cross section near the base of these leaves cuts from four to six resin ducts, while a normal leaf does not contain more than two of these structures.

*Chermes floccus*, Patch.

Host *Picea mariana* (Mill) B.S.P.

In this species the gall is produced by the swelling of the entire shoot. In comparison with the former species, the leaves are little, if any, swollen at the base but are more numerous on the gall than on an equal length of normal stem, owing to the shortening of the stem axis. The larval cells are in the cortex of the stem at the bases of the needles.

Dimensions:—Average length 2-6 cm.

The abnormal development of the cortex, especially that part contained in the wings on the stem, produces the entire mass of this gall. The stimulation has increased the number of resin ducts in the cortex. Several cross sections of galls were compared with corresponding sections from normal stems. The average number of resin ducts in the abnormal to that in the normal was in the proportion of 20 to 12. The smaller accessory resin ducts are shown in Fig. 13. In every section examined the additional ducts were in an irregular circle outside the normal ducts. The ducts produced under stimulation were larger than the corresponding normal ducts, but those that were found only in the abnormal tissues were smaller than the normal structures.

Fam. Psyllidæ.

*Pachypsylla celtidis-mamma* Riley.

Host *Celtis occidentalis* L.

A complicated form of pouch-gall produced in the mesophyll of the leaf of the host. On the upper surface of the leaf the gall is indicated by a decided depression in the centre of which is a slight elevation that marks the opening of the gall. The part projecting from the lower surface, is oblate-spheroidal in shape, attached to the leaf by a slightly tapering cylindrical stalk. The average number of galls found on a leaf is usually about ten, but in some cases much higher. The surface of the gall is smooth except for a few fine scattered hairs, glaucous and greenish-yellow in colour.

Dimensions:—Height from point of attachment 6-7 mm.; width 7-8 mm.

The anatomical structure of this gall shows it to be a more complex type than any other of the Hemiptera discussed in this paper.

Besides the folding of the leaf the blade has been further changed in thickness and in the character of the cells. The production of the greater part of the abnormal tissue is due to a wide, well differentiated cambium layer, that extends right across the gall and at its margin passes into the tissues of the normal leaf between the palisade and the spongy parenchyma (Fig. 15). The larval chamber is lined by this cambium sheath which thus functions as a nutritive layer. Bordering this zone is a well developed protective tissue composed of cells with uniformly thickened walls. The sclerenchyma is laminated and penetrated by branched canals, presenting the same character as that found in the galls of the Cynipidæ.

Outside of this protective zone lies the chief mass of the gall, composed of thin-walled irregularly shaped cells, as illustrated in Fig. 15. Typical cells of the protective sheath are also found scattered throughout this tissue. As the gall becomes older these cells increase in number.

*Summary.*

These galls are characterized by a folding and wrinkling of the leaf when they occur on that organ; in this particular they resemble the Phytoptocecidia. This common characteristic is due to the fact that in the orders Acarina and Hemiptera the stimulation is all from one side. The spherical type of the Cynipidæ is produced by a stimulus equally disseminated in all directions.

The tendency to produce trichome structures from the stimulated surface, so marked a characteristic of the Acarina forms, is in this group practically absent; the only hairs produced are those surrounding the gall apertures.

In most species of both groups there is little differentiation of tissues, so that the protective sclerenchyma zones mentioned in the genus Pachypsylla and the unclassified species on *Populus balsamifera* L. mark a distinct advance on the specialization attained by the Acarina galls and an approximation to the more complex types found in the orders Diptera and Hymenoptera.

The increased number of resin ducts in the tissues of the Coniferæ stimulated by species of the genus Chermes is an important feature of these galls.

## ORDER LEPIDOPTERA.

The Lepidopterous producers referred to in this paper occupy the following positions in Dyar's List of North American Lepidoptera, United States National Museum, Washington, 1902.

Fam. Sesiidæ.
*Memythrus tricinctus* Harris.
Fam. Tortricidæ.
*Eucosma scudderiana* Clemens.
Fam. Gelechiidæ.
*Gnorimoschema gallæsolidaginis* Riley.
*Gnorimoschema gallæasterella* Kellicott.
Fam. Tineidæ.
*Stagmatophora ceanothiella* Cosens.

The host plants of the various species are:—
*Memythrus tricinctus* Harris.
*Populus tremuloides* Michx.

*Eucosma scudderiana* Clemens.
*Solidago canadensis* L.
*Solidago serotina var. gigantea* Gray (seldom).
*Gnorimoschema gallæsolidaginis* Riley.
*Solidago canadensis L.*
*Solidago serotina var. gigantea* Gray.
*Solidago rugosa* Mill (seldom).
*Gnorimoschema gallæasterella* Kellicott.
*Solidago latifolia L.*
*Solidago cæsia var. axillaris* Gray (seldom).

In speaking of the host plant of this producer Busck[19] makes the following statement: "I have before me specimens from Miss Clarke, which were unquestionably bred from the white wood-aster, *Aster divaricatus* L. (*A. corymbosum* Ait.) near Boston."

*Stagmatophora ceanothiella* Cosens.
*Ceanothus americanus L.*

Tucker[43] states that *C. ovatus* Desf. is also a host plant of this species.

The following dates taken from records of specimens represent approximately the time of emergence of the moths:

*Memythrus tricinctus* Harris—July 4 to 8.
*Eucosma scudderiana* Clemens—June 8 to 20.
*Gnorimoschema gallæsolidaginis* Riley—August 5 to 15.
*Gnorimoschema gallæasterella* Kellicott—August 12 to 19.
*Stagmatophora ceanothiella* Cosens—June 23 to 30.

The two species of the genus Gnorimoschema pass the winter in the imago stage but Eucosma and Stagmatophora in the larval form.

Several galls of the Eucosma moth were opened December 11, and the data collected were as follows:—The larva was in a dormant state in the portion of the stem of the plant immediately below the gall. Before passing into this inactive condition the larva had carefully prepared for the emergence of the imago from the gall. The wall of the gall cavity had been eaten through until the part remaining was thin enough to permit the passage of light. The exit thus prepared was located at the upper end of the gall and was on an average 2 mm. in diameter.

A silk lining covered the whole of the interior of the gall and a partition of especially strong silk crossed the cavity just opposite the opening mentioned above. This partition did not pass straight across the gall but was found always in a slanting direction. It was attached to the gall wall just above the aperture and was always higher on that side.

Galls produced by the Stagmatophora moth were examined a few days later and the larvæ were found to be passing the winter under very similar conditions to those described in the case of the Eucosma species. The Stagmatophora larvæ were not perfectly dormant, however, and soon became quite lively in a warm room. They were found invariably in the gall cavity with their heads a short distance below the prepared exit. This had been constructed as in the preceding case and was situated at the same place. The silk lining covered the interior of the gall but in this case was gradually narrowed to the size of the hole around the edges of which it was attached. As the plant stem was not hollow above the gall, the roof of the gall cavity occupied much the same position as the slanting silk partition in the Eucosma gall.

The silk lining common to both of these galls helps to prevent the loss of moisture and the consequent desiccation of the larva.

The cross partition of the Eucosma gall and the tapering neck found in the lining of the Stagmatophora species seem to have the function in common of guiding the occupant of the gall to the prepared exit.

### *Memythrus tricinctus* Harris.

This form has hitherto never been considered a true gall maker—just why it is difficult to understand. Beutenmüller[3] reports it as a borer in stems of poplar and willow and in galls of *Saperda concolor.* I have repeatedly, however, bred this species from swellings on the smaller branches of young trees of *Populus tremuloides* Michx. These swellings were spindle-shaped, gradually tapering at each end to the size of the normal stem. In external form they were quite typical galls of the Lepidopterous class.

A comparison of the larval chamber of this gall with that of the Eucosma species shows that the two have certain features in common. Thus, although the opening in the stem made by the young larva in entering closes in the Eucosma gall, but not in this one, it can be found in the earlier stages of both. The silk lining in the larval chamber is not present, but the slanting silk partition has a similar structure and position to that found in the Eucosma species. This partition shuts off the permanent larval entrance from the part of the chamber in which pupation takes place. The place of exit has the same relation to this partition as that described in the Eucosma gall. The opening is prepared in the same manner. The larva eats through the wall of the gall until the part remaining is translucent just as in the case of the Eucosma or Stagmatophora forms. The larvæ in the two latter species prepare this opening in the fall, but the Memythrus larva does not complete it until shortly before pupation in the spring.

Dimensions:—As the size of the gall varies with that of the stem, an average of several specimens was taken. Length, 60 mm.; width, 20 mm.; diameter of normal stem at place of location of the gall, 12 mm.

A cross section of this gall, when compared with the normal stem, shows an abnormal thickening of the cortex and an increase in width of the bast and wood. Throughout the annual rings of wood are bast fibres, sometimes arranged irregularly in patches, in other cases forming fairly definite zones on the outside of the annual ring. The fibres are shown in Fig. 16.

*Eucosma scudderiana* Clemens.

"The galls are at the top of the main stems of the plants, usually within the flowering panicle, rarely on the branches of the panicle; usually but one gall on a plant, occasionally two, rarely three.

"The galls are spindle-form, varying in size from 10×16 mm. to 12×28 mm.; diameter of stem below gall from 4 mm. to 5 mm.; the average of ten galls collected in ten seasons, 100 specimens, was $9\frac{1}{2}\times21\frac{1}{2}$ mm., diameter of stem below gall 5 mm."—Brodie.[17]

The gall mass in this case is produced from the vascular bundles and the intervening parenchymatous strands. When the larva enters the stem it first eats out the pith. After the exhaustion of this source of nourishment, its food is supplied by the radial thickening of the bundles into the gall cavity. The secondary wood elements thus formed remain somewhat parenchymatous and can scarcely be distinguished from the cells of the medullary rays. The cortex is somewhat thicker than that found in the normal stem but this is not a very marked feature in the gall production.

In the normal stem of *Solidago canadensis* L. there is a gland opposite each bundle both on the side of the cortex and on that of the pith. The glands in the cortex of the gall are the same in number but are very much larger (Fig. 21). Likewise they are not regularly arranged but grouped two or three together. This is due to the fact that since some of the bundles have developed much more rapidly than others, their alignment has been destroyed.

The glands corresponding to the normal inner row were not found in the gall. This is accounted for by the early removal of the pith of the stem by the producer larva.

*Gnorimoschema gallæsolidaginis* Riley.

"Galls usually on the lower third of the stems of *Solidago canadensis* L. occasionally on the upper third, rarely at the summit of the stem. The galls vary in form from spindle-form to prolate and oblate spheroid; and in size from 10×21 mm. to 18×30 mm.

"Some observers say the interior of the gall is lined with silk. I have never found this, but preparatory to the exit, the mature larva before pupating constructs a silken hammock in the upper end of the gall, and opposite the aperture of exit. The larva resting in this hammock bites out a hole to the epidermis of the gall which is carefully left. The hole is bevelled towards the outside, and then neatly filled up with the material gnawed out, mixed with a silk-like substance, doubtless from a gland, which forms a tight-fitting, hard plug which cannot be pushed in from the outside but is easily pushed out from the inside."—Brodie.[17]

The anatomical features of this gall are very similar to those described in the Eucosma species. The gall mass is produced by the radial increase in thickness of the bundles and the growth into the gall cavity of the intervening parenchymatous strands seen in Fig. 20. There is greater proliferation of the cortical tissue in this case than in that of the Eucosma gall and the cells produced are much larger than those found in the normal stem.

The remarks concerning the gland production and distribution of the preceding species are also applicable to this form.

*Gnorimoschema gallæasterella* Kellicott.

"In a collection of galls made May 29, 1890, a few miles north of Toronto, most of them were at the top of the stem, surmounted by a few leaves, occasionally but one, usually two. The galls at this date seemed to be mature, subtriangular, corresponding to stem of plant; from 20 mm. to 32 mm. long, and from 10 mm. to 15 mm. diameter. In size, form and structure the galls closely resemble the galls of *G. gallæsolidaginis* Riley. Rarely they occur on the middle and lower third of the stem of the plant."—Brodie.[17]

"The gall produced on *Solidago cæsia var. axillaris* Gray by this producer is quite unlike the *S. latifolia* gall in appearance, but as both galls are merely spindle-shaped enlargements of the stems of the host plants, this difference in outward form can easily be explained. The glaucous, terete and slender stem of *S. cæsia* produces a gall with glaucous epidermis, circular in cross section and gradually tapering towards each end. On the other hand, the smooth, angled and comparatively thick stem of *S. latifolia* gives rise to a gall with smooth epidermis, somewhat triangular in cross section. This gall has also a greater diameter and tapers more abruptly than the *S. cæsia* gall."—Cosens.[25]

The anatomy of this gall presents the typical structure of a gall of the Lepidopterous class. The cortex of the stem does not play an important rôle in the production of the abnormal tissue; but when the host plant is *Solidago latifolia* L. the gall cortex is thicker than that of the normal stem. As in the case of the gall produced by *G. gallæsoli-*

*daginis* Riley, the bundles and the medullary rays are extended into the gall cavity and furnish the principal part of the tissue proliferation. Only a very shallow seam of normal wood is found in the galls produced on *S. cæsia var. axillaris* Gray.

Glands do not occur in the normal stems of either of the host plants and were not found in the tissues of this gall.

A section through the aperture of exit of a gall on *S. cæsia var. axillaris* Gray showed that the edges of the opening had been prepared by the larva for the reception of the "plug" that closed the opening. The sides of this aperture, roughened by the gnawing away of the tissue, would not admit of the "plug" fitting tightly and at the same time slipping out easily when occasion required. Consequently the gnawed surface is smoothed over by a layer of material that presents a perfectly even surface. This levelling-up material is uniform in character and does not show any trace of vegetable débris. At right angles to its free surface, an effect resembling checking takes place, a change that it has probably undergone in drying. This is illustrated in Fig. 22.

The "plugs" of the galls produced by the genus Gnorimoschema have been reported as consisting of silk and material gnawn out by the larvæ in preparing the openings. My observations incline me to the belief that the material, forming the plug and lining the opening, consists entirely of an exudation from the larva. It seems to be a plastic silk-like substance.

*Stagmatophora ceanothiella* Cosens.

"These abnormal growths are found commonly on a main stem, but rarely on a branch. The flower cluster is sometimes entirely aborted, but usually only partly so, the lower pedicels in the cluster remaining normal. In the majority of cases this gall is terminal, but in a few instances the stem was found to project a short distance beyond it.

"The gall has the relatively simple structure of a spindle-shaped enlargement of the stem. In length it varies from 10 to 15 mm. and in greatest width from 5 to 8 mm. It is roughened on the outside by the stumps of the aborted branches. On account of the shortening of the stem axis and the consequent crowding of the nodes, these branches are more numerous on a gall than on a corresponding length of normal stem. This gives the gall a gnarled surface and forms a strongly protected case for the larva. The gall in some cases is surmounted by a tuft of leaves growing from its apex.

"The aperture through which the moth escapes from the gall is made always near the upper end."—Cosens.[24]

As in the preceding galls described, the principal part of the gall tissues in this species is originated from the vascular bundles and parenchyma strands (Fig. 17). The latter are very wide and the abnormal cell division is more marked in them than in the bundles. The wood elements produced remain undifferentiated and pith-like. The cuticle of the gall epidermis is much stronger than that found in the normal stem. The epidermis itself has responded to the stimulation by the production of an extra layer of cells. The cortex of the gall contains approximately one-third more cell layers than the normal cortex as seen in Fig. 18.

The normal stem of *Ceanothus americanus* L. contains glands in the cortex. These are fairly regularly spaced around the stem but are larger and more numerous at the nodes. Glands occur also in the pith of the stem, the petioles of the leaves and the reproductive axes. But in parts of stems, contiguous with galls, though glands occur in the pith there are none in the cortex, except at the nodes. Glandular cells, however, are plentiful in the cortex of such stems.

A cross section of a gall shows larger and more numerous glands than a corresponding section of the normal stem. The probable explanation of this is that owing to the shortening of the stem axis, nodes are cut more frequently. In the gall cortex there are also narrow, elongated, glandular cavities, that do not seemingly correspond to anything seen in the normal stem. They require further elucidation. They are in groups each containing three or four glands, as illustrated in Fig. 19.

*Summary.*

The galls are all of a comparatively simple type, for while there is considerable proliferation in the tissues there is little differentiation. The medullary rays and vascular bundles respond the most readily to the gall stimulus, yet cell division takes place in the epidermis of the species *Stagmatophora ceanothiella* Cosens.

The highly specialized habits of the larva, developed in caring for the welfare of the imago, make the group very interesting. Thus in each of the forms studied provision is made by the larva for the emergence of the moth from the gall. These habits are seen at different stages of development. In *Stagmatophora ceanothiella* Cosens and *Eucosma scudderiana* Clemens the gall wall is simply gnawn partly through, while in the Gnorimoschema genus an aperture of exit is carefully prepared and plugged. These different methods of procedure are remarkably suited to the habits of the insects. In the former a plugged exit would not be suitable as the insect winters in the larval condition and the drying of the gall would prevent the plug from slipping out easily. In the latter the galls are still green when the insect becomes mature and the plug mechanism is preferable. It is clear then that in these galls the producer is much more active in providing for its own welfare than in the higher types and the plant renders a relatively smaller amount of assistance. As the stimulation of the animal participant becomes more effective, the plant is coerced into providing more suitable conditions for the maturing of the producer, which consequently becomes less active on its own behalf and more dependent on the host.

While glands are invariably larger in the gall tissues than in the corresponding normal stems, *Stagmatophora ceanothiella* Cosens furnishes the only example where there is a distinct increase in the number of glands.

An unusual cell division occurs in the species *S. ceanothiella* Cosens and *G. gallæasterella* Kellicott. The daughter cells are in clusters, usually four in number, clearly showing they have originated from a common progenitor. The septations between the cells are always very straight and the elongated nuclei are pressed closely against the division walls. This form of mitosis produces only a very small portion of the gall tissues in these species, but in the Dipterous gall *Neolasioptera perfoliata* Felt (Fig. 23) it originates nearly the whole mass. This form will be referred to again and the cell division illustrated in the part of this paper dealing with Dipterous galls.

As I have repeatedly found the opening through which the larva of *Eucosma scudderiana* Clemens has entered the stem, it is certain that this Lepidopterous producer always oviposits on the outside of the host, and this may prove to be true of the entire group.

## ORDER DIPTERA.

The anatomy of the following species is considered:—

Order Diptera,
- Fam. Cecidomyidæ.
  - *Cecidomyia bulla* Walsh.
  - *Cecidomyia balsamicola* Lintner.
  - *Cecidomyia impatientis* O.S.
  - *Cecidomyia majalis* O.S.
  - *Cecidomyia ocellaris* O.S.
  - *Cecidomyia pellex* O.S.
  - *Cecidomyia triticoides* Walsh.
  - *Lasioptera corni* Felt.
  - *Lasioptera impatientifolia* Felt.
  - *Neolasioptera perfoliata* Felt.
  - *Rhabdophaga batatas* Walsh.
  - *Rhabdophaga strobiloides* Walsh.

Fam. Trypetidæ.

*Eurosta solidaginis* Fitch.

The classification is as far as possible in accordance with Aldrich's catalogue of North American Diptera, Smithsonian Institute, Washington, D.C., 1905.

*Cecidomyia bulla* Walsh.

Hosts { *Helianthus decapetalus* L.
*Helianthus divaricatus* L.

"Galls found usually on the stem, often from leaf axils, occasionally on petiole and midvein of leaf, rarely on flower disc, protruding from between scales of involucre.

"The galls are attached by an ample base and are very irregular in form and position, usually somewhat compressed, varying from nearly spherical to flask and cone shaped and from equilateral triangular to spur-shaped.

"Dimensions:—The average of twenty galls was, base, 5.5 mm. thick and extending 8 mm. from stem."—Brodie.[16]

On the side of the stem from which the gall originates the vascular bundles are very irregularly arranged and elongated transversely in the direction of the gall axis. From these bundles vascular strands pass out into the gall mass. The principal part of the tissues in this gall originates from the medullary rays, as can be seen in Fig. 39. When the cortex of the stem passes into the abnormal cortex it becomes considerably thicker; this is due chiefly to the increase in size of the cells as the number of rows remains approximately the same as in the normal cortex.

Glands are found in the normal cortex of Helianthus; they are arranged in such a manner that a gland is placed opposite each fibro-vascular bundle. These glands are very much larger in the abnormal cortex of the gall. Besides these glands there are others that have not a counterpart in the normal stem. These are elongated in the direction of the gall axis and are most abundantly produced in the vicinity of the fibro-vascular strands.

There are practically only two zones represented in this gall, the epidermal and the parenchyma. The cells of the latter become slightly smaller towards the larval chamber but a well defined nutritive layer is not differentiated.

*Cecidomyia balsamicola* Lintner.

Host *Abies balsamea* (L) Mill.

A monothalamous gall formed by a folding of the leaf with the upper surface on the inside (Fig. 29). An enlargement ellipsoidal in shape is thus produced. The needles affected are near the apex of the stem and the galls are situated close to the base of the needles.

Dimensions:—Diameter along the leaf average 2.5 mm.; shorter diameter, average 1.5 mm.

The abnormal part of the leaf differs very markedly from the normal. The cuticle is entirely absent from the upper surface of the leaf that lines the interior of the gall. While the epidermis is uniformly thickened the normal cells have much heavier outer walls. The normal mesophyll cells are circular to widely elliptical in outline (Fig. 28), but the abnormal cells are very much elongated (Figs. 29, 30). Since the endodermis is poorly developed the mesophyll is not clearly separated from the pericycle. In this region the transfusion tissue is well represented, but the non-pitted parenchyma is not so abundant as in the normal (Fig. 31). The abnormal resin ducts are increased in size and have the protective layer irregularly developed.

In tabulated form is given a comparison of the anatomical structure of a normal leaf with one infected by the gall producer *Cecidomyia balsamicola* Lintner and one from a witches' broom produced by *Æcidium elatinum* on *Abies balsamea* (L.) Mill.

The data for the last named were obtained from Anderson.[2]

| Leaf Structure. | Normal Leaves. | Affected with *Æcidium elatinum* | Affected with *Cecidomyia balsamicola* Lintner. |
|---|---|---|---|
| Cuticle | Well developed on both surfaces. | Present but less developed. | Abnormally thickened on the lower surface (outside of the gall), not developed on the upper (inside). |
| Epidermis | The outer are thicker than the inside walls. Both are laminated and perforated by pores. | Epidermal cells more irregular than in normal; less thickened and seldom laminated and provided with pore canals. | On the outside of the gall the epidermal cells are irregular and have uniformly thickened walls; they are not clearly laminated but pore canals are more plentiful than in the normal. The inner epidermis is not thickened. |
| Stomata | More numerous on the lower than on the upper leaf surface. | Like the normal but fewer on each surface. | The same as the preceding affected by the fungus. |
| Hypoderm | Well developed at the basal half of the leaf. | Hypodermal cells fewer, but usually larger, thicker walled and more irregular than in normal leaves. | Cells irregularly developed, invariably curved and completely filled with laminated sclerenchyma. |

| | | | |
|---|---|---|---|
| Mesophyll | Usually two layers of palisade parenchyma developed on the upper leaf surface. The remainder of the mesophyll consists of spongy parenchyma (Fig. 28). | No distinction between palisade cells and spongy parenchyma. | The same as the preceding in the fungus, but the cells are very much elongated in a plane perpendicular to the midrib and parallel to the epidermis. |
| Resin Canals | Two circular canals present. These consist of an outer layer of thick walled cells and an inner epithelial layer of thin walled cells. | Irregular; varying in form and size, on account of the absence of the layer of strengthening cells. | Resemble the normal cype in shape and are the same in number, but are considerably larger and the strengthening layer consists of very irregularly shaped cells. |
| Endodermis | Consists of a single layer of thin-walled elliptical cells that bound the mesophyll on the inside and separate it from the pericycle (Fig. 31). | Endodermis seldom distinguishable. Cells irregular in form and size. No distinct boundary between mesophyll and pericycle. | Only a few cells differentiated and these are irregular in shape and much enlarged (Fig. 30). |
| Transfusion Tissue of the Pericycle. | Always present: found in two masses, one bordering each phloem area (Fig. 31). | Nearly always present. | Found in from 2-4 layers around the inner side of the endodermis. It comprises the greater part of the pericycle. The cells contain protoplasmic material (Fig. 30). |
| Non-pitted Parenchyma of the Pericycle | Fills between the two divisions of the bundle and projects on each side but more plentifully on the dorsal (Fig. 31). | More irregular in form and size. Larger and thicker walled than in normal. | Developed only between the bundles and in a single row along the edge of the bast (Fig. 30). |
| Fibro-vascular Bundle | Phloem and xylem consist of an average of 7 rows of cells. Medullary rays found between the rows. | Phloem and xylem less developed than in normal. The cells are often larger and thicker walled. Medullary rays are absent. | Phloem and xylem better developed than in the normal, the latter is more irregular. The medullary rays are absent. |

*Cecidomyia impatientis* O.S.
Host *Impatiens biflora* Walt.

A spherical, polythalamous gall attached to the host plant by a tapering stalk. Produced by the deformity of a flower bud.

Dimensions:—Diameter at right angles to stalk axis 6 mm.

There are three well differentiated zones. Immediately inside the small celled epidermis is a mass of large thin-walled cells irregularly arranged. The walls of these cells are seldom straight but usually present a wavy outline. They diminish in size progressively, passing in from the periphery of the gall until they merge into quite a well defined nutritive zone. This tissue is illustrated in Fig. 32. In this zone the cells are very much smaller and are arranged in rows radiating out from the larval chamber. Vascular strands pass irregularly throughout the gall. There is no indication of a protective layer separating the two inner zones.

*Cecidomyia majalis* Bass.

Hosts { *Quercus rubra* L.
*Quercus coccinea* Muench.

A flat pouch-like gall on the under side of the leaf. The opening which extends the entire length of the gall is on the upper side. It is produced by a folding of the blade of the leaf; this fold is parallel with and very close to the midrib or a main vein.

Dimensions:—Along the line of its attachment to the leaf, diameter 4-7 mm.

The gall has been formed in this case by a folding of the blade of the leaf. The resulting type recalls the pouch-like form usually associated with the Eriophyidæ or more rarely the Aphididæ.

The part of the blade included in the fold has not a well defined palisade and spongy parenchyma, the mesophyll being practically uniform throughout. The cells of this region are much larger than those of the normal leaf and are placed together without intervening air spaces. At the apex of the fold the leaf blade is much thicker than at any other part of it (Fig. 27).

The epidermis that lines the interior of the fold seems to remain intact throughout all the developmental stages of the larva.

*Cecidomyia ocellaris* O.S.

Host *Acer rubrum* L.

A circular ridge on the under side of the leaf and a slight convexity on the upper surface constitute the chief part of this gall. In the depression the larva rests covered with a viscid fluid secretion. The effect of the stimulation extending out from this centre is shown in the different coloured concentric rings produced in the leaf blade. These colours change in the course of development of the gall through various shades of red, green or yellow.

The slight depression in the leaf blade that constitutes this gall has been produced in the following way. The part of the leaf blade that forms the bottom of the depression has remained practically normal, but around this the blade of the leaf has become about five times as thick as the normal organ. A circular ridge is thus formed that produces a saucer-shaped hollow in the leaf blade. This can be clearly seen in Fig. 33. The cells that form this ridge are placed at right angles to the blade of the leaf, in nearly the position of the palisade parenchyma. There has been very little increase in the number of the cells, the accretion in thickness of the blade being due principally to the lengthening of the cells already present in the normal leaf.

Wherever a vein occurs in the gall, the cells are arranged in less regular rows and the individual cells are much larger and not nearly so elongated in outline. Intercellular spaces are not found in any part of the gall tissue. The feeding habits of the larvæ are such as do not necessitate the destruction of the epidermis lining the gall.

*Cecidomyia pellex* O.S.
Host*Fraxinus americana* L.

This gall is formed by a swelling of the blade of a leaflet on each side of the midrib, the cortex of which also undergoes a proliferation that merges insensibly with the mesophyll. Since the production of tissue is unequal on the two sides of the leaf, a folding of the blade occurs with the upper surface on the inside and the midrib at the apex. The depression thus formed constitutes the larval chamber.

Dimensions:—Along the line of the midrib 10-25 mm.

The greater part of the gall mass is produced from the mesophyll of the leaflet but a small part originates from the cortex of the midrib. The epidermal cells have not been stimulated to division. It is possible to determine the origin of the cellular elements from the circumstances that in the gall, as in the normal leaf, the veins mark the boundary between the palisade and the spongy parenchyma. About two-thirds has originated from the spongy parenchyma and the remainder from the palisade layer. The greater amount of tissue thus produced from the lower surface causes the folding of the leaflet with the sinus of the fold above.

The cells produced from the spongy parenchyma are several times larger than the normal. They constitute a tissue in which intercellular air spaces are entirely lacking. On the other hand, the cells that owe their origin to the palisade parenchyma, while larger than the normal cells, are considerably smaller than those originated from the spongy parenchyma. The latter with their epidermal covering constitute the nutritive layer of the gall. Near the surface of this tissue, where the larvæ are feeding, the cells have initiated divisions; here too they show signs of collapsing.

*Cecidomyia triticoides* Walsh.

"On *Salix cordata* Muhl. A polythalamous woody gall .70-1.23 inch long and .30-.37 inch in diameter, bearing a remote resemblance to a head of wheat with the kernels elongated, naked, pointed and very protuberant, its general outline oval or elongate-oval, and formed by the swelling of a twig to 2 or 3 times its former diameter, the swelled portion being very much contracted longitudinally, so as to bring each kernel-like bud nearly or quite into contact with the base of the one that precedes it in the same row, the whole number being arranged in four irregular rows."—Walsh.[44]

The larval chambers in this gall are placed usually along the line of the fibro-vascular bundles of the stem, and wherever a chamber is situated the vascular tissues are not developed.

An examination of a young stage of this gall shows that nearly the whole of the pith and cortex of the stem consists of a well defined aeriferous tissue. It is absent in only a few cell layers that surround the larval chambers. Represented in Figs 34, 35, 36. At this stage there is a well differentiated protective sheath, of about five cells in depth, around each larval cavity. The cells of this layer have uniformly thickened walls and are arranged in concentric rows around the larval chamber. Each cell of this zone contains either a crystal aggregate or a well defined single crystal of calcium oxalate. Inside of this protective sheath is a nutritive layer which consists of about six rows of thin-walled cells. The cells of this zone have the same tangential arrangement as those of the protective sheath. Many of them are empty, this being especially the case in the innermost row. Likewise, many are commencing to collapse on account of the withdrawal of their contents. These zones are represented in Fig. 38.

A section of a gall at a much more advanced stage of development presents several important differences. The aeriferous tissue is very much compressed in the pith and somewhat in the cortex. The cell walls of the protective zone are now much thicker, and a well defined crystal of calcium oxalate completely fills the lumen of each cell (Fig. 37).

Weidel[45] has recorded a phenomenon similar to this occurring in the gall *Andricus corticis* Hart.

"Oft ist das ganze an sich schon grosse Zellumen durch einen einzigen Kristall ausgefüllt, dem anscheinend so ansehnliche Zellulosemassen späterhin waren sie verholzt, aufgelagert worden sind, dass diese die Wand des Behälters erreicht haben und mit ihr verwachsen sind."

My observations differ in one respect from Weidel's, namely, there is no ensheathing mass of cellulose around the crystals found in the gall dealt with here. In deciding this point tests were made at different stages with Schulze's solution.

There is a cambium layer lying just outside the protective zone in the later stages. The nutritive layer consists of a mass of collapsed cells that stain deeply with hæmatoxylin. These layers are shown in Fig. 37.

*Lasioptera corni* Felt.

Hosts { *Cornus alternifolia* L.
*Cornus paniculata* L'Her.

This gall appears on the upper side of the leaf as a circular elevation but does not project on the under side.

The colour is entirely green when young but becomes surrounded by a circle of red at later stages.

In anatomical structure the tissues that compose this gall are the same as those in the normal leaf.

The lower epidermis and the row of mesophyll cells immediately in contact with it remain in the normal position. The upper epidermis and the remainder of the mesophyll become arched and thus separate from the lower epidermis and the part of the mesophyll that adheres to it in the manner shown in Fig. 40. In the space thus formed the larvæ are found.

*Lasioptera impatientifolia* Felt.

Hosts { *Impatiens biflora* Walt.
*Impatiens pallida* Nutt.

A monothalamous gall, projecting chiefly from the under side of the leaf. It consists of an elongated, spindle-shaped swelling of the midrib.

Dimensions:—Longer diameter 8-12 mm.
Shorter diameter 3-4.5 mm.

Practically all the abnormal tissue in this case is produced from the cortex of the midrib of the leaf. The stimulation has extended out only a very short distance into the adjoining mesophyll. The general mass of gall tissue consists of large cells with a few small intercellular air spaces. The epidermal cells are larger than those of the normal epidermis, their increased length being particularly noticeable. The features are shown in Fig. 41.

A nutritive layer is not differentiated.

*Neolasioptera perfoliata* Felt.

Host *Eupatorium perfoliatum* L.

A spindle-shaped swelling of the stem forming a monothalamous gall. It varies in size in proportion to the diameter of the stem or branch from which it originates.

It may be stated as an almost invariable rule, that when a gall and the plant organ from which it originates have a common epidermis the cell walls of that epidermis are thicker in the area covering the gall than elsewhere. But this gall is an exception to the rule. While the outer walls of the epidermal cells are considerably thickened in the normal they are much less so in the gall. Also the two layers of collenchyma cells underlying the epidermis in the normal stem are absent.

The increase in size of the stem where the gall is situated is due principally to increased cell division in the cortex, since the epidermis produces only two additional layers. The cells produced in the cortex are larger than the normal, but the most peculiar feature to be noted is the mode in which division has taken place and the relative arrangement of the products of division. The location of this tissue is illustrated in Fig. 23. The method of cell division is clearly the same in this species as in the two Lepidopterous types *Stagmatophora ceanothiella* and *Gnorimoschema asterella*. The clusters contain from 2 to 6 members produced from a single cell. The dividing walls are straight, and at the stage examined had the greatly elongated nuclei in close contact with them. These nuclei were seldom exactly opposite but usually diagonally across from one another. These characteristics are represented in Fig. 23. Schürhoff[41] has described the mode of division in callus, contrary to the views in vogue, he states that the nuclei divide mitotically only. There is good reason to believe that the phenomena observed here correspond very closely to those given in his account.

Near the inner edge of the cortex, glands are regularly spaced around the stem. This is a rather remarkable fact as they do not occur normally in this part of the stem. Indeed it was only after a careful search that they were located in the transition region between root and stem. The search was extended to other species with the result that they were found in *Eupatoria purpureum* L. in the roots, the cortex and the reproductive axis, but in *E. urticæfolium* Reichard as in *E. perfoliatum* L. only at the base of the stem.

*Rhabdophaga batatas* Walsh.

"On *Salix humilis* Marsh. A polythalamous gall of very variable shape and size, pale green when young, the colour of the bark when mature, growing on twigs .06-.19 inch in diameter and always some distance from the tip of the twig. Sometimes it resembles a small kidney-potato pierced lengthways by a twig, and has then most generally a smooth polished surface studded with a few buds, one or two of which occasionally give birth to a shoot, and it then reaches 1.35 inch in length and .6 inch in diameter. Sometimes it resembles a young apple pierced lengthways by a twig and attains a diameter of .3 inch."—Walsh.[44]

In this gall the larval cells are situated in the pith of the host plant, just inside the line of the fibro-vascular bundles. The epidermis has a much thicker cuticle than that borne by a normal stem of corresponding age. The cortex is approximately four times as thick as the cortex of the normal stem. This is due principally to the increased size of the cells. The cells of the nutritive layer are very similar to those of the surrounding tissues but a well marked protective zone defines its outer limits. This is clearly shown in Fig. 25.

The cells of the protective zone present a characteristic very rare in Dipterous galls, although frequently found in the Cynipid galls, namely, the walls of the cells are not uniformly thickened but are much heavier on the side next the nutritive zone. This unequal sclerification is illustrated in Fig. 26. Crystals of calcium oxalate, that were so characteristic a feature of this zone in *C. triticoides* Walsh, seem to be entirely absent in this gall.

*Rhabdophaga strobiloides* Walsh.

Host *Salix cordata* Muhl.

"The galls are very uniform in size and form, usually top-shaped, some inclining to spherical, a little oblate below and prolate above, and as the female oviposits but one egg in the terminal bud of the willow shoot, the galls are terminal and monothalamous.

"The gall is a rather tightly and regularly arranged mass of from 70 to 80 aborted leaves, representing perhaps about 1 m. of the leafage of a normal branch.

"The average measurement of 200 galls was 12 mm. $\times$ 15 mm., and the length of the deformed part of the branch included in the gall around which the aborted leaves were packed was 6 mm."—Brodie.[18]

The leaves that constitute the principal mass of this gall do not take any part in supplying the larva with food. The tissue that has this function is composed of a mass of small, thin-walled cells. It terminates the stem axis and the larva is in immediate contact with it (Fig. 24). This tissue which really furnishes a nutritive layer seems to originate from a cambium-like tissue at the base of the mass of cells.

An important factor in the production of this gall is the practical cessation of growth of the bud axis.

The aborted leaves that compose the gall exhibit very slight anatomical aberrations.

*Eurosta solidaginis* Fitch.

Host *Solidago canadensis* L.

A monothalamous gall produced by the swelling of the stem of the host plant. Very rarely it is found on a branch of the flowering panicle. A separate gall is almost perfectly spherical in form but occasionally two are produced together forming a common gall, prolate-spheroidal in shape.

Dimensions:—Average diameter of fifteen galls, 23 mm.

The cells that compose the principal mass of this gall are slightly smaller than those of the normal pith but in other respects they resemble them very closely. The irregularity in position of the fibrovascular bundles and their imperfect development are well marked features. Yet a sufficient water supply is ensured to the tissues by vascular strands that are given off from the bundles. These strands extend in a radial direction towards the centre of the gall.

The cortex is considerably thicker than that present in the normal stem. This is due in part to the greater number of cell layers, but also to an increased size.

The glands that are present in the normal stem of *Solidago canadensis* L. occupy certain fixed positions. One gland is present in the cortex outside each bundle and one inside in the region of the pith. The glands found in the cortex of the gall are very much enlarged and have not their characteristically regular arrangement. In the gall pith they are abundant throughout (Fig. 42), but decidedly more plentiful in the vicinity of the fibro-vascular strands. This is the most striking example of gland proliferation found in the galls studied.

The tissues that supply the larva with food are not differentiated into a nutritive zone.

*Summary.*

The galls produced by this order of insects vary very much in their degree of complexity. Some forms such as *Cecidomyia ocellaris* O.S. are as simple in structure as an Acarina, "Dimple", gall; other species as *Rhabdophaga batatas* Walsh present all the specialized anatomical characteristics of a Cynipid gall.

The abundant production of glands in tissue under stimulation is very clearly exemplified in *Eurosta solidaginis* Fitch. At first sight it appeared as if glands were not present in the host of *Neolasioptera perfoliata* Felt, but they were located at the base of the stem and in other species of Eupatoria.

The unequal thickening of the tangential walls of the sclerenchyma protective layer in *Rhabdophaga batatas* Walsh is a very unusual phenomenon in this group.

*Cecidomyia triticoides* O.S. is the only gall of this group in which a well defined crystal layer was found. In it each cell lumen is entirely filled with a single crystal of calcium oxalate.

The production of the aeriferous tissue, that occupies practically the entire pith in the gall *Cecidomyia triticoides* Walsh, is one of the most interesting phenomena exhibited in this group. The nature of this will be discussed in the biological section of the paper.

The collapsing of the nutritive zone after the cell contents are withdrawn is well exemplified in *Cecidomyia triticoides* Walsh (Fig. 37).

The unusual type of cell division in the cortex of the hosts infected by certain Lepidopterous forms, e.g. *Stagmatophora ceanothiella* Cosens and *Gnorimoschema gallæasterella* Kellicott and described in that group, is also found in the Dipterous gall *Neolasioptera perfoliata* Felt (Fig. 23). It was not found in any Cynipid form.

A comparison of a leaf of *Abies balsamea* (L.) Mill infected by *Cecidomyia balsamicola* Lintner with one from a witches' broom produced on the same host by *Æcidium elatinum* (*Melampsora Caryophyllacearum*) brings out a number of interesting points. These are given in the tabulated form following the description of the species *C. balsamicola* Lintner.

ORDER HYMENOPTERA.

Following Marlatt's Revision of the Nematinæ of North America, U. S. Dept. of Agriculture, Washington (1896), the species considered in this paper are comprised in the Subfamily Nematinæ, Family Tenthredinidæ. They are included in two genera, Pontania and Euura. The species referred to are:—

*Euura S. gemma* Walsh.
*Euura S. ovum* Walsh.
**Euura* (undescribed).
*Pontania pisum* Walsh.
*Pontania pomum* Walsh.
*Pontania desmodioides* Walsh.
*Pontania hyalina* Norton.
**Pontania* (undescribed).
*Gall on *Salix lucida* (undescribed).
Gall on *Salix humilis* (undescribed).

*Specimens of the first three producers marked (undescribed) were sent to S. A. Rohwer of the Smithsonian Institution.

I have been successful in rearing the producers of all of the undescribed forms except in the case of the one on *S. humilis* Marsh. This was accomplished in the following manner. The galls were collected at the time of the falling of the leaves of the host plants and were placed on earth in breeding jars which were kept under conditions of heat and moisture approximating as closely as possible to that of the natural habitat. Pupation took place at a distance of about a couple of inches below the surface of the soil and the adults emerged the following spring. The dates of emergence were:—

*Pontania* (undescribed), April 14 to April 24.
*Euura* (undescribed), May 2 to May 6.
Gall on *S. lucida* (undescribed), April 20 to April 22.

*While this paper was in press, Rohwer[46] published the description of these producers. Following the order above the names assigned are,—*Euura serissimæ* Rohwer, *Pontania crassicornis* Rohwer, *P. lucidæ* Rohwer.

The close restriction of sawfly gall producers to definite species of Salix can be illustrated by means of the forms mentioned in this paper. The host plants of the species are:—

*Euura S. gemma* Walsh
*Pontania desmodioides* Walsh
*Pontania* (undescribed)
found on *Salix humilis* Marsh.
*Pontania hyalina* Norton
on *S. alba* L.
*Pontania pomum* Walsh
on *S. cordata* Muhl.
*Euura* (undescribed)
on *S. serissima* Fernald.
Gall (undescribed)
on *S. lucida* Muhl.
*Pontania pisum* Walsh
on *S. discolor* Muhl.

In this locality I have not found the above species on any other host than that mentioned. When the type of gall is higher it would seem to be axiomatic that the relations between the host plant and producer would be more intimate than when the gall does not stand so high in the scale and as a consequence the restriction to one host plant would be a necessity. Yet the galls produced by the Cynipidæ are often found on two or three different hosts; as, for example, *Amphibolips inanis* O.S. on both *Quercus rubra* L. and *Q. coccinea* Muench, *Dryophanta palustris* O.S. on *Quercus rubra* L. and *Q. coccinea* Muench. *Aulax nabali* Brodie on *Prenanthes alba* L. and *P. altissima* L.

*Euura S. gemma* Walsh.

"On *Salix humilis.* The lateral bud of a twig enlarged so as to be twice or thrice as long, wide and thick as the natural bud before it begins to expand in the spring; its external surface otherwise entirely unchanged both in texture and colour. Internally, instead of the normal downy embryo leaves, it contains early in the autumn a homogeneous grass-green fleshy matter, which is afterwards gradually consumed by the larva, leaving nothing at last but a mere shell partly filled with excrement. The gall is monothalamous, sometimes one only on a twig, sometimes two or three or more at irregular intervals, very rarely as many as three or four formed out of three or four consecutive buds.

Length .17 to .36 inch
Breadth .10 to .17 inch.—Walsh.[44]

The anatomy of this gall presents little differentiation of tissue. A cross section shows that the entire mass of the gall consists of small thin-walled cells, shown in Fig. 68. The bud scales surrounding this group of cells resemble those of the normal bud except that the cuticle of the epidermis is abnormally thickened.

*Euura S. ovum* Walsh.

"On *Salix cordata*. An oval or roundish, sessile, monothalamous swelling, .30 to .50 inch long, placed lengthways on the side of small twigs, green wherever it is smooth, but mostly covered with shallow longitudinal cracks and irregular rough scales which are pale opaque brown. Its internal substance fleshy in the summer like that of an apple, but with transverse internal fibres. When ripe in the autumn filled with reddish-brown spongy matter, with close-set transverse internal fissures at right angles to the axis of the twig. On cutting down to the twig at any time a longitudinal slit about .20 inch long becomes plainly visible."—Walsh.[44]

As already noted the host of this gall in this locality is *Salix humilis*, it remains to be determined whether there are two distinct species of producers or one species with two hosts. Walsh's description of the gall on *Salix cordata* corresponds to the form occurring here on *S. humilis*.

The ovipositor of the producer has in this case made a longitudinal cut in the stem. A transverse section at the place where the gall is located shows that this wound extends in from the epidermis to the boundary of the pith. The activity of the young tissues, abnormally stimulated, soon fill this fissure with a mass of small, angular parenchyma. The rapid division of these cells forces the exposed edges of the cortex and central cylinder apart so as to form a wedge-shaped opening which is filled up with the gall mass (Fig. 71). It should be stated that the newly formed cells originate mainly from the division of a cambium bordering the pith at the bottom of the fissure. But other tissues also respond to the stimulation initiated by the ovipositor of the insect. Thus a section of the stem at a short distance from the gall shows that the outlying cambium has become abnormally active and has produced a layer of bast nearly one-third thicker than that found in the normal stem. Likewise the activity of a cork-cambium layer has thrown off a strongly cuticularized epidermis present in the earlier developmental stages.

Undescribed Sawfly Gall (*Euura N.S.*) on *Salix serissima* Fernald.

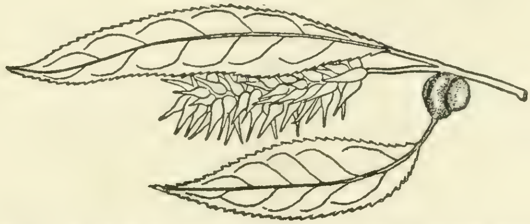

**Fig. 1.—A nearly mature gall attached to a leaf of the host plant.**

This gall is produced by the abnormal swelling of the petiole of the leaf. The leaves infected are those borne on the branchlets from which spring the pistillate catkins. In the majority of cases, the leaf that bears the gall is the one from the axil of which the peduncle of the catkin arises. The swelling is so close to the branchlet that after the leaves have fallen, the gall appears to have originated from it. This misleading appearance is due to the petiole of the leaf breaking just above the gall. The galls are cone-shaped with the apex towards the blade of the leaf. They are marked deeply by three or four grooves that meet at the tip.

Dimensions:—Height of gall 7-8 mm.; diameter at base 6-7 mm.

The anatomy of this gall presents a very compact tissue, owing to the cells being placed close together without intervening air spaces. The very much thickened cuticle of the epidermis is the greatest departure from the normal tissue. Of the three bundles of the normal petiole two are lacerated by the ovipositor of the insect, as shown in Figs. 69, 70. In the mature gall the halves of these two are found in four widely separated regions (Fig. 69), owing to the abundant production of tissue between them. Indeed practically all the abnormal tissue is produced from the undifferentiated cells stimulated by the cutting of the bundles.

*Pontania pisum* Walsh.

"On *Salix discolor*. A subspherical, pea-like, hollow, pale yellowish-green gall, always growing on the under side of the leaf and almost always from one of the side veins (in one case from the midrib), and attached to the leaf by only a minute portion of its surface; 0.18 to 0.28 inch in diameter and a few miniature, only 0.08 inch in diameter. Almost invariably there is but one gall to the leaf, but on four leaves there were two, and occasionally two are confluent. Surface in some smooth and even without pubescence; in others a little shriveled, generally studded in the medium-sized ones with four to twelve small, robustly conical nipples, which in the larger ones have burst into a scabrous brown scar. Only in three out of sixty-two was there any rosy cheek as in *P. pomum*. The point of attachment is marked on the upper side of the leaf by a brown sub-hemispherical depression."—Walsh.[44]

Walsh is incorrect in supposing that this gall originates from a midrib or vein. A section shows that it is clearly a product of the mesophyll and is attached to that part of the leaf. The side vein, near which it is always placed, is cut by the ovipositor, however, and vascular strands pass out from it into the gall body.

The mature gall consists of a peripheral layer of thin-walled cells, irregular in outline surrounding a central cavity (Fig. 81). This tissue is clearly derived from the mesophyll and epidermis of the leaf, but a stage was not secured young enough to show the relative amounts produced from each. The epidermis bears numerous lenticels, organs which Küster[35] mentions as occurring on the gall produced by *Pontania salicis.*

At the point of attachment of the gall the blade of the leaf is strengthened by several rows of cells derived from the upper epidermis and the palisade parenchyma, as shown in Fig. 81. These cells seem to have remained unmodified in any way, since their arrangement in rows is still clear in fairly old stages of the gall. Consequently they differ very markedly from the irregularly arranged cells of the main part of the gall body.

*Pontania pomum* Walsh.

"On *Salix cordata* (and very rarely on *S. discolor*). A smooth, fleshy, sessile, globular or slightly oval, monothalamous gall, resembling a miniature apple, .30 to .55 inch in diameter, growing on one side of the midrib of a leaf, and extending to its edge or sometimes a little beyond it. The principal part of the gall generally projects from the under side of the leaf, and only about one-sixth of its volume from the upper side, although very rarely it is almost equally bisected by the plane of the leaf. Scarcely ever more than one gall on a leaf and very rarely two of them, more or less confluent so as to seem like one kidney-shaped gall. External colour greenish-yellow, generally with a rosy cheek like an apple especially on the upper surface and often with many dark little dots on its surface."—Walsh.[44]

The ovipositor of the producer of this gall has been thrust laterally through the midrib of the leaf into the mesophyll. The wound has completely severed the bundle of the midrib, as seen in Fig. 76.

The full-grown gall presents an epidermis with a very thick cuticle. The remainder of the gall consists of a complex of thin-walled cells arranged so as to constitute a typical aeriferous tissue (Fig. 77). A similar arrangement of cells is not found in the normal leaf, the mesophyll of which consists of a fairly compact tissue. The vascular strands growing out from the wounded bundle form a complete ring around the gall, situated about half way between the epidermis and the centre.

I was successful in obtaining this gall at such an early stage that the egg membrane was still unbroken (Fig. 76). This phase shows that the epidermis, the palisade and the spongy parenchyma mutually take part in the gall production. Counting along a line passing through the centre, four of the cell layers are seen to have arisen from the lower epidermis and six from the upper, eight from the palisade and fifteen from the spongy parenchyma of the leaf. Hence it is noteworthy that the new tissues are not the product of a cambium but have been contributed to by every morphological region of the leaf. The cells that are produced at this stage are in rows generally in exact alignment with the cells from which they have arisen. They thus do not have the arrangement of the aeriferous tissue of later stages to which they give rise. The cuticle, so marked a feature of the older stages of the epidermis, is exceedingly thin. The epidermis bears trichomes springing from the bottoms of deep pits (Fig. 76). This condition has arisen through the circumstance that the primary epidermal cells from which hairs have grown out have not experienced the periclinal divisions participated in by their fellows and so have been left far below the general surface as shown in the text fig. below.

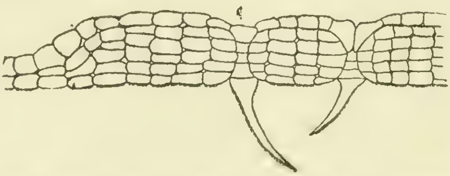

Fig. 2.—Hairs originating from pits in the epidermis of *P. pomum* Walsh.

*Pontania desmodioides* Walsh.

"On *Salix humilis.* A smooth, flattish, fleshy, sessile, yellowish-green monothalamous gall of a semicircular outline, the chord of the semicircle adjoining the midrib of a leaf; its general shape like the seed of a Desmodium or like the so-called "quarter" of an orange, the thin inside edge of the "quarter" closely hugging the midrib of the leaf, and the robust outer surface not biangulated but rounded off. No rosy cheek. The volume of the gall is generally about equally divided between the upper and lower sides of the leaf but sometimes the lower portion is rather the larger. Usually there is but a single gall on a single leaf, but occasionally there are two of them, either on the same side or on opposite sides of the midrib."—Length .23 to .50 inch Walsh.[44]

When mature this gall shows in cross section a cavity surrounded by a peripheral layer of little differentiated tissue. The epidermis has given rise to a very thick cuticle that is not present in the normal leaf. The bundle of the midrib has been injured only slightly by the ovipositor of the producer. The vascular strands given off from it almost encircle the gall along a line half way in from the epidermis.

A stage of the gall so young that the larva was unhatched shows the gall tissue to have been produced by cell division in the upper epidermis, the spongy parenchyma and the palisade parenchyma of the normal leaf (Fig. 80). At the thickest part of the gall, when it is in this stage, the upper epidermis has produced four layers of cells, the spongy and palisade parenchyma seven layers each. The lower epidermis has not divided as yet, and probably takes no part in the production of the gall. The abnormal cells from the palisade parenchyma show clearly their origin by their arrangement in rows at right angles to the surface of the leaf. The cells produced by the spongy parenchyma, on the other hand, are not regularly placed but include air spaces. The result is that the abnormal tissue in this case also resembles the normal tissue from which it is derived.

This stage of the gall shows that the cavity present in the mature gall has arisen between the tissue produced by the spongy and that derived from the palisade parenchyma of the normal leaf.

*Pontania hyalina* Norton.

"Fleshy galls occurring in two parallel rows, one on either side of the midrib, sometimes touching but not originating from the latter, and rarely extending to the edge of the leaf; sometimes as many as twenty on a single leaf; in other cases confined to a row on one side of the leaf or occasionally occurring singly; shape irregular elongate-ovate, projecting equally on both surfaces of the leaf; length 7 to 10 mm.; the abortive ones smaller. Colour on upper side more or less brownish red; beneath white, with slight purplish tinge."—Marlatt.[37]

The anatomy of this gall presents scarcely any differentiation of tissue. When mature it consists of a mass of thin-walled chlorophyll-bearing cells, the innermost of which are arranged in rows almost at right angles to the blade of the leaf, as seen in Fig. 75. Cells are so much alike that they afford no clue as to their origin.

Again I was able to obtain material so young that the larva was still confined within the egg membrane (Figs. 73, 74). It shows that the spongy parenchyma, the palisade parenchyma and the epidermis of the normal leaf were jointly concerned in the production of the abnormal tissue. The spongy parenchyma has contributed nearly half of the entire mass, the epidermes three layers each, and the row of cells immediately overlying the lower epidermis three layers. The remainder has been derived from the palisade parenchyma.

Undescribed Sawfly Gall (*Pontania N.S.*) on *Salix humilis* Marsh.

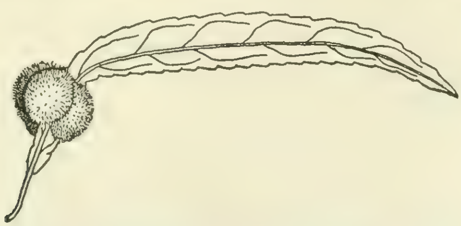

**Fig. 3.—Two galls attached on opposite sides of the midrib.**

This is a monothalamous gall found on the leaves of *Salix humilis.*

It is spherical in shape and in that feature resembles *P. pomum,* but in other respects it differs very markedly. It extends from the side of the midrib almost out to the margin of the leaf and is divided into two hemispheres by the leaf blade. In consequence the gall protrudes nearly equally from each leaf surface. Usually there are two or three galls on a leaf. When two are present they come in contact with the midrib at the same place but on opposite sides, as illustrated in Fig. 79. In a few cases four and even five galls were found on one leaf. The galls are pubescent but not as densely as the under surface of the leaf.

Dimensions:—Average diameter 1 cm.

The mesophyll of the leaf and the upper epidermis are mutually concerned in the production of this gall. In one, sufficiently immature to show the relative amount of tissue arising from each source, it was found that the upper epidermis had produced two cell layers, while the lower had not responded to stimulation; and that the palisade and spongy parenchyma had each produced one-half of the remaining mass. The hollow in the gall, present from the earliest stages, has been formed between the tissue arising from the palisade and the spongy parenchyma respectively.

When only one gall originates from the midrib at any point, the vascular bundle is cut approximately half through (Fig. 78). But more frequently two galls are located opposite one another, one on each side of the midrib, in which case the two incisions meet and completely sever the bundle, as seen in Fig. 79.

Vascular strands pass almost completely around the gall, along a line half way between the epidermis and the gall cavity. These strands originate from the midrib in the neighborhood of the injury and pass in opposite directions.

Undescribed Sawfly Gall on *S. lucida* Muhl.

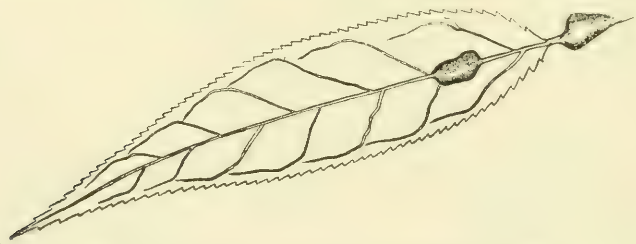

**Fig. 4.—Two galls produced on the same leaf of the host.**

This gall consists of an enlargement of either the petiole or midrib of *S. lucida.* Neither of these organs bears, as a rule, more than one gall at a time, but occasionally the petiole of a leaf carries two or even three and the midrib in rare instances two.

The midrib galls are fairly regularly elliptical in outline with the shorter diameter across the leaf. The swellings in most cases are nearly equally divided between the upper and the lower leaf surfaces. The petiole galls vary from spherical to ovoid in shape. In the latter case the smaller end of the gall is towards the apex of the leaf.

Dimensions of the gall:—Longer diameter 6-12 mm.; shorter diameter 3-7 mm.

The very marked proliferation of tissue in this gall is not accompanied by a differentiation that presents many points of interest. The cells are larger than those of the normal leaf and the nuclei are correspondingly larger. The bundle is cut nearly through by the ovipositor (Fig. 82). The free ends of the bundle thus stimulated grow out until in some cases they almost surround the gall. This elongation is produced in part by the increased diameter of the vessels but also by the production of new cellular elements.

The pith, exposed by the cutting of the bundle, produces almost all the abnormal tissue (Figs. 83, 84), but the cortex contributes some. The cells are arranged in curved lines that pass across from one elongated end of the bundle to the other. Between these rows are many air spaces which are elongated in the direction of the lines of cells (Fig. 84).

Undescribed Sawfly Gall on *Salix humilis* Marsh.

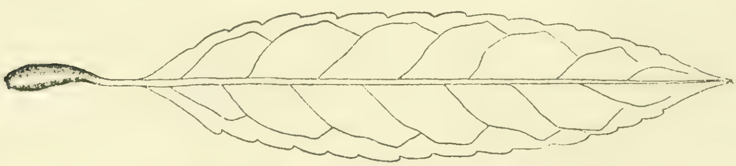

Fig. 5.—Leaf of the host with attached gall.

This is a monothalamous gall produced by the abnormal swelling of the leaf petiole of S. *humilis*. It is conoidal in shape with a long tapering apex which is towards the blade of the leaf. As it is situated at the base of the petiole the uniform enlargement of that organ is often prevented by the axillary bud. This causes the gall to project to a greater extent on the outside of the petiole and produces an irregularity in the outline of the gall. The surface is quite glabrous in spite of the fact that the epidermis of the leaf is decidedly pubescent.

Dimensions:—Length of gall 6-9 mm.; width 3-4 mm.

Nearly the entire mass of this gall originates from the vascular bundle of the petiole which has been stimulated to activity by the insect's ovipositor. The small thin-walled cells of the gall substance spring from a cambium layer produced in the pith of the bundle near the ovipositor wound. The cells arising from this tissue force the severed ends of the bundle apart until the vascular elements form only a narrow line of cells between the gall proper and the cortex of the petiole; it is shown at this stage in Fig. 85. This cortex is not materially thickened but shows signs of stimulation in that there appears a small amount of aeriferous tissue located near the place of entrance of the ovipositor. This tissue is shown on each side of the wound in Fig. 85. This tissue was not found in the normal cortex of the petiole. The cuticle is very much thickened.

*Summary.*

Great proliferation of tissue with little differentiation is a common characteristic of all sawfly galls.

All the leaf tissues of the genus Salix appear to be susceptible to stimulation by sawfly producers.

The pith of the bundle produces practically the whole mass of the gall when the place of origin is the petiole or the midrib of the leaf. In the case of a stem gall a layer of cells bordering the pith produces the chief proliferation.

When the gall originates from the mesophyll of the leaf the bundle of the midrib produces relatively only a very small part of the total gall mass.

Of the remaining tissues of the leaf the upper epidermis responds more readily to stimulation than the lower and the spongy parenchyma more actively than the palisade parenchyma.

In some cases the abnormal tissues exhibit the characteristics of the normal from which they have originated. The cells produced to form a solid base of attachment for the gall *Pontania pisum* Walsh never lose their arrangement in vertical rows, and the cells that originate from the same tissue in *P. desmodioides* Walsh are also in vertical series (Figs 80, 81).

Adler[1] secured specimens of *Nematus vallisnierii* in which the larva was still within the egg. I have been equally fortunate with the species *Pontania pomum* Walsh, *Pontania hyalina* Norton and *Pontania desmodioides* Walsh. At this early developmental stage considerable proliferation of tissue had already occurred. Adler even reports that the gall was nearly full grown. My experience has been that the larvæ are invariably found feeding unless the material is secured almost as soon as the galls are visible to the unaided eye. At this time little swelling of the leaf tissues is apparent, but a discoloration of the leaf enables the wound of the ovipositor to be detected. Owing to cell proliferation preceding the emergence of the larva, Adler concluded that the immediate cause of cell activity, productive of sawfly galls, is the wound caused by the act of ovipositing. But there is a slight possibility that secretions or excretions from the developing larva may be active through the egg membrane.

The protective sclerenchyma sheath of the more advanced types of galls is absent in this group, and the only protective device appears to be the cuticularizing of the epidermis and the presence of tannin in the cells. The cuticle has also a more important function in preventing the desiccation of the underlying thin-walled tissues of the gall.

The possible significance of the aeriferous tissue found in *Pontania pomum* Walsh will be discussed later in this paper.

Lenticels on galls seem to occur very rarely. They were found in this group only in the one species, *Pontania pisum* Walsh, a leaf gall.

The restriction of the various species in many cases to single hosts seems noteworthy when the minor specific differences between the members of the Salicaceæ are considered.

A series of the undescribed species of Euura on *Salix serissima* Fernald furnished undoubted examples of cell proliferation produced by the excrement of the larval producer (Fig. 72). This fact is discussed in the biological section of the paper.

## LOCALIZATION OF TANNIN-BEARING TISSUE IN SAWFLY GALLS.

Küstenmacher[33] has discussed the question of tannin in certain Cynipid galls and Cook[22] has detected it in different stages of a number of galls, but no attempt has been made up to the present to work out its distribution in the family Tenthredinidæ.

### *Pontania pomum* Walsh.

Tannin-containing cells are abundant in the epidermis of this gall. They are found also in the "Aeriferous tissue," but are not so numerous there. They are plentiful in the vascular strands, but can scarcely be demonstrated in the tissue next the larva.

In the normal leaf of *Salix cordata* Muhl. these cells are abundant, especially so in the vascular tissue and the epidermis.

### Undescribed Pontania Gall on *S. humilis* Marsh.

Tannin-containing cells are very plentiful in the epidermis and in six or seven rows of cells that immediately underlie that tissue. They are also present in the vascular strands and in the tissue next the larva.

In the normal leaf of *S. humilis* Marsh these cells are not present in the epidermis of the midrib but are found in the bundle of the midrib especially in the bast portion.

*Pontania hyalina* Norton.

Tannin cells are found abundantly in the epidermis and in the gall tissue generally, except the cells on which the larva is feeding.

In the normal leaf of *S. alba* L. on which this gall is found, these cells are not present in the epidermis of the midrib but are plentiful in the wood and bast of the bundle.

*Pontania desmodioides* Walsh.

Tannin cells are plentiful in the epidermis and in the underlying tissue, but gradually diminish in number in the tissues nearer the larva.

This gall also is found on *S. humilis* Marsh.

Undescribed gall on petiole of *Salix lucida* Muhl.

Tannin cells are found practically all through the tissues of the gall, but tannin is most plentiful in the epidermis and in the petiole that is involved in the gall swelling.

Tannin cells are found throughout the normal petiole except in the parenchyma tissue immediately underlying the epidermis.

Conclusions concerning Tannin-bearing Tissue.

(1) Tannin is more plentiful in gall tissue than in the normal tissue from which it originates.

(2) In gall tissues it is most abundant in the epidermis and the bast.

(3) It is more abundant in the older than the younger stages of galls.

(4) It does not appear to function as food for the larvæ as the tannin cells are less abundant in the tissue on which the larvæ feed.

(5) As tannin is always plentiful in the gall epidermis it may serve for protection by rendering the gall tissues unpalatable.

Technique used in Testing for Tannin.

The test substance used was a saturated solution of ammonium chloride saturated with ammonium molybdate.

Razor sections of the galls were used for testing.

## NOTES ON OVIPOSITING BY SAWFLY GALL PRODUCERS.

*Pontania hyalina* Norton.

The leaves of *Salix alba* L. are folded in the bud with the under surfaces towards the outside. The ovipositing takes place before the leaf selected has separated from the others in the same bud. As a consequence of this the ovipositor is inserted from the ventral surface of the leaf (Fig. 74).

May 27th, 1911.—On this date a producer was observed ovipositing in young leaves, but other leaves on the same stem lower down bore galls that were almost full size.

June 3rd and 4th.—On these dates producers were seen ovipositing.

June 18th.—Producers ovipositing.

August 11th.—Galls were found in which the ovipositing could have taken place only a few hours before. The ovipositing in this species must continue over a period of at least two months.

*Pontania pomum* Walsh.

*Pontania desmodioides* Walsh.

These producers begin to oviposit at about the same date as the above species. The period of ovipositing must comprise a comparatively short space of time as the galls of these species are all at about the same stage of development on the same date.

The galls produced respectively on *Salix cordata* Muhl. and *Salix humilis* Marsh. by these producers are not found near the tips of the young stems, but the galls on *Salix alba* L. produced by *Pontania hyalina* Norton are found on leaves along the whole length of the young stems. This difference in the location of the galls is caused by the period of ovipositing being much longer in *Pontania hyalina* Norton than in the other two species.

The first effect of ovipositing by *Pontania pomum* Walsh, visible to the unaided eye, is a dark red colour produced in the leaf blade surrounding the spot where the ovipositor has entered. This colour is also visible for a short distance along the midrib of the leaf. When the gall is opened at this stage the egg of the producer can be found with the aid of a lens. It is elliptical in outline and of pearly lustre. The membrane is translucent and the egg contents can be distinguished through it.

## ORDER HYMENOPTERA.

Whenever possible the specific names have been selected from the monographs by Wm. Beutenmuller,[5-14] that are now being issued from the American Museum of Natural History, New York. These publications give full synonymy and bibliography of the different species.

The following species are here described:—

Fam. Cynipidæ.

*Holcaspis globulus* Fitch.
*Holcaspis bassetti* Gillette.
*Philonix erinacei* Beut.
*Philonix hirta* Bassett.
*Philonix nigra* Gillette.
*Amphibolips confluens* Harris.
*Amphibolips inanis* O.S.
*Dryophanta palustris* O.S.
*Andricus imbricariæ* Ashmead.
*Andricus singularis* Bassett.

*Andricus piger* Bassett.
*Andricus petiolicola* Bassett.
*Andricus* (undescribed).
*Rhodites multispinosus* Gillette.
*Rhodites lenticularis* Bassett.
*Rhodites ignotus* O.S.
*Rhodites bicolor* Harr.
*Rhodites gracilis* Ashm.
*Rhodites nebulosus* Bassett.
*Cynips? constricta* Stebbins.
*Solenozopheria vaccinii* Ashm.
*Aulacidea nabali* Brodie.
*Neuroterus majalis* Bassett.
*Aylax glechomæ* Linné (referred to the section on Cytology).

*Holcaspis globulus* Fitch.
Host *Quercus alba* L.

A monothalamous, spherical gall produced at the nodes of the stem of the host.

It occurs singly or in groups of from two to four. The colour is yellowish-green usually with a reddish tinge. When mature the oval larval chamber is free from the remainder of the gall. The aperture of exit of the producer is placed at the end of this larval cell.

Dimensions:—Average diameter 13 mm.

When this gall is so young that it is still soft, it has the following anatomical characteristics. The larval chamber is in organic continuity with the remainder of the gall. Beneath the small celled epidermis are four or five layers of cells with their long axes parallel to the periphery of the gall. Inside this tissue is the more typical part of the parenchyma zone. Here the cells are in radial rows forming a fairly compact tissue with only a few small air spaces. Their radial walls are more elongated the nearer they are to the larval chamber. Inside of the parenchyma zone is a poorly defined cambium tissue that passes gradually into a crystal layer. Each cell of this zone contains a large crystal mass. A second cambium tissue, in this case well defined, bounds the crystal layer on the inside. From this cambium the nutritive layer is produced. This consists of cells, almost square in outline, arranged in radial rows (Fig. 65).

The protective zone is differentiated only in the later stages of development. It is found, however, when the gall is mature, forming the entire wall of the free larval chamber and extending a short distance beyond it. Its cells are of the usual sclerenchyma type with uniformly thickened, laminated walls perforated by branched simple pores.

*Holcaspis bassetti* Gillette.
Host *Quercus macrocarpa* Michx.

A monothalamous gall occurring singly or in clusters around the stems of the host. When grouped the galls often cover completely 4 to 5 inches of the stem.

When the gall is not deformed by crowding, it is irregularly circular in outline at the base, gradually tapering to a distinct point that is recurved in most cases. The gall is attached to the host by a small stalk at the centre of the base. Colour green, often tinged with pink when young; becoming brown when more mature. The larval chamber resembles closely that found in the former species in being oval and free at maturity, but it differs in being placed nearer the base of the gall and in tapering to a point at the end nearer the twig.

Dimensions:—Diameter at base, average, 16 mm.

Except in a few details the anatomical structure of this gall is the same as that found in the species just described. In this species the outer part of the parenchyma zone is composed of cells almost square in outline, but towards the larval chamber the cells become more elongated and arranged in distinctly radial lines. Rays of from one to three cells in width pass in radial lines throughout this zone. The cells composing them are much smaller than the ordinary cells of the zone. The cells of the nutritive layer are much more elongated radially than those of *H. globulus* Fitch (Figs. 58, 65). The cambial layers and the crystal-bearing tissue hold the same relative positions as in the preceding species. The relation of the crystal layer to the nutritive zone is shown in Fig. 58. The protective sheath in the mature gall extends out almost to the epidermis. Except in its distribution it cannot be distinguished from the corresponding zone in *H. globulus* Fitch.

*Philonix erinacei* Beut.
Host *Quercus alba* L.

A polythalamous gall springing usually from the midrib but rarely from a principal vein of the leaf. It originates from the under or occasionally the upper surface of the leaf.

The gall is spherical or ellipsoidal and slightly flattened on the surface in contact with the leaf. The point of attachment is narrow and elongated in the direction of the vein. The epidermis of the gall is divided up into numerous facets, each of which is drawn out at the centre into a trichome structure that becomes more spiny as the gall approaches maturity. The colour of the surface of the gall is yellowish with occasional red tints. The trichomes vary in shade from pink to red.

Dimensions:—Longer diameter 10-15 mm.; shorter diameter 5-10 mm.

In the earliest stage examined the gall was 2 mm. in diameter. At this time none of the cell walls are sclerenchymatous and the nutritive zone is only about four narrow cells in width. Outside of this layer is a part of the parenchyma zone in which each cell contains a large crystal mass.

At a stage in which the gall is full grown but still soft, all the zones are differentiated. The epidermis is thrown into folds and is covered with a heavy cuticle (Fig. 64). This is absent in the sinuses of the folds and on the epidermis covering the spines. The parenchyma zone is gradually converted into a protective tissue of porous sclerenchyma. The thicker deposit is usually on the walls of the cells nearer the periphery of the gall. Along the outside of the nutritive zone and throughout the protective layer generally are lines of small cells almost square in outline. The walls of these cells are very thick and the lumen of each is filled with a single crystal or a mass of crystals. In galls that had become hard all the cells of the parenchyma zone were found to have sclerified. The sclerification is partially complete in Fig. 64.

The nutritive layer of this gall differs very little in appearance from the parenchyma zone. Its cells do not contain the rich protoplasmic contents common to the nutritive zones of typical Cynipid galls.

*Philonix hirta* Bassett.

Host *Quercus macrocarpa* Michx.

A monothalamous, spherical gall originating from a principal vein of the leaf. Found somewhat irregularly spaced along the vein and about equally distributed between the upper and lower surfaces of the leaves.

The epidermis has the same faceted appearance found in the preceding species, but in this form the trichomes are represented only by short points. Colour greenish yellow. When the leaves become tinted in the autumn the galls assume a reddish brown colour.

Dimensions:—Diameter 2-3 mm.

The anatomical structure of this gall differs from *P. erinacei* Beut. only in the distribution and nature of the protective zone. This tissue is limited to a layer 3 to 4 cells in thickness, just outside the nutritive zone. The sclerifying deposits are limited almost entirely to the outside tangential walls of these cells and gradually entirely fill them. As a result of this the pores pass completely across the cells in the older stages. The small square crystal-bearing cells are, in this species, just outside the regular protective sheath.

*Philonix nigra* Gillette.

Host *Quercus alba* L.

A monothalamous gall attached to the principal veins on the under side of the leaf.

This species is spherical in form and has an epidermis covered with a short dense pubescence that gives a felty appearance to the exterior of the gall. A fibrous mass of cells surrounds the centrally placed larval chamber. Colour gray turning darker when dry. Individuals of this species are so numerous that the ground, under the trees infested by them, is often covered thickly with galls.

Dimensions:—Average diameter 8 mm.

Outside the nutritive zone is a wide crystal layer, each cell of which is completely filled with a crystal mass. The sclerenchyma of the protective zone is formed in a very unusual manner. The sides of contiguous cells are thickened in such a way that there is an almost spherical deposit at the points where the cells are in contact.

Radiating out from the protective layer are long narrow cells which form the minor part of the parenchyma zone. The remainder of this zone consists of irregularly elliptical, thin-walled cells. The epidermis is covered with a dense growth of trichomes with thick laminated and sclerified walls.

*Amphibolips confluens* Harris.
Host *Quercus coccinea* Muench.

A monothalamous gall attached to the petiole or midrib of the leaf. The midrib is never continued beyond the point of origin of the gall.

Globular to prolate spheroidal in shape and invariably terminating in a minute point. The thick walled larval cell at the centre of the gall is surrounded by a sponge-like mass of fibres that is at first white but becomes dark brown when the gall is dry. At a very early stage of development the epidermis of the gall is pubescent but later it becomes smooth. The colour is at first green but this changes to a lustrous light brown when the gall is old.

Dimensions:—Average diameter 40 mm.

(*a*) Stage in which the gall is 2 mm. in diameter.

Almost the entire gall consists of a compact tissue, which is composed of small uniform cells. Lines of narrow elongated cells, however, pass in a radial direction throughout this tissue. These cells do not extend into the gall cavity nor out to the epidermis, they traverse about two-thirds of the gall radius. As they approach the epidermis the lines curve around and run parallel to its surface. Spiral vessels are in some cases differentiated in these rays and the elements are more numerous near the point of attachment of the gall.

(*b*) Older stage 9 mm. in diameter.

The gall wall can now be divided roughly into three sections. That part lying next the larval cell resembles closely the compact tissue described in the preceding stage, except that immediately adjoining the cavity a typical nutritive layer has been formed by the elongation of the cells in a radial direction. In the centre zone the lines of cells containing the vessels are much more apparent at this stage, since the intervening tissue has become loose and skeleton-like. The cells composing it are long, very narrow and frequently branched. In many cases a branch is attached to the main cell without the formation of an intersecting partition between the two. The outside zone of the three is composed of somewhat elliptical cells. These form a fairly firm tissue constituting the rind of the gall.

(*c*) Mature stage.

The protective zone is now the most characteristic feature of the anatomical structure. The part of the protective sheath adjoining the larval cavity consists of a few layers of elliptical cells arranged in tangential rows. The sclerenchymatous deposits on the outside walls of these cells are much heavier than those on the inside. Further out the protective cells are formed in radial rows and their walls are uniformly thickened. This protective strengthening of the cell walls extends even into the loosely arranged filament-like cells, some of which are heavily sclerified.

*Amphibolips inanis* O.S.

Hosts *Quercus coccinea* Muench.
*Quercus rubra* L.

Resembles the preceding species in external appearance and in its attachment to the midrib or the petiole of the leaf.

In shape it is more nearly spherical than *A. confluens* Harr. and it has a much thinner rind than is found in that species. The epidermis of the gall, which is at first green with dark spots, becomes light brown with darker patches at a later stage. The larval cell in this case is held in position by a number of fine radiating fibres.

Dimensions:—Average diameter 35 mm.

In the earlier stages the anatomical structure of this gall is practically the same as *A. confluens* Harr. The vascular strands surrounded by elongated cells are present, but as the gall becomes older the connecting tissue from between the strands disappears.

In the mature gall the protective zone is very apparent. It consists of 8 to 10 rows of comparatively small elliptical cells. The walls of these cells are uniformly thickened, constituting a porous sclerenchyma.

*Dryophanta palustris* O.S.

Hosts { *Quercus rubra* L.
*Quercus coccinea* Muench.

A monothalamous gall produced singly or in groups of two or more on the leaves of the host plant. It is spherical in form and extends almost equally on each side of the leaf. In the majority of cases the gall extends out almost to the margin of the leaf and only the edge of the blade rims its outer side. Rarely this gall is found originating from the peduncle of the staminate catkin of the host.

The very young gall of this species is densely pubescent, while the well-grown specimens are usually quite smooth. In galls collected when the leaves are just beginning to unfold from the bud the larval cell and the outer zones of the gall are united, but very soon a separation occurs and the larval cell is left rolling freely around in the outer gall. Colour of mature gall green with patches of red in some places.

An average of about three weeks elapses from the time of the opening of the buds until the producers emerge from the galls. After another week the galls are wrinkled, dried up and brown. About ten days before the time of emergence of the producers the larval chambers were removed from several galls and placed under dry conditions. While the time of emergence of these producers was not appreciably changed, the insects in almost every case had difficulty in freeing themselves from the larval cells and one wing usually remained shrunken. It would appear that the outer gall during the later stages of development functions only as a moist chamber for the prevention of the desiccation of the larval cell.

The youngest galls examined were obtained from leaves that were just breaking out of the bud. At this stage the larval chamber still has organic connection with the remainder of the gall (Fig. 49). A well-defined cambium zone, in which mitosis is taking place, divides the gall wall into nearly equal parts. The parenchyma layer on the outside extends from the cambium to the epidermis. It consists of small cells that resemble closely those of the cambial zone. The inner half of the gall, forming the nutritive layer, is composed of much larger cells arranged in rows radial to the larva. A canal passes from the outside into the larval chamber. The epidermal lining of this canal is continuous with that of the epidermis of the gall and is covered with the same class of trichomes (Fig. 49). It gradually passes over into the innermost layer of the nutritive zone.

In a very short time after the opening of the buds, the larval chamber is severed from the remainder of the gall. The break occurs near the outside of the cambium zone, and separation has commenced in Fig. 50. At this stage the protective layer is not yet differentiated. Soon after the separation occurs it is produced, however, and the four zones of a typical Cynipid gall are complete.

The cells of the protective sheath are placed tangential to the larva. There are two layers of these cells, both of which have one tangential wall thicker than the other. In the outer row the thicker wall is towards the larval chamber, but in the inner row the reverse is the case. On the outside of the protective zone are about two layers of round, loosely connected parenchyma cells (Fig. 51). The canal mentioned in the early stage is still visible, penetrating the outer wall of the gall and that of the larval chamber. A layer of collapsed tissue is now clearly defined around the inside of the nutritive zone (Fig. 51). The inner layer of the parenchyma zone is also showing this same tendency to collapse.

In the mature gall the nutritive zone is represented by only a narrow layer of shrunken tissue (Fig. 52), the individual cells of which cannot be distinguished. The inner layer of the parenchyma zone is now almost completely collapsed and the cell walls of the whole zone are wrinkled.

*Andricus imbricariæ* Ashmead.

Host *Quercus coccinea* Muench.

A globular gall issuing from the stem of the host plant. Several galls are found near each other on the stem but they are never crowded.

It is usually monothalamous, but occasionally dithalamous forms are found, the larval cells are closely connected with the remainder of the gall. When the gall drops off its point of attachment is marked by a small, elliptical, depressed area surrounded by thin scales of tissue. These scales represent tissue forced aside by the emergence of the young gall.

Dimensions:—Diameter 6-9 mm.

This species has the four zones well differentiated. The most striking features of the anatomical structures are the following:—

The cells of the protective layer contain large crystal masses and have their walls uniformly thickened. Radiating lines of cells pass out from this protective zone (Fig. 48), through the parenchyma sheath and end near the epidermis. These bands are composed of narrow, elongated cells and are from 1 to 3 cells in width. These rows of cells contain a great deal of starch and a substance that takes a very deep stain with saffranin. Large cells of the parenchyma zone separate these bands of cells from each other, as seen in Fig. 48.

*Andricus singularis* Bassett.

Host *Quercus rubra* L.

In the majority of cases this gall originates from the mesophyll of the leaf blade but rarely it is found attached to the petiole. It is situated near the margin of the blade of the leaf and projects about equally from the upper and lower surface.

It is a monothalamous gall closely resembling in external form *Dryophanta palustris* O.S., but its outer wall is much firmer and it does not wither so quickly after the producer emerges. The ellipsoidal, larval chamber is suspended at the centre of the gall by radiating bands of tissue which pass inwards from the gall rind; this gives the species a superficial resemblance to small specimens of *Amphibolips inanis* O.S.

Dimensions:—Diameter 10-15 mm.

The larval chamber in this species is suspended at the centre of the gall by fine strands of tissue. These are composed of long, narrow, filament-like cells interspersed with spiral vessels. These fibres represent the inner part of the parenchyma zone. The outer part of this zone resembles closely that found in the gall produced by *Dryophanta palustris* O.S. The cell walls of the epidermis are strongly thickened and this is the case also in the underlying layer of cells of the parenchyma sheath. The protective zone, when the gall is full grown, consists of two rows of porous, laminated sclerenchyma cells. The outside tangential walls of these cells are much more thickened than the inside walls. The cells of the nutritive layer are unusually large and almost square in outline. By the time the gall is nearly mature many of them have been emptied of their contents and a wrinkling in the radial walls shows that the whole tissue is collapsing (Fig. 59).

*Andricus piger* Bassett.
Host *Quercus coccinea* Muench.

A polythalamous gall produced by the swelling of the petiole or midrib of the leaf. It is situated always near the distal end of the petiole or the proximal end of the midrib.

It is an irregular, elongated structure, somewhat triangular in cross section. When it originates from the midrib the projection is almost entirely from the under surface of the leaf, the broad flattened part of the midrib above rising very little above the general surface of the blade. On the under surface of the leaf along each side of the gall is a row of small openings. The larval cells are in two rows following the line of the openings. The total number in the gall varies from 20 to 30.

Dimensions:—Length of longer diameter 20-25 mm.

A nearly mature specimen shows the following anatomical characteristics. The four typical zones are well defined. Surrounding the nutritive zone are three rows of cells that form the protective zone. The walls of these cells are porous laminated and uniformly thickened. Outside of the protective sheath is a zone of tissue of about the same width, each cell of which contains a large crystal aggregate. These masses of crystals alone distinguish this tissue from that of the parenchyma zone into which it gradually passes by the crystal groups becoming less plentiful.

Connected with the openings mentioned in the macroscopic description are remarkably straight canals that extend in as far as the protective sheath. At this point they are closed by cone-shaped plugs of sclerenchyma (Figs. 43, 44), that extend out from the protective zones of the larval cells towards which the canals are passing. The cells of this tissue are identical with those of the ordinary protective zones.

From analogy with *Dryophanta palustris* O.S. (Fig. 49), and with other species of Andricus it would seem safe to infer that this canal opens into the larval chamber at earlier stages in the development of this gall. This also appears more likely to be the case since the protective zone that blocks the way, is differentiated only in the later stages.

*Andricus petiolicola* Bassett.
Host *Quercus alba* L.

This gall is produced in the same manner as *A. piger* Bassett by the swelling of the petiole or midrib. It is also located at the same place on the leaf as that species.

It has an irregular, spherical shape drawn out at some place on its surface into a short tapering projection. At the summit of this elongated part of the gall is an opening surrounded by a dense ring of coarse, brown trichomes. The larval cells are numerous and very variable in number. They are arranged around the axis of the gall at about the same distance from the epidermis.

Dimensions:—Diameter of the swollen basal part 10-12 mm.

In this species the protective layer is much thicker than in *A. piger* Bassett, but the individual cells composing it are the same in both species. The galls sectioned were nearly mature but the crystal layer of the former species was not found.

In this species also there is a canal passing towards each larval chamber (Fig. 46). These canals do not open directly to the outside but into a main canal of larger bore that extends a considerable distance into the mass of the gall (Figs. 45, 46). The branch canals are blocked by the protective sheath as in the preceding species. All of the canals are lined with a cuticularized epidermis, continuous with the gall epidermis (Fig. 45). The lining of the main canal produces abundant trichomes but these structures do not appear to be present in the tributaries. A tubular outgrowth of the protective zone surrounds the main canal. This sclerenchymatous sheath is separated from the canal by several layers of parenchyma cells. Outside of this protective tube a cork cambium is differentiated.

Andricus (Undescribed).
Host *Quercus macrocarpa* Michx.

The swelling of the midrib of the leaf produces this gall. It resembles closely *A. piger* Bassett, but is always found within the blade of the leaf, although close to its base in most cases.

The openings mentioned in the two preceding species are in this case found on the surface of the gall which appears on the upper side of the leaf. They correspond to the larval cells, varying from 3 to 7 in number.

Dimensions:—Length parallel to axis of midrib 10-15 mm.

Although nearly mature specimens of this gall were sectioned, a protective zone was not found.

In this species each larval chamber has a canal related to it. In this respect it resembles *A. piger* Bassett. A section of the gall at a very early stage of development shows that the canals open into the larval chambers. When the gall becomes older, each canal is blocked by two plugs of sclerenchyma. One of these occupies the same position relative to the larval chamber as in the two preceding species; the other is formed near the external opening. These masses of sclerenchyma are shown in Fig. 47. Trichomes do not appear to be produced in the canals.

*Rhodites multispinosus* Gillette.
Host *Rosa blanda* Ait.

A globular to ovoid polythalamous gall produced by the swelling of the stem or branches of the host plant. Since the larval cells are arranged around the stem axis at about the same distance from the periphery of the gall, the abnormal swelling completely encircles the stem.

The gall is reddish brown in colour and has its surface usually densely covered with fairly stout prickles.

Dimensions:—Average diameter 25 mm.

The principal mass of this gall is formed from the cortex of the stem. The larval cells are embedded in it and a common parenchyma zone is thus formed. A well-marked protective tissue, composed of cells with porous, sclerenchymatous walls, separates this parenchyma zone from the nutritive tissue that lines each larval cell.

The response of the gall epidermis to stimulation is shown in the production of the numerous prickles that are so marked a characteristic of this gall. Since the stem of the host is usually unarmed this feature appears the more remarkable.

*Rhodites lenticularis* Bass.
Host *Rosa blanda* Ait.

A monothalamous, lens-shaped, thin-walled gall produced in the mesophyll of the leaf of the host. They sometimes occur singly but usually several are located on one leaflet. They often are so crowded that they lose their circular outlines.

This gall projects chiefly from the under side of the leaflet.

Dimensions:—Longer diameter 2-3 mm.; shorter diameter 1-2 mm.

Since it is possible to trace a considerable part of the unaltered mesophyll of the leaf along the upper surface of this gall, proliferation must have commenced in the spongy parenchyma of the leaf. The normal epidermis of the leaf passes over the surface of the gall without modification. On the upper surface of the leaf a protective layer of about five cells in depth separates the normal part of the leaf from the gall tissue. On the under surface a corresponding protective layer occurs at a distance of three rows of cells below the epidermis. The cells of this protective zone have uniformly thickened sclerenchymatous walls. The general structure of the gall is shown in Fig. 63. Inside this layer a cambial tissue is differentiated, from which the cells of the nutritive zone are produced directly. The nutritive cells are rectangular in outline and arranged in radial lines, presenting very much the same appearance as the cambium from which they have originated.

*Rhodites bicolor* Harr.
Hosts {*Rosa blanda* Ait. / *Rosa carolina* L.}

A monothalamous, spherical, hollow gall with a wall 1 to 2 mm. in thickness.

They originate singly or several close together from the upper surface of the leaf.

The gall bears numerous stiff prickles that average about the same length as the diameter of the gall. Colour green with red tints, turning brown at maturity.

Dimensions:—Average diameter 11.5 mm.

The anatomical structure of this gall presents very little differentiation of tissue. The parenchyma zone consists of large irregularly shaped cells. This tissue passes into the nutritive layer with little change in the shape or size of the cells. The protective zone is entirely absent.

*Rhodites ignotus* O.S.
Host *Rosa blanda* Ait.

A polythalamous or occasionally monothalamous gall attached to the under side of the leaves by a small extent of surface. These galls are generally found clustered together and often deform the entire leaf.

Dimensions:—Average longer diameter 11 mm.; average shorter diameter 3-5 mm.

While somewhat variable, the shape approximates usually to an irregular oblate-spheroid. At the apex of the gall is a shallow depression containing a small scale-like patch of tissue. The epidermis is glaucous and light brown in colour.

The anatomical structure of this species presents the rare feature of two protective layers. These are each of about five cells in thickness in the full-grown gall. One of them is found in the usual position separating the parenchyma and the nutritive zones. The other is situated in the parenchyma just beneath the small-celled epidermis. This outside protective sheath gradually passes into the parenchyma zone by the constituent cell walls becoming thinner. The large size of the cells in the parenchyma layer marks them out from the rounder and smaller cells of the nutritive zone.

Below the depressed area, mentioned in the macroscopic description, is a small patch of sclerenchymatous cells. In position and character these cells appear to be homologous to the groups of cells that block the canals in different species of Andricus. Only the mature stage of this gall was examined, but in all probability the depression at the top is the remains of a canal that connected the gall cavity with the outside in the early stages of development. A part of the normal epidermis of the leaf was held fast by the closing of this canal, and when the gall was forced out beyond the leaf tissues a small patch of the epidermis of the leaf was carried out on it. This persists in the later stages of development as the scale of tissue in the depression.

*Rhodites gracilis* Ashm.
Host *Rosa blanda* Ait.

A thin-walled, monothalamous gall produced from the mesophyll of the under surface of the leaf of the host. Occurs singly or in clusters on the leaflets.

It is irregularly spherical with a broadened top, in the centre of which is the same shallow depression and scale-like patch found in *R. ignotus* O.S. Numerous ridges radiate out from the point of attachment of the gall, pass up its sides and project as short blunt tubercles around the top.

Dimensions:—Diameter 5-6 mm.

This species resembles closely *R. bicolor* Harr. in anatomical structure. It presents little differentiation of tissue. The protective sheath is not present, and the parenchyma and nutritive zones are marked out from each other only by the cells of the latter being slightly smaller and more circular in outline. The observations on the preceding species concerning the depression at the summit of the gall and the discussion of them also apply to this species.

*Rhodites nebulosus* Bass.
Host *Rosa blanda* Ait.

This species, as the preceding, is monothalamous and thin-walled. It also originates from the mesophyll of the leaf of the host. It occurs usually in dense clusters deforming the entire leaflet.

The gall is spherical in form, bearing at the summit the depressed area and scale-like patch characteristic of the two preceding species.

The surface of the gall is smooth or covered with short weak spines. Colour green, tinted strongly with red.

Dimensions:—Diameter 5-6 mm.

This gall resembles closely the preceding species in anatomical structure. The cells of the nutritive and parenchyma layers differ in much the same way and to the same extent. Further, the protective zone is again absent. The explanation given in the two preceding forms, to account for the scale in the depression at the summit of the galls, is applicable also in this case.

*Cynips? constricta* (Stebbins).
Host *Quercus coccinea* Muench.

A monothalamous gall originating from the midrib or a principal vein of the leaf. Its origin from a vein is shown in Fig. 53. It is usually found on the under side of the leaf but occurs occasionally on the upper side.

This gall has the form of a sphere surmounted by a short cylindrical neck, which is slightly constricted at the base. The general form is shown in Fig. 54. A very small portion of its surface attaches it to the leaf. The epidermis on the main body of the gall is smooth, shiny and green in colour. The neck is red at the tip.

Dimensions:—Diameter of spherical part 2.5-3.5 mm.

At an immature stage of the gall the parenchyma zone in the spherical part consists of a mass of cells that gradually decrease in size from the epidermis to the inner limit of the layer. At the epidermis the cells are nearly circular in outline but become square or rectangular in proportion to their proximity to the centre.

Bounding this zone on the inside is a crystal layer of about three cells in thickness, each cell containing a large crystal mass. Around the inside of this tissue is a nutritive zone, the cells of which are regularly rectangular.

At the top of the main part of the gall is a well-defined cambium tissue which produces the cylindrical projection that caps the spherical portion (Fig. 54). The anatomical structure of this part shows clearly that it functions as an outer nutritive zone. Its walls are thin and the cell contents take the same stain as those in the nutritive zone surrounding the larva. Large starch grains are also scattered throughout the cells. This zone is separated from the cambium tissue in the later developmental stages by a protective layer of typical porous sclerenchyma. These cells are filled with protoplasmic material, and the system of canals between the individual cells is very complete and clearly defined. This feature is very important since the nourishment from the outlying nutritive zone has to pass through this tissue to reach the larva.

*Solenozopheria vaccinii* Ashmead.

Hosts { *Vaccinium pennsylvanicum* Lam.
*Vaccinium canadense* Kalm.

A polythalamous gall originating from the lower part of the stem of the host plant.

In the majority of cases this gall is reniform in shape but rarely it is irregularly spherical. The surface is depressed where it is attached to the stem, which is almost invariably bent at that point. The colour is green, often with red tints turning to brown as the gall becomes older.

Dimensions:—Longer diameter 10-30 mm.

At an early stage, while the tissues are still soft, the anatomical structure of this gall presents practically no differentiation. It consists of a mass of dense tissue, the cells of which are small and placed very close together. The small-celled epidermis is covered with an exceedingly heavy cuticle. At regular intervals small papillæ occur on the epidermis which seem to secrete a glandular material from small openings at their tips.

When the gall is mature all the cells, except a few layers below the epidermis, have sclerified walls. The thickenings are decidedly heavier on one wall than on the opposite.

*Aulacidea nabali* Brodie.

Hosts { *Prenanthes alba* L.
*Prenanthes altissima* L.

A polythalamous gall originating from the stem or the main root of the host plant. It occurs at or near the base of the stem, usually just below the surface of the ground but in some cases it is situated some distance above the ground.

The single galls are irregularly spherical, but these are generally clustered in such a way as to form roughly cylindrical masses. In some cases these completely surround the stem, but in others they only partly encircle it.

Dimensions:—Diameter of single gall 5-10 mm.

The cambium of the stem stimulated to unusual activity produces the abnormal tissues in this case (Fig. 66). Along the line of contact of the gall with the normal stem, the cambium produces wood and bast, but in abnormally large amounts, as can be seen in Fig. 66. In the gall tissue proper, in place of wood, radial lines of nucleated thin-walled cells occur. A few rows of vessels are interspersed among these cells. The stimulated cambium produces these parenchyma cells also on the side where the bast would normally occur. In the gall tissue on the outside of the line of the cambium, small patches of vessels are found. These have arisen from clumps of cells detached from the original cambium.

Associated with these isolated masses of vessels, often occurs a small amount of bast that appears normal. When the detached cambium is curved, wood is almost invariably produced on the inside of the curve and bast on the outside, giving rise in some cases to almost perfect concentric bundles.

The club-shaped cells of the nutritive zone do not follow the general rule and radiate out from the larval cell, but are oriented with their long axes at right angles to the cambium. The nuclei of the cells in this zone are abnormally large and often present good examples of amitosis (Text Fig. 6).

The normal cortex passes over the gall with little alteration during the early stages of development, but later a cork cambium is differentiated that throws off the cortex and covers the gall with its characteristic corky layer.

*Neuroterus majalis* Bassett.
Host *Quercus alba* L.

A polythalamous gall originating in the mesophyll of the leaf and divided into two nearly equal parts by the blade. The galls are found usually in contact with the side of the midrib and extending out to the margin of the leaf.

This gall is characterized by a flat, irregular shape and a finely granular epidermis. It is translucent and of a light green colour until the producers emerge when it becomes light brown and opaque.

The apertures of exit of the mature insects seem to occur invariably on the upper surface of the gall.

Dimensions:—Diameter parallel to leaf blade 12-24 mm.; diameter at right angles to leaf blade 7-9 mm.

Only the mature gall was examined. At this stage the nutritive zone consists merely of a narrow line of collapsed tissue (Fig. 67). From two to three rows of cells constitute a protective layer. The tangential walls of these sclerified cells are unequally thickened, the heavier deposit being on the wall nearer the larval chamber. The parenchyma zone consists of large thin-walled cells, the majority of which are empty and devoid of nuclei. A small-celled epidermis continuous with that on the normal leaf passes over the gall.

*Summary.*

All the galls in this group have three tissue zones developed and only very seldom is the fourth absent. The three always present are the epidermal, the parenchyma or tannin and the nutritive. The parenchyma zone, as shown by Cook[23] is subject to a great amount of variation. The fourth, not always present, is the protective or sclerenchyma zone.

Even in one genus there may be considerable variation in the degree of development of the protective zone. It is entirely absent in *Rhodites gracilis* Ashm. and *R. bicolor* Harr., but two distinct layers are found in *R. ignotus* O.S.

In several species of the genus Andricus canals were found passing from the exterior towards the larval chambers. In the early developmental stages these opened into the gall cavity, but later were blocked by outgrowths of sclerenchyma from the protective zone. They were located in the species *Andricus piger* Bassett, *A. petiolicola* Bassett and *Andricus* N.S. (Figs 43-47).

A canal similar to those in the Andricus genus was found also in *Dryophanta palustris* O.S. In this species the plug of sclerenchyma is not developed (Fig. 49).

An epidermal scale was found in the bottom of a depression at the apex of the galls produced by certain species of Rhodites. Below each scale a small mass of sclerenchyma is differentiated. These structures seem to be homologous to the canals in the genus Andricus. They are present in the following species: *Rhodites ignotus* O.S., *R. gracilis* Ashm. and *R. nebulosus* Bassett.

The gall *Solenozopheria vaccinii* Ashmead has the sclerified tangential walls of its protective zone much thicker on one side than on the opposite. This is very unusual in stem galls, although a common feature in leaf galls.

The collapsing of the cells of the nutritive zone after the withdrawal of the contents is exemplified in almost any gall studied. It is, however, particularly noticeable in *Dryophanta palustris* O.S. (Fig. 52).

Empty cells were found throughout the nutritive zones in the later stages of nearly all the galls examined. Good examples of this phenomenon are furnished by *Andricus singularis* Bassett and *Aylax glechomæ* Linné.

The separation of the tissues so as to produce a free larval chamber gall is shown in the species *Holcaspis globulus* Fitch and *H. bassetti* Gillette; also in *Dryophanta palustris* O.S. (Fig. 50). In the last species, as Cook[23] has shown, the separation of the larval chamber takes place at a very early developmental stage.

Mitotic phenomena were observed in the cambium and near it in the adjoining parenchyma zone of *Dryophanta palustris* O.S. The number of chromosomes remains as in the normal. Good examples of amitosis were located in the nutritive tissues of *Aylax glechomæ* Linné, and *Aulacidea nabali* Brodie (Text Fig. 6).

The parenchyma zone of *Amphibolips confluens* Harris furnishes an example of a tissue consisting of long filamentous cells from which branches are given off without the formation of intercepting walls. It seems to represent an exaggerated form of the spongy parenchyma.

Proliferation of glandular tissue is shown in *Aulacidea nabali* Brodie.

*Cynips? constricta* Stebbins furnishes an example of an outer accessory nutritive zone that clearly assists in supplying the larva with nourishment (Fig. 54).

## NOTES ON THE PROTECTIVE ZONE.

This zone is typical for the Cynipid galls, but as already stated it is differentiated in certain Dipterous forms, such as *Rhabdophaga batatas* Walsh (Figs. 25, 26) and *Cecidomyia triticoides* Walsh (Figs. 37, 38), and also in the Hemipterous gall *Pachypsylla celtidis-mamma* Riley (Fig. 15).

In the Cynipidæ it usually bounds the nutritive zone on the outside, but it does not invariably occupy that location. When two layers are present the inner occupies that position, but the outer is situated nearer the periphery of the gall.

The term, "protective," has been applied to this tissue without a very clear idea as to what it protects from. The common notion appears to be that it forms an inner line of defence against parasites and small animals other than insects. The latter class of enemies appears to interfere very seldom with galls. Cook[23] mentions one example—he found birds tearing open the galls of *Pemphigus vagabundus* Walsh. Very few examples of such cases have come under my notice. Galls of *Holcaspis bassetti* Gillette are occasionally opened by woodpeckers, and the larvæ of *Eurosta solidaginis* Fitch are sometimes taken from the galls by field mice. Chipmunks will also tear open the galls of *Pemphigus rhois* Walsh to get at the inhabitants. Not only are galls seldom attacked by such animals but a sclerenchymatous tissue would be a very poor defensive device against them.

Adler[1] has advanced the idea that this zone protects against insects that are parasitic on the producer-larva. This appears very unlikely since the parasites oviposit at a comparatively early stage, and the sclerenchyma is differentiated relatively late in the development of the gall. The same writer cites the large size of the gall and the thickened epidermis as other protective devices against parasites. The same argument is applicable in this case; the gall is not large nor is the epidermis abnormally thick at the time the parasites are ovipositing. Were Adler correct the gall *Amphibolips confluens* Harris should be almost immune against parasites, as it is large, has a thick epidermis and a well-developed protective sheath. In spite of all these apparent advantages this gall has a heavy casualty list owing to parasitism. During last season hundreds of this species were opened and on an average about 75% were found to be parasitized. In some cases a tree would not yield a single perfect producer, although a couple of dozen galls were examined.

It seems safe to conclude that if this zone has ever functioned as a means of defence against parasites, it is no longer operative. Apparently the only protective function that can be ascribed to this tissue is the prevention of injury to the producer by desiccation during its later larval and pupal stages of development. A thick or cuticularized epidermis would also afford protection in the same manner.

Concerning the form of the elements comprising this zone, Weidel[45] has recently made some interesting observations. He makes the following too sweeping statement in his summary,—

"Auch das gallentragende Organ der Mutterpflanze hat einem Einfluss auf die Gestaltung der Elemente in der Galle, denn die blattbürtigen Gallen führen in der Schutzschicht einseitig verdickte, die übrigen allseitig gleichmässig verdickte Zellen."

That this can be accepted only as a general rule, and at least requires further study, is indicated by the fact that our American galls furnish undoubted exceptions. Thus the gall produced on the stem of *Vaccinium pennsylvanicum* Lam. by *Solenozopheria vaccinii* Ashmead has cells that have a much thicker deposit of sclerenchyma on one tangential wall than on the other. In some cases practically the entire cell lumen is filled with sclerenchyma and the deposit has grown entirely from one side of the cell. Also a number of leaf galls have their protective zones composed entirely of cells with uniformly thickened walls. The following species furnish examples of this: *Amphibolips inanis* O.S., *Rhodites lent cularis* Bass. and *Neuroterus majalis* Bassett. The statement quoted is true, however, in the majority of cases and is important as indicating a possible effect of environmental conditions on the elements composing the gall.

## CYTOLOGY OF GALLS.

Cell division in the Cynipid galls was not found to present any unusual phenomena. In the cambial layer of *Dryophanta palustris* O.S. in which mitosis was taking place the chromosomes were found to be eight in number. They are slightly curved and show a decided tendency to group in pairs when moving out from the equatorial plate. The root tips of the host *Quercus coccinea* Muench. were found to give the same chromatic count and the chromosomes present the same feature of moving out to the poles of the spindle in groups of two.

In several galls amitosis was noted and very marked examples in the nutritive zones of the galls *Aulacidea nabali* Brodie (Text Fig. 6) and *Aylax glechomæ* Linné. Cell division did not appear to accompany the phenomenon in any of the cases examined.

In galls other than the Cynipidæ, the only cytological phenomena that presented unusual features were found in the orders Diptera and Lepidoptera. An unusual type of cell division was observed in the cortex and epidermis of *Neolasioptera perfoliata* Felt (Text Fig. 7) and in the cortex of *Gnorimoschema gallæasterella* Kellicott and *Stagmatophora ceanothiella* Cosens. This has been already referred to in the descriptive part of the paper and only the main features will be noted here. The mother cells produce from 2 to 5 daughter cells and these remain in groups that are easily recognizable. The elongated nuclei are found in contact with the septating walls but not exactly opposite each other. In the Dipterous genus Neolasioptera this was the only form of cell division that occurred in the gall, but in the Lepidopterous genera it was found only in a limited area of the abnormal tissue.

Fig. 6.—Nuclei from the nutritive layer of *Aulacidea nabali* Brodie.

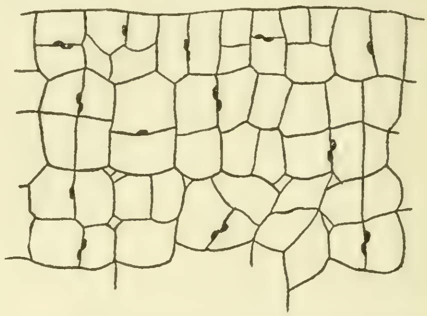

Fig. 7.—Cell division in the epidermis and cortex of *Neolasioptera perfoliata* Felt.

## THE BEGINNING OF GALL DEVELOPMENT.

In some species of galls that originate from stems, veins or petioles, the eggs of the producer are deposited within the tissues of the host in or near the cambium zone. Adler and Küstenmacher have detected eggs actually placed in that region, and while my own observations in the case of *Cynips? constricta* Stebbins were made on older developmental stages, yet the nature and arrangement of the tissues were such as would seem to preclude any other conclusion. The origin of this gall from the vein is shown in Fig. 53. In leaf galls that are produced in the blade as *Rhodites lenticularis* Bass. (Fig. 63), a cambium is differentiated in the mesophyll into which, in this case, the egg is inserted. Two independent observers, Beyerinck and Weidel, have demonstrated beyond a doubt, however, that the egg is in some cases placed on the epidermis of the host, and consequently there are at least two distinct methods of ovipositing.

The two observers, who deal with the development of galls from eggs deposited on the outside of the host, hold entirely different opinions concerning the early stages. Beyerinck[15] supposes that after the egg is placed at the selected spot, the tissues under it grow very little, if at all, but those immediately adjacent undergo rapid proliferation until the egg is completely enclosed, forming a gall of the "Umwallung" type. According to his view the larva possesses the power to stimulate the tissues through the egg membrane without rupturing it.

Weidel, on the other hand, holds an entirely different opinion concerning the enclosing of the larva by the tissues of the host. He has been able to convincingly demonstrate that in the gall *Neuroterus vesicator* Schlecht, the cuticle of the leaf is punctured before the larva is completely free from the egg membrane. "Die in der Eihaut noch vollständig eingeschlossene Larve durchbricht diese an einer Stelle und senkt in die Epidermis des Blattes ein Organ ein durch das die Cuticula durchbrochen und das pflanzliche Gewebe verletzt wird."—Weidel.[45] The influence of the larva[45] soon produces proliferation in the tissues of the leaf, and following this a degeneration commences at the epidermis and extending quickly forms a cavity of sufficient size to hold the larva. Into the larval chamber thus prepared the producer gradually passes, and the opening through which it entered is soon closed by the growth of the stimulated tissues.

While the excellent work of Weidel cannot be questioned concerning this particular gall, it is not necessary to assume that this is the only method by which a larval cavity is formed. In my opinion the method as described by Beyerinck is found in some of our American species of Andricus and Dryophanta, reference to which will be made later. Weidel's objections contained in the following quotation do not seem serious enough to warrant the setting aside entirely of the "Umwallung" type of development. "Gerade diese Stelle war es, die mich zu meinen Untersuchungen anregte, denn eine grosse Anzahl von Fragen bleibt bei diesen Ausführungen Beyerinck's unaufgeklärt: Wie kommt es, dass an der Stelle, wo das von der Larve abgesonderte Enzym am stärksten wirken muss, keine Vergrösserung der Zellen stattfinden soll, sondern nur in einiger Entfernung? Was wird aus Epidermis unmittelbar unter dem Ei? Aus Beyerinck's Figuren muss man annehmen, dass sie in Nährgewebe umgewandelt wird, da sie die Larve unmittelbar berührt. Wie kommt das, "Sinken," oder, "Vergraben," zustande, Vorgänge, für die ihn seine Erklärungen selbst nicht befriedigen?"—Weidel.[45]

Concerning the first question, as to why the proliferation is more pronounced around the larva than in immediate contact with it, it may be stated that this is a usual occurrence in the lower groups of galls in which the stimulus is applied in one direction only. The stem mothers of the genus Chermes thus become surrounded by a ring of tissue that grows out around the point of attachment of the insect (Fig. 11). The Dipterous gall *Cecidomyia ocellaris* O.S. also furnishes a very striking example of this phenomenon. In this species the leaf is scarcely at all thickened under the larva, but the proliferation is so marked around it that the producer ultimately lies in a concavity, not formed by the leaf becoming depressed, but by the outgrowth of the circular ridge of tissue (Fig. 33). Any explanations offered to account for these facts are merely conjectural, but it seems likely that the enzyme content requires a certain degree of concentration in order to exhibit its maximum activity, and that immediately in contact with the larva it has not the requisite dilution to cause the greatest proliferation. It is a well-known fact that the amount of growth of plants in culture solutions varies with the degree of concentration of the nutrient substance in the medium; thus there is an optimum quantity and as this is exceeded growth is more and more inhibited. An example of this is furnished by the checking of the growth of Penicillium when the culture solutions are too concentrated.

With regard to the question, "What becomes of the epidermis under the egg?" I agree with Weidel that there is little likelihood of abnormal cell production until the larva punctures the egg membrane, but when this occurs the epidermis becomes part of a nutritive zone and will undergo such rapid changes that its epidermal characteristics will soon disappear. The chief alterations will be expressed in the much richer contents of the cells and in their steady collapsing as these contents are withdrawn (Figs. 49, 51, 52). The latter change makes it extremely difficult to follow the normal into the abnormal epidermis unless at an extremely early stage. While the enclosing of the larva is due chiefly to the growth of the surrounding tissues, yet the collapsing of the nutritive layer will assist it to a certain extent.

Weidel's photographs show that in Neuroterus there is not at any stage an opening into the larval cavity that is lined with the epidermis of the leaf, and that after the larva enters its prepared chamber the opening is very soon closed. In the method of development as stated by Beyerinck we would expect to find such an opening persisting for some time, and if we do, that must be accepted as confirmatory evidence of the truth of his hypothesis. In two different genera, namely Dryophanta and Andricus, I have found canals leading into the gall cavity in the early developmental stages (Figs. 43-49). The epidermis of these structures is continuous with the gall epidermis and it bears the same class of trichomes as the latter. The canal is very marked in *Dryophanta palustris* O.S., and its lining which is the same as the gall epidermis, can be traced until it passes over into the inside layer of the nutritive zone (Fig. 49). This canal can still be detected in well-grown specimens.

Only mature material of *Andricus piger* Bassett and *Andricus petiolicola* Bassett was obtained, and while the canals with the epidermal lining are well marked, they are shut off from the larval cavity by outgrowths of sclerenchyma from the protective sheath (Figs. 43, 44). There is little doubt, however, but that in early developmental stages they open into the gall cavity as in the genus Dryophanta. This view, indeed, I have practically confirmed in the examination of an undescribed species of Andricus on *Quercus macrocarpa* Michx. In this form the canal is blocked at maturity by sclerenchyma (Fig. 47) as in the former species, but at an early stage I have found it extending into the larval chamber.

*Summary.*

The evidence seems conclusive that there are two types of early developmental stages of galls when the egg is deposited on the epidermis of the host. The method of formation of the larval chamber as described by Beyerinck is found in certain genera, as Dryophanta and Andricus, while the method worked out by Weidel occurs in Neuroterus and in all probability other forms.

## FEEDING HABITS OF THE LARVÆ OF GALL PRODUCERS.

With the exception of the family Tenthredinidæ, all gall-producing larvæ have started to feed before the abnormal production of tissue commences. The narrowing of the problem of gall production to the influence of the larvæ on the tissues of the host has given additional importance to the problems dealing with the feeding habits of these larval producers.

Order Arachnida.

Fam. Eriophyidæ.

The members of this family have mouth parts of the sucking type. With their cone-shaped beaks they pierce the cell walls and withdraw the liquid contents. The cell walls are not used as food.

Order Hemiptera.

Fam. Aphididæ.

Fam. Psyllidæ.

The feeding habits of these families are similar to the preceding. The possession of a suctorial proboscis makes it possible for them to obtain the liquid contents of the cells by merely puncturing the walls.

Order Lepidoptera.

The larvæ in this case consume the entire cells that line the interior of the galls.

Order Coleoptera.

Feeding habits as in the preceding order.

Order Diptera.

Fam. Cecidomyidæ.

Fam. Trypetidæ.

Concerning the feeding habits of this order, Packard[38] states that the Cecidomyia larvæ must absorb their nourishment through the skin or suck it in at the mouth. He bases his conclusion on the facts that the larvæ are devoid of jaws and that excrement is not found in the mature galls.

Walsh[44] from the same data has come to the conclusion that the larvæ abrade the interior of the galls with the chitinous structure, the so-called breast bone, on the ventral surfaces of their bodies. The irritation produces a flow of liquid from the cells and upon this the larvæ feed. He further states that the mouth of the larva of *Eurosta solidaginis* Fitch possesses a horny, black termination that probably serves the same purpose of abrasion as the breast bone of the Cecidomyidæ.

Both of these observers have concluded that the nourishment is obtained by the larvæ without the destruction of the cell walls, and that these do not form a part of the food of the larvæ. My observations confirm this view. In several species such as *Lasioptera corni* Felt and *Cecidomyia ocellaris* O.S. (Figs. 33, 40), the walls of the cells, through which the larvæ were obtaining food, were apparently uninjured. In other forms as *Cecidomyia triticoides* Walsh (Fig. 37), and *Cecidomyia pellex* O.S., the cells of the nutritive zone had collapsed as the contents were withdrawn.

Order Hymenoptera.

Fam. Tenthredinidæ.

By the time the larvæ in this family are full fed, nothing remains of the galls but a thin rind on the outside of each. Both the cell walls and contents are swallowed indiscriminately.

Fam. Cynipidæ.

In this family the larvæ are invariably surrounded by a layer of thin-walled cells which usually present a radial elongation especially in the innermost rows (Fig. 58). The cells of this nutritive zone contain sugar, starch, oil emulsion and albumen. The amount of starch varies directly and the sugar inversely with the distance of the cells from the larvæ.

With regard to the manner in which this zone is used as food by the larva at least two views are current. The following statement of Kerner[32] may be presented as an adequate expression of one of these theories: "The larva when hatched finds the inner wall of the chamber which has been fitted for its temporary abode always provided with the necessary food, and it immediately attacks and devours the juicy tissue with great avidity. The cells which are demolished, wonderful to relate, are replaced almost at once. The cells of the gall pith remain capable of division as long as the larva in the chamber requires food, and the surface cells which have been devoured in the gall chamber are soon replaced by new cells."

Küstenmacher[33] has advanced an entirely different view and his opinion may be taken as representing the theory of the other school of observers.

He states,—"Die im Innern entschlüpfte Larve, welche ihren Tisch reichlich gedeckt findet, beisst die innern Zellen des Nahrungsgewebes, welche lose, von der Eiweiss-Zucker-Oel-Emulsion strotzend, hervorragen, an und saugt dieselben regelmässig ringsherum aus, während die sehr dünnen Wandungen schmal schlauchartig übrig bleiben."

In deciding between these two theories the question to be answered is, does the larva eat both the walls and contents of the cells as stated by Kerner, or does it extract in some way the contents of the cells, leaving the walls practically intact? Several different points are involved in the discussion of this question. (*a*) The absence of frass in the larval chamber. (*b*) The completeness of the alimentary canal in the larva. (*c*) The nature of the stomach contents. (*d*) The presence of collapsed tissue and empty cells in the nutritive zone.

When a mature Cynipid gall is examined the larval chamber, in which the producer has passed through its early stages, is found unsoiled by excrement. Concerning this matter my observations agree with those made by Walsh in respect to the Cecidomyia larvæ. By way of comparison, if a mature gall is examined, the larva of which is known to eat the entire cells, a comparatively large quantity of excreted material is found (Fig. 68). The mature larva and its frass from a gall of *Pontania pomum* Walsh were dried in a desiccator and weighed. The following result was obtained:

Larva .0115 gm.
Frass .0319 gm.

In view of the comparatively large amount of frass in the sawfly gall, its absence in those of the Cynipidæ appears significant.

This fact concerning the larvæ of the Cynipidæ has not received attention since it has been supposed that the intestine of the Cynipid larva ends blindly. Comstock[21] makes the following statement on this point: "The larvæ are maggot-like and without a caudal opening to the alimentary canal." Serial sections were made of the larvæ of the producers *Philonix nigra* Gill (Fig. 61), and *Amphibolips confluens* Harris (Fig. 62). These sections prove conclusively the completeness of the intestinal tract throughout, and that therefore if Kerner's theory be correct frass should be found as in the sawfly galls.

Further evidence in favor of Küstenmacher's view is furnished by a comparison of the stomach contents of a Cynipid and an inquiline larva. The former consists of a mass of extremely fine particles, among which can be detected nothing that is recognizable as having formed a part of a cell (Fig. 55). As this material passes along the digestive tract it becomes less dense the nearer it is to the posterior opening, and is entirely absent in the last part of the canal (Figs. 61, 62). The latter consists of much coarser material in which crystals, similar to those in the surrounding cells, and parts of cell walls can be easily detected. These contents are shown in Fig. 56, and at a higher magnification in Fig. 57. So characteristic is this difference between these two classes of stomach contents that by means of it alone a Cynipid can be easily distinguished from an inquiline larva.

The data already presented furnish indirect proof that only the contents of the cells form the food of the Cynipid larva. An examination of the walls of the cells immediately surrounding the larva gives direct evidence in favour of this hypothesis. The nutritive layers of a large number of Cynipid galls were examined at different stages of development, and in none of the examples did the walls of the cells appear to have been eaten away by the larva. A layer of collapsed tissue (Figs. 52, 59, 60), especially in the older specimens, is often found around the inside of the larval chamber and there are also many empty cells throughout the nutritive zone. These are shown in the inner row of cells in Figs. 59, 60. In some cases the radial walls of the cells are wrinkled, indicating that these cells are gradually contracting. This can be seen with the aid of a lens in Fig. 59. The folds are not found in the tangential walls of the cells. The majority of the empty cells are found in the row that lines the interior of the larval chamber (Fig. 60), but others are distributed irregularly throughout the entire nutritive zone. These can be seen in Figs. 59, 60. There does not seem to be the slightest possibility of doubt that the larva withdraws the contents from the cells of the nutritive zone without dest oying the walls, and that in consequence the cells surrounding the larva gradually collapse.

If an inquiline larva is feeding in the gall, a ragged, broken edge of tissue is found lining the cavity in which it is living, a marked contrast to the smooth interior of the Cynipid larval chamber. This uneven edge is shown in Fig. 56, compare with Fig. 55. Neither of these views takes into account the possibility of enzyme action in rendering more soluble the contents of the nutritive zone.

A number of investigators have suggested that some form of enzyme is secreted by the larvæ of the Cynipidæ. Küstenmacher[33] indeed states in this connection that he could detect a distinctive odor from these larvæ, but enzyme action has always been considered in relation to the gall-producing stimulus and never with the feeding habits. The gradual decrease in the proportion of sugar to that of starch, in the contents of the cells, from the inside of the nutritive zone to the outside, would seem to indicate a relation between the relative amount of sugar and the proximity of the larva. Experiments were accordingly undertaken with the purpose of deciding whether the larva was capable of producing this change and of thus rendering the cell contents more easily soluble.

FIRST SERIES OF EXPERIMENTS.

Forty larvæ of *Amphibolips confluens* Harris just removed from the galls were placed in about 7 c.c. of starch solution made of corn meal. The test tube containing the larvæ was placed in a bath at 50° C., along with a control.

This starch was tested for sugar with Fehling's solution. No sugar was found at the end of 2 hrs. but after 20 hrs. a test for sugar was readily obtained.

SECOND SERIES OF EXPERIMENTS.

Forty-two larvæ were placed in the same quantity of starch solution and treated as in preceding case.

No sugar was found at the end of 8 hrs. but after 12 hrs. from the beginning of the experiment sugar was detected, and again at the end of 24 hrs.

THIRD SERIES OF EXPERIMENTS.

Thirty-five larvæ were placed in 7 c.c. of water and left for about 3 hrs. This water was then placed in an equal quantity of starch solution and kept at about 50° C. as before. The water was tested before it was poured into the starch and found to give an acid reaction. In this case sugar was detected in 50 hrs. and a very decided reaction was obtained after 70 hrs. The larvæ that had been washed were placed in starch and kept at 50° C. as before but sugar could not be detected.

In all the cases cited above, as a control experiment, starch without the larvæ was kept in the bath under the same conditions as that which contained the larvæ. This starch did not give the slightest indication of sugar at any time. From these experiments we conclude that the Cynipid larvæ must secrete an enzyme that has the property of changing starch to sugar. It seems quite possible that other ferments may be employed by the larva for similar purposes. To my knowledge no tests have been made, but the observations of Weidel[45] point conclusively in this direction. He noted that the walls of the protective sheath become delignified; this is strongly suggestive of the presence of a hadromase or allied ferment.

With the purpose of discovering the source of the enzyme a number of species of Cynipid larvæ were examined for glandular structures. An enlargement of the first two segments immediately below the mouth was found to be a common characteristic of all these specimens. Regularly arranged on these projections are two pairs of openings as shown in Text Fig. 8. Longitudinal serial sections of *Philonix nigra* Gillette and *Amphibolips confluens* Harris show that these openings are connected by ducts with cavities lined by a glandular epithelium composed of large cells. From these cells the enzyme containing material passes into the cavity and from thence to the outside by means of the duct. There seems little reason to doubt but that these structures are salivary glands opening externally, and that they are the source of the enzyme. A gland with the connecting duct is shown in Text Fig. 9. Only the two species mentioned have been examined by serial longitudinal sections, but the external openings were noted in several forms and in all probability these glands are a characteristic common to all the Cynipidæ.

Fig. 8.—Head of Cynipid larva showing external openings of the salivary glands just below the mouth.

Fig. 9.—Longitudinal section of the larva of *Philonix nigra* Gillette, passing through a salivary gland and its associated duct.

Concerning the feeding habits of the larvæ of the Cynipidæ, we can state positively that the cell contents alone furnish the nourishment and that these are withdrawn from the cells without destroying the walls. An enzyme secreted by the salivary glands of the larva partially predigests this food. This ferment must act through the *cell membrane

*I have found that the froth on plants in which the "Spittle Insects" of the Family Cercopidæ develop, also contains an enzyme that rapidly changes starch to sugar. Experiments by Miss J. McFarlane that are not yet fully completed seem to indicate a larger amount of sugar in the stems surrounded by the froth than in corresponding parts of unaffected stems.

lining the interior of the larval chamber. None of the nourishment, taken into the alimentary canal, passes from it as excrement; it is either completely absorbed or remains in the digestive tract until the completion of the larval stage.

The invariable inert appearance and partially coiled condition of the larva would seem to indicate inactive feeding habits, but the theory of food absorption through the body wall is quite untenable; since the complete digestive tract, containing often large quantities of nourishment, as in Fig. 62, shows conclusively that the food enters the canal through the mouth.

## GALL-PRODUCING STIMULUS.

All actively growing tissues are capable of responding to a gall-producing stimulus; the growth energy already present in them is controlled and compelled to expend itself in a definite direction. These abnormal tissues that result have the common characteristic of remaining longer in a plastic state than if they had been produced under normal conditions of growth.

The stimulating influence produces an effect on tissues at a considerable distance from the centre of application. Thus in the Acarina galls this influence extends to tissues other than the epidermis on which the mites are located, and in such a case as *Stagmatophora ceanothiella* Cosens the epidermis of the stem undergoes division, although the larva is feeding in the pith (Fig. 17).

The power to stimulate tissues to abnormal activity is not confined to gall-producing larvæ. Certain inquilines likewise exhibit this ability to a limited extent. By a fortunate chance I have been able to establish this fact in the case of an inquiline larva found in the gall of *Holcaspis globulus* Fitch. Reference to Fig. 65 will show that a nutritive layer has been developed around the inquiline. That it possesses the power of stimulation to a less extent than the producer is obvious from the fact that it was unable to originate a cambium of its own, and in consequence the nutritive zone is incomplete on the side opposite to the producer-larva. This is shown in Fig. 65. Yet it is equally obvious that, feeding as it was in proximity to the cambium of the producer, it was able to excite that zone to the production of typical nutritive cells instead of the parenchyma zone cells that would have resulted had the producer alone been in control. Küster[35] records a similar instance of inquiline-produced galls in *Rhodites eglanteriæ*.

Küster[35] states that the excrement of the larval *Pontania salicis* is capable of producing cell division. I have found this phenomenon occurring also in *Pontania pomum* Walsh and particularly good examples in the undescribed sawfly gall on *Salix serissima* (Bailey) Fernald (Fig. 72). While I have made no attempt to determine by experiment the cause of this unusual example of cell proliferation, yet it would seem highly probable that the enzymes, introduced into the protoplasm by the ovipositor of the producer and swallowed by the larva, have not entirely lost their power by passing through the digestive tract but are still able to excite cell division.

The gall producer's influence works remarkable changes in the affected part of the host; even apparently new tissues, glands, trichomes, etc., make their appearance. The activity of its protoplasm is so much increased that hypertrophy or hyperplasia is an invariable accompaniment of gall production. The conventional view to account for these phenomena is that the protoplasm has been endowed with entirely new characteristics and power to produce something foreign to the normal host. But this is probably true only in a very limited sense, for according to my experience at least the prototypes of such apparently new tissues, etc., have been found elsewhere in the host or its relatives. Seemingly the correct explanation is that not only are dominant characteristics in the protoplasm stimulated but also in certain cases latent properties are called into activity, and thus apparently new structures appear in the host. Attention has already been drawn to examples confirming this opinion, but the evidence will now be more fully elaborated in the case of glands, trichomes and aeriferous tissue.

It may be stated as an unvarying rule, that when glands are present in the normal tissue they are always more plentiful or larger in the gall originating from that tissue. This is exemplified in the galls produced by *Eurosta solidaginis* Fitch (Fig. 42), *Aulacidea nabali* Brodie (Fig. 66), and numerous other species to which attention has been directed in the descriptive part of this paper.

But glands also occur in certain galls on parts of the host that are normally glandless; thus they are plentiful in the gall produced by *Neolasioptera perfoliata* Felt on *Eupatoria perfoliatum* L. (Fig. 23), but are not found at the same location in the normal. At first sight they appeared to be new structures, but were finally discovered in the normal host at the base of the stem. In *E. urticæfolium* Reichard they likewise occur in the transitional region between stem and root, while in *E. purpureum* L. they are present in the roots, petioles, and flowering axes as well as in the cortex and pith of the stem. In the case of gland production it is clear that not only have active characteristics of the protoplasm in that direction been stimulated to an activity greater than the normal maximum but nearly dormant properties have sometimes been aroused into action.

The trichomes worked out in a manner very similar to the glands. When the gall produced types different from the normal they were searched for successfully on the reproductive axes of the host. The unicellular, acicular hairs of *Eriophyes querci* Garman (Fig. 6) are totally unlike the stellate hairs of the leaf, but their exact counterparts are found on the reproductive axes of the host *Quercus macrocarpa* Michx. The much convoluted type of hair present in the Acarina dimple gall on the leaves of *Acer negundo* L. (Fig. 4) are found plentifully distributed over the reproductive axes, although the normal leaf hairs are straight.

The production of aeriferous tissue in certain Salicaceous galls substantiates in quite as striking a manner the view I have advanced. These galls contain examples of a typical aeriferous tissue, comparable indeed to that found in such aquatics as Nymphæa, Potamogeton or Saururus, while in the corresponding part of the host it does not occur. Indeed, this statement may be extended to include all the species of the host genus. A cross section of the gall originated on *S. cordata* Muhl. by *Cecidomyia triticoides* Walsh shows this tissue surrounding each larval cell. It is present throughout the cortex of the stem and extends entirely across the pith (Figs. 34, 35, 36). This tissue is found also in the gall originated on the leaf of the same willow by *Pontania pomum* Walsh (Fig. 77), but is not found in the normal tissues; indeed, the mesophyll of the leaf of *S. cordata* Muhl. is peculiarly compact in structure. It is figured by Cook[22] in the cortex of the stem gall produced on *S. discolor* Muhl. by *Cecidomyia rigidæ* O.S.

With the purpose of determining the distribution of this tissue in the normal stem a number of species of Salicaceæ were examined by Mr. T. A. Sinclair and myself with the following results, a detailed description of which will be published later. It was found in the primary cortex of the stems of the following species and invariably more plentiful at the nodes,—*Salix humilis* Marsh., *S. alba* L., *S. rostrata* Richards, *S. lucida* Muhl., *S. discolor* Muhl., *S. nigra* Marsh., *S. longifolia* Muhl., *S. serissima* (Bailey) Fernald, *S. cordata* Muhl., *Populus deltoides* Marsh., *P. balsamifera* L., P. *tremuloides* Michx. and *P. grandidentata* Michx. It was also differentiated to some extent in the pith of the stems of *P. balsamifera* L. and *P. deltoides* Marsh., *P. grandidentata* Michx. and *P. tremuloides* Michx. The only indication of this tissue found in the stem pith of Salix was in sections through the bases of branches of *S. cordata* Muhl. and *S. alba* L. Possibly it may be present in the corresponding region in other species. It can be traced a greater distance from the growing tip in the cortex of Populus than in Salix before it becomes unrecognizable owing to compression. It is apparently nearly always present in the pith and cortex of the reproductive axes of Populus and

Salix. The leaf petioles of the following species were found to contain it,—*Populus balsamifera* L., *P. deltoides* Marsh., *Salix humilis* Marsh., *S. alba* L. and *S. cordata* Muhl. The tissue is developed much more plentifully on the side adjacent to the stem.

In general then this tissue is indicated in the pith of the stem of Populus but is restricted in Salix to the bases of the branches. It is well represented in the primary cortex of the stems of both Populus and Salix, rather better so in the case of the former genus. It is abundant in such primitive regions as the reproductive axes, nodes and leaf traces. Thus the unexpected appearance of this tissue in the galls cited is readily explainable on the same grounds as in the case of glands and trichomes, namely, the power to produce this tissue is latent in the protoplasm of the host and it becomes sufficiently active to reinstate the tissue only when the gall-producing stimulus gives rise to unusual conditions.

Concerning the nature of this powerful stimulating agent there is at present a growing tendency to ascribe it to enzymatic action. It is difficult to say just how wide the application of this method of stimulus may be, but as plants present so many features in common in their reactions to produce the different types of galls, universal enzyme action would seem to be at least a safe working hypothesis. It is only, however, in the case of the Cynipidæ that we have any experimental evidence concerning enzymatic action. As described in a previous part of this section, I have been able to prove, in the case of the gall *Amphibolips confluens* Harris, that the larva secretes an enzyme capable of changing starch to sugar. It is now my purpose to discuss this fact in its relation to gall production.

Küster,[34] after experimenting with Cynipid galls in culture solutions, arrived at a conclusion that furnishes some experimental data on the subject. "Bei normaler Entwickelung wird der Inhalt der Nährgewebe von den Gallentieren verzehrt; unter abnormalen Verhältnissen kann aber das Nährmaterial von den Pflanzenzellen selbst verbraucht werden. Gallen von Pediaspis Aceris (Cynipide), die von ihren Bwohnern befreit und auf nährstoffarmen Lösungen oder auf gewöhnlichem Leitungswasser belassen werden, bleiben wochenlang am Leben; der Inhalt der Nährgewebe schwindet dabei. Werden Gallen gelicher Art ceteris paribus auf Zuckerlösung verbracht, so bleibt der Inhalt der Nährgewebe unverbraucht oder erfährt noch eine geringe Vermehrung."

These experiments prove that a gall is able to extract nourishment from the nutritive zone to assist in its growth in general. It appears axiomatic then that the greater the quantity of soluble food there is in the nutritive layer, in excess of what the larva requires, the larger is the supply the gall has at its command and the more marked will be the proliferation of gall tissue. The larva consequently by accelerating the rate of change from starch to sugar is indirectly stimulating the protoplasm and thus controlling the growth of the gall. The general principle is applicable here that the available food supply governs very largely the size of an organ and consequently must influence the activity of its protoplasm. It is interesting to note in this connection that the size of the gall and the contained larva are directly proportional to each other. The relations between the two are reciprocal. The larger larva ensures a greater enzyme production and hence a more abundant food supply and presumably a larger excess for the stimulation to cell proliferation. The amount of enzyme action appears clearly to be proportional to the size of the larva. The evidence seems conclusive that the nutritive zone functions as an organ for preparing soluble food materials for both the larva and the gall. This evidence receives further confirmation from the fact that in addition to the empty cells lining the larval chamber there are others scattered throughout the nutritive zone often to its outermost layers (Fig. 59). This also seems to point to the conclusion that the contents of these cells have been used in supplying food for the proliferation of tissue in the other parts of the gall.

Summing briefly, the larva secretes an enzyme, capable of changing starch to sugar, which acts on the starchy constituents of the nutritive zone and accelerates the rate of their change to sugar. The material thus prepared supplies nourishment for both the larva and the gall. The protoplasm of the latter is thus rendered unusually active since it receives an abnormal quantity of available food material in a limited area. The hypertrophy and cell proliferation and probably also the appearance of vestigial tissue or other primary characters are the response of the protoplasm of the host to the additional food supply.

Attempts were made to substantiate this theory by further and more direct experiment. Diastase in solution was injected into seedling Windsor beans at different points with the purpose of stimulating the tissues to increased cell proliferation. When the place selected was just below the arch of the hypocotyl, a decidedly large callus was obtained in some of the experiments. These were not conclusive, however, owing to the variation in size of the normal plant in that region and the very great if not insurmountable difficulty of detecting increased callus formation when only differences in amount are to be expected. It is further very difficult to simulate the action of the producer-larva in bringing the diastase into contact with the proper tissue.

The discovery of an enzyme as an exudation from gall-producer larvæ recalls the statement of Laboulbène[36] that he had induced cell proliferation by injecting into plant tissue the water in which larvæ had been washed.

The theory, just stated, furnishes an explanation intended to account only for the stimulation of the protoplasm expressed in cell proliferation, hypertrophy and the production of unusual structures. There are other gall characteristics, however, that can scarcely owe their origin to the action of enzymes alone on the protoplasm of the host. For example, the colour of galls appears to be controlled partly at least by the intensity of the illumination. Thus the galls produced on *Salix cordata* Muhl. by *Pontania pomum* Walsh are little, if at all, coloured when the host is growing in deeply shaded stations. Besides this environmental effect, however, there is another factor that may also have an influence on the colour of this gall. De Vries[26] states that the red colour in plants is a dormant characteristic in the protoplasm that can be reinstated by stimulation. As a distinct confirmation of his view he found that red tints were produced in the leaves of *Viburnum opulus* L. as a consequence of bruising. This experiment seems to be closely paralleled in the sawfly gall *Pontania pomum* Walsh, where a red colour is apparent in the leaf of *Salix cordata* Muhl. in a very short time after oviposition. It seems very probable that in this case as in that of Viburnum the dormant red characteristic has been reinstated by the mere mechanical injury. It is noteworthy in this connection that shades of red are the predominating tints in gall structures, so that in the production of colour enzymatic action may frequently be operative in reinstating the dormant character red, especially in the case of galls in which the mechanical injury is negligible.

Further, the shape of the gall and the relation of the various zones to each other are not explainable by reference to any one factor. They doubtless result from a combination of factors. Just what all of these may be is yet not apparent but this much is certain that there appears to be an entire lack of evidence supporting the view that the protoplasm of the host has become endowed with a property that enables it to produce a fairly definitely shaped but withal abnormal structure. Such a pronounced change would surely be expressed in the hereditary characteristics, yet there is not a vestige of proof tending to show that insect galls ever produce the slightest variation in the descendants of the host. Not only so, but in the case of stems growing beyond the gall, there is no certainty that the prolongations are abnormal except for the slight dwarfing which is possibly explainable on the basis of an interrupted food supply. Examples of such stems are furnished by *Cecidomyia triticoides* Walsh on Salix, *Chermes abietis* Linn. on Picea, or *Eurosta solidaginis* Fitch on Solidago. Küster also found in his regeneration experiments that the roots produced from specimens of *Pontania salicis* were perfectly normal. There is still another argument to be cited in opposition to this view, in the fact that one gall may be parasitic on another. Thus when

*Biorhiza forticornis* Walsh is produced on *Neuroterus batatus* Fitch the stimuli from the different producers are exerted on nearly the same region of the host at the same time, as both these species are stem galls and commence to develop just as the buds are opening. In such a case as this if we assume that the protoplasm of the host has acquired characteristics necessary to the production of a certain form of gall, it seems unlikely that it could also possess the characteristics that would enable it to originate an entirely different type at the same time.

With the exclusion of the likelihood that the genetic characteristics of the protoplasm have been modified in any way, we must turn to the environmental factors to account for the shape of the gall and the relations of its various zones. Among these one feature that must have a certain amount of controlling effect is the direction in which the stimulus is applied. The various types of dimple and pouch galls, in which a curving of the affected organ is a very marked feature, are originated by stimuli disseminated in one direction only, while a Cynipid gall with its characteristic, spherical inner gall arises when the influence is about equally distributed in all directions. In some species it is also clear that the location of the egg has produced an effect on the external form of the gall. If the egg is deposited on the epidermis of the host and the tissues grow up around it, a gall of the type produced by *Cecidomyia ocellaris* O.S. results (Fig. 33). Even in the Cynipidæ this factor has been in operation. In species of Andricus the openings of the canals give a characteristic appearance to the galls, and in *A. petiolicola* Bassett the gall is drawn out to a decided tip in the region of the canal. These canals owe their origin to the fact that the galls are of the "Umwallung" type, and the larvæ have been enclosed by the growth of the surrounding tissues.

In some galls such as *Dryophanta palustris* O.S. a cambium is differentiated at a very early developmental stage, and has a very marked influence on the general relation of the zones in the gall. This cambium layer is shown in Fig. 49. The cells produced from the inside of this cambial tissue constitute the nutritive and sclerenchyma zones, while those given off from the outside form the parenchyma zone and epidermis. The former that are under the immediate control of the larva and less exposed to external conditions come to differ more markedly from the normal than do the latter that are nearer the outside limit of the larva's sphere of influence.

## *Summary.*

The idea that the gall-producing stimulus must of necessity be applied directly to the cambium layer is not true in all cases, as any actively growing tissue will respond to a producer's influence.

The effect of this stimulus is operative on tissue at a considerable distance from the centre of application.

Certain inquilines in Cynipid galls possess the gall-producing power but to a less extent than the real producer.

Cynipid producers and probably others secrete an amylalytic ferment that pre-digests food for the larva and may indirectly stimulate cell proliferation by storing the nutritive zone with an unusually large quantity of available nourishment which can diffuse to all parts of the gall.

The gall-producing stimulus renders the protoplasm of the host more active and awakens in it dormant characteristics, but apparently does not endow it with power to produce entirely new structures. This has been demonstrated in the case of glands, trichomes and aeriferous tissue.

The red colour of galls is perhaps a dormant characteristic that may be reinstated by enzymatic action but there are other possible inducing factors such as the light relations and in sawfly galls mechanical injury by the act of oviposition.

The shape of galls is controlled partly at least by the direction of the stimulus and the location of the egg of the producer. In galls such as the Lepidopterous types, where the larva burrows into the tissues after leaving the egg, this feature has no effect.

The relation of the various zones in the Cynipid galls is influenced in some cases by the early differentiation of a cambium layer.

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## EXPLANATION OF PLATES.

### PLATE I.

Fig. 1. *Eriophyes Sp.* (*Populus tremuloides* Michx.). Section showing the folding of the upper epidermis of the leaf. ×50.

Fig. 2. *Eriophyes Sp.* (*Populus grandidentata* Michx.). Section showing the nature of the folding produced on the lower surface of the leaf. ×60.

Fig. 3. *Eriophyes Sp.* (*Fagus grandifolia* Ehrh.). Section through a number of capitate trichomes. The almost normal character of the leaf is shown. ×50.

Fig. 4. *Eriophyes Sp.* (*Acer negundo* L.). Section through the gall, showing a large number of convoluted trichomes. ×35.

Fig. 5. *Eriophyes Sp.* (*Prunus nigra* Ait.). Longitudinal section in which is shown the elongation of the cells in the direction of the long axis of the gall. The peculiar nature of the trichomes is also shown. ×30.

Fig. 6. *Eriophyes querci* Garman (*Quercus macrocarpa* Michx.). Section in which the long acicular trichomes are shown, as also the thickening of the leaf blade. ×30.

Fig. 7. Unclassified gall on the leaf of *Populus balsamifera* L. The uniform nature of the abnormal cells is apparent. The gall cavity is occupied by the mycelium of a fungus. ×10.

Fig. 8. Transverse section of band of sclerenchyma from the preceding gall, showing the pores that traverse the tissue. ×120.

### PLATE II.

Fig. 9. Aphid corrugations on the leaf of *Betula lenta* L. produced by the fourth generation of *Hamamelistes spinosus* Shimer. The formation of the larval chambers by the closing of the folds is shown. ×22.

Fig. 10. *Hamamelistes spinosus* Shimer on the leaf of *Hamamelis virginiana* L. Transverse section that passes through a spine, cross sections of two bundles are shown. ×35.

Fig. 11. *Chermes abietis* Chol. on the stem of *Picea abies* (L) Karst. Longitudinal section, showing two larval chambers with their apertures of exit. A number of resin ducts are cut near the margin of the section. ×30.

Fig. 12. *Hormaphis hamamelidis* Fitch on the leaf of *Hamamelis virginiana* L. Longitudinal section passing through the aperture of exit. ×10.

Fig. 13. *Chermes floccus* Patch on the stem of *Picea mariana* (Mill.) B.S.P. Transverse section, showing the smaller accessory resin ducts. ×25.

Fig. 14. *Pemphigus rhois* Walsh on the leaf of *Rhus typhina* L. Longitudinal section of a young gall, showing a number of glands. ×15.

PLATE III.

Fig. 15. *Pachypsylla celtidis-mamma* Riley on the leaf of *Celtis occidentalis* L. Section through the larval cavity, showing the cambium tissue and the sclerenchyma sheath bordering it on the outside. ×15.

Fig. 16. *Memythrus tricinctus* Harris on the stem of *Populus tremuloides* Michx. Cross section through the thickened annual rings, showing the clumps of bast fibres. ×20.

Fig. 17. *Stagmatophora ceanothiella* Cosens on the stem of *Ceanothus americanus* L. Cross section, showing secondary growth in the wood and the abnormal glands in the cortex. ×50.

Fig. 18. Normal stem of the host of the preceding species. Section taken near the gall; glands are not present in the cortex. ×50.

Fig. 19. Glands found in the cortex of *S. ceanothiella* Cosens; these correspond to those shown in Fig. 17. ×150.

Fig. 20. *Gnorimoschema gallæsolidaginis* Riley on the stem of *Solidago canadensis* L. Transverse section showing an abnormally large gland in the cortex. ×45.

PLATE IV.

Fig. 21. *Eucosma scudderiana* Clemens on the stem of *Solidago canadensis* L. Transverse section showing the proliferation in the bundles and the medullary rays and also the enlarged glands in the cortex. ×75.

Fig. 22. *Gnorimoschema gallæasterella* Kellicott on the stem of *Solidago latifolia* L. A transverse section through one side of the aperture of exit, the material used by the larva in smoothing the sides of the hole for the reception of the plug is shown. The cross checking in this material can also be seen. ×120.

Fig. 23. *Neolasioptera perfoliata* Felt on the stem of *Eupatorium perfoliatum* L. Transverse section showing an unusual type of cell division in the cortex and epidermis of this gall. The glands shown near the inner boundary of the cortex are not found in the normal stem at the same height. ×55.

Fig. 24. *Rhabdophaga strobiloides* Walsh on the stem of *Salix cordata* Muhl. Longitudinal section showing the larva in contact with the small celled tissue at the apex of the stem. ×25.

Fig. 25. *Rhabdophaga batatas* Walsh on the stem of *Salix humilis* Marsh. A transverse section that shows the larval chamber surrounded by a nutritive zone which is bounded on the outside by a well defined protective sheath. ×22.

Fig. 26. A part of the protective sheath of the preceding species enlarged to show the unequal thickening of the tangential walls. ×200.

Fig. 27. *Cecidomyia majalis* O.S. on the leaf of *Quercus coccinea* Muench. Section at right angles to the midrib. The folding of the leaf is shown and the uniform character of the mesophyll of the gall. The epidermis lining the gall cavity is shown intact. ×15

PLATE V.

Fig. 28. *Abies balsamea* (L.) Mill. Transverse section of normal leaf. ×35.

Fig. 29. *Cecidomyia balsamicola* Lintner on the leaf of *A. balsamea* (L.) Mill. Transverse section showing the folding of the leaf and the elongation of the mesophyll cells. The irregularity of the cells in the strengthening layer of the resin ducts can also be seen. ×35.

Fig. 30. *C. balsamicola* Lintner on the leaf of *A. balsamea* (L.) Mill. Transverse section through the midrib. The chief points shown are the irregularity in the development of the endodermis, the large amount of the transfusion tissue and the relatively small amount of the non-pitted parenchyma. ×100.

Fig. 31. *Abies balsamea* (L.) Mill. A section, through the midrib of a normal leaf, corresponding to the preceding section (Fig. 30). ×100.

Fig. 32. *Cecidomyia impatientis* O.S. on *Impatiens biflora* Walt. Section through a larval chamber, showing the general nature of the cells of the gall and the smaller cells of the nutritive layer. The two dark masses attached to the nutritive tissue in the lower part of the gall cavity consist of the mycelium of a fungus. ×30.

Fig. 33. *Cecidomyia ocellaris* O.S. on the leaf of *Acer rubrum* L., showing the almost unchanged character of the leaf immediately below the larva and the great amount of proliferation in the region surrounding it. The general arrangement of the cells at right angles to the leaf blade is also shown. ×30.

Fig. 34. *Cecidomyia triticoides* Walsh on the stem of *Salix cordata* Muhl. Transverse section in which is shown the general arrangement of the larval chambers and the distribution of aeriferous tissue throughout the cortex and pith of the gall. ×10.

PLATE VI.

Fig. 35. *Cecidomyia triticoides* Walsh on the stem of *Salix cordata* Muhl. Transverse section showing the character of the aeriferous tissue. ×50.

Fig. 36. *Cecidomyia triticoides* Walsh on the stem of *S. cordata* Muhl. Transverse section of a young gall, showing the well defined nutritive layer lining the larval cavity and the protective zone bounding this tissue on the outside. The aeriferous tissue is also shown. ×60.

Fig. 37. *Cecidomyia triticoides* Walsh on the stem of *S. cordata* Muhl. Transverse section through the nutritive and protective zones of a mature gall. At the top of the figure is a dark band of collapsed nutritive cells; below that a lighter coloured and wider band of sclerenchymatous cells, the lumen of each filled with a crystal of calcium oxalate; and below that again a layer of cambium of nearly the same width as the preceding zone. ×150.

Fig. 38. *Cecidomyia triticoides* Walsh on the stem of *S. cordata* Muhl. Transverse section of a young gall, corresponding to the preceding mature form. The nutritive zone is at the top of the figure, its cells are filled with rich protoplasmic contents, with the exception of those in the upper row and a few scattered ones throughout the zone. The protective zone is shown below this tissue, but the cambium layer is not differentiated in the early stages. ×150.

Fig. 39. *Cecidomyia bulla* Walsh on the stem of *Helianthus divaricatus* L. Transverse section through stem of host and attached gall, showing the elongation of the fibro-vascular bundles in the direction of the gall axis and the very marked proliferation in the medullary rays. At the upper part of the figure, in the gall cortex, an enlarged gland is partly shown and also other glands at the junction of the gall and the stem of the host. ×18.

Fig. 40. *Lasioptera corni* Felt. on the leaf of *Cornus alternifolia* L. The section shows the lower epidermis and one row of mesophyll cells in normal position and also the strongly curved character of the upper epidermis and the remaining mesophyll cells. The normal appearance of all the cells is also apparent. ×18.

Fig. 41. *Lasioptera impatientifolia* Felt. on the leaf of *Impatiens biflora* Walt. Section at right angles to the midrib, showing the generally uniform character of the cells. Cells containing the mycelium of a fungus are shown a short distance in from the

gall cavity and above it. These cells give a false appearance of a protective zone. ×20.

Fig. 42. *Eurosta solidaginis* Fitch on the stem of *Solidago canadensis* L. Transverse section, showing the proliferation of glandular tissue and the general arrangement of the glands along the lines of the fibro-vascular bundles. ×25.

## PLATE VII.

Fig. 43. *Andricus piger* Bassett on the leaf of *Quercus coccinea* Muench. At the lower part of the figure a thick nutritive layer is shown, bordering the larval chamber; outside of this tissue is the protective zone from which a cone-shaped projection originates that blocks the canal leading in from the outside. The epidermis lining this canal is shown continuous with the general epidermis of the gall. ×25.

Fig. 44. *Andricus piger* Bassett on the leaf of *Q. coccinea* Muench. Section showing a nearly complete larval chamber. The other parts correspond to those in the preceding figure. The epidermis lining the canal is not shown so well in this case, as the section passes along the edge of the canal. ×25.

Fig. 45. *Andricus petiolicola* Bassett on the leaf of *Q. alba* L. Section passing through the main canal. The epidermis of the gall is shown passing into the trichome bearing lining of the gall. ×25.

Fig. 46. *Andricus petiolicola* Bassett on the leaf of *Q. alba* L. Section passing through the termination of the main canal, showing a number of trichomes and two larval chambers blocked by masses of sclerenchyma. ×45.

Fig. 47. *Andricus* (undescribed) on the leaf of *Quercus macrocarpa* Michx. Section passing through the edge of a canal and showing the two masses of sclerenchyma almost united. ×35.

Fig. 48. *Andricus imbricariæ* Ashmead on the stem of *Q. coccinea* Muench. Section showing the numerous bands of cells radiating out from the boundary of the protective sheath, the light coloured layer in the figure. The darker coloured nutritive zone bounds the protective layer and lines the gall cavity. ×20.

## PLATE VIII.

Fig. 49. *Dryophanta palustris* O.S. on the leaf of *Quercus coccinea* Muench. Section of a very early stage in which the inner and outer galls are still in contact. The following points are shown, a canal passing from the outside into the larval chamber, the

trichome bearing epidermis of the gall continuous with the lining of this canal and passing into the inner row of cells of the nutritive zone, the bay-like depression in this zone where the canal enters. ×30.

Fig. 50. *Dryophanta palustris* O.S. on the leaf of *Q. coccinea* Muench. Section of a somewhat more mature stage than the preceding, showing the commencement of the separation of the inner gall from the outer in the region of the cambium layer. ×12.

Fig. 51. *Dryophanta palustris* O.S. on the leaf of *Q. coccinea* Muench. Section of the wall of the inner gall, showing the nutritive zone with a line of collapsed cells next the larval chamber and a row of empty cells just inside the collapsed tissue. The protective layer borders the nutritive on the outside and a few round cells of the parenchyma adhere to the protective zone. ×70.

Fig. 52. *Dryophanta palustris* O.S. on the leaf of *Q. coccinea* Muench. Section of the larval chamber of a mature specimen, showing the insect breaking out of the inner gall. At this stage the nutritive layer has entirely collapsed. ×15.

Fig. 53. *Cynips ? constricta* Stebbins on the leaf of *Q. coccinea* Muench. Longitudinal section showing the origin of the gall from the midrib of the host in the region of the cambium layer. ×100.

Fig. 54. *Cynips ? constricta* Stebbins on the leaf of *Quercus coccinea* Muench. Longitudinal section of an early developmental stage showing the general structure of the gall. The dark mass at the top of the figure represents the supplemental nutritive zone of the gall; it is separated from the spherical part of the gall by a cambium tissue. The protective sheath that separates the nutritive from the cambium in later stages is not yet differentiated. A nutritive zone is also shown lining the larval chamber. ×40.

## PLATE IX.

Fig. 55. *Holcaspis bassetti* Gillette on the stem of *Quercus macrocarpa* Michx. Section through the gall cavity with enclosed larva. The character of the cells of the nutritive zone is shown and the unbroken edge of its inside boundary. The finely divided material of the stomach contents of the larva is also shown. ×60.

Fig. 56. Section of a larval inquiline from the gall *Holcaspis bassetti* Gillette. The broken edge of the tissue on which the larva has been feeding is shown, also the comparatively coarse material of the stomach contents. ×60.

Fig. 57. Contents of the stomach of the preceding inquiline. The black masses are parts of cell walls, while the lighter roundish particles are crystals. ×300.

Fig. 58. *Holcaspis bassetti* Gillette on the stem of *Q. macrocarpa* Michx. Section through the nutritive zone of a nearly full grown specimen. The nutritive zone is shown to consist of elongated cells next the larval chamber and elliptical further out. The dark zone is a crystal layer that bounds the nutritive zone on the outside. A cambium is differentiated between the nutritive and the parenchyma layers but it is not well shown in the figure. ×60.

Fig. 59. *Andricus singularis* Bassett on the leaf of *Quercus rubra L.* Section through the nutritive and protective zones, showing empty cells throughout the nutritive layer and the wrinkling of the radial walls of its cells in general. ×100.

Fig. 60. *Aylax glechomæ* Linné on the leaf of *Nepeta hederacea* (L.) Trevisan. Section through the nutritive and protective zones, showing the unbroken lining of the gall cavity and the row of empty cells that borders the larval chambers. ×80.

## PLATE X.

Fig. 61. *Philonix nigra* Gillette. Longitudinal section of the larva, showing the external opening of the alimentary canal. ×15.

Fig. 62. *Amphibolips confluens* Harris. Longitudinal section of the larva, showing the completeness of the digestive tract. ×15.

Fig. 63. *Rhodites lenticularis* Bassett on the leaf of *Rosa blanda* Ait. Section through the larval chamber, showing the nutritive layer lining it. Bordering this tissue on the outside is the cambium zone from which practically the entire gall is originated. The dark band shown plainly at the right of the figure is the protective sheath. ×20.

Fig. 64. *Philonix erinacei* Beut. on the leaf of *Q. alba* L. Section in which the four typical zones of a cynipid gall are shown, namely nutritive, protective, parenchyma or tannin, and epidermal. The sclerification can be seen to have passed out into the parenchyma zone. ×25.

Fig. 65. *Holcaspis globulus* Fitch on the stem of *Q. alba* L. Section through adjoining larval chambers of a producer and an inquiline, a complete section of the latter is shown. The nutritive tissue that supplies the inquiline with nourishment can

be seen to have originated entirely from the cambium differentiated by the producer of the gall. Its irregularity on the side opposite to the producer is very marked. ×30.

Fig. 66. *Aulacidea nabali* Brodie on the stem of *Prenanthes alba* L. Section through the stem of the host and the attached gall. The relation of the cambium of the host to the cells of the gall tissue is shown. ×30.

PLATE XI.

Fig. 67. *Neuroterus majalis* Bassett on the leaf of *Quercus alba* L. Section through a larval chamber containing the pupa of the producer. The dark band around the inside of the gall cavity consists of the collapsed nutritive zone and the protective layer. At the upper right of the figure the general nature of the cells of the parenchyma zone is shown. ×50.

Fig. 68. *Euura S. gemma* Walsh on *Salix humilis* Marsh. Section through a mature gall, showing a larval chamber containing a pupal producer and several large masses of excrement. The general nature of the small celled tissue of the gall is also shown. ×30.

Fig. 69. *Euura* (N.S.) on the leaf of *Salix serissima* Fernald. Transverse section, showing one uninjured bundle of the petiole and the parts of two others widely separated by the proliferation of the tissue stimulated by the laceration of the bundles. ×35.

Fig. 70. *Euura* (N.S.) on the leaf of *Salix serissima* Fernald. Section of a younger stage than the preceding, showing as before one uninjured and two injured bundles. ×35.

Fig. 71. *Euura ovum* Walsh on the stem of *Salix humilis* Marsh. Transverse section through the stem of the host and the gall originated from it. It shows the wedge-shaped cavity occupied by the gall mass and the origin of the latter from a cambium tissue at the boundary of the pith of the host. ×18.

Fig. 72. *Euura* (N.S.) on the leaf of *Salix serissima* Fernald. Section of the gall showing proliferation induced by the excrement of a larval producer. ×18.

PLATE XII.

Fig. 73. *Pontania hyalina* Norton on the leaf of *Salix alba* L. Section of gall with larva still within the egg membrane. Proliferation is shown well advanced in all the tissues of the leaf. ×35.

Fig. 74. *Pontania hyalina* Norton on *Salix alba* L. Section showing the wound of the ovipositor. ×25.

Fig. 75. *Pontania hyalina* Norton on the leaf of *Salix alba* L. Section of a more mature stage than numbers 73 and 74. The amount of gall tissue derived from the various sources can no longer be distinguished. The uniformity of the tissue is very marked. ×25.

Fig. 76. *Pontania pomum* Walsh of the leaf of *Salix cordata* Muhl. Section through an early developmental stage in which the larva had not freed itself from the egg membrane. There is shown the laceration of the bundle of the midrib by the ovipositor and the proliferation in the various tissues of the leaf. ×20.

Fig. 77. *Pontania pomum* Walsh on *Salix cordata* Muhl. Section of a nearly full-grown gall, showing the distribution of the aeriferous tissue and the location of the vascular strands. ×18.

Fig. 78. *Pontania* (N.S.) on the leaf of *Salix humilis Marsh.* Section at right angles to the midrib of the leaf to which the gall is attached. The general character of the gall tissue is shown and the distribution of the vascular strands from the wounded bundle. ×20.

Fig. 79. *Pontania* (N.S.) on the leaf of *Salix humilis* Marsh. Section through the midrib from which two galls had originated. The bundle is shown completely severed. ×8.

## PLATE XIII.

Fig. 80. *Pontania desmodioides* Walsh on the leaf of *Salix humilis* Marsh. Section through a chamber containing an unhatched larva. Proliferation is well marked in all the tissues of the leaf. ×40.

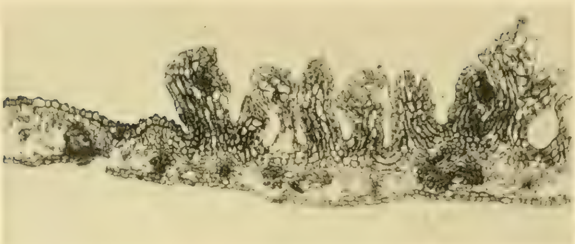
Fig. 81. *Pontania pisum* Walsh on the leaf of *Salix discolor* Muhl. Section of a mature gall, showing the general character of the tissues. The dark band at the upper right of the figure marks the line of attachment of the gall to the blade of the leaf. Just beneath this line the proliferation in the palisade parenchyma is shown. .×20.

Fig. 82. Undescribed gall on the leaf of *Salix lucida* Muhl. Section of a young gall on the midrib, showing the commencement of the proliferation in the pith of the bundle. ×20.

Fig. 83. Normal leaf of *S. lucida* Muhl. Section through midrib for comparison with the preceding. ×25.

Fig. 84. Undescribed gall on the leaf of *Salix lucida* Muhl. Section of a well-grown gall on the leaf petiole. The two arms of the bundle are shown widely separated by proliferation set up in the pith. The arrangement of the cells of the gall tissue in curved rows is shown and the presence of elongated air spaces between these. ×15.

Fig. 85. Undescribed gall on the leaf petiole of *Salix humilis* Marsh. Section showing the ovipositor wound. Around the edge of the incision is shown the cambium tissue from which the greater part of the gall tissue has been produced. ×18.



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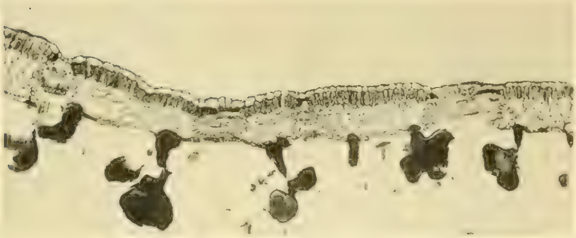

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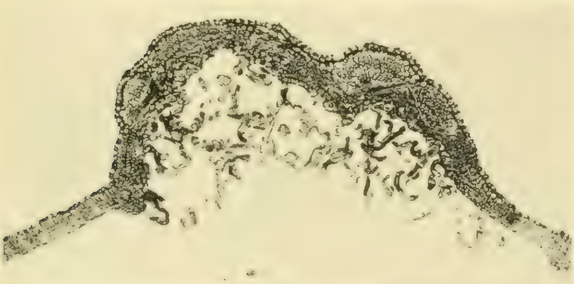

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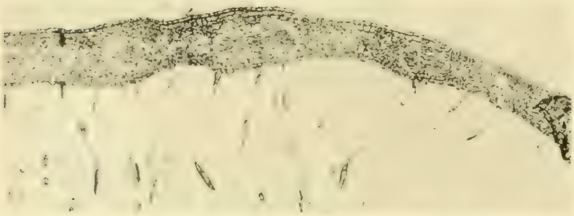

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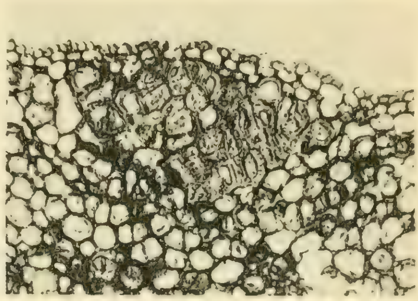

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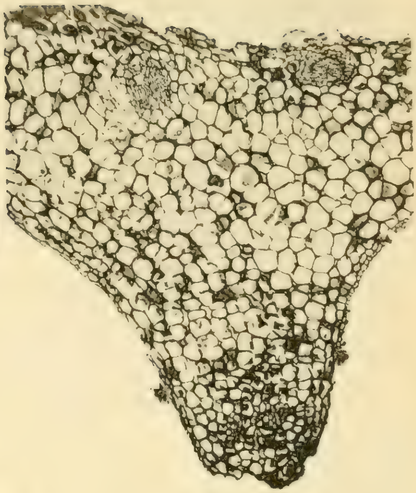
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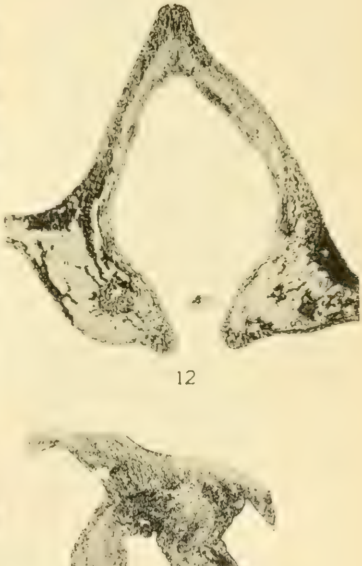
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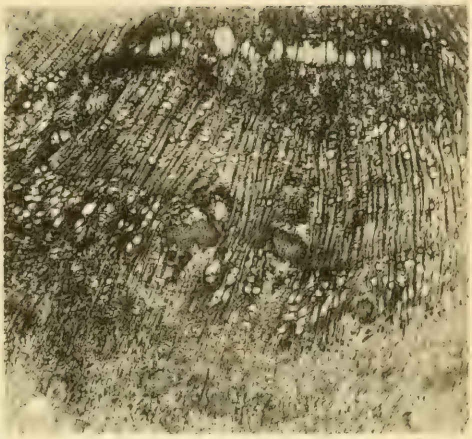

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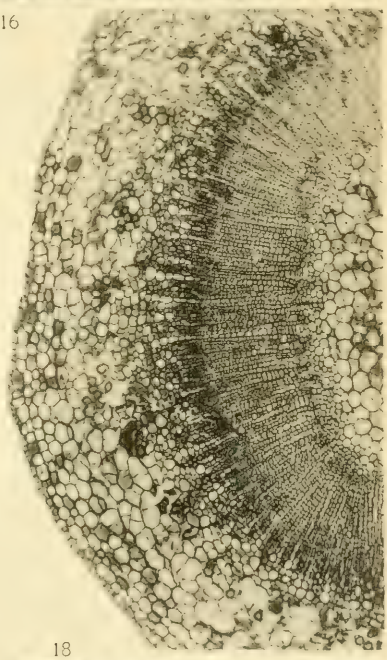

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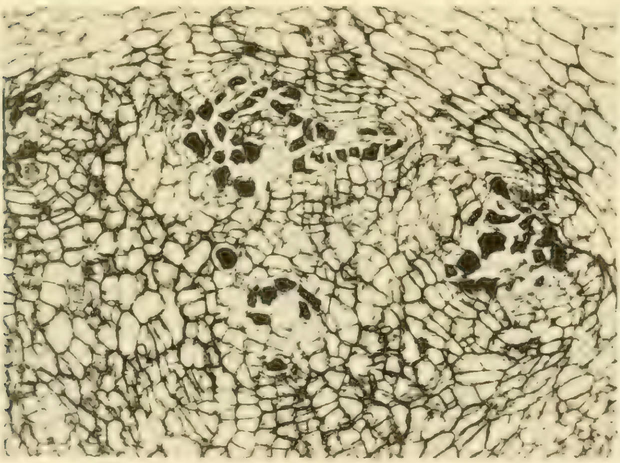

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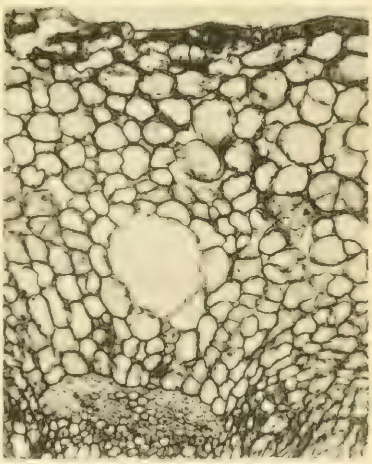

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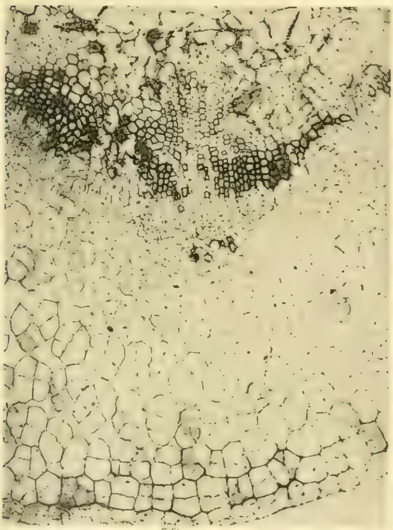

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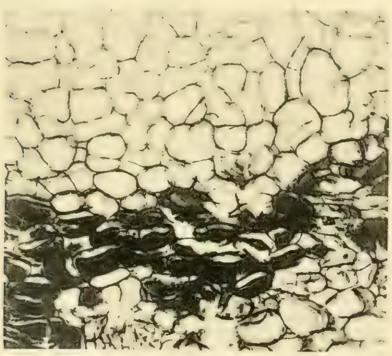

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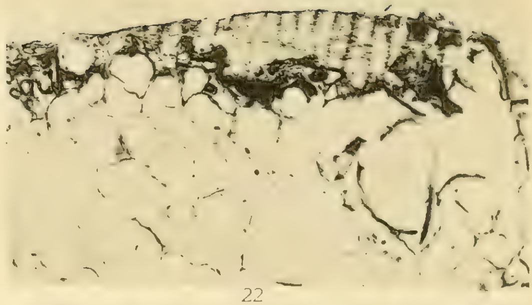

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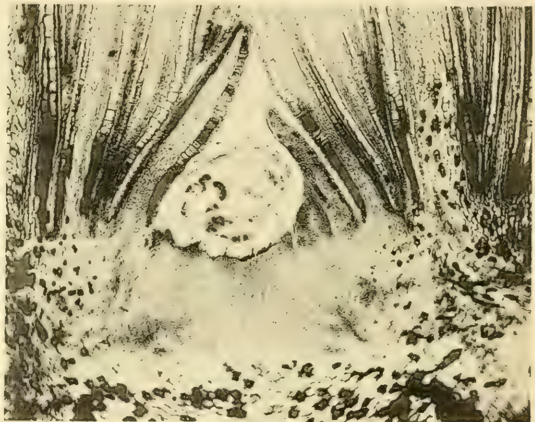

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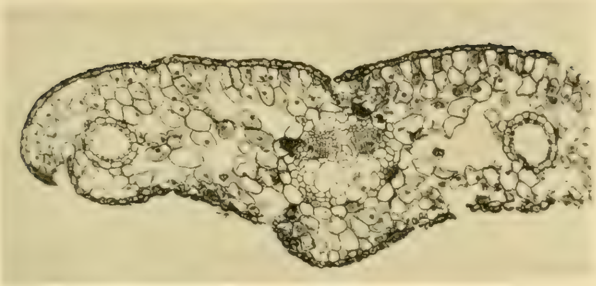

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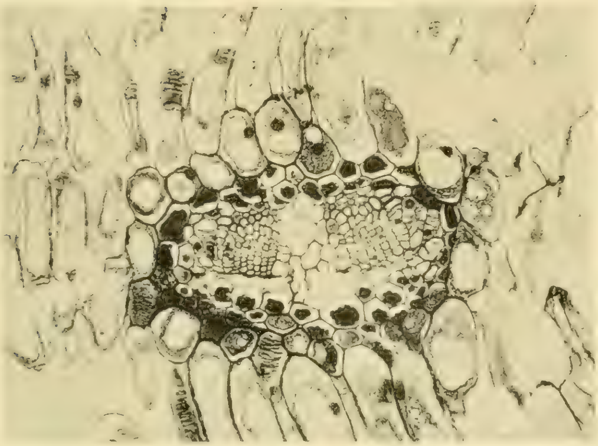

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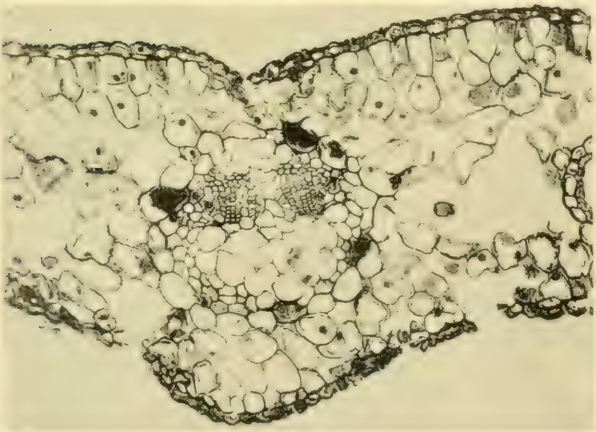

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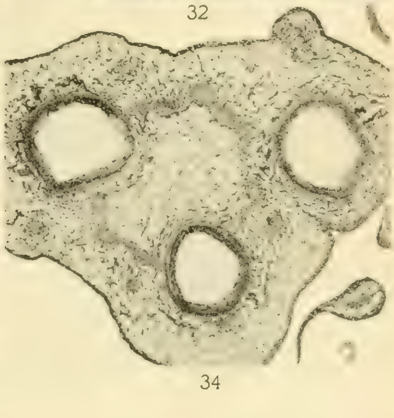

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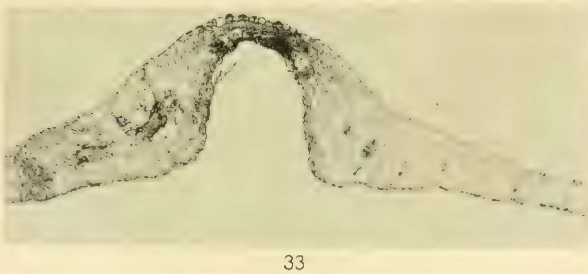

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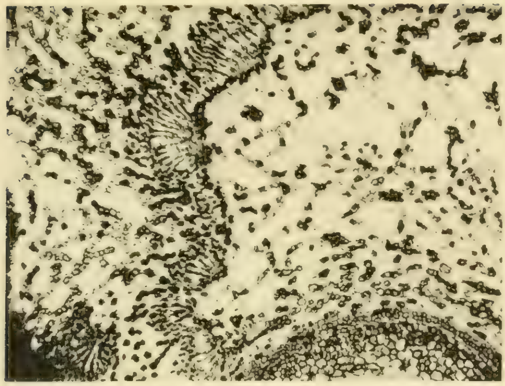

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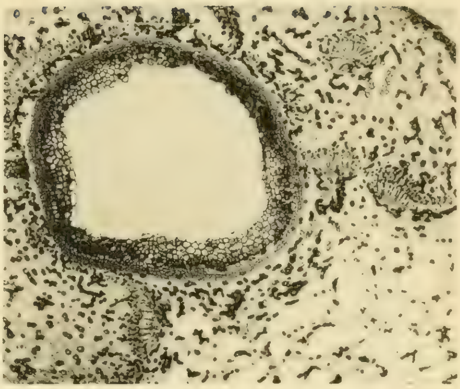

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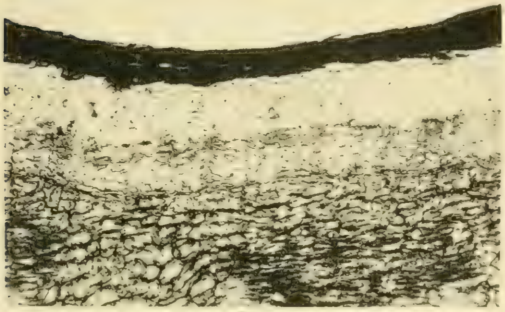

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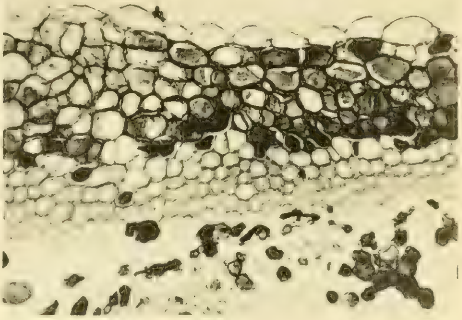

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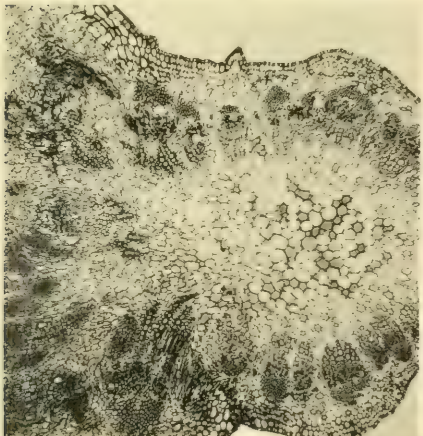

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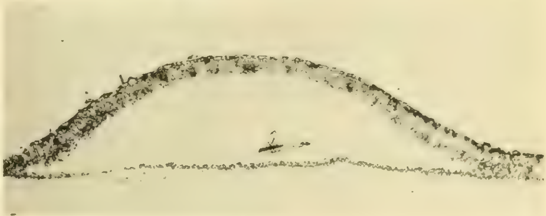

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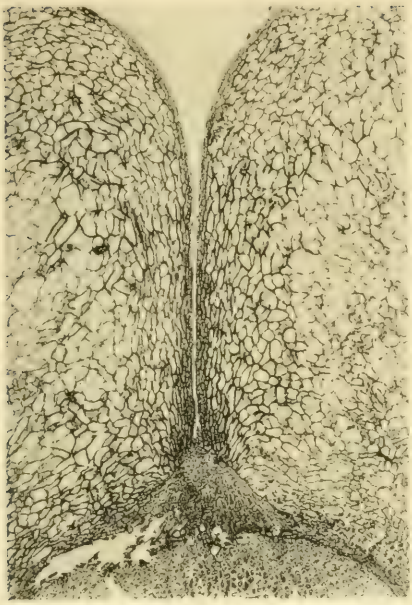

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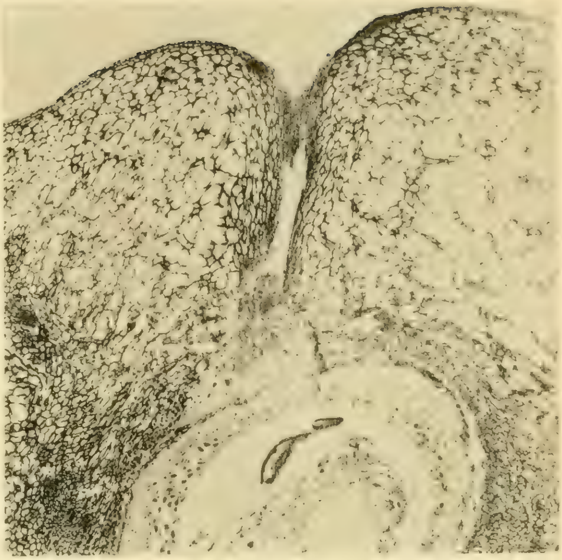

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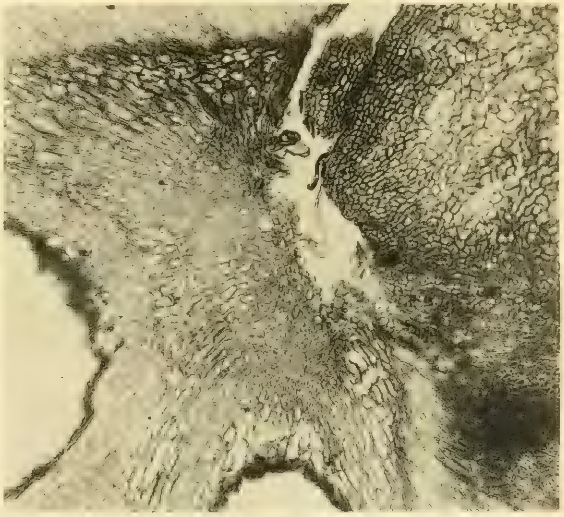

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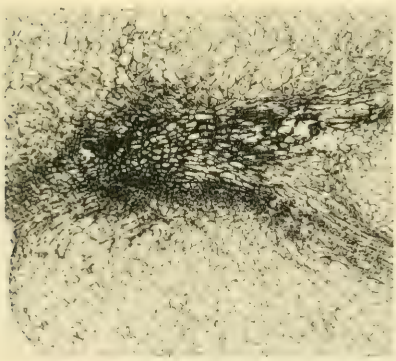

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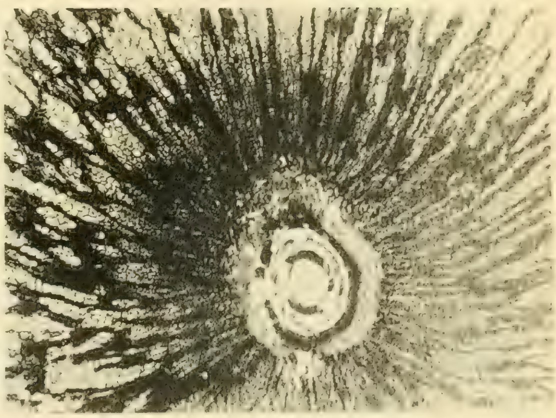

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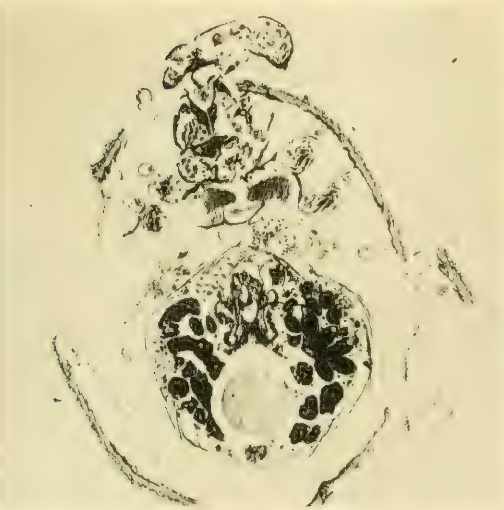

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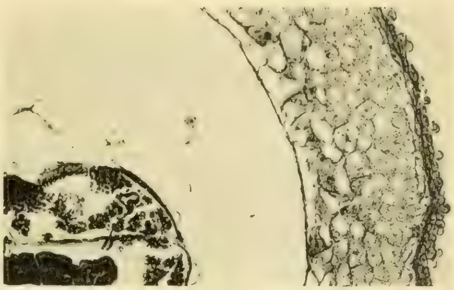

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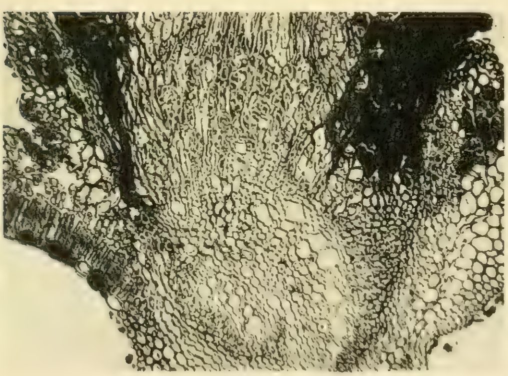

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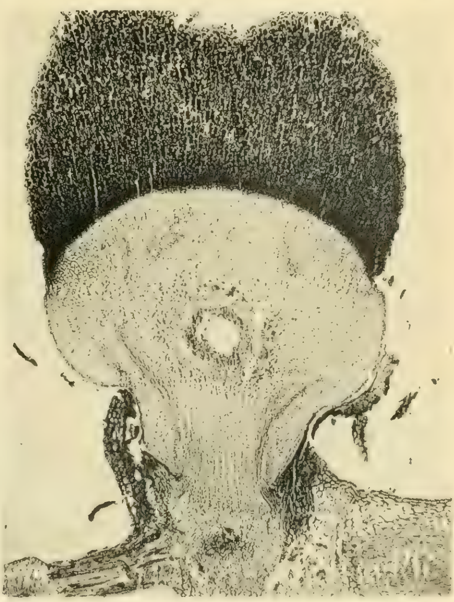

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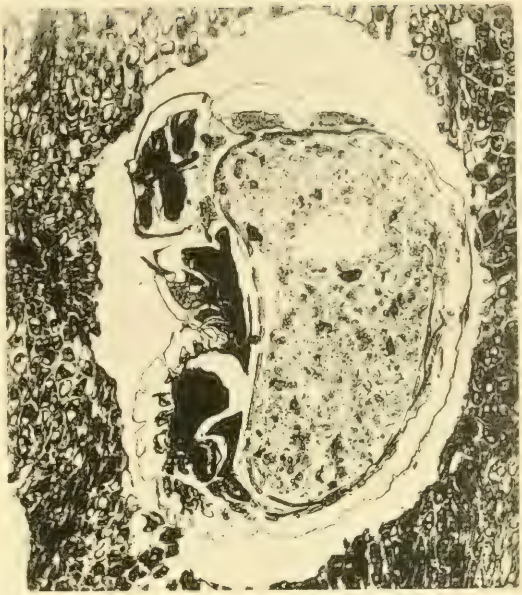

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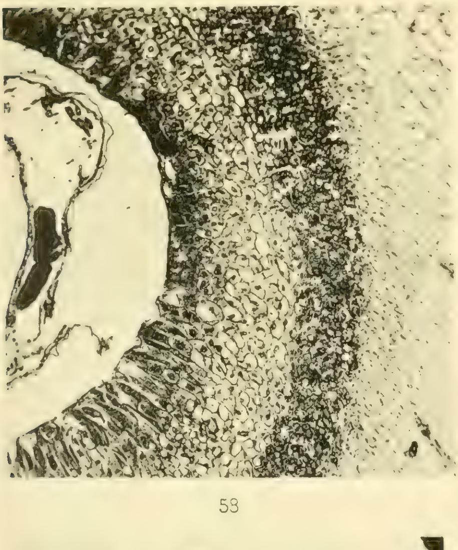

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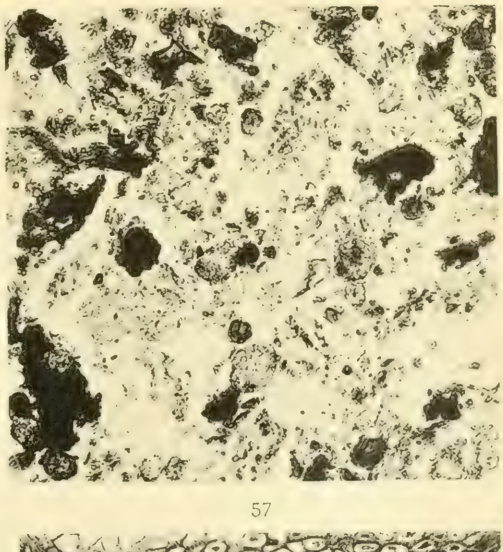

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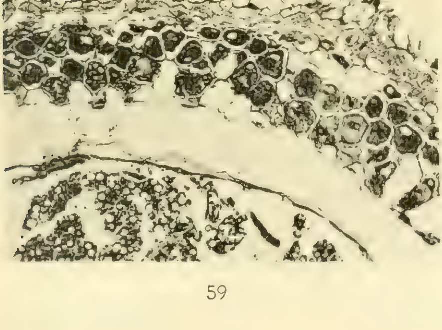

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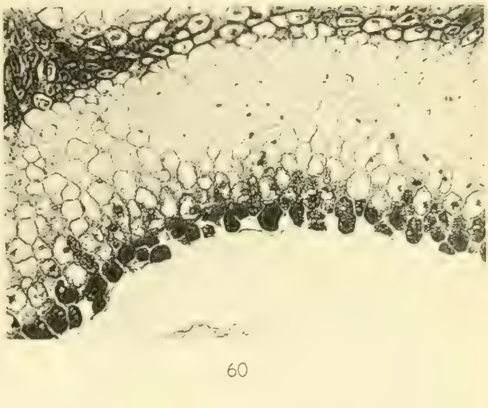

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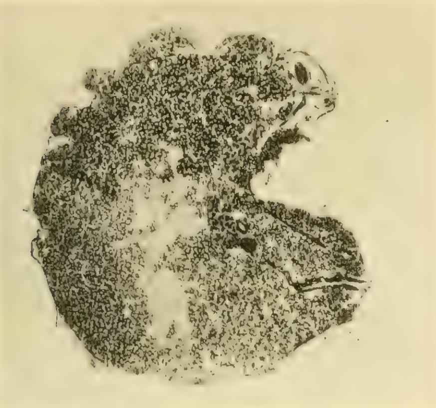

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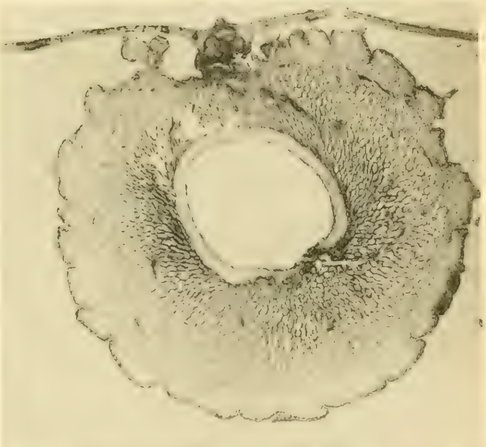

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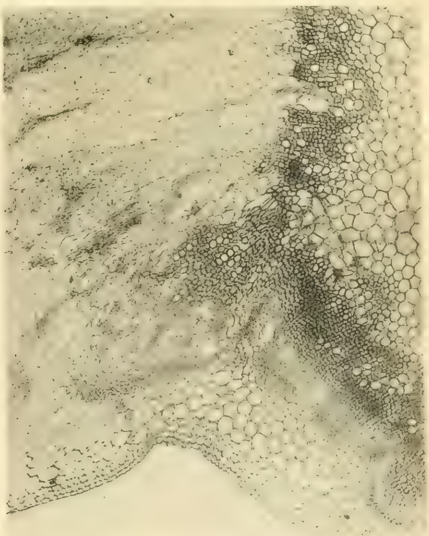

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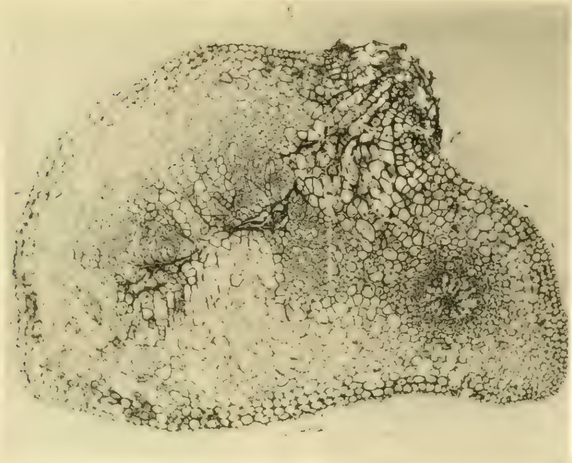

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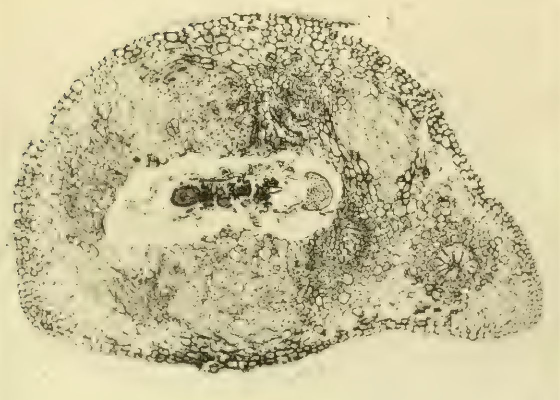

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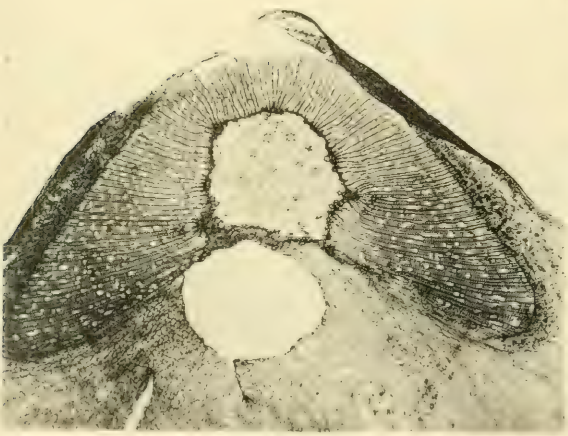

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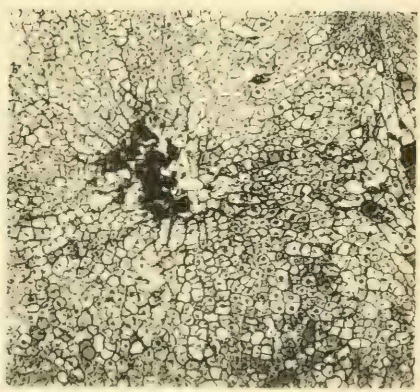

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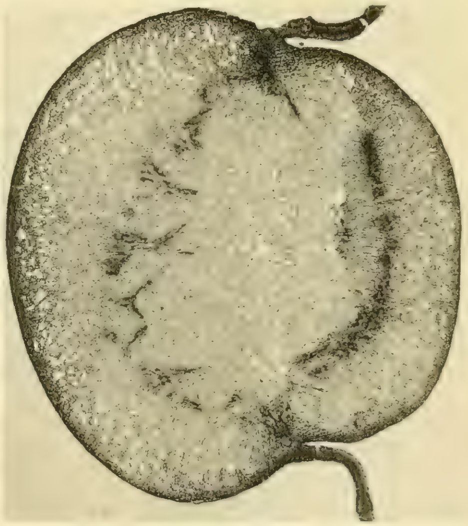

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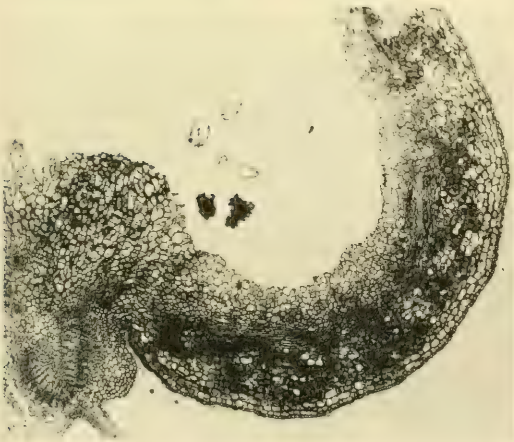

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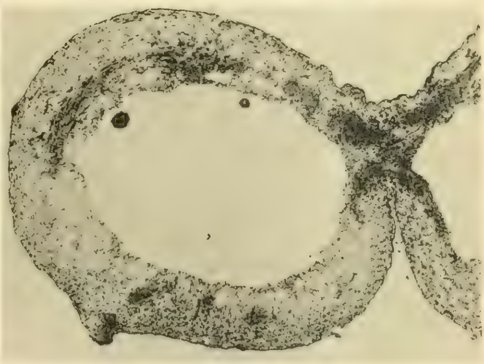

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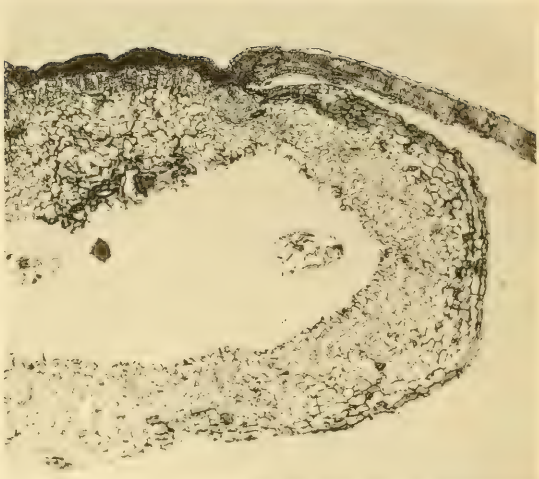

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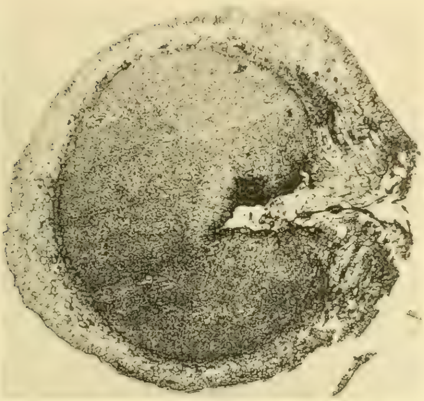

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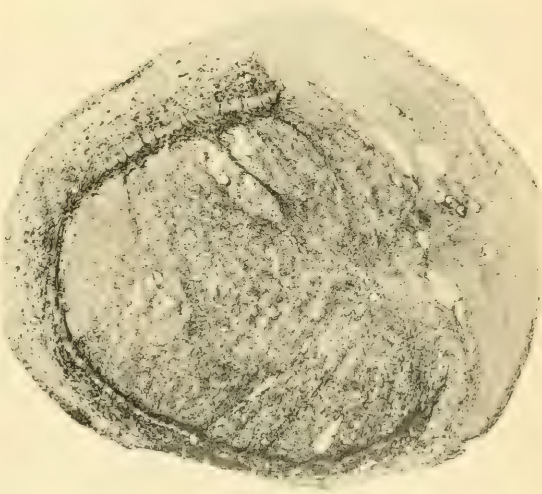

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# ON THE DISTRIBUTION OF POTASSIUM IN RENAL CELLS.

By C. P. Brown, M.A.,

Fellow in Biochemistry in the University of Toronto, 1910-11.

## I. Introduction.

Although investigation of the problems of renal secretion has given us some information regarding the manner in which the kidney carries out its function, it has hitherto thrown very little light on the character of the cellular processes which are fundamentally concerned in the elimination of salts and metabolites from the blood by the renal tubules. This is in large part due to the fact that although our cytological and histological methods are highly developed, yet the results which they give when applied to the kidney do not enable us to understand how a renal cell acts when performing the excretory function. We can by the application of histological and cytological methods distinguish stages in the activity of the cells in the pancreatic and peptic tubules, and we are able to recognize the presence in these cells of the antecedent substances, the zymogens of the ferments which the glands produce. The changes which we distinguish in such gland cells do not give us a very profound view of the processes of cellular secretion involved, for those changes as we observe them are of a more or less superficial character, but in the renal cells the changes which precede, or are consequent on, rest and activity are much less in evidence. It has indeed been claimed that in the active renal cell there are "secretion vesicles" which are not present when the cell is at rest or is relatively inactive, and more or less marked vesiculation of the free border of the renal cells obtains under the influence of powerful diuretics, but the "secretion vesicles" are held by some to be artefacts, and the vesiculation of the free border is not necessarily an indication of the processes which the cell under ordinary conditions undergoes.

The failure of cytological methods to reveal fully the cellular processes of renal excretion has made it necessary to employ other lines of investigation on this subject. In the microchemistry of the cell from its inorganic side there are methods some of which at least are already available for developing to a certain extent a knowledge of these processes, and it is probable that a full achievement of that knowledge will occur when more than one of those methods, specially adapted, are skilfully applied to investigate the distribution of salts in the cells of the renal tubules in the various stages of activity. Of the methods now available, that for the microchemical demonstration of potassium, first employed by Professor A. B. Macallum,[2] has been already used by him in studying the excretion of the salts of that element in the renal cells of frogs kept in the laboratory tanks through the winter. The results thus obtained were such as to indicate that the method might profitably be applied in a more extended investigation along the same line, and the author, acting on the suggestion of Professor Macallum, undertook the research of which the present contribution is the outcome.

## II. METHODS OF INVESTIGATION.

The method used is that fully described by Professor Macallum for the microchemical demonstration of potassium in animal and vegetable cells. It will, therefore, be necessary only to review here very briefly the reaction and preparation of the reagent.

The reagent is prepared by dissolving 20 grams of cobalt nitrite and 35 grams of sodium nitrite in 75 c.c. of dilute acetic acid (i.e., 10 c.c. glacial acetic diluted to 75 c.c.). A vigorous evolution of nitrogen peroxide results. It is allowed to stand for some hours, when, if any trace of potassium has been present in the sodium nitrite used, a precipitate forms which may be removed by filtration. The filtrate is diluted with water to 100 c.c., and is then ready for use. The precipitate produced by the reagent, when added to a solution of potassium salt, is a triple compound, the hexanitrite of cobalt, potassium and sodium. Its composition is given by Gilbert[3] as $Co(NO_2)_3\ 3(K/Na)NO_2,\ nH_2O$, the value of $n$ being 1 1/2, 2, or 2 1/2. Its composition varies, however, with the potassium salt content of the original solution. It consists of chrome yellow crystals of dodecahedra of varying microscopic size.

The tissue examined was removed from the body as soon as possible after the animal was killed, so as to insure a perfectly fresh, normal condition. It was at once placed on the plate of a $CO_2$–freezing microtome, where it was immediately frozen and sections made from it, and placed immediately in the reagent. Here lay perhaps the crucial point of the technique. First, the tissue must be frozen quickly and while perfectly fresh. In the second place, it is absolutely essential that the knife and the atmosphere in which the sectioning is done should be thoroughly chilled to a distinctly freezing temperature in order that the section should not thaw before the entrance into its reagent. If this object is attained the diffusion of the salts in the sections is reduced to a minimum. The slightest thawing permits diffusion of the salts, in which case the distribution of the potassium compounds, as observed, would be other than that obtaining in the living tissue. Even with the greatest care the knife will warm a little and cause surface diffusion in cutting. It is thus necessary to prepare a large quantity of material and examine each section carefully under the microscope after it has been appropriately treated. Nearly all the drawings of the plates of this contribution have been made from sections in the preparation of which these precautions were observed, and in which surface diffusion, consequently, had been almost wholly prevented. The sections were cut at 10 to 20 $\mu$, the thickness depending on the firmness of the tissue.

The sections were allowed to remain in the reagent from three-quarters of an hour to an hour and a half, according to convenience. The longer time was preferable to attain better fixation of the tissue. They were then washed gently from half an hour to an hour in ice-cold water which was frequently changed. This dissolved the uncombined reagent and the precipitates which the reagent forms with creatin or ammonium salts. Immediately after washing, the sections were mounted on a glass slide in a mixture of equal parts of 50 per cent. glycerine and concentrated ammonium sulphide solution.

After this treatment the distribution of potassium in the sections was revealed by the localization of the black precipitate due to the formation of cobaltous sulphide. The staining of the preparation by the reagent itself varies in colour from a deep brownish yellow to a light gray. In animal tissues I have found the nuclei, if apparent, to be so from their lighter colour as compared with the rest of the section. In nerve cells the nuclei are stained much deeper, and Professor Macallum states that in vegetable cells they are stained still deeper and of a reddish shade. This is probably due to the nitrous acid reaction affecting the cytoplasm and the nuclear material differently.

That the uncombined reagent is readily removed from the sections by washing with ice-cold water has been many times shown in preparations of which Fig. 1 is representative. This was drawn from a section which, immediately after it was cut, was put in distilled water to remove all the potassium salts present, then placed in the reagent and treated further as described. The absence of a black reaction or of a dark shading in the preparations is evidence that all the cobalt reagent has been extracted.

Frogs were largely used, other animals as occasion offered. The frogs had been kept in a cool tank until January, and so were considered to have ceased to secrete actively. Hence they are referred to as being in a condition of inanition. This condition was varied by keeping them in a warm room for some days and also by subcutaneous injections, into the dorsal lymph sac, of various diuretics. In some instances the spinal cord had been previously cut. Details on these points are given in the index to the Figures. The various animals used were *Necturus*, frog, dog, cat, rabbit, and pigeon.

## III. RESULTS.

In the kidney from the inanition frog there were heavy condensations of potassium about the periphery of the tubules and at the margins of their lumina (Fig. 2). Practically no potassium was found in the cytoplasm except in the region bordering on the lumen, although the cellular outline was not sufficiently evident to state definitely in the majority of instances whether it was within or without the cell. By comparison, however, of a large number of preparations obtained under different conditions the peripheral deposit was judged to be on the lymph-tubule interface outside the cells, the central deposit being in the cytoplasm adjacent to the lumen.

The active kidney did not differ quantitatively from the inactive one, but the distribution of potassium was more uniform about the periphery of the tubules and frequently about the lumina as well. This was shown best in the frog under a mild dextrose diuresis (Fig. 3), also in the frog under moderate sodium sulphate diuresis (Fig. 4). In the latter the spinal cord had been cut previous to injection, to lower the blood pressure so as to prevent a flow of urine and, consequently, the actual localization of the potassium in the active kidney was more evident. The peripheral distribution can be clearly recognized as being external to the tubule and the central as being in the cytoplasm bordering on the lumen.

In cases of excessive diuresis the conditions were less uniform, the potassium being found on the intercellular membranes, in the intracellular spaces, on the surface of the nuclei, and, if the diuresis had been induced by an injection of potassium salts, frequently diffused throughout the cytoplasm as well. This distribution was not associated with any apparent increase in amount of potassium in the preparations from the frog after excessive dextrose diuresis (Fig. 5), and also after excessive sodium sulphate diuresis (Fig. 6). No potassium was found throughout the cytoplasm of the cells in these. The preparations from one of these kidneys under excessive sodium sulphate diuresis showed curious protrusions which by comparison with stained preparations were recognized as migrating leucocytes (Fig. 7*a*), protruding red blood cells (Fig. 7*b*) and epithelial cells (Fig. 7*c*). These were found in restricted regions of the kidney where large numbers of leucocytes had gathered, the excess of diuretic apparently having acted as an irritant producing a necrosis similar to the condition found in preparations from the kidney of a dog which had been treated with cantharidin. Whether the striking aggregation of potassium salts on the surface of these structures is due to precipitation or condensation it is difficult to say. It appears to be analogous to that found by Professor Macallum in the root hairs of *Equisetum arvense* and in the outgrowing processes of conjugating *Spirogyra*.[5]

Where the excessive diuresis was occasioned by injection of potassium salts, *e.g.*, potassium phosphate, a similar distribution was observed (Fig. 8), accompanied, as one would expect, by an increase in the amount of potassium present. Not only were the intercellular membranes and the surfaces of the nuclei heavily charged, but the potassium was frequently found throughout the cytoplasm as well, either in a sort of network, or else distributed fairly uniformly. The rapidity with which an iodide penetrates tissues was demonstrated in one animal injected with potassium iodide and killed five minutes later. The heavily loaded tubules showed different states of activity. In the inactive tubules, as illustrated in Fig. 9, the potassium iodide was more or less irregularly distributed, but in the very active tubule the salt was chiefly condensed on the external surfaces of the tubules and in the cell at the lumen border (Fig. 10).

The preparations from the kidney of a dog which had been under A.C.E. anæsthesia for two hours, and in which the kidney would thus be in a fair state of activity, illustrated the peripheral and central condensations most strikingly (Fig. 11). The peripheral condensation was more frequent than the central, the latter being oftener seen when the urine flow was checked by pithing. Where the tubules had been thrown into activity by phloridzin the same distribution was found, differing only in that the condensations of potassium were distributed more uniformly about the tubules and a larger proportion of the tubules manifested the condensation (Fig. 12). It is difficult to illustrate this, as one only comes to this conclusion after examining a considerable number of preparations, but I have endeavoured to select tubules representative of each condition. In these preparations, in all of which the different regions of the kidney could be recognized, the localization was found in the convoluted tubules and in the loops of Henle, but in no case was a distinct localization evident in the region of the collecting tubules. Owing to the unstained nature of the preparations it was impossible to refer the localization of potassium more definitely to the individual portions of the tubule.

Similar condensations were found in the rabbit. But, comparing the sections of the kidney from the pithed animal (Fig. 13, *a*, *b*), which had been excised before the injection of the dextrose, with those from the remaining kidney (Fig. 14, *a*, *b*) after it had been acted on by the diuretic, a distinct difference would be seen between the two. In the inner portion of the boundary zone from the former kidney there were only about half as many tubules which exhibited the condensation about the lumen as compared with those from the same region in the diuretic kidney, a larger number of these latter also showing the potassium in the lumen as well. These two kidneys gave the distinction between active and inactive most clearly, the localization in the active kidney being much more definite and uniform.

The cat (Fig. 15) and pigeon (Fig. 16) also evidenced the peripheral and central condensations. In some preparations from the kidney of a fœtal cat (Fig. 17) a few isolated convoluted tubules showed a certain amount of peripheral condensation, but no central condensation was observed. Sections from the kidney of *Necturus* were also prepared, and in them was found a similar distribution, except that the cells seemed to retain their individuality to a greater degree than in the kidneys from the higher forms. This occasioned a distribution which tended to be cellular rather than tubular in character. The same peculiarity was observed in preparations of the pancreas from *Necturus*.

The glomeruli in all the forms showed a characteristic pattern which would be traced as lines composed of black dots of cobaltous sulphide (Fig. 19). By comparison with stained and other preparations this was judged to be largely in the walls of the blood vessels, with less marked precipitations in the interepithelial walls and in the connective tissue. In one preparation in which a surface view of Bowman's capsule (Fig. 20) was seen the localization was confined to the cement substance of the cells and to the connective tissue strands. Some of the potassium had apparently slightly diffused before the reagent completely penetrated. In the intertubular spaces the potassium was found concentrated on the strands of connective tissue (Figs. 9 and 10). In a few preparations from the dog's kidney the basement membrane became slightly separated during preparation and was observed to be impregnated with the potassium salt. In no instance was any potassium demonstrated in a cell nucleus.

That these concentrations of potassium were the result of actual localization of the potassium salts in the kidney, and not artefacts, was apparent from inspection of the sections. They could not have been so distributed by the knife in cutting, for, if so, the heavy precipitates would appear in more or less parallel lines at right angles to the direction of cutting and in much coarser aggregations, as was the case in some preparations in which diffusion had occurred before precipitation. Nor could they have been due to a penetration of the reagent into the lumina and intertubular spaces first, then into the cells. The character of the section excludes this possibility. The reagent comes in direct contact with a cross section of a tubule from $10\mu$ to $20\mu$ thick. It will penetrate directly at all points and not first to the interspaces, then to the basement membrane and so diffuse throughout a tubule of $18\mu$ radius.

It might be urged that the reagent, penetrating the tissue at some points quicker than at others, precipitates the potassium with which it first comes in contact at these spots. Then the rest of the potassium in the cytoplasm, from its great diffusibility, would immediately gather and precipitate at the centres thus formed. This might be a real danger in organs limited by a cuticle or membrane, but in these preparations it could not obtain. The conditions are all against such a result, for a frozen cross-section dropped into the reagent while still frozen thaws equally and uniformly throughout and permits of the penetration of the reagent at all points of the surface at the same time. If this tendency toward diffusion to the point of initial precipitation operated, one would expect to find a heavy surface precipitate over the membranes, for these, being firmer, stand out as it were and first meet the reagent. Here would be the first precipitation, and to this would diffuse, not only the potassium in the cytoplasm, but that from the deeper portions of the membranes themselves. This would be apparent immediately on adjusting the microscope so as to focus the deeper portions of the section with little or no precipitate in contrast with the heavy peripheral and central surface precipitates thus supposed to occur. If only the surface layers were affected by this first diffusion, then, as the section thaws, the reagent would penetrate the cytoplasm more quickly than the membrane, and a heavy deposit in the deeper portion of the cytoplasm would result.

But none of these conditions obtain, actually the opposite being the case. Where diffusion has taken place on the surface before contact with the reagent, it is found that the tendency is for a uniform distribution over the entire surface of the section. The same applies to the deeper portions as well, the tendency being to a uniform distribution throughout. In Fig. 21*a* is shown a tubule in which a large measure of surface diffusion has taken place, this being a drawing of the surface view only, while Fig. 21*b* is of the same tubule observed at a deeper level of the section. What, however, may be considered the strongest argument for the normal character of the result is that in the same section the regions of the convoluted tubules and Henle's loops show the localization while the region of the collecting tubules do not. If it were due to an artefact occasioned in the freezing or subsequent treatment the whole section would be uniform. Again, there is the fact that in many tubules where a cut and an uncut surface can be distinguished, the uncut surface will show the potassium deposit while the cut section will be entirely free. Further, those tubules that evidence the localization are as a rule more heavily stained by the reagent than those that do not exhibit it, thus showing that the protoplasm in the two instances must differ in some respect.

## DISCUSSION.

Special attention was drawn by Professor Macallum[3] two years ago to the various suggestions that surface tension might play a part in different processes of the living organism. He has discussed these suggestions and expanded them to apply to cellular activity in general. In any attempt to relate surface tension to renal function one must bear in mind that protoplasm is of more or less colloidal nature, and also that it is living material. What factors modifying the ordinary forces of surface tension this introduces have not been fully investigated, but, as surface tension appears to be involved in renal secretion, a discussion of its action in relation thereto may be permitted.

The kidney cells, whether considered individually or collectively in the tubule, form peripherally a system with lymph-cytoplasm interfaces, a condition somewhat analogous to a liquid-liquid interface, the two liquids forming the latter differing greatly in density. Centrally, if the lumen be filled with fluid, a cytoplasm-fluid interface would result, though if the tubule were collapsed this would not obtain. Now in a drop of liquid surrounded by air, organic substances lower the surface tension, while most inorganic solutes raise it. Hence in accordance with the law that energy tends ever to a minimum in a system, the organic solute is found concentrated at the surface of the drop, while the inorganic solute is more dilute at the surface as compared with the interior of the drop. This is called the Gibbs-Thomson principle, and had been expressed mathematically in a formula deduced by Gibbs for the concentration of one of the phases at an interface separating a two-phase system. When, however, the drop is in contact with another fluid with which it does not mix or is in contact with a solid (*e.g.*, glass), the surface tension of the drop on the contact surface is greatly diminished and, in consequence, there the solutes condense whether they ordinarily tend to raise or to lower surface tension at the liquid-air surface. As far as has been investigated the tendency is for all substances in solution under these conditions to concentrate at the interface where the tension is lowered.

The degree of concentration has been investigated experimentally by Lewis[7] in the case of a number of solutes. For this purpose he allowed a known volume of a hydrocarbon oil to ascend through aqueous solutions in a tall cylinder. As the diameter and, consequently, the number of the droplets were ascertained the total surface area they presented was also known. The oil was collected at the top of the cylinder in a suitable apparatus. Each aqueous solution contained a substance soluble in water but insoluble in oil, viz., sodium glycocholate, methyl orange or Congo red. These lowered the surface tension in proportion to their concentration in solution. The degree of adsorption of each of these solutes on the surface of the oil droplets was from twenty to eighty times the theoretical value calculated according to the Gibbs formula. Lewis further investigated the effect of electrolytes[8] and found they manifested a similar but less marked condensation, the adsorption of potassium in potassium chloride solution being thirty times that calculated. Indeed, in all cases the adsorption was such that a process of gelatinisation at the surface was suggested as an explanation. It would further appear that all substances in solution are adsorbed at a fluid-fluid or fluid-solid interface.

Mayer[9] has shown that the surface tension of blood plasma is lower than that of an isotonic salt solution, and this would favour adsorption on cell-lymph interfaces. We may, therefore, perhaps be justified in concluding from this that the concentrations of potassium on the renal tubules, which we have described, are the result of surface tension differences on the surface of the tubules. In the production of these differences metabolism may play a part. We know that the oxygen intake in the kidney is very high, indicating a considerable liberation of energy, which the cells may transform to surface energy, using it either to obtain material for metabolic purposes or in the functional activities of excretion. The excess absorption of oxygen during the period of diuresis over the period of rest in the experiments of Barcroft and Brodie[10] is equal to 0.0401 c.c. $O_2$ per gram per minute. The secreting area for dog's kidney has not been calculated, but for comparison the area of a human kidney of similar weight may be given. According to Pütter[11] the secreting area of a kidney of 45 gr. is 2.2 $m^2$. Transforming the excess of oxygen consumption into dynes per $cm^2$., after allowing 1/20 for concentration of urine, we find an expenditure of 271.3 dynes per $cm^2$.

When we consider that only a portion of the kidney is active at one time we see the energy expenditure, if expressed as surface units, would appear very ample for excretory purposes.

As found in the preparations referred to, the potassium is localized on the periphery of the excreting portion of each tubule and in the cytoplasm of the cells forming it. As indicated above, the peripheral deposit can be explained only as condensation, due to surface tension, from the lymph bathing the surface of the tubule. This condensation effect would involve also the sodium, magnesium and calcium salts and the metabolites, such as urea and uric acid, and if there were a microchemical reaction for each of these as sensitive as the one employed for potassium the application of it would probably show such a condensation layer, although perhaps in every case not to the degree illustrated by the potassium preparations. The results of Lewis' estimations of the concentration of the condensation layers of different compounds from their solutions on the surface of droplets of paraffin oil rising or of mercury falling through such solutions seem to indicate very distinctly that the concentrations may greatly exceed the proportions postulated by the concentrations in the solutions, and, as already pointed out, this is specially the case with potassium salts. We might, therefore, expect the respective concentrations of the salts and metabolites on the external surface of each excreting tubule to exceed very greatly their concentrations in the lymph.

It is not unreasonable to suppose that the basal surface of each excreting renal cell, on which the condensation has occurred, is permeable to the constituents of the deposit. The entrance of potassium and other salts into the cell would bring them into a new system in which their distribution would be affected by the surface tension of the cell as a whole and of its individual parts. In consequence, condensations would occur, and particularly on interfaces and surfaces where the surface tension is very low. In fluids this condensation occurs quickly, but it is possible that in a colloidal system, such as the renal cell illustrates, the condensation might not be effected so quickly, and yet it would occur with such rapidity as to keep down the concentration in the cytoplasm generally.

The occurrence of a condensation of potassium salt in the cytoplasm of the renal cell immediately adjacent to the lumen of the tubule would seem to indicate that this border of the cell has a low surface tension as compared with the other surfaces of the cell, and especially with the basal one, and, consequently, other salts than those of potassium would be condensed there also. This difference in surface tension could only be maintained by a constant expenditure of energy in the cell, and perhaps this would account for the very large amount of energy liberated in the kidney during diuresis, as calculated from the oxygen consumption of the organ by Barcroft and Brodie.

The maintenance of this difference in the tensions of the free and basal surfaces of the cell would not, however, be of much service in the way of explaining the mode of action of the cell if the condensation of the free (lumen) surface of the cell were not affected by another force. In renal activity the glomeruli, it is believed, separate from the blood plasma a fluid which is more or less free from salts and metabolites, and this thin watery fluid passing down the lumina of the convoluted tubules, sweeps over the free surfaces of the excreting renal cells in which the surface condensation of potassium and other salts obtains. The membrane of each cell at this point is extraordinarily thin and presumably permeable to water, which, however, owing to the low tension in the cell at the lumen surface, would not convey the salts there condensed into the interior of the cell, and they, therefore, would diffuse only into the lumen. The fluid in the latter would thus, as it passed down the tubule, become more and more concentrated, and in this way the higher concentration of the urine in solutes, as compared, with the blood plasma and lymph, would be accounted for. This removal of the potassium and other compounds in the condensation layer would not cause the latter to disappear, for so long as a difference exists in the tension on the basal and free surfaces of the cell, and so long as the latter is permeable to salts on its basal border, the concentration of the adsorption layer in the cell at its free border would be maintained. The condensation process would thus parallel the extraction process so long as the cell is in activity.

The difference in surface tension between the free and the basal borders and the surface tension in the lymph on the external surface of the excreting tubule would thus, of course, be subject to the metabolic activity of the renal cells and to the composition of the lymph. Anything that affects this metabolic activity, therefore, would affect surface tension in the renal cells. The difference of surface tension between the basal and free surfaces of the cells would thus be diminished or enhanced. In the former case the elimination of salts would be lessened, in the latter case it would be increased. On the other hand, a change in the composition of the lymph must influence to a greater or less degree the condensation on the surface of the tubules, and this would involve a lessened or increased diffusion of the condensed salts into the renal cells.

Such alterations in the surface tension of the lumen border of the cell and of its basal surface may be brought about by diuretics. This would explain the results obtained in the dog's kidney undei the influence of phloridzin and in the rabbit's kidney in dextrose diuresis. A substance that promotes very vigorous diuresis may, directly or indirectly, influence unequally the tension of the lymph and the tension on the basal and free surfaces of the excreting renal cells. This would explain many differences observed between the renal cells in very marked diuresis and the renal cells engaged in ordinary activity. In the renal cells in excessive diuresis, as already described, the condensations are irregular, occurring not rarely on the surface of the cell nuclei and the lateral walls of the cells, particularly so in the cases in which injections of potassium salts, and especially the iodide, had been given. Similar but less striking condensations of potassium were found in kidneys in diuresis caused by injections of sodium sulphate.

Potassium salts were occasionally found in the lumina of the tubules in all preparations, but particularly in those from the rabbit that had been subjected to the action of dextrose after the animal was pithed. In these the amount of glomerular fluid formed was diminished, and, in consequence, the potassium diffused into the lumen of the tubule from the adjacent condensation layer was to a certain extent retained in the fluid of the lumen. Where, therefore, potassium salts were found in the lumina of some of the renal tubules of unpithed animals, it may be reasonably explained as due to diminished activity on the part of their glomeruli.

No evidence of the occurrence of potassium salts in the free space of the glomerular capsule was obtained.

Whether potassium in its salts or compounds serves in the kidney any special purpose in renal excretion is a question which presents itself. The potassium of the condensation layers, abundant though it is, cannot be regarded as the whole of the element which obtains in the kidney, for although the hexanitrite reagent is an exceedingly sensitive one for potassium, it cannot demonstrate what is below the limit of sensitivity. Indeed, the very fact that in the cells of the convoluted tubules which show condensation of potassium in the cytoplasm adjacent to the lumen borders, the remaining cytoplasm itself does not give a reaction for potassium is evidence of this, for the condensation itself predicates a certain concentration, although excessively dilute, in the fluid system constituted by the cell as a whole.

Support for the view that potassium serves a special function in the kidney is afforded by analyses which the author made and which show the amount of the sodium and potassium in the organ. For this purpose frogs and dogs were used. In the case of the frog a large number of kidneys removed from recently killed animals were collected in bulk to weigh 17–22 grm.; each mass thus made was carefully dried in a platinum dish till a constant weight was obtained; it was then carefully incinerated and the soluble portion of the ash extracted with hot water acidulated with hydrochloric acid. From the combined extraction fluids the calcium and magnesium and the sulphuric and phosphoric acids were removed by precipitation and filtration, and the filtrate, treated with hydrochloric acid, was evaporated to dryness, then heated to expel any traces of ammonium chloride. The residue, which consisted of the chlorides of sodium and potassium, was carefully weighed, then appropriately treated by the platinum method to determine the amount of potassium present, which, calculated as the chloride and subtracted from the total chloride found, gave the amount of sodium chloride present. In the dogs' kidneys the same method of estimating the total sodium and potassium present was used, but only one kidney was used in each analysis.

The analyses gave the following:—

Frog.

| Analyses | Sodium | Potassium | Na(=100) : K |
|---|---|---|---|
| 1 | 0.1995 | 0.2031 | 100 : 101.8 |
| 2 | 0.2319 | 0.1995 | 100 : 86.3 |
| 3 | 0.160 | 0.1897 | 100 : 114.8 |
| Average | 0.1974 | 0.1974 | 100 : 100.2 |

Dog.

| Analyses | Sodium | Potassium | Na(=100) : K |
|---|---|---|---|
| 1 | 0.1995 | 0.2227 | 100 : 111.6 |
| 2 | 0.1746 | 0.2235 | 100 : 128.0 |
| 3 | 0.1657 | 0.2471 | 100 : 150.5 |
| 4 | 0.1758 | 0.2394 | 100 : 136.3 |
| 5 | 0.1846 | 0.2452 | 100 : 132.8 |
| Average | 0.1798 | 0.2356 | 100 : 130.9 |

In the analyses are, of course, included the sodium and potassium of the blood and lymph held in the excised kidney, and this constitutes a source of error, for the more blood and lymph the dog's kidney contains the lower is the proportion of the potassium to the sodium. Abderhalden's[13] analyses of dog's blood gave 0.2721 per cent. of sodium and

0.0212 per cent. of potassium. The value* Na(=100) : K of the blood would, therefore, be 100 : 7.8. The quantitative composition of dog's lymph has not been determined, but it cannot be very different from blood plasma and serum, so far as the inorganic constituents are concerned, and in the serum according to Abderhalden's analyses the sodium and potassium are 0.3175 and 0.0217 per cent. respectively, or in the proportion of 100 : 6.8.

If, therefore, the dog's kidney could, before analysis, be freed of all its blood and lymph, it would show a very considerable excess of potassium over sodium. It would be much more than ten times richer in potassium than the blood or blood plasma, while it would contain much less sodium than the blood or blood plasma.

No analyses have been published giving the composition of the blood in the frog, and consequently one cannot determine whether the retention of blood or lymph in the frogs' kidneys analyzed influenced very materially the analyses, but, on comparison with the results furnished by the analyses of the dogs' kidneys, it would appear as if there were no important difference between the two series of analyses in regard to the potassium.

The kidney is not the only organ in which potassium is richer than sodium. Katz[14] found that in the striated muscle of the dog potassium is three and a half times as abundant as the sodium, and Stoklasa[15] determined that the dried pancreas of the pig contains 2.08 per cent. of potassium and 0.28 per cent. of sodium. It is also known from Geoghegan's[16] analyses that potassium in brain tissue exceeds the sodium in amount.

In muscle certainly and probably in the pancreas the metabolic processes are very active. In striated muscle fibre Macallum has shown that the potassium is confined to the doubly refractive portion of the sarcous elements in which, there is reason to believe, the chief metabolic processes of the fibres occur. It is not at all unlikely that potassium plays a part in these processes, and that in the pancreas a similar rôle is filled by the element. In the active kidney, as shown by its consumption of oxygen, the metabolism is very pronounced, and consequently it may be suggested that here, also, the potassium so abundantly present is in some manner associated with that metabolism.

One must not, however, exclude the possibility that potassium is so abundant in tissues simply because of a special tendency to condense on surfaces of systems affected by low surface tension. From Lewis'

*Calculated from Abderhalden's values which were given for $Na_2O$ and $K_2O$ respectively.

observations already referred to, it would appear that some solutes in such systems undergo condensations differing in concentration for each solute, and potassium from its chloride condenses more than silver does from its nitrate. The relation of potassium to sodium in this respect was not investigated, but one may suspect there is a difference, perhaps an important one. This might account for the contrast between the sodium, which is 0.3175 per cent. in the serum and 0.1783 per cent. in the kidney, on the one hand, and on the other, the potassium, which is 0.0217 per cent. in the serum and 0.2356 per cent. in the kidney. The sodium is thus decreased 44 per cent., while the potassium is increased over 1000 per cent. Such a difference, as suggested, in the degree of condensation would furnish an explanation for the difference in the quantities of sodium and potassium in the plasma or serum which are in the proportion approximately of 15 to 1.

## SUMMARY.

1. The sodium cobalt hexanitrite reagent $(CoNa_3(NO_2)+{}_6nH_2O)$, as prepared by Professor Macallum, is a suitable reagent for the localization of potassium in kidney tissue.

2. It is essential that the tissue be frozen while perfectly fresh and that the sections prepared from it be kept frozen until they come in contact with the reagent.

3. There is a definite localization of potassium on the external surface of the convoluted tubules and frequently about their lumina as well.

4. The uniformity of this localization about the tubules tends to increase in direct proportion to the state of activity of the kidney.

5. In the resting condition or during ordinary activity the only potassium demonstrable in the cytoplasm of the cells of the convoluted tubules is condensed in a layer immediately adjacent to the lumen border in each cell.

6. This localization appears to be in accordance with surface tension phenomena.

7. The presence of potassium in the lumina of the tubules and absence of potassium in the glomerular cavity is evidence that the inorganic salts are excreted by the tubule cells.

8. No evidence bearing on the manner in which the glomeruli perform their function was obtained.

9. In no instance was any potassium found in a cell nucleus.

10. The amount of potassium in the kidney of the dog and even of the frog exceeds that of the sodium, and in the dog it exceeds greatly the amount of potassium in the blood or plasma.

I desire to acknowledge the kind criticism and advice which I received during the progress of this work from Professor Macallum, at whose suggestion and under whose guidance it was carried out.

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## EXPLANATION OF PLATES.

The figures were drawn with the camera lucida. The distribution of potassium salts is indicated by the black shading which represents the cobaltous sulphide reaction given by the triple salt of potassium, sodium and cobalt hexanitrite when ammonium sulphide is applied to it.

Fig. 1. Kidney tubule, frog, diuresis with $K_2HPO_4$; the potassium salts were washed out of the freshly cut section, which was then treated with the cobalt and sodium hexanitrite reagent in the usual way. × 820.

Fig. 2. Kidney tubule, frog in inanition. × 820.

Fig. 3. Kidney tubule, frog, in the dorsal lymph sacs of which ½ c.c. of 30 per cent. dextrose solution had been injected 4 hours before it was killed. The frog had previously been kept several days in a room of about 20° C. temperature. × 820.

Fig. 4. Kidney tubule of frog which had been kept for several days in warm room, then pithed and injected with 1 c.c. of half saturated $Na_2SO_4$ solution, 17½ hours after which it was killed. × 820.

Fig. 5. Kidney tubule, frog, taken from cold room (temperature about 10° C.) into the dorsal lymph sacs of which 4 c.c. of 30 per cent. dextrose had been injected four hours before it was killed. × 820.

Fig. 6. Kidney tubule of frog which had been kept for several days in warm room and into which 4 c.c. of a half-saturated solution of $Na_2SO_4$ had been injected two hours before it was killed. × 820.

Fig. 7. Cells from kidney of frog which had been subjected to excessive $Na_2SO_4$ diuresis. *a*, leucocyte; *b*, red blood cell; *c*, epithelial cell. × 820.

Fig. 8. Kidney tubules of frog into which had been injected 4 c.c. $\frac{N}{10}$ $K_2HPO_4$ and which was killed two hours later. × 820.

Fig. 9. Portions of two kidney tubules of frog in which 4 c.c. $\frac{N}{10}$ KI had been injected. Animal killed five minutes later. × 820.

Fig. 10. Portions of three kidney tubules from same preparation as Fig. 9. × 820.

Fig. 11. Kidney tubules, dog, A.C.E. anæsthesia, otherwise normal. × 820.

Fig. 12. Kidney tubules, dog, A.C.E. anæsthesia; 0.5 grm. phloridzin in 10 c.c. of a 1 per cent. NaCl solution was injected into external jugular; kidney excised as soon as urine showed glycosuric condition. × 820.

Fig. 13. *a* and *b*. Tubule of Henle's loop and convoluted tubule respectively, rabbit, pithed, and kidney immediately excised during slight A.C.E. anæsthesia. × 820.

Fig. 14. *a* and *b*. Tubule of Henle's loop and convoluted tubule respectively from rabbit from which preparation giving Fig. 13 was taken. Kidney excised 45 minutes after cord was cut; blood pressure 30 mm. Hg. 24 minutes before excision 4.5 grms. dextrose in warm water were injected into the internal jugular vein. × 820.

Fig. 15. Tubule of Henle's loop, cat, normal condition. × 820.

Fig. 16. Convoluted tubule, pigeon, normal condition. × 820.

Fig. 17. Kidney tubule, fœtal kitten. × 820.

Fig. 18. Kidney tubule, *Necturus;* gastric digestion active, animal kept in cold aquarium. × 820.

Fig. 19. Glomerulus, dog, from same animal indicated in the case of Fig. 12. × 540.

Fig. 20. Bowman's capsule, frog, from same specimen as in the case of Fig. 8. × 540.

Fig. 21. *a* and *b*. Kidney tubule, dog; *a*, surface view; *b* deeper view of same. × 820.


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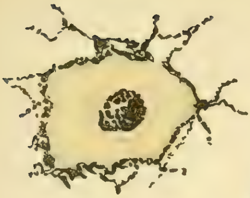

14a.

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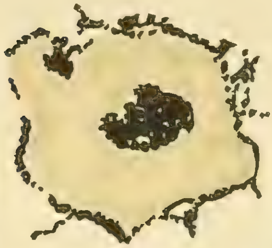

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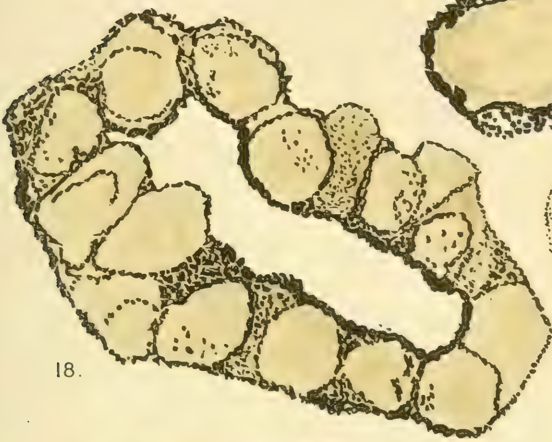

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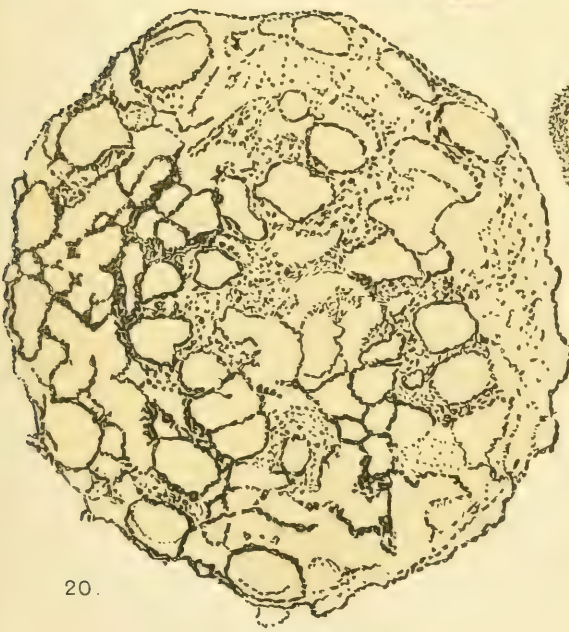

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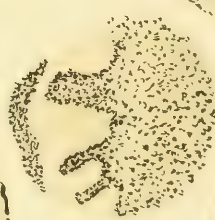

21a.

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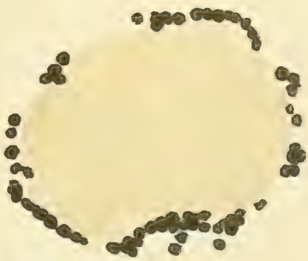

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