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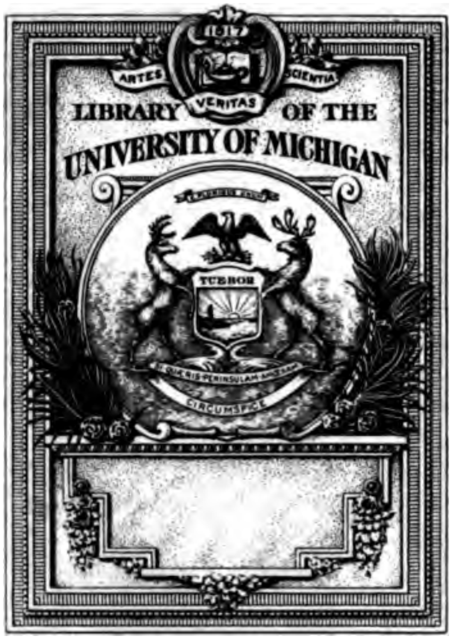
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The University of Maine
Studies

No. 1

The Effect of Magnetization
UPON THE
Elasticity of Rods

BY

JAMES STACY STEVENS
Professor of Physics

ORONO, MAINE
OCTOBER, 1900

*THE EFFECT OF MAGNETIZATION UPON THE ELASTICITY OF RODS

The relation existing between magnetization and the modulus of elasticity has been studied from a theoretical point of view for a number of years. The usual method of attacking the problem has been to note the changes that take place when ,a body already magnetized was subjected to a force which tended to bend, stretch or twist it. In 1847, for example, Matteucci. examined the change in magnetization undergone by an iron rod when twisted. Further investigations along this line have been carried on by Wertheim, Wiedemann, Kelvin and others.

The general conclusion reached by these and similar experiments has been that the amount of magnetization of a body undergoes a change when the body is subjected to any kind of deforming stress. In the experiment described in this paper the problem has been attacked from the opposite point of view. Bodies were subjected to stresses which in turn tended to bend, twist and stretch them. They were then strongly magnetized and the effects upon their elastic moduli were observed and measured.

In the PHYSICAL REVIEW, Vol. II, No. 4 and Vol. III, No. 6, is described a series of important experiments which show the relation between temperature and elasticity in a wire. In one of the papers the statement was made that the results seem to indicate that the magnetizing effect of the current through the wire increases the modulus of elasticity. The increase in temperature in the wire was produced by sending a current directly through it, and also by sending a current through the helix which surrounded it. The author stated that "the magnetization produced by the first method had no appreciable effect on the result, and that if there is any difference in the effects produced upon the elasticity of a wire by magnetizing it, that difference is too small to be detected with any certainty by this experiment."

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Mr. G. A. Shakespear (See Phil. Mag. June, 1899) while at work on another problem, reached the conclusion incidentally, "that there seemed to be an undoubted decrease in the modulus on putting on the magnetic field." He adds, however, that his observations were not quite satisfactory.

The experiments carried on in this laboratory may be divided into three parts: the effect of magnetization upon elasticity of flexion; the effect of magnetization upon elasticity of torsion; the effect of magnetization upon elasticity of traction. Considering these in the order given, the accompanying figure will make clear the method of operation. A series of carefully prepared rods, whose dimensions are given below, were in turn supported in the ordinary manner for determining the elastic modulus at points 3.2 cm. from their ends on adjustable knife-edges. In the center of the rod suspended from a hook was the load causing the deflection, and on the upper surface one of the mirrors of an interferometer. Surrounding the rod was first an air space, then a chamber for the passage of a stream of water, and on the outside two series of coils having a resistance of 54.4 ohms each. When the rod was bent by the deflecting weight the interference fringes were found in the usual manner. A sodium lamp was used as the source of light radiations. It is obvious that any change in the modulus of elasticity due to magnetizing the bar would produce a corresponding motion in the fringes seen in the mirror.

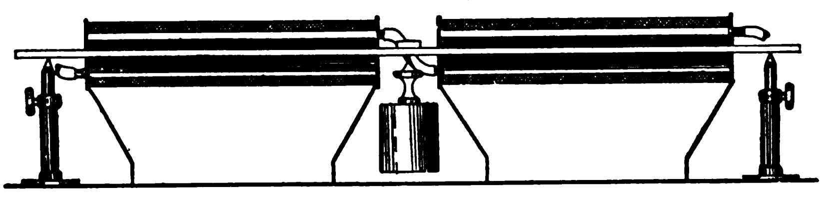


FIG. 1.

The great source of error to be guarded against in this work was the effect on the modulus due to heat. That this was eliminated will, we think, appear from the following considerations:

(*a*) A stream of water was caused to run through the chamber between the coils and the rod while the observations were made.

(*b*) The motion of the fringes appeared to be instantaneous when the current was turned on. When the circuit was kept closed for some time a creeping motion of the fringes (probably due to temperature changes) was observed.

(*c*) A copper bar of the same dimensions as those previously used was substituted, and no such instantaneous motion of the fringes was observed.

(*d*) The fringes came back to their initial position immediately when the current was turned off, when the steel rod was used.

(*e*) A thermometer reading by estimation to hundredths of a degree showed no appreciable change of temperature in the air surrounding the rod while the displacement of the fringes was being measured.

Among the difficulties encountered were:

(*a*) The arrangement of the mirrors so as to get good fringes. The conditions for producing interference were extremely unfavorable, as the adjustment of the mirror on the bar had to be made entirely by hand. It was supported on wax of such a consistency that it could be easily moved, but when once adjusted it kept its place. The difficulty here referred to, however, was one which needed only practice and patience to overcome, and whenever the observations were recorded the fringes were sufficiently distinct.

(*b*) Although the apparatus was mounted in a basement laboratory, on a stone slab supported by a brick foundation which did not come in contact with the floor or any other part of the building, a clock striking four stories above it caused a rhythmical motion of the fringes. It may be judged from this illustration that the work had to be done at such times as we could find the building free from ordinary disturbances.

(*c*) Another difficulty was encountered at first arising from the use of homogeneous light, and the consequent similarity of the fringes. With the mirror adjustments used here it would have been next to impossible to have obtained the colored fringes, which may readily be identified; but it was soon found that the displacements were never of an order of magnitude greater than one wave-length, and therefore the necessity of identification was avoided.

The following data were employed:

Length of rods,	66.3	cm.
Distance between knife-edges,	60.0	"
Breadth of rods,	1.0	"
Thickness of rods,	0.54	"
Length of magnetizing helix,	53.0	"
Number of layers of wire,	9.6	
Number of turns of wire,	7026.0	
Minimum current used,	0.12	amp.
Maximum current used,	0.82	"
Number of turns per cm.,	132.0	

In the tables which follow are shown the current, the magnetizing force, the intensity of magnetization and the accompanying displacement of the fringes. In every case the direction of displacement indicated an *upward* movement of the mirror, and hence an *increase* in the modulus of electricity.

TABLE I.

STEEL BAR. LOAD 1K.

Current in Amperes.	Magnetizing Force.	Intensity.	Displacement in Wave-lengths.
0.46	77.5	A nearly uniform intensity of about 700.	0.06
0.54	89.6		0.15
0.57	93.8		0.20
0.60	99.6		0.25
0.64	106.2		0.38
0.66	108.7		0.45
0.68	112.9		0.50
0.71	117.9		0.50
0.75	124.5		0.63

TABLE II.

STEEL BAR. LOAD ½K.

Current in Amperes.	Magnetizing Force.	Intensity.	Displacement in Wave-lengths.
0.44	73.0	A nearly uniform intensity of about 700.	0.06
0.45	74.6		0.06
0.46	77.5		0.06
0.62	102.9		0.13
0.64	106.2		0.19
0.65	107.9		0.25
0.66	109.6		0.25
0.68	112.9		0.31
0.71	117.9		0.50
0.75	124.5		0.50

Table III.

WROUGHT IRON BAR. LOAD 1K.

Current in Amperes.	Magnetizing Force.	Intensity.	Displacement in Wave-lengths.
0.12	19.9	389.7	0.08
0.15	24.9	516.5	0.22
0.27	44.9	735.2	0.28
0.33	54.1	838.2	0.35
0.38	61.3	....	0.38
0.54	89.7	....	0.48

Table IV.

WROUGHT IRON BAR. LOAD ½K.

Current in Amperes.	Magnetizing Force.	Intensity.	Displacement in Wave-lengths.
0.16	26.6	615.1	0.20
0.33	54.8	730.0	0.50
0.43	71.6	838.2	0.63
0.60	99.6	868.8	0.75
0.76	125.9	1075.0	0.88

Discussion of Results

The difficulties encountered in making these observations, and the fact that it was necessary to make them quite rapidly conspired to render the results recorded in the last columns of the tables rather unreliable as quantitative measurements. So far as practicable, however, they represent the mean of several observations taken by two persons. If they were plotted either with the magnetizing force or the intensity of magnetization they would not yield a straight line or any other regular curve. In every case, however, an increase of current was accompanied by an increased displacement. In the case of the steel bar it was necessary to keep the current within a limited range, and as shown in the tables the intensity remained nearly constant. With the wrought iron we were able to use a greater range of current and secured a greater deviation in the displacement column.

The following may be set down as the results of the experiment.

TABLE III.

Steel Rod, 183 *cm. long. Moment of Torsion* 9.8×10^7 *dynes.*

Magnetizing Force.	Scale Readings.	Angular Rotations (Minutes).	Magnetizing Force.	Scale Readings.	Angular Rotations (Minutes).
7.7	0.1	2.6	76.5	0.2	5.2
15.3	0.1	2.6	91.8	0.3	7.8
22.9	0.1	2.6	137.7	0.3	7.8
30.6	0.1	2.6	145.4	0.3	7.8
35.2	0.1	2.6	153.0	0.4	10.4
38.3	0.2	5.2	168.3	0.4	10.4
58.1	0.2	5.2	214.1	0 5	13.0
61.2	0.2	5.2			

TABLE IV.

Iron Rod, 163 *cm. long. Moment of Torsion* 9.8×10^7 *dynes.*

Magnetizing Force.	Scale Readings.	Angular Rotations (Minutes).	Magnetizing Force.	Scale Readings.	Angular Rotations (Minutes).
12.4	0.05	1.3	79.4	0.4	10.0
19.9	0.15	3.8	107.1	0.4	10.0
27.5	0.2	5.0	130.0	0.5	12.5
30.6	0.2	5.0	137.0	0.5	12.5
38.3	0.3	5.0	153.0	0.5	12.5
61.2	0.3	7.7	183.6	0.6	15.1
68.8	0.4	10.0	198.9	0.6	15.1
76.5	0.4	10.0			

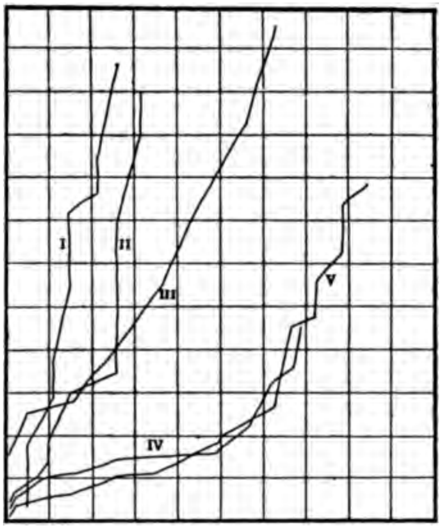
TABLE V.

Iron Rod. 183 *cm. long. Moment of Torsion* 13.6×10^7 *dynes.*

Magnetizing Force.	Scale Readings.	Angular Rotations (Minutes).	Magnetizing Force.	Scale Readings.	Angular Rotations (Minutes).
33.7	0.01	0.6	91.8	0.67	18.3
47.4	0.04	1.2	183.6	1.14	28.2
53.6	0.08	1.8	229.5	1.14	31.2
56.6	0.26	7.2	306.0	1.17	31.8
64.3	0.48	13.2	382.3	1.19	32.4
82.6	0.58	15.9	405.5	1.22	33.3

Measurements were also taken with no weight added to the arm of torsion except the small one used with the dash pot. The moment of torsion was 6.3×10^6 dynes. While a deflection was noted with each magnetizing force used, the scale readings were quite irregular and the zero not constant.

By use of the device for multiplying the scale readings, it is thought that the error in estimation need not exceed eight seconds.



The above curves were plotted with magnetizing force divided by 4 and corresponding angles of rotation expressed in minutes as co-ordinates. *I* is for the steel rod, *II* the short iron rod, *III, IV* and *V,* the longer iron rod with moments of force 13.6×10^7, 4.8×10^7 and 9.8×10^7 dynes respectively. Without doubt, the lack of regularity of the lines is due in large measure to errors of observation.

From the general consideration of the experiments, and the inspection of the tables and plots, the following conclusions may, I think, be written down:

1. Magnetization of an iron or steel rod increases its torsional elasticity. This would be expected from the results of the experiments mentioned in the first part of this paper dealing with its effects upon elasticity of flexion.
2. The effect is greater in iron than in steel rods of the same dimensions.
3. The increase in elasticity varies with the length of the rod.

In the third part of the investigation the effects upon the modulus of elasticity by traction was studied. Figure 3 shows the general form of the apparatus.

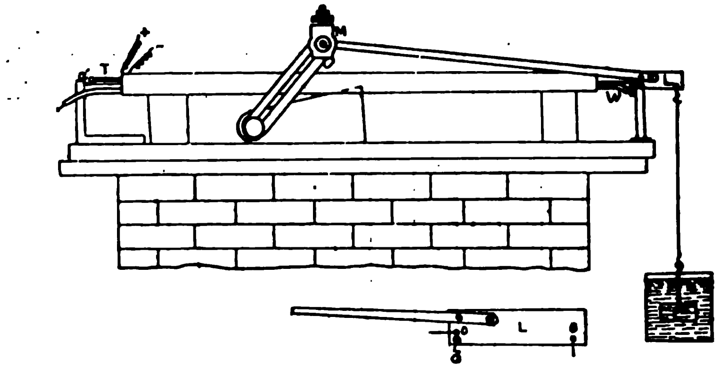


FIG 3.

A coil of wire was wound on a brass tube through which passed a stream of running water, in which was carried the wire to be tested. One end of the wire was fastened to a rigid iron support and the other was attached to a bent lever with a multiplying power of about 11. At the other end of the lever were attached weights which gave a tension on the wire of 5.39×10^6, 10.78×10^6 and 19.6×10^6 dynes respectively. The changes in length were communicated to another arm of the same lever, which multiplied the effect 110 times. The free end of this lever moved under the field of a micrometer microscope. A thermometer whose bulb was inserted in the stream of water completed the arrangement.

DATA

Length of coil	131.1	cm.
No. of turns of wire	1612.0	
Diameter of wire	0.13	cm.
Length of wire tested	175.0	cm.
Diameter of wire A	0.73	mm.
Diameter of wire B	0.98	mm.
Tension weight A	5.5	kgm.
Tension weight B	11.0	kgm.
Tension weight C	20.0	kgm.
Multiplying power of first lever	11.0	
Multiplying power of second lever	110.0	
Microscope constant 28.33 turns per min.		
Current	2.2—7.6	Amp.

The procedure consisted in setting the cross wires of the microscope on some point for zero, then turning on the current and noting the deflection of the end of the lever. The tables which follow give the current, zero readings, the difference, and the change in the length of the wire reduced to centimeters.

TABLE I.

Wire B. Tension B.

Current.	Initial Reading.	Final Reading.	Difference.	Change in Length in cms.
2.12-2.18 amps.	42	88	46	15×10^{-6}
	75	18	43	14 "
	79	10	31	10 "
	68	16	48	15 "
	82	26	44	14 "
	79	15	36	11 "
	59	92	33	11 "
	41	80	39	12 "
	4	36	32	10 "
	81	14	33	11 "
	56	5	49	15 "
	51	87	36	11 "
	41	74	33	11 "

The above table shows complete readings in order to set forth the degree of constancy which the experiment afforded. This was about an average set of readings. The tables which follow this give the mean only of a number of readings, usually about 12.

TABLE II.

Wire B. Tension B.

Current amps.	Change in Length cms.	Current in amps.	Change in Length cms.
2.62	13×10^{-6}	5.30	26×10^{-6}
3.95	16 "	6.50	48 "
4.50	20 "		

TABLE III.

Wire B. Tension A.

Current amps.	Change in Length cms.	Current amps.	Change in Length cms.
2.6	6.0×10^{-6}	4.2	12.8×10^{-6}
3.5	9.0 "	4.7	16.0 "

TABLE IV.

Wire A. Tension A.

Current amps.	Change in Length cms.
4.0 7.7	12.8×10^{-6} 25.4 "

TABLE V.

Wire B. Tension C.

Current amps.	Change in Length cms.	Current amps.	Change in Length cms.
6.9 7.1	15.0×10^{-6} 16.1 "	7.6	19.2×10^{-6}

TABLE VI.

Wire B. Tension B.

Current amps.	Change in Length cms.
6.8 8.0	10.2×10^{-6} 11.2 "

From the tables we may draw the following conclusions:

1. The modulus of elasticity of traction *increases* when the body is magnetized.
2. The increase is fairly proportional to the magnetizing force.
3. With the same wire the change in the modulus varied with the stretching weight.
4. With wires of different cross sections, stretched by the same load, the change in modulus was greater with the smaller wire.

It was considered that errors due to change in temperature were entirely avoided or reduced to negligible quantities. The stream of water in which the wires were placed kept the temperature so constant that changes greater than 0.1 degree did not occur in fifteen minutes. Moreover the change in the length of the wire due to magnetization was noted in about fifteen seconds. It may therefore be assumed that temperature changes during the time in which the observations were made were about of the order of 1-600 of a degree F. This was about ⅓ of the value of the smallest observed change. The principal test for absence of temperature effects, however, was the fact that, as in former experiments already noted, the changes in length due to magnetization are suddenly and easily distinguished from the temperature effects, which are creeping. Whatever changes may be due to temperature must of course be added to the results above given since they take place in the opposite direction. The same remarks will apply to changes in the length of the wires due to magnetization alone.

In connection with this part of the work the attempt was made to measure the effects of magnetization upon the elasticity of compression. The experiment proved an interesting one although purely negative results were obtained. A drawing of the apparatus and data for the observations follow.

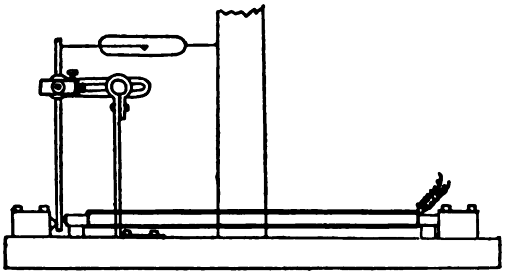


FIG. 4.

DATA

Length of rod	134.5 cm.
Diameter of rod	2.54 cm.
Resistance of coil	3.3 ohms.

Wound with No. 16 double cotton covered magnet wire 1830 turns.

Ratio of power arm	1 to 120.
Ratio of index	1 to 106.7

Constant of micrometer microscope, 28.33 turns to 1 mm.

The tables which follow are self explanatory.

The University of Maine Studies

No. 2

The Life-History of Nucula delphinodonta (Mighels)

BY

GILMAN ARTHUR DREW

Professor of Biology

ORONO, MAINE
November, 1901

The University of Maine
Studies

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BY

GILMAN ARTHUR DREW
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(Reprinted from the Quarterly Journal of Microscopical Science, Vol. 44, Part 3, 1901, pages 313-391.)

ORONO, MAINE
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THE LIFE-HISTORY OF NUCULA DELPHINODONTA (MIGHELS).

The material upon which these observations were made was secured at Casco Bay, Maine, during the summers of 1897 and 1898. Nucula delphinodonta is a small form, seldom growing to be more than 4 mm. in length, and as it lives below low-tide mark it is not very well known by collectors. By using a sufficiently fine dredge, however, unlimited numbers of adult and young specimens may be procured. Individuals may be found living under very different conditions; in inlets and protected places, and exposed to the open sea, and from near low-tide mark to a depth of several fathoms. The principal habitat, however, is in the shallow inlets and near the heads of sounds, where the bottom is composed of fine mud, mixed with some sand, broken shells, and decaying vegetable matter. Individuals are most numerous just outside of the eel grass which skirts the shore where the bottom is of this character, in water which at low tide is from one to three fathoms deep. The mud in which they live is much like that inhabited by Yoldia limatula, except that it is not so free from shore débris. Although some specimens may be obtained where Yoldia is most abundant, they are generally more numerous somewhat nearer the shore, and they may be very numerous at considerable distances from places where Yoldia is known to thrive.

In picturing the conditions under which these animals live along the coast of Maine, the reader should not fail to take into account the average tide of about ten feet, which keeps the water very pure over a comparatively foul bottom. The fauna and flora of these bottoms are very abundant and diversified, but have not been carefully catalogued. Diatoms of several species abound, and form a large part of the food of Nucula. Other Algæ, Ostracods, Foraminifers, small Lamellibranchs, and Gastropods are also very abundant, and small individuals of most of these forms are occasionally found in the stomachs of preserved specimens.

While I have never succeeded in getting individuals to form brood-sacs in captivity, they live well in aquaria, and may be kept for several weeks either in vessels containing the mud in which they normally live, or in vessels without this mud. It is not even essential that the water be changed very frequently.

When placed in vessels containing mud they bury themselves, and seem never to come to the surface to stay for any considerable time. They are at all times comparatively sluggish, and seem to wander around in the mud by slow thrusts and retractions of the foot, which is a very perfect burrowing organ. When placed in mud that is just sufficiently deep to cover them, their movements can be followed fairly well by the movements of the mud. To see them feeding it is necessary to use only a very thin layer of mud. The action of the palp appendages can then be observed. They perform the same function that is performed by similar appendages on the palps of Yoldia (1), that is, they are food collectors. Nucula delphinodonta seem normally to feed beneath the surface of the mud, so feeding cannot be observed as easily as it can be in the case of Yoldia (text-fig. T).

The movements of the foot are best observed by placing specimens in shallow dishes of sea water. When specimens are placed on mud they bury themselves so promptly that the movements of the foot cannot be carefully followed. The movements are all such as would be of service in burrowing in mud. Although specimens have been kept under observation under different conditions for long periods of time, I have never known one to execute movements that could be interpreted as creeping. In 1853 Forbes and Hanley, in describing Nucula nucleus (4), made the following statement:—"The foot is white, and as if pedunculated and deeply grooved, so as to expand into a broad leaf-shaped disc with serrated margins; by means of this organ it can creep like a Gasteropod, and we have seen it walk up the sides of a glass of sea water." This seems to be the only observation of this kind on record, although many students have worked on this and related forms. The authors who have adopted the view that the foot functions as a creeping organ in members of this group have, in nearly every case, had only preserved material to work upon, and perhaps have been influenced by finding so many characters that seem to them to denote generalised structure. Some Lamellibranchs are able to pull themselves over smooth surfaces, but my observations lead me to believe that the form and structure of foot found in this group is especially poorly adapted for such a purpose (3). The expanded foot of Nucula delphinodonta is relatively very large, and the almost spherical shell is frequently turned from one side to the other, but nothing comparable to creeping has been observed.

Although many Lamellibranchs carry their eggs and developing embryos, I think this is the first case reported where a special external sac is formed for the purpose. This sac (fig. 1) is composed of a mucus-like material, mixed with foreign bodies, and is attached to the posterior ends of the valves of the shell. Although the process of making the sac has never been observed, it seems probable that the mucus-like material is secreted by the hypobranchial glands. This material is probably passed posteriorly by the action of the cilia on the mantle, and very likely the respiratory currents of water swell it into a sort of bubble that remains attached to the posterior ends of the shell-valves, and, while still soft, adheres to the foreign particles with which it comes in contact.

That the hypobranchial glands are concerned in the formation of the material from which the brood-sac is formed is indicated by their appearance before and after the sacs have been formed. In females in which the ovaries are still full of eggs, the cells of the hypobranchial glands are large and gorged with secretions, while in females that have formed the brood-sacs the cells are shrivelled and almost devoid of secretions.

The eggs are deposited in the brood-sac (fig. 1), and in it the embryos are carried until they reach an advanced stage in development, probably for a period of three or four weeks.

The eggs of this species are brown, opaque, few in number, and correspondingly large. From about twenty to seventy may be found in a sac, and they average about .21 mm. in diameter. Each egg is enclosed in a membrane that is probably secreted by the egg, but its formation has not been observed. Fertilization is probably accomplished in the brood-sac. Eggs and young embryos do not live well after they are removed from the brood-sacs, so the ages of the various stages have not been determined. Processes of maturation and cleavage proceed slowly. The time between the appearance of the first and the second polar body is frequently as much as two hours, and the time between cleavages seems to be nearly or quite as long. It is not beyond doubt, however, that the removal of the eggs from the brood-sacs influenced the length of time. That development is slow is not to be doubted. Embryos taken from the brood-sacs of specimens kept under as nearly natural conditions as possible for a month, had only reached the stage where two gill-lobes were formed.

It seems probable that the polar bodies may be formed by eggs that have not been fertilised. Eggs were sometimes obtained that formed polar bodies and developed no further.[1]

Just before each polar body is formed, a more or less distinct, and frequently a very pronounced swelling, makes its appearance on the side of the egg opposite the point where the polar body will appear. In the preparation for the first cleavage a similar swelling is formed on the side opposite the polar bodies. When the egg divides, the dividing wall passes to one side of this swelling. The two blastomeres are accordingly rather unequal in size. The difference in the size of the two blastomeres seems to depend upon the size of the swelling that precedes their formation. Cleavage into four and eight cells (text-figs. C and D) are typical. The polar bodies retain their position on the animal pole until the embryo acquires cilia, when they are rolled around on the inside of the membrane. No attempt has been made to follow out the fate of the individual cells.

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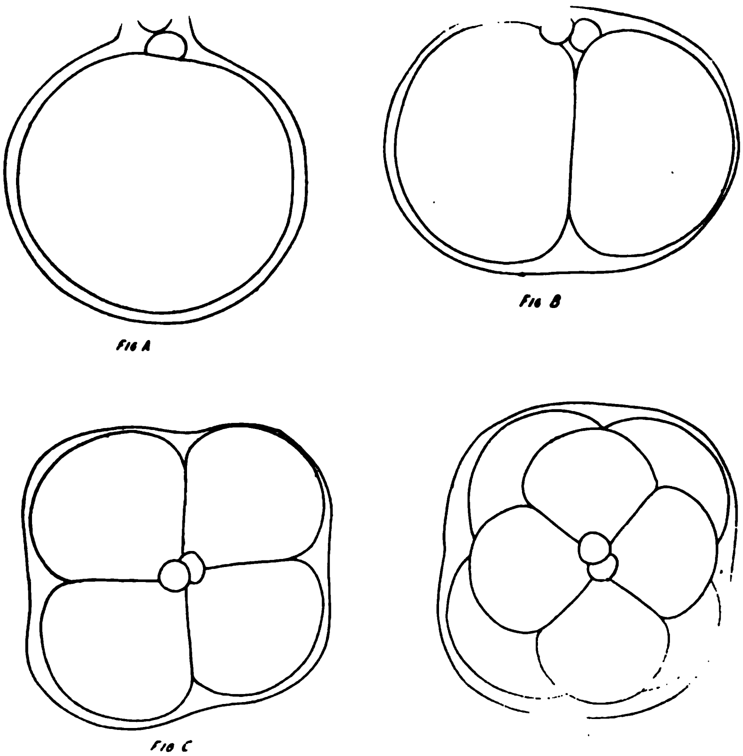
[1] Most of the eggs of an isolated specimen of Nucula proxima, a form that throws its eggs free into the water, formed the polar bodies, and a few eggs cleft the first time. It is possible that some sperm were in the water, but the water had not been changed for nearly twenty-four hours before the eggs were laid, and sperm of this species do not seem to retain their vitality for nearly so long a time.



TEXT-FIGS. A, B, C, and D.—Early stages in the development of Nucula delphinodonta.

In the sixteen-celled stage (figs. 2 and 3) a small cleavage cavity is present. Later this becomes slightly more pronounced. The cells on one side of the blastula divide more rapidly than those on the other side, and push over them in the form of a cap (fig. 4). A pocket appears between the large cells at such a point as is indicated by the asterisk in fig. 4. Just how this pocket is formed is still a matter of some doubt, but it seems to be formed by the separation and division of some of the larger cells. This pocket (fig. 8) can now be compared with the invaginate portion of a gastrula. It represents the first appearance of the gut.

About the time that the pocket is formed most of the smaller surface cells acquire cilia (fig. 6), and the embryo begins to roll around in the membrane. The cilia are all short, similar in appearance, and seem to be evenly scattered over the surfaces of the cells. In whole mounts the boundaries of the surface cells are not very distinct, but the cells do not seem to have a very definite arrangement.

From these small surface cells, that at this stage appear very much alike, the test,[1] the apical plate, and the cerebral ganglia are formed.

The large cells near the blastopore do not bear cilia, at least none could be found on preserved specimens. They are concerned in the formation of the shell-gland.

The embryo is still nearly spherical, and so opaque that, while alive, internal changes cannot be followed. A few cells, probably the beginning of the mesoderm, lie above and by the sides of the gut. About this time some of the surface cells around the blastopore divide, and push in to form a stomodæum. Other cells near the blastopore become enclosed by the surface cells, and together with cells probably derived from those forming the stomodæum, finally form a portion of the new ectoderm, that soon covers the body of the embryo inside of the test. When the ectodermal layer is complete it joins, but does not enclose, the stomodæum. In position as well as origin the stomodæum is ectodermal.

Before the ectodermal layer is complete the embryo begins to elongate, and the surface cells close in over the shell-gland from the sides and anterior end. At the same time the surface cells become arranged in rather definite rows. It is very difficult to get satisfactory views of these cells in whole mounts, but there seem to be five rows, beside a group at the anterior end that forms the apical plate. Two or three of the posterior rows are interrupted in the region of the shell-gland, but this interruption disappears as the shell-gland becomes closed in. Closing is never complete. A small opening is left dorsal to the blastopore, separated from it by the width of one test cell (fig. 15). The

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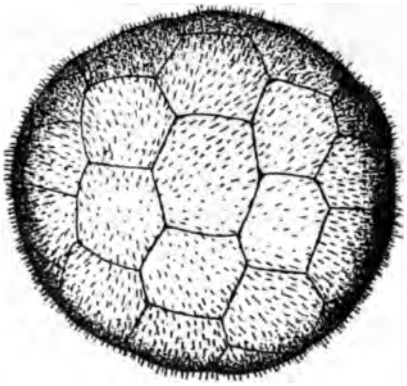
[1] I use the term "test" here, as in former publications, to designate the surface cells that bear cilia and may be homologized with the velum of other forms.

anus comes to lie near this opening at a later stage (fig. 24). Before the shell-gland is covered, the gut turns toward the dorsal side (fig. 11, *mg.*), and the mesoderm cells take up a position near the posterior end of the embryo. Two of the mesoderm cells are large, and have very large and conspicuous nuclei. These cells are far posterior, and lie side by side.

Soon after the shell-gland is covered, the gut begins to grow posteriorly, almost, if not quite, in contact with the shell-gland dorsally, and separated from the stomodæum ventrally by a few mesoderm cells (fig. 15). A small space appears among these mesoderm cells, which later becomes connected with a space that is formed between the gut and the shell-gland.

At no stage in its development is the shell gland invaginated. From the time of its formation it arches dorsally to some extent (figs. 7 and 9, *sg.*). Just before it becomes covered by the test it flattens somewhat (figs. 11 and 12), but it soon arches dorsally again and becomes quite convex (fig. 17, *sg.*).

The cells that give rise to the cerebral ganglia are few in number (fig. 15, *cg.*), and lie ventral to the anterior end of the stomodæum. They frequently come to the surface, but they may be entirely covered by test cells. A more or less distinctly recognisable test cell lies between the cerebral ganglia and the apical plate, but beneath this test cell the the cerebral ganglia and the apical plate are in contact. The two cerebral ganglia seem to

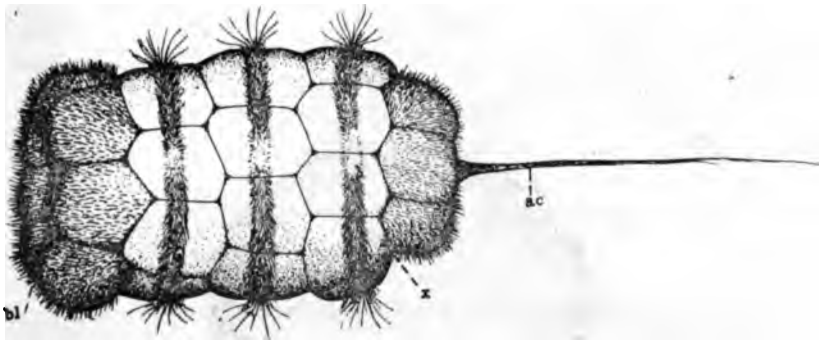


TEXT-FIG. E.—Surface view of a young embryo of Nucula delphinodonta.

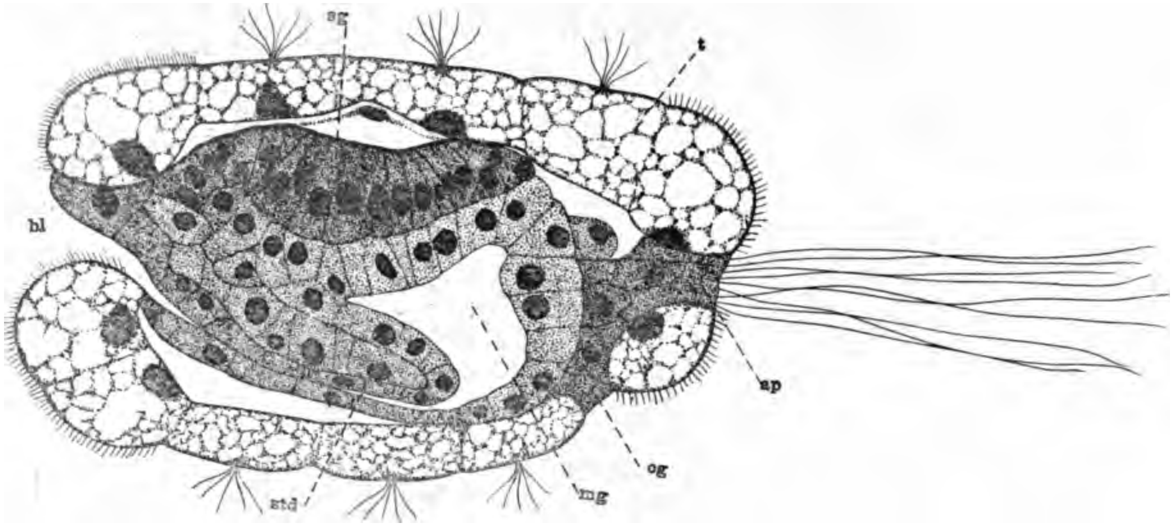
originate from a single mass of cells. There is no indication of the formation of cerebral pouches, as in Yoldia (text-fig. V). The position occupied by the developing body of Nucula does not make it necessary for the cerebral ganglia to shift their position from the point of their formation until the test is shed.

The apical plate is composed of a number of cells, the walls of which are rather indistinct (fig. 15, *ap.*). They bear cilia that in size and distribution resemble those that cover the test cells.

Under favourable conditions the test cells can be seen to be arranged in five rows; occasionally part of a sixth row is present. As in other stages, the boundaries between the test cells are poorly marked, and it is quite impossible to sketch them accurately. Text-fig. E shows their general arrangement, but it must be understood that this is quite diagrammatic. The cilia on the test cells of this species are not collected into bands as they are in Yoldia (text-fig. F), but are evenly scattered over their surfaces. The embryo becomes free from the egg membrane about the time that the shell-gland becomes covered by the test, but the cilia are barely powerful enough to move the embryo slowly on the bottom of a dish. The absence of the bands of cilia, and of the long tuft of apical cilia, is probably due to the protected life of the embryo. Nucula proxima lays its eggs free in the water, where they are fertilised and develop. These embryos have to shift for themselves, and are very active. Here, as in Yoldia, the cilia on each of the three intermediate rows of test cells are



TEXT-FIG. F.—Surface view of a forty-five hour embryo of Yoldia limatula. *ac.* Apical cilia. *bl.* Blastopore. *x.* Depression where the cells that form the cerebral ganglia come to the surface.



Text-fig. G.—Median sagittal section of a thirty-six hour embryo of Yoldia limatula. *ap*. Apical plate. *bl*. Blastopore. *cg*. Cells from which the cerebral ganglia are formed. *mg*. Mid-gut. *sg*. Shell-gland. *std*. Stomodæum. *t*. Test.

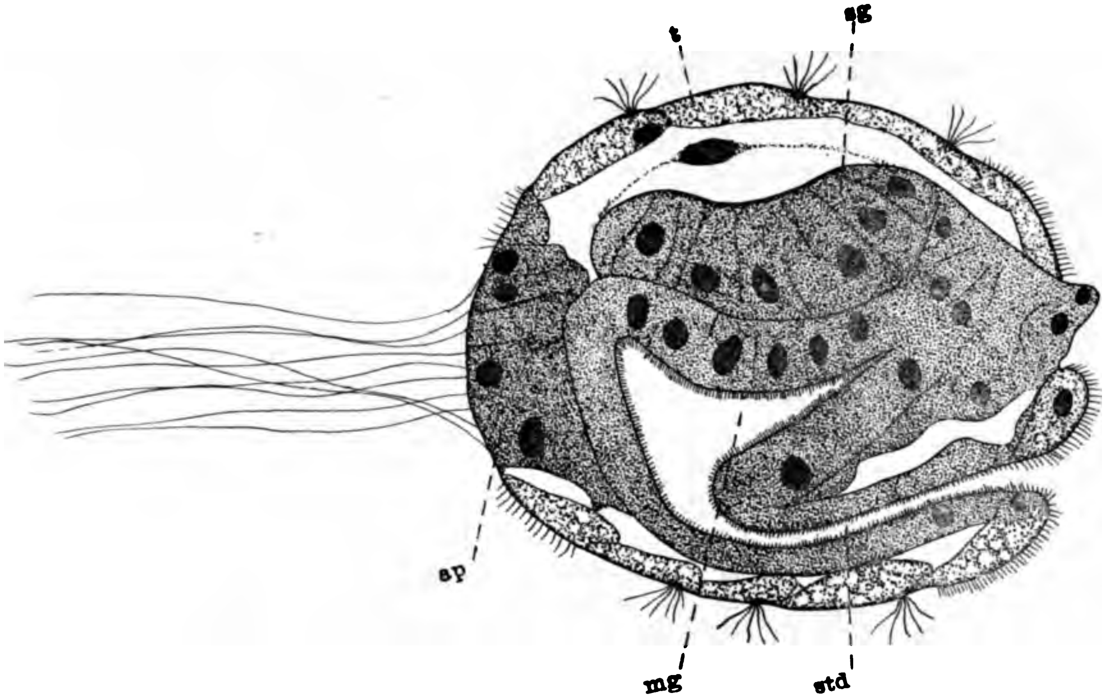
long and collected into a band (text-fig. H). Sometimes part of a fourth band is present. The end rows of test cells have the cilia evenly scattered over their surfaces. The apical cilia are long and bunched into a sort of whip that precedes the embryo when it swims. In fact, the embryo resembles that of Yoldia so closely that, except for a difference in size and a slight difference in shape, a description of the surface appearance and movements of one will do very well for the other also.

The cilia on the embryos of Nucula delphinodonta may then be regarded as arrested in their development. Life in the protecting brood-sac makes active locomotion unnecessary and even dangerous, inasmuch as active embryos would be likely to find their way out of the brood-sac, and so be exposed to outside dangers.

The embryos continue to elongate and begin to flatten slightly laterally (fig. 23). In the living embryo, viewed by transmitted light, this stage is marked by the appearance of a light spot near the dorsal margin. A smaller, much less distinct light spot has been present near the ventral margin for some time, and corresponds in position to the cavity that was mentioned as appearing in the mesoderm, ventral to the gut. This space has enlarged considerably (fig. 24), but is covered laterally by rather thick walls of ectoderm and by some mesoderm, so it is not very distinct. The dorsal space is formed by the arching up and flattening out of the cells of the shell-gland, which are now beginning to form the mantle lobes (fig. 20). It is bounded dorsally, laterally, and posteriorly by the mantle, anteriorly by the mantle and the apical plate, and ventrally by the gut and by the body-wall. A few cells, apparently mesodermal, lie in this space, generally attached to the mantle or to the gut.

At a little later stage (fig. 25) two fibre-like cells stretch from the anterior end of the gut posteriorly and dorsally to the mantle. They are quite conspicuous in living embryos, and they retain their position until after the test is thrown away.

About this stage the gut, which has grown posteriorly, acquires an anus (fig. 24). The anus is not directly applied to the pore that opens between the test cells, but it opens into a cavity that is continuous laterally with that portion of the embryo



TEXT-FIG. H.—Median sagittal section of a twenty-five hour embryo of Nucula proxima. *ap*. Apical plate. *mg*. Mid-gut. *sg*. Shell-gland. *std*. Stomodæum. *t*. Test.

that, as the mantle continues to grow, becomes the mantle chamber. This communication will be described in a later stage.

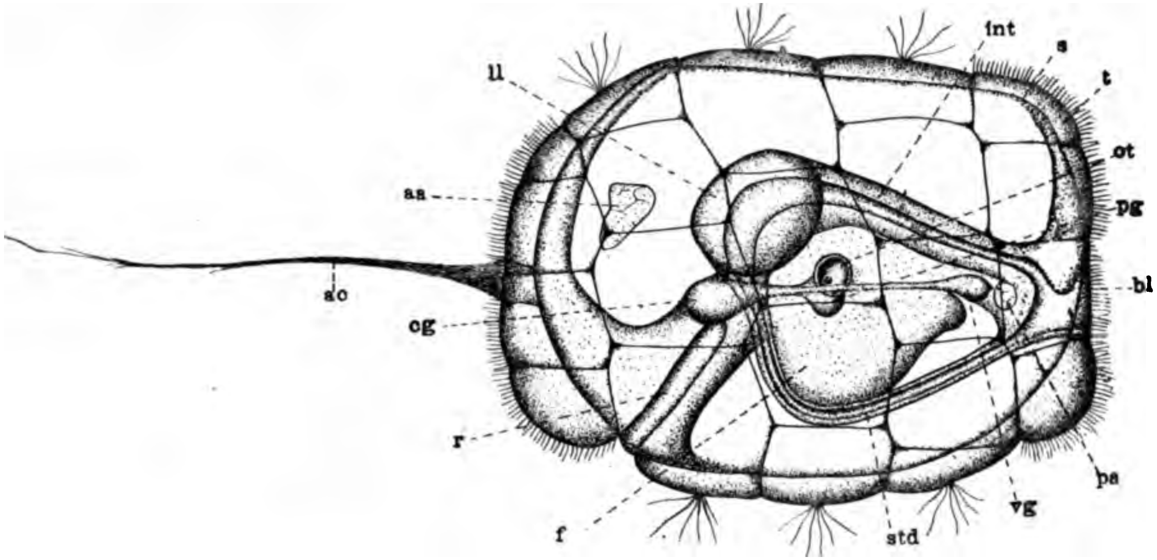
The embryo flattens laterally until its thickness equals about two-thirds of its dorso-ventral width, and the dorsal space becomes considerably enlarged (fig. 25). Near the anterior end of this space the anterior adductor muscle (*aa.*) makes its appearance. At first it consists of a very few fibres, and is not conspicuous. The anterior enlarged portion of the gut takes on the distinctive characters of the stomach (*sto.*), and the liver grows out as paired right and left pouches (*l.*). The anterior end of the stomach is carried dorsally, and a more or less distinct bend is made where it joins the intestine.

The relationship of the various cavities in the embryo to each other, and of the anal pore in the test to the mantle chamber, can be best understood by comparing the sagittal, horizontal, and tranverse sections of embryos, represented on Plate 22, with the reconstruction of an embryo at the same stages of development (Plate 21, fig. 25). The position of the horizontal and transverse sections are indicated on fig. 25 by numbers that correspond to the numbers of the figures.

The dorsal cavity is separated from the ventral cavity by the gut (fig. 28). In some sections the two cavities communicate around the sides of the gut. This may be due to shrinkage, but it seems more likely that the two portions are parts of a single cavity. It is just possible that the cleavage cavity never entirely disappears, and that this cavity can be traced back to the blastocœle, but I am of the opinion that it is a later formation, and represents a schizocœle. Its fate is of interest, and will be referred to in later stages.

The lobes of the mantle are now well formed, a distinct shell-cuticle has been secreted, and some lime salts have been deposited. The stomodæum for most of its length is joined, but is not enclosed by the body ectoderm (fig. 28), which in this region forms the walls of the foot (*f.*). Near its external opening the stomodæum has become free, and is more or less closely joined to the test cells.

The relation of the anal test pore to the mantle chamber can now be understood. As shown by a sagittal section (fig. 26), this pore opens into a small cavity that receives the anus. This



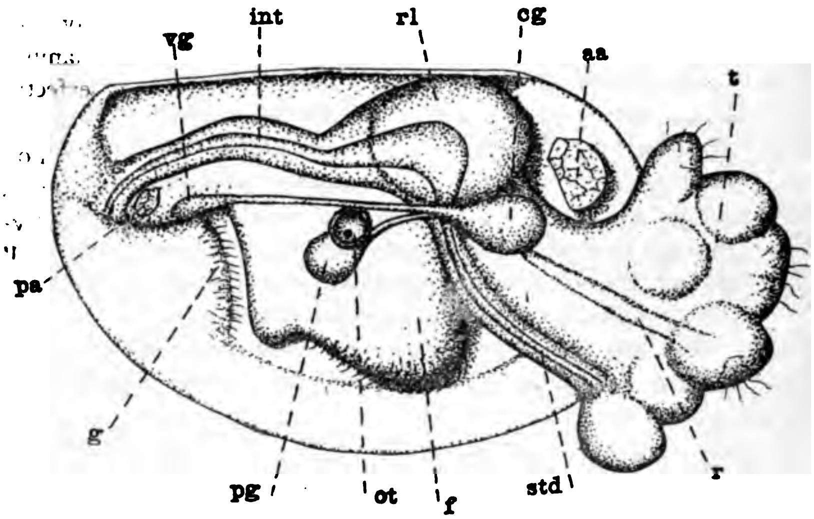
TEXT-FIG. I.—Reconstruction of an embryo of Yoldia limatula at a stage just before the test is cast off. The embryo is seen from the left side. Specimens are .2 mm. long without the apical cilia. *aa.* Anterior adductor muscle. *ac.* Apical cilia. *bl.* Blastopore. *cg.* Cerebral ganglion. *f.* Foot. *int.* Intestine. *ll.* Left lobe of the digestive gland. *ot.* Otocyst. *pa.* Posterior adductor muscle. *pg.* Pedal ganglion. *r.* Pouch leading from the surface to the cerebral ganglia. *s.* Shell. *std.* Stomodæum. *t.* Test. *vg.* Visceral ganglion.

cavity is bounded anteriorly by the posterior wall of the ventrally either by the stomodæum or by cells covering portion of the stomodæum. Transverse (fig. 27) and hori (fig. 31) sections show that this cavity spreads out laterall becomes continuous with that portion of the mantle cha posterior to the foot. At this stage the foot is very imp formed, and contains the cavity that has been referred to as the ventral cavity. The cavity soon disappears, and the ectoderm on the two sides of the foot fuse ventrally, dorsal to the stomodæum. The foot is still very small, and shows no sign of its future activity. At a corresponding stage the foot of Yoldia is quite well developed (text-fig. I). This is about the condition of the embryo when the test is thrown away.

It takes several hours for embryos of this species to cast the test, a process that with Yoldia limatula and Nucula proxima is completed within a very few minutes after it is begun. The test cells in the region of the anal pore break apart, and the whole mass is frequently pushed forward to the region of the apical plate. This stripping forward carries the outer end of the stomodæum forward to some such position as is shown by fig. 34. The cilia on the test cells remain feebly active for a considerable time. While the test cells, stomodæum, and apical plate still adhere to the embryo, the stomach and liver pouches are drawn some distance dorsally into the schizocœle (fig. 34, *sto.* and *l.*). Whether the fibres extending from the stomach to the mantle are important in effecting this movement is not known. Their position is suggestive, but I have no direct evidence that they contract. The position now occupied by the stomach causes the bend where the intestine joins the stomach to become quite abrupt.

At the same time that the stomach moves dorsally, the cerebral ganglia (fig. 34, *cg.*), which are still a mass of rather undifferentiated cells, are carried up, and come to lie posterior and a little ventral to the anterior adductor muscle (*aa.*). The foot (*f.*) retains its position beneath the intestine and stomach, and in the general dorsal movement is carried a little further from the margin of the shell. A similar stage for Yoldia is represented by text-fig. J. At the end of several hours the stomodæum

(std.) breaks across near the tip of the foot, and together ical plate and the remnants of the test cells is thrown from appearances I am inclined to believe that the whole of the apical plate is thrown away, but this may not be the case. The test cells may or may not remain attached to the apical plate and stomodæum until these are thrown away. Generally many of them break loose or go to pieces before this change occurs, but some of them nearly always remain.



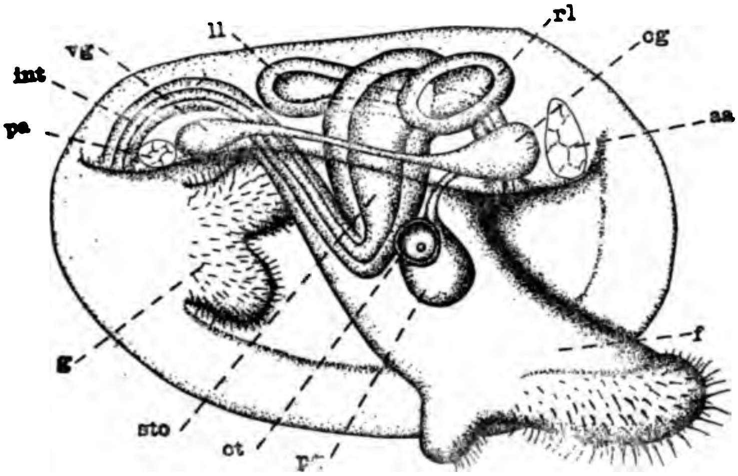
TEXT-FIG. J.—Reconstruction of an embryo of Yoldia limatula at a stage during casting. Represented as seen from the right side, with the right shell-valve and mantle lobe removed. *aa.* Anterior adductor muscle. *cg.* cerebral ganglion. *f.* Foot. *g.* Rudiment of gill. *int.* Intestine. *ot.* Otocyst. *pa.* Posterior adductor muscle. *pg.* Pedal ganglion. *r.* Pouch that leads to the cerebral ganglia. *rl.* Right lobe of the digestive gland. *std.* Stomodæum. *t.* Adhering test cells. *vg.* Visceral ganglion.

After casting is completed (fig. 35) the stomach (*sto.*) and the liver lobes (*l.*) are drawn further into the schizocœle, and the liver lobes begin to be flattened out against the mantle. The cerebral ganglia (*cg.*) lie almost directly posterior to the anterior adductor muscle (*aa.*), and the ectodermal thickenings that result in the formation of the pedal and visceral ganglia soon begin to form (fig. 36).

Thus far in the development of the animal the shell-valves have remained gaping, but after the removal of the apical plate and the stomodæum they are free to close. This is effected by the contraction of the anterior adductor muscle, and materially diminishes the space between the shell-valves.

The closing of the shell is accompanied by important changes in the liver pouches, changes similar to those that have been described for Yoldia (1). Apparently as the result of the mechanical pressure, the liver pouches go to pieces, and the large cells of which they were composed become rounded and scattered through most of the schizocœle (fig. 36, *z.*). The posterior portion of the schizocœle is not filled by the scattered liver-cells. This persists and finally becomes the pericardium.

The foot (fig. 39, *f.*) grows and soon executes feeble movements. The pedal ganglia (*pg.*) and visceral ganglia (*vg.*) take on definite form; the posterior adductor muscle (*pa.*) appears; and the invaginations that result in the formation of the



Text-fig. K.—Reconstruction of a ten-day embryo of Yoldia limatula. Represented as seen from the right side with the right shell-valve and mantle lobe removed. *aa.* Anterior adductor muscle. *cg.* Cerebral ganglion. *f.* Foot. *g.* Gill. *int.* Intestine. *ll.* Left lobe of the digestive gland. *ot.* Otocyst. *pa.* Posterior adductor muscle. *pg.* Pedal ganglion. *rl.* Right lobe of the digestive gland. *sto.* Stomach. *vg.* Visceral ganglion.

otocysts are formed. Very possibly commissures connect the ganglia at this time, but I have not been able to distinguish them from the surrounding tissue until a somewhat later stage. A thickening on the inner surface of the posterior end of each lobe of the mantle indicates the beginning of the formation of the gill (fig. 39, *g.*).

About this time a little invagination on the mid-line of the ventral portion of the foot, just anterior to the heel-like projection, makes its appearance (fig. 39, *bg.*). This develops into the byssal gland. It grows rapidly until it becomes proportionately very large (fig. 45, *bg.*), then ceases to grow, and possibly shrinks somewhat. In the adult it is comparatively insignificant (fig. 48). No signs of byssal threads have ever been observed, nor have the secretions ever been seen to protrude from the duct of the gland.

The foot grows rapidly, and the projection that looks like a heel becomes more marked (fig. 40, *f.*). Anterior to this projection the sides grow ventrally faster than the intermediate portion, and finally form the side flaps that are so characteristic of the foot of the adult. Movements of the foot now become energetic.

The gill (fig. 40, *g.*) becomes more pronounced, and soon unequal growth causes it to be divided into two lobes. The dorsal wall of the stomach re-forms, and the liver-cells begin to be rearranged. The commissures between the ganglia are distinctly visible. The otocysts (*ot.*) are quite large, and contain granules. Although adults have canals leading from the otocysts to the exterior, I have not been able to demonstrate their existence in this or somewhat older stages. The presence of the otocystic canal had been explained (13) as the persistent opening of the otocyst, which was formed as an invagination from the surface of the body. This seems to be the natural explanation, but if canals are present at this stage they are certainly very small. I am inclined to regard the exceedingly small size or absence of these canals as evidence against the view that the otoliths are foreign particles.

Thus far most of the embryos have been carried in the brood-sacs, but many of them now become free. They are not set free by any act of the mother, but they individually find their way into the mantle chamber of the mother and so to the exterior.

Frequently younger embryos become free, but they generally do not live long. Many embryos remain in the brood-sacs until a much later period, but they do not seem to be in need of its protection after the stage that has just been described. The brood-sacs frequently remain intact after all of the embryos have left them.

The more dorsal of the gill lobes elongates into a finger-like process, and the ventral lobe broadens and becomes divided into two lobes (fig. 41, *g.*). New lobes are thus formed as the result of unequal growth of the most ventral lobe.

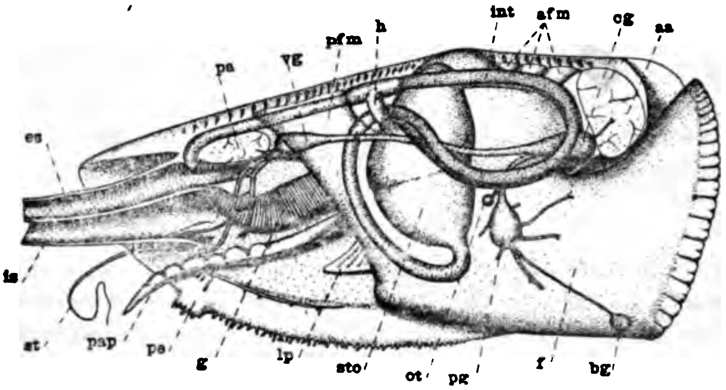
About the time that the third lobe of the gill begins to form, a few papillæ appear along the margins of the side flaps of the foot (fig. 41, *f.*). The liver lobes also become hollowed out and lose most of the rounded cells. Part of these cells seem to go to pieces much as if digested (fig. 43), and it seems quite possible that this is the case.

The heart (fig. 41, *h.*) is apparently formed from mesodermal tissue that collects to form a strand, that runs across the pericardium from one side to the other. I have found no indication of its being formed as paired pouches, as described by Ziegler (20) for Cyclas cornea, nor have I found any evidence that it originates as two masses that grow toward each other. Its first appearance seems to be in the form of a mesodermal strand of tissue that soon hollows out and encloses the intestine. The fact that the heart forms around the intestine, and not dorsal to it, is of interest, and will be discussed under the head of the Circulatory System.

The growth of the kidneys, which are now present as small tubes, seems later to force the sides of the heart up around the intestine (fig. 68), so that the ventral portion of the ventricle becomes drawn out into a trough in which the intestine lies. As the kidneys grow the trough becomes deeper. By gradually closing in dorsal to the intestine at the anterior and posterior ends, the trough is shortened, and the intestine finally becomes free from the heart and lies ventral to it (fig. 69). This is accomplished by a very slow process, and is not completed until after the animal has become sexually mature.

I am inclined toward the opinion that the kidneys are formed by the differentiation of mesodermal tissue. When they first appear each is a very narrow tube, and extends from its external opening in the mantle chamber to the mid-line of the body. I have not succeeded in demonstrating the inner, pericardial openings, of the kidneys in this or in later stages. The cells soon become large and vacuolated, and the kidneys grow rapidly and crowd anteriorly ventral to the pericardium, where they become coiled and sacculated.

With the formation of the fourth lobe of the gill (fig. 45) processes make their appearance on the bases of the lobes, between them and the mantle lobe to which the gill is attached. These processes grow to form what have been called the outer gill plates, but in this species their position is better described as posterior than outer. The lobes, at the bases of which the outer plates are formed, develop into the inner plates. Viewed from the side, both sets of plates are visible. The gills of Yoldia hang so that in a side view the outer plates hide the inner plates, which lie directly behind them (text-fig. L). When viewing Nucula from the side we see that portion of the gill that corresponds to the ventral portion in Yoldia.



TEXT-FIG. L.—Adult specimen of Yoldia limatula. Represented as seen from the right side. Reconstructed to show internal organs. Fully grown specimens may be 6 cm. long. *aa*. Anterior adductor muscle. *afm*. Anterior foot muscles. *bg*. Byssal gland. *cg*. Cerebral ganglion. *es*. Exhalant siphon. *f*. Foot. *g*. Gill. *h*. Heart. *int*. Intestine. *is*. Inhalant siphon. *lp*. Labial palp. *ot*. Otocyst. *pa*. Posterior adductor muscle. *pap*. Palp appendage. *pe*. Posterior expansion of the margin of the mantle. *pfm*. Posterior foot muscle. *pg*. Pedal ganglion. *st*. Siphonal tentacle. *Sto*. Stomach. *vg*. Visceral ganglion.

The labial palps appear as patches of cilia on embryos with three gill lobes (fig. 41). The outer palps soon begin to grow out as flaps (fig. 45, *lp.*), and by the time that the fifth pair of gill plates are formed the inner palps are present as folds. The formation of the ridges on the ciliated surfaces of the outer palps begins with embryos having six pairs of gill plates, and the palp appendages are formed soon after (figs. 55 and 56). The development indicates that each palp appendage (fig. 56, pap.) is to be regarded as a pair of ridges with an enclosed groove, developed and modified so that it may be extended beyond the edges of the shell.

Little remains to be described in this general sketch of the development, further than to call attention to the formation of the loops of the intestine, that are indicated in different stages of development by text-figs. M to S; to the formation of the cartilage pit and teeth on the valves of the shell; to the formation of more gill plates and foot papillæ as these organs continue to grow; to the appearance of the otocystic canals about the time that the sixth pair of gill plates are formed; and to the formation of the genital organs.

Mention should be made of a peculiar closed pouch (figs. 40, 48, and 63, *v.*), of unknown function, that lies just anterior to the anterior adductor muscle. It makes its appearance in embryos that are just getting the second gill lobes, and is fairly conspicuous in adult animals.

GERM LAYERS.

An almost spherical embryo is formed as the result of the first few cleavages (fig. 5), the cells on one side of which are much larger than those on the other side. The large cells extend far into the interior of the embryo, and the smaller cells form a cap over the larger ones (fig. 4).

In reaching this stage of development the embryo has passed through a blastula stage, in which the cleavage cavity was very small (fig. 3). As the cells become arranged in the manner described, the greater part of the cleavage cavity disappears. It has not been determined whether any of it remains or not. A depression appears near one side of the group of larger cells at a point corresponding to the asterisk in fig. 4. This depression seems to be formed by the separation and further division of some of the large cells, and results in the formation of the gut (fig. 8, *mg.*).

The surface cells may now be regarded as ectoderm, and at least two kinds may be distinguished: small ones, which finally form the test, the apical plate, the cerebral ganglia, the stomodæum, and a considerable portion of the future ectoderm of the embryo; and large ones that form the shell-gland.

The endodermal pouch is carried further into the interior by the division and pushing in of ectodermal cells in the region of the blastopore (figs. 9 and 11, *mg.*). In this way a long stomodæum is formed on the ventral side of the developing embryo. The ectodermal covering of the later embryo, exclusive of that derived from the shell-gland, seems to be formed in connection with the formation of the stomodæum, by cells that wander in from the region of the blastopore, and perhaps from the cells derived from the stomodæum itself.

About the time that the stomodæum begins to form, a few cells, two of which are quite large and conspicuous, make their appearance by the sides of the endodermal pouch, and extend between it and the shell-gland. These are mesodermal cells. Their exact origin has not been traced. As the embryo elongates, the two large cells come to lie near the posterior end of the embryo (fig. 19). They probably correspond to similar cells that have frequently been described for other forms. Similar cells are found in Yoldia in a corresponding position.

TEST.

As the result of the first few cleavages a number of large cells become covered on one side by a cap of smaller cells (fig. 4). A part of the smaller cells become covered with cilia, about the time that the gut is formed (fig. 8); others near the blastopore divide rapidly and form the stomodæum (figs. 9 and 11); still others form the cerebral ganglia; while others in the region of the blastopore wander in and form a part of the future ectoderm.

The cells that bear cilia are concerned in the formation of the test and apical plate. These cells soon cover the surface that is not occupied by the shell-gland and the cerebral ganglia.

Both the apical plate and the cerebral ganglia are small at this stage, consist of a very few cells, and can hardly be distinguished from the surrounding cells. The apical cells acquire cilia about the time that the test cells do (figs.9 and 11), and for some time they cannot be distinguished from them. Later the apical plate may be told by its shape and position (figs. 15 and 24. *ap.*).

As development proceeds the test begins to close in over the shell-gland from the sides and anterior end (figs. 10—13). Five rows of test cells can now be seen under favorable conditions, but their outlines are very hard to determine. Until the shell-gland is covered, two or three of the posterior rows are incomplete dorsally. A small pore is left near the posterior end, separated from the blastopore by the width of one test cell (fig. 15). The anus comes to lie near this opening (fig. 24).

The five rows of cells are now arranged much as shown in text fig. E. From the formation of the test until its ultimate disappearance its cells are evenly ciliated with short cilia. In this respect the embryos differ from those of Yoldia limatula (text-fig. F) and Nucula proxima (text-fig. H). Both of these forms have the cilia on each of the three intermediate rows of test cells collected into a band. Sometimes a fourth more or less complete band is present. The cilia on the end rows of the test cells of all of the forms are short and evenly scattered over the surfaces of the cells.

In this connection it is of interest to observe that the cilia on the apical plate of Nucula delphinodonta are short and independent, while those on the apical plates of Yoldia limatula and Nucula proxima are long and bunched together. They all seem to have a rather scattering origin, and when animals are killed the cilia become separated from one another.

In both species of Nucula the embryo differs from that of Yoldia limatula in having a posterior opening in the test, dorsal to the blastopore (fig. 15, and text-figs. G and H). This difference might easily be accounted for by a slight difference in the closing in of the test over the shell-gland.

The ciliated embryos of Nucula delphinodonta, unlike those of the other two forms, are not able to swim freely in the water. At the most they are barely able to move on the bottom of a glass dish. This is probably the result of their being carried in a protecting brood-sac. It seems but natural that the bands of strong cilia and the apical tuft of cilia would not be developed by embryos such as these, where there is no need for active locomotion, and where active locomotion would be dangerous. It is for the best interest of embryos that they remain in the brood-sacs, where they are protected from many enemies. Were they capable of active movement, many would probably escape and perish. In the two related forms, Nucula proxima and Yoldia limatula, the embryos have to depend on their own activities for their existence.

It is highly probable that the embryos of the ancestors of Nucula delphinodonta led an active, free-swimming existence. The rearing of embryos in protecting brood-sacs is very possibly connected with the present life of the animal beneath the surface of the mud, and, in any case, has probably been acquired at a comparatively recent day. Again, the test in its present condition is of no appreciable value to the embryo, and no doubt is to be regarded as a vestige of a once functional organ.

Young embryos of Nucula delphinodonta when taken from the brood-sacs do not live well, and it is accordingly difficult to determine how long the test is retained. As near as could be judged, it seems to be retained about two weeks. Its cells then begin to break apart near the posterior end of the embryo, and many of them move toward the anterior end, where they remain attached to the apical plate and the stomodæum (fig. 34). Sometimes most of the cells of the test seem to accumulate at the anterior end, but they frequently become detached and go to pieces before reaching this position. In any case they, together with the apical plate and the stomodæum, to the position of the future mouth, are finally thrown away (fig. 35). In many cases the process of casting occupies several and sometimes as many as fifteen hours. The process is much more rapid for both Yoldia limatula and Nucula proxima (2). It is quite possible that the difference in the length of the time occupied by the different embryos is connected with the difference in the conditions under which they develop.

Further study has tended to confirm my view that the test should be regarded as the homologue of the velum of other forms. In a former publication (1) I made the statement that "in either Dentalium or Patella, if we imagine the velum to be stretched posteriorly over the shell-gland dorsally, and the foot ventrally, so as to enclose the body, the œsophagus will be pulled out into a narrow tube ventral to the foot, and the position of the blastopore will correspond to its position in Yoldia. Furthermore the position of the foot and shell-gland will correspond, and the alimentary canal will be bent in the same way." This states the case backward, and may be a little confusing. If we begin with the condition found in Yoldia and Nucula, and imagine the test to shrink until it consists of a band of ciliated cells surrounding the embryo anterior to the mouth, the condition would be comparable to that shown by embryos of Dentalium and Patella.

As in the case of Yoldia, the closest resemblance to the test, outside of the group, is shown by Dondersia. Although Pruvot's (15) account of these embryos is very short, and only three figures are given, there is quite a striking external resemblance. In both cases the surface cells are arranged in five rows, all of which bear cilia. They are both provided with apical plates, and with both the test is finally thrown away. The bodies of the embryos of Dondersia protrude posteriorly during development. A slight posterior protrusion of the body of Nucula sometimes takes place through the opening dorsal to the blastopore.

The resemblances shown by embryos of Dentalium (8 and 9) and Patella (12) are not so striking, but they are somewhat similar. The apparent posterior protrusion of the body in each of these forms is such as might be produced if the body of Nucula were to grow and protrude to a corresponding extent. In such a case the test of Nucula would occupy a corresponding position to that occupied by the velum in the other forms.

APICAL PLATE.

At an early period the cells of the apical plate cannot be distinguished from those that form the test, but as development proceeds they become marked off as a rather definite plate at the anterior end of the embryos (figs. 11, 15, and 24, *ap.*). This plate is relatively large and thick, and extends posteriorly as far as the stomach. The cells from which the cerebral ganglia are formed lie venral to it (figs. 15 and 24, *cg.*). Beneath the test the cerebral ganglia and the apical plate are in contact.

The cells of the apical plate are evenly ciliated with short cilia, like those borne by the test cells (fig. 15). In this respect this species differs from both Nucula proxima and Yoldia limatula. Both of these forms have long apical cilia (text-figs. G and H) that during life are bunched together (text-fig. F). Nucula proxima has an apical plate that in extent may be compared to that of Nucula delphinodonta, but the apical plate of Yoldia is comparatively very small. The short, diffuse cilia on the apical plate of Nucula delphinodonta are probably the result of the conditions that make active locomotion at this stage both unnecessary and dangerous. (See what is said regarding this under the head of Test.) Certainly most of the apical plate, and probably all of it, is cast away when the test is shed (figs. 34 and 35).

SHELL.

Some lime salts are deposited soon after the cuticle of the shell begins to be secreted, which takes place about the time that the lobes of the mantle begin to form (fig. 20). When the test is shed (figs. 34 and 35), the shell-valves are white, glossy, and quite transparent. They do not correspond to the adult valves in shape (fig. 50), and they do not have the long, straight hinge-line of the prodissoconch of Yoldia (text-fig. K). The hinge-line is not very definitely marked off from the rest of the shell, but it can be distinguished as a nearly straight or slightly curved portion on the dorsal margin (fig. 36). The difference in the shape of the prodissoconches of Nucula and Yoldia is quite marked, more marked than might have been expected for forms so closely related, when there is so much resemblance between the prodissoconches of many Lamellibranchs (6). They both conform to the same type, however.

At first the valves are thin and have neither cartilage pit nor teeth. Soon after casting, a little knob of cartilage (fig. 36, *ca.*) makes its appearance near the middle of the hinge-line. The teeth do not form until a much later stage (fig. 46). About the time that the fifth pair of gill plates are formed, a tooth appears on each valve in front of the cartilage pit. This is soon followed by another, which is added anteriorly. The teeth posterior to the cartilage pit begin to appear about the time that the third tooth anterior to the cartilage pit is formed. New teeth in the posterior series are added posteriorly. Only about half as many teeth are formed posterior to the cartilage pit as anterior to it. Apparently as long as the shell continues to grow in size new teeth are added. Shells of fully grown specimens are about 4 mm. long, but they sometimes occur nearly 5 mm. long.

Each shell-valve is very convex (figs. 50 and 51), slightly oblong, and moderately thick. The beaks are directed posteriorly and placed far back on the shell. This gives an appearance quite the reverse of most Lamellibranch shells, which have the beaks nearer the anterior than the posterior ends, and directed forward. The cuticle of the shell differs in different specimens from horn colour to dark brown or nearly black. It may be considerably broken near the beaks, but it is generally quite perfect and smooth. Unlike most Lamellibranchs, the shells of this species contain so much animal matter that they retain their forms after the lime salts have been dissolved away. The material is quite tough, and frequently causes much trouble in cutting series of sections.

Each valve of the shell of fully adult animals has from ten to twelve teeth in the series anterior to the cartilage pit and five or six posterior to it (figs. 50 and 51). All of the teeth are more or less conical, pointed, curved toward the dorsal margin of the shell, and distinctly grooved on the side away from the cartilage pit. Each series of teeth forms a ridge some distance from the dorsal margin of the shell, which disappears dorsal to the adductor muscle-scar. The teeth of the two valves interlock so completely that it is frequently quite impossible to separate the valves without breaking some of them. The cartilage pit is large and deep. The adductor muscle-scars and pallial lines are faintly marked.

MANTLE.

The shell-gland is formed early. About the time that the gut is formed it consists of a number of large cells that lie near the blastopore, on what may be distinguished as the dorsal side of the embryo. Its cells do not seem to bear cilia, but only preserved material was at hand for the determination of this point. The surrounding ciliated cells, those that form the test, begin to grow over the shell-gland from the sides and anterior end (figs. 10, 11, 12, and 13, *sg.*). At the same time the shell-gland flattens slightly, and the cells along its margin push up and form a slight ridge, that keeps the surface of the shell-gland separated from the overgrowing test. Soon after the shell-gland is covered by the test, it arches dorsally, and the two come to lie close together (figs. 17 and 18, *sg.*). As the embryo flattens laterally the shell-gland arches dorsally still more (fig. 20), and a space appears between it and the intestine. This space seems to be formed by the multiplication and flattening of the cells of the shell-gland, which arches dorsally and becomes separated from the intestine. Lateral folds (fig. 20, *m.*), the beginnings of the mantle lobes, are soon formed. About this time the shell cuticle is secreted and some lime salts are deposited.

Soon after casting has been completed, swellings, the beginnings of the gills (fig. 39, *g.*), are formed near the posterior margin of each lobe of the mantle. The gills are thus formed as appendages of the mantle.

The mantle now has the adult structure and appearance, except that at a later stage a portion of its inner epithelium, and of the epithelium covering the suspensory membranes of the gills, becomes converted into the hypobranchial glands. These glands are present in both sexes, but just before the breeding season they are much better developed in the females than in the males, and there is considerable evidence that they furnish most, if not all, of the material from which the brood-sacs are formed. The margins of the mantle lobes remain thickened and contain the glands that secrete the cuticle of the shell. Some cells along the ventral and posterior borders of the mantle lobes bear cilia. Pallial muscles are attached to the shell-valves, and extend out to the margins of the mantle. These serve to retract the margins of the mantle when the shell is tightly closed.

The movements of the foot of this species when compared with the movement of the foot of Yoldia are very deliberate, but the foot is so large, and the muscles so powerful, that burrowing is quite rapid. Individuals of this species seem normally to live entirely covered by mud, in which they wander around by slow thrusts and retractions of the foot. Specimens do not seem to come to the surface of the mud to remain for any considerable time, and it seems probable that the greater part of the lives of individuals are passed beneath the surface of the mud. Observations made on specimens kept in dishes of sea water in which there was no mud show that individuals of this species execute movements very similar to those executed by Yoldia (1), but that in all cases they are much more deliberate (3). Leaping movements are absent, but slow thrusts with the flaps extended may frequently be observed. In former publications attention has been called to the characteristic movements of the foot, and they need not here be redescribed (1 and 3). As in the case of other members of this group, the movements of burrowing are very effective. The somewhat spherical shape of the shell, and the relatively large size of the foot, make it possible to raise the shell from the bottom of a dish, and occasionally to keep it balanced for a few seconds over the expanded foot. My observations lead me to believe that the animals never creep.

As in Yoldia, the foot is supplied with complicated and powerful muscles (1 and 3). It is attached to the shell by three pairs of muscles, and by a few fibres that lie ventral to the genital mass and liver. The posterior pair of foot muscles is very powerful. These muscles are attached to the shell at the bases of the teeth, just anterior to the posterior adductor muscle, and extend along the sides of the foot in an anterior and ventral direction. They are the powerful retractor muscles of the foot. Fibres from them are extended into the muscular flaps, and are important in spreading them apart.

The two anterior pairs of foot muscles correspond to the three anterior pairs of foot muscles in Yoldia. They are inserted on the shell close together along the bases of the teeth, just posterior to the anterior adductor muscle. The more anterior pair has much the same distribution as the two anterior pairs in Yoldia, and in some cases each muscle seems to be slightly separated into two near its origin. They spread out along the sides of the foot, and are distributed to its posterior and ventral portions. These muscles seem to be closely connected with the muscle-fibres that are attached along the sides of the shell ventral to the genital mass and liver. The more posterior of the two anterior pairs of foot muscles passes between the pair just mentioned, and is distributed to the anterior and ventral portions of the foot.

In the foot all of the muscles are closely bound together by their own fibres and by interlacing fibres, so that many movements occur that cannot be explained by direct pulls of individual muscles. It should constantly be borne in mind that the attachments of the fibres are all along the sides of the foot, and that many, if not most of the muscle-fibres pull from one portion of the body-wall to another, without changing the relation of the body to the shell. Thus the flaps can be spread apart after the shell has been removed. By compressing the blood contained in the large spaces of the foot, many movements, especially those connected with protruding the foot, may be performed.

As in the case of Yoldia, the foot muscles are so large that they are attached along a considerable portion of the dorsal surface of the shell. I regard this as the result of the size of specialised muscles, and do not agree with Pelseneer (13) that it should be regarded as a primitive character.

BYSSAL GLAND.

The byssal gland is formed as an invagination, just anterior to the posterior projection of the foot, about the time that the side flaps of the foot begin to form (fig. 39). Although there is but a single external opening, the gland at first consists of right and left pouches that extend into the foot near its posterior side. The cells forming the upper portion of the gland soon become somewhat swollen, and do not stain very well with hæmatoxylin. The lumen of the gland soon shows traces of a secretion, but the secretion has never been seen protruding from the duct.

The gland soon enlarges to a remarkable extent, becomes quite irregular, and the paired appearance disappears. At this stage, which extends from about the time that the gill acquires its third lobe (fig. 41) until about the time that it acquires its fifth pair of plates (fig. 45), the byssal gland extends through a considerable portion of the foot, and in the posterior side of the foot it may extend to a position somewhat dorsal to the pedal ganglia. The cells of the gland during this stage are greatly swollen and vacuolated, and have thin, almost indistinguishable walls. They are crowded together so as to almost obliterate the lumen of the gland. The result is that stained sections of the gland have the appearance of a fibrous or recticular mass that is so mixed up as to be hardly intelligible.

As the embryo gill begins to acquire its fifth pair of plates the byssal gland generally becomes less extensive. In the adult it is reduced to a small pouch (fig. 48, *bg.*) that opens in the median groove of the foot, just anterior to the heel-like projection. The dorsal, blind end of the pouch consists of comparatively large cells with small nuclei, and seems to be secreting. They are not generally distended with secretion, and the duct is generally quite empty. Nothing comparable to byssal threads have been observed. Towards the opening of the gland the cells become smaller and bear cilia.

I have described the adult condition that seems most frequently to prevail. In a few specimens the gland cells are much shrunken, and seem to contain little or no secretion. In some specimens of Nucula proxima the gland is more extensive and the cells are greatly distended. This would seem to indicate that the gland is functional, but not as an organ for the formation of threads. The present use of such a secretion is problematical.

It is very natural to compare this gland to the mucus-secreting glands of Gastropoda, but there seems to be little direct evidence that they are homologous.

ALIMENTARY CANAL.

There is a stage when the embryo resembles an epibolic gastrula (fig. 4). A pouch appears between the large cells, at a point corresponding to the asterisk, that seems to be formed by the separation of some of the larger cells, accompanied by their division into smaller cells. This pouch is the first indication of the alimentary canal (fig. 8, *mg.*). Partly by the division of cells forming it, and partly by the addition of ectodermal cells around the blastopore, the gut is carried further into the interior (figs. 9 and 11), and comes to lie at the end of a narrow tube, the stomodæum (fig. 15, *std.*). The blastopore never closes, so from its first appearance the stomodæum is connected with the gut.

The blind end of the gut turns dorsally beneath the shell-gland (fig. 11, *mg.*), and soon begins to grow posteriorly (fig. 15, *int.*). It finally comes to the surface at the posterior end of the embryo at a point ventral to the shell-gland and dorsal to the blastopore (fig. 24), where the anus is formed. The anus does not open directly to the exterior, but opens into the mantle chamber near an external opening in the test.

The alimentary canal at this stage consists of three distinct parts (fig. 24): a slender tube, the stomodæum (*std.*), opening through the blastopore and extending forward nearly to the apical plate, that is formed from the ectoderm; a rather thick-walled stomach (*sto.*) that lies dorsal to the anterior end of the stomodæum, and ventral to the shell-gland; and the intestine (*int.*), which joins the posterior end of the stomach, and at first has rather thick walls.

Dorsal to the stomach and intestine, between them and the shell-gland, a cavity makes its appearance that communicates by lateral passages with another cavity that lies ventral to the stomach and intestine, between them and the stomodæum. The ultimate fate of these cavities has been referred to in the sketch of the life-history, and in connection with the foot, and will again be referred to in connection with the pericardium. For some time they are rather large, and a portion of the alimentary canal is left quite free from surrounding tissue, except where it seems to rest on the walls of the developing foot (fig. 28). A short time before the test is shed the liver pouches make their appearance (fig. 25, *l.*). These are formed from the sides of the anterior end of the stomach.

The cells of the epithelial walls of the stomach are of two kinds. Those at the anterior end of the stomach carry comparatively few cilia, and those at the posterior end carry many cilia. At this stage some of the cells on the dorsal side of the stomach, near its anterior end, begin to secrete a mucus-like material that extends posteriorly in the lumen of the stomach as a small rod that probably represents the crystalline style (fig. 26). Later the posterior portion of the whole dorsal division of the stomach (the part that at this stage is the dorsal part of the anterior portion) is given over to secreting this material, but a definite rod may not be present.

About the time that the embryo casts its test the stomach grows dorsally into the space above it, so that a ventral bend is formed where the stomach joins the intestine (fig. 26). This is the beginning of the abrupt bend that marks this portion of the alimentary canal in later life. Two fibre-like cells stretch across the dorsal space from the anterior end of the stomach to the mantle (fig. 25). Their position suggests that they may aid in moving the stomach into the more dorsal position, but there is no direct evidence that this is the case.

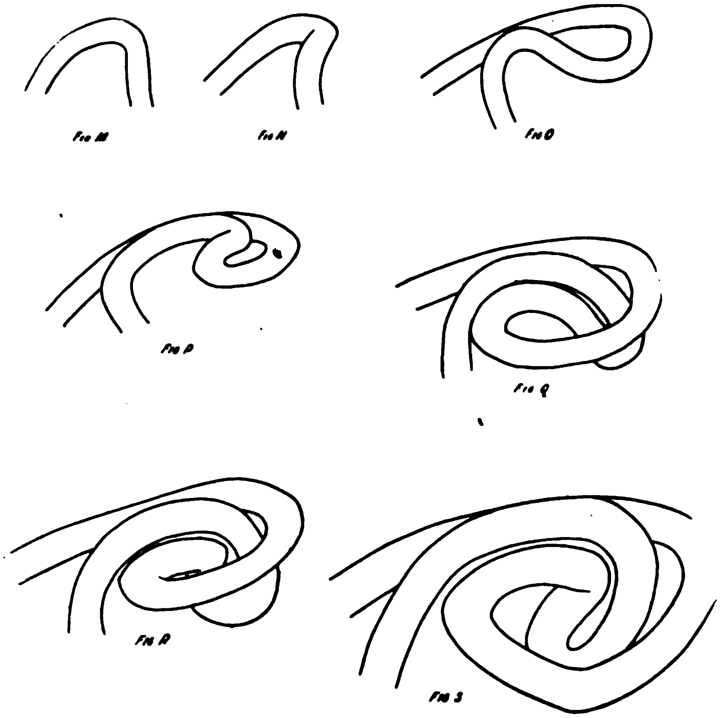
When the test is cast away and the adductor muscle pulls the shell-valves together, the stomach is crowded further into the dorsal space, and the bend in the intestine becomes more pronounced (figs. 34 and 35). The same pressure apparently causes the liver pouches to go to pieces. Their cells become more or less separated, and fill the larger part of the cavity dorsal to the stomach (figs. 36—39, *z.*). The same changes have been noticed in embryos of Yoldia limatula and Nucula proxima. In all of these forms the changes occur in connection with the closing of the shell. Until the test is shed, tissue lies between the valves of the shell so that they cannot be shut together. When the tissue is removed, and the shell is closed, there is no longer room for the liver pouches to lie on the sides of the stomach and retain their original shape. They are accordingly flattened and pressed into the unoccupied space dorsal to the stomach. The cells are no longer arranged to form definite walls (figs. 36—39, *z.*), but later some of them seem to form liver pouches again (figs. 42 44). A small portion of the space into which the stomach and liver are crowded is not filled, and finally forms the pericardium (figs. 39—41).

The rupture of the liver pouches leaves the dorsal part of the stomach without side walls, and the dorsal wall is commonly broken (figs. 37 and 39). The dorsal wall is formed again before the liver pouches regain their cavities (fig. 40). Some of the separated liver cells find their way into the open stomach (figs. 37 and 38), and together with mucus practically fill it.

For a period of two or three days after casting, the animal is not active, and it is doubtful if it feeds. At the end of this time the walls of the stomach begin to re-form, and the mass of material that has filled the stomach has largely disappeared. For a number of days the liver does not form definite pouches. The rounded and scattered cells are finally collected into two masses (figs. 40 and 42) that finally form new liver lobes. The left is slightly larger than the right mass, but the masses are more nearly equal in size than is the case with Yoldia. In both cases it seems that the difference in the size of the two liver lobes causes the developing loops of the intestine to take up a position on the right side. Cavities gradually extend out into the liver pouches from the stomach (figs. 43 and 44). In the formation of the cavities some of the rounded cells seem to go to pieces in much the same way as they would if digested.

The elongation of the intestine that results in the formation of the loops begins about the time that the embryo acquires its fourth pair of gill plates (fig. 45). This elongation carries the portion of the intestine that lies dorsal to the posterior adductor muscle toward the posterior wall of the stomach and nearer the dorsal margin of the shell. The end of the loop is forced over to the right side, and is extended anteriorly nearly to the anterior wall of the stomach. At this stage (text-fig. O) the loop of the intestine is much like the loop that occurs in adult Yoldia limatula (text-fig. L). The dorsal bend now begins to elongate and project anteriorly (text-fig. P). This continues until the loop is extended between the limbs of the loop that was made first (text-fig. Q). The lower limb of the loop begins to elongate (text-fig. R), and the adult condition is soon reached (text-fig. S and fig. 48).

The heart makes its appearance some time before the loops of the intestine begin to be formed (fig. 41). From the first appearance of its cavity the heart surrounds the intestine. This condition continues for a long time, until the loops of the intestine have been formed, and, in fact, until after the animal has reached sexual maturity. At first the intestine passes through the middle of the heart (fig. 67). The sides of the heart seem later to be forced dorsally by the growth of the kidneys, and the intestine becomes applied to the ventral wall of the heart. By the continued growth of the kidneys the ventral portion of the ventricle is drawn out into a trough, in which the intestine lies (fig. 68). The growth is continued until the trough is considerably deeper than the width of the intestine. By gradually closing in dorsal to the intestine at the anterior and posterior ends the trough is shortened, and the intestine finally becomes free from the heart and lies ventral to it (fig. 69).



TEXT-FIGS. M, N, O, P, Q, R, AND S.—Stages in the development of the loops of the intestine in Nucula delphinodonta.

In the adult animal (fig. 48) the œsophagus is a rather broad and long, nearly cylindrical tube, that opens between the palps just posterior to the anterior adductor muscle. I find no indication of anything that can be interpreted as salivary glands at any stage in the development (13). Throughout its length it is evenly ciliated and quite devoid of ridges. The corners of the mouth are continuous with the groove between the two labial palps. The stomach is large, somewhat spindle-shaped, and extends from near the dorsal margin of the shell to the level of the pedal ganglia. Near its middle there is a nearly complete ridge of elongated epithelial cells, and frequently a more or less well-marked external groove that divides it into a dorsal and a ventral portion. The posterior and part of the lateral walls of the dorsal portion of the stomach are formed by long and slender epithelial cells that stain but slightly. They secrete a mucus-like material that stains deeply, and probably corresponds to the crystalline style. In adults this secretion seldom takes the form of a rod, but in embryos a rod is commonly present (figs. 26, 28, 30, and 64). The remaining cells in the dorsal portion of the stomach are short, stain deeply, and are evenly ciliated. The ducts from the liver open in the dorsal end of this portion of the stomach. The epithelial cells of the ventral portion of the stomach are short, stain deeply, and carry a quantity of short cilia. Leaving the ventral end of the stomach, the intestine bends dorsally, and follows the posterior walls of the stomach nearly to its dorsal end. Here the loops already described are formed. From the loops the intestine passes posteriorly ventral to the heart, bends around the posterior side of the posterior adductor muscle, and opens into the mantle chamber. It is composed of short ciliated cells that stain deeply. Its lumen varies greatly in size, according to the amount of matter it contains.

LABIAL PALPS.

Soon after the embryo acquires its second gill lobe the epithelium around the mouth, and for a short distance along the sides of the body, becomes ciliated (fig. 41). This ciliation precedes the formation of the palps, and, to a certain extent, marks out the region where they will form. The cilia are more numerous immediately anterior to the mouth than they are immediately posterior to it, and they soon extend along the sides of the body for about half the width of the foot. The position of the ciliated patches on the body-wall is such that the dorsal portion of each tends to lie horizontally, and the ventral portion tends to the vertical position (fig. 62, *lp.*). The groove thus formed becomes the groove between the outer and the inner palps. The portion above the groove forms the outer palp, and that below the groove the inner palp. This is accomplished by the growth and folding of the body-wall. The outer palp begins to grow first, and in such a way that the line marking the dorsal limit of the cilia becomes the free margin of the palp. This leaves the inner surface of each outer palp covered with cilia, and the outer surface unciliated. The two outer palps are continuous anterior to the mouth, where they form a slight ridge (figs. 54 and 63).

For some time after the outer palps form folds, the inner palps are represented by ciliated ridges (fig. 54), that reach some distance beyond the posterior ends of the outer palps. These ridges grow so that the lines marking the ventral limit of the cilia become the free margins of the inner palps. The two inner palps are continuous posterior to the mouth, where they form a slight ridge (figs. 55 and 63). Like the elevation anterior to the mouth, this never becomes prominent.

The inner surface of each outer palp becomes folded near its anterior end to form ridges and grooves (fig. 55), and the postero-ventral portion protrudes to form a lobe. This lobe is the beginning of the formation of the palp appendage. The edges of this lobe soon begin to thicken, and a groove is left between the ridges thus formed. This is accompanied by a considerable growth in length (fig. 56, *pap.*). At this stage of development the palp appendage is seen to correspond to two of the ridges on the general surface of the palp, with a groove enclosed between them.

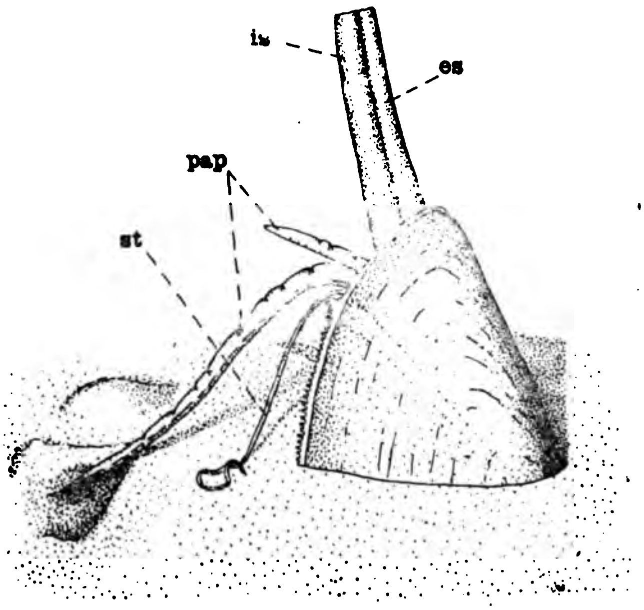
Posterior and dorsal to this appendage another smaller appendage is formed (fig. 56). This is also on the outer palp, and consists of two ridges with a groove between them. It never grows to be very long, but resembles the large appendage that lies ventral to it in its formation.

As development proceeds the larger appendage (fig. 56, *pap.*) twists, so that its groove opens dorsally and posteriorally (fig. 57, *pap.*), and the smaller appendage twists so that its groove opens ventrally. This double twisting brings that portion of the small appendage that was dorsal nearly or quite in contact with that portion of the large appendage that was ventral, so that for a short distance the two grooves together form a canal that opens anteriorly between the two palps (fig. 57). During the development of the palp appendages both outer and inner palps have grown to be quite large, and their ciliated surfaces have been thrown into series of ridges and grooves.

The palps on each side of an adult animal consist of two large, somewhat triangular folds of tissue (fig. 48, *lp.*), united to each other along their dorsal margins, and suspended from the body-wall by a thin membrane. The outer palps on the two sides of the body are connected in front of the mouth by a small ridge that occupies the position of an upper lip. In the same way the inner palps are connected by a ridge posterior to the mouth that is comparable to a lower lip. The corners of the mouth are continuous with the space between the two palps of each side. The opposed surfaces of the palps are densely ciliated, and thrown into a series of ridges and grooves that tend to lie opposite each other on the two palps. Near the free margins this arrangement may be considerably broken. Large blood-spaces follow along these ridges. Each outer palp is supplied with two grooved appendages that originate near its dorsal margin. The most ventral of these appendages (fig. 48, *pap.*) can be extended far beyond the margin of the shell, and is used to elevate mud with the contained food. The dorsal appendage sets over the anterior end of the groove of the ventral appendage, and with it forms a short canal that opens between the palps. Each ventral palp appendage is supplied with longitudinal muscles (fig. 66, *lm.*), that are continued in from the body-wall; with a large nerve (*pn.*) that originates in a cerebral ganglion, and runs posteriorly along the united dorsal margins of the outer and inner palps; and with a continuous blood-space (*bs.*). The epithelium lining the groove of the appendage is very thick, and is densely covered with cilia. The nuclei of these epithelial cells are very long and slender. The muscles in the palp appendages are so placed that their contraction causes the appendages to curl, as shown in fig. 48, *pap.*

It is not easy to observe individuals of this species while they are feeding, as they normally live entirely covered by the mud. If specimens are placed in a dish of sea water, in which there is only a thin layer of mud, the action of the palp appendages may be observed. It is well to use as much mud as possible without affording the animals an opportunity to bury themselves, and to use specimens that have not been in mud for several days and are accordingly hungry. The mud is passed along the grooves of the palp appendages by the action of the cilia, and finally conducted between the palps, where tne cilia carry it to the mouth. Very few specimens have shells that are transparent enough to allow observation of processes carried on inside of the shell, but there can be no doubt as to the path taken by the mud after it has started up the grooves in the palp appendages.

Feeding is much more easily observed in the case of Yoldia limatula. In this species the animal has frequently as much as



TEXT-FIG. T.—An adult specimen of Yoldia limatula as it appears while feeding. *es*. Exhalant siphon. *is*. Inhalant siphon. *pap*. Palp appendages. *st*. Siphonal tentacle.

one-third of the posterior end of the shell above the mud while feeding (text-fig. T). The palp appendages are protruded, and one at least bends over and inserts its tip in the mud. By the action of the cilia in the longitudinal groove, large quantities of mud and food are elevated. There is no reason to suppose that the palp appendages of Nucula are not as effective as those of

Yoldia, but the method of life makes observation more difficult. As suggested by Mitsukuri (11), it seems probable that the large palps with their numerous large blood-spaces may be important respiratory organs.

GILLS.

A short time after the embryo sheds its test, a portion of each lobe of the mantle near its posterior border begins to thicken (fig. 39, *g.*) and then to project anteriorly. These thickenings are the beginnings of the gills. They grow rapidly, acquire cilia, broaden dorso-ventrally, and each begins to divide into two lobes (fig. 40, *g.*). The formation of the lobes is due to unequal growth more than to constriction. Each lobe is at first a little knob that is flattened slightly laterally. As growth proceeds the ventral lobe broadens and flattens along its anterior border preparatory to the formation of another lobe. Coincident with these changes in the ventral lobe, the dorsal lobe grows anteriorly, and forms a rather long finger-like process or filament, that closely resembles the filaments of the developing gills of other Lamellibranchs (fig. 41, *g.*). New lobes are added to the gill by the unequal growth and division of each ventral lobe in its turn, and as the new lobes are formed the more dorsal lobes lengthen.

Throughout life the gill occupies a decidedly dorso-ventral position, but growth carries the ventral end some distance toward the posterior end of the animal, so that the adult gill lies somewhat diagonally (fig. 48, *g.*). In Yoldia (text-fig. L) the gills lie more nearly parallel to the long axis of the body.

The chitinous support of the gill makes its appearance when the gill is still in the two-lobed condition. At first it consists of a thin plate lying just beneath the epithelium on the anterior border of the gill, and is continued from one lobe into the other. Its ends lie near the anterior extremity of each lobe. As the ventral lobe flattens the chitinous plate is extended along its anterior border, so that with the formation of the third lobe the plate is extended into it. In this way, as new lobes are formed, the chitinous plate is extended into each, and continues to be connected throughout the length of the gill. As the lobes grow to form filaments, the chitinous plates extend with them, and each becomes trough-shaped with the open side of the trough directed away from the corresponding lobe of the mantle. Later the free edges of the trough are brought near together, and the support in each filament practically assumes the form of a tube that extends out nearly to the tip of each filament. The tubes that support the different filaments are united at their bases, so the chitinous support is continuous throughout the gill.

As the lobes elongate to form filaments, the cilia on each becomes restricted, so that the side that is turned away from the lobe of the mantle to which it is attached becomes quite free from them. On the remaining sides the cilia are long and powerful.

About the time that the fourth division of the gill is formed the mantle begins to thicken at the bases of the filaments, between them and the shell (fig. 45). These thickenings are generally opposite the bases of the filaments, and connected with them, but as there are sometimes more plates on one side of the gill[1] of the adult animal than on the other, the thickenings are probably not always formed in this position.

They represent the beginnings of the outer plates of the gill. The filaments, at the bases of which these thickenings are formed, form the inner plates of the gill.

For a considerable time the outer plates remain much smaller than the inner plates, and they never quite equal them in size (fig. 53). As the outer plates of the gill are formed, the chitinous support is carried out into them as branches from the portion that runs lengthwise of the gill. These branches become trough-shaped, with the open part of the trough directed away from the inner plates. Finally, the free edges of the troughs come close together, as described in connection with the other set of filaments or plates.

The chitinous material at the bases of the two sets of plates also become trough-shaped, and has the open portion of the trough directed away from the plates. Thus the chitinous support of the gill consists of two series of troughs, bent so as to form tubes, each of which is connected by one end to the side of a larger trough that runs lengthwise of the gill. The whole

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[1] The term gill is for convenience applied to the respiratory organ on one side of the animal, although writers agree that it probably corresponds to the two gills found on each side of most Lamellibranchs.

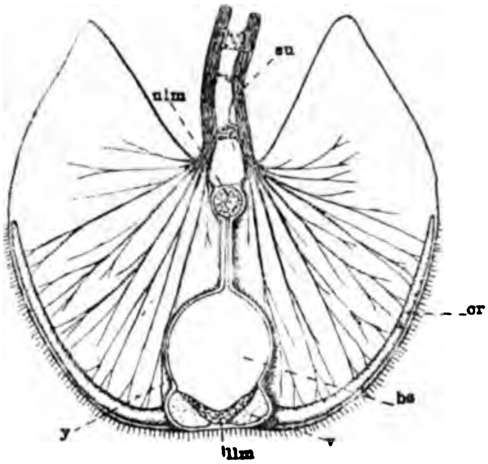
might be compared to a large trough with a series of spouts leaving each side, the individual spouts of the two series being placed opposite each other. Later, bridges are built across the main trough in the intervals between the side spouts. The whole system is in direct communication with the blood-spaces of the gill, but probably is not concerned with the circulation of the blood.

The two sets of plates do not lie parallel to each other, but they grow away from each other at an obtuse angle. The inner plates grow almost in an anterior direction, and the outer plates grow laterally and a little posteriorly, so that the angle formed by the two sets of plates on the two sides of the gill is visible when the animal is viewed from the side. The suspensory membrane, formed by the growth of the mantle at the base of each gill, makes it possible for the gill to take up this position.

The filaments begin to grow into flattened triangular plates about the time that the fourth division of the gill is formed. This is accomplished by slow, unequal growth, and throws no light on the phylogeny of the gill. It seems to be a matter of individual opinion whether each of the plates should be considered to be homologous with a descending filament of an ordinary Lamellibranch gill, or whether it should be considered to be homologous with both a descending and an ascending filament.

The adult structure of the gill of Nucula has been so carefully and accurately described by others, that were it not for the sake of completeness, it would not be necessary to describe it here. Mitsukuri's (11) description of the gill of Nucula proxima holds good in all essentials for the gill of this species, and since his description was published others have verified and supplemented his results (7, 13, and 16) until our knowledge of the structure is comparatively complete.

The adult gill of Nucula delphinodonta is suspended from the body-wall by a fold of tissue, the suspensory membrane (fig. 53, *gs.*), that was originally a fold on the inner surface of the mantle lobe. The suspensory membrane contains between its walls a large blood-space that communicates near its anterior end with an auricle of the heart, and throughout its length communicates with blood-spaces in the mantle. At intervals it communicates with similar spaces in the body proper. Unlike the suspensory membrane of Yoldia (text-fig. U), this membrane is not very muscular, but some muscle-fibres are always present. The epithelium covering the outer surfaces of the suspensory membranes, those surfaces that are turned away from the mid-line of the body, is modified to form a portion of the hypobranchial glands.



TEXT-FIG. U.—A pair of plates from a gill of Yoldia limatula. *bs*. Blood-space. *cr*. Chitinous rod. *llm*. Lower longitudinal muscle. *su*. Suspensory membrane. *ulm*. Upper longitudinal muscle. *v*. Cut surface of a chitinous rod. *y*. Cut wall of the gill plate where it bends to join the plate anterior to it.

Each suspensory membrane bears two series of gill plates that generally lie opposite each other. Occasionally a gill occurs in which there are more plates on one side than on the other, but even in these cases the order is interrupted only for a short distance. The number of plates differs with the size of the individual, but about twenty pairs seem to be common for well-grown specimens. Each plate is thin and triangular, and is composed of epithelial walls, between which there are loose connective tissue, large blood-spaces, and the chitinous framework. The epithelial walls on the edges of the plates that are directed away from the suspensory membranes are thickened and covered with strong cilia. This thickened ciliated epithelium extends between the plates for a short distance, but most of the epithelium is quite thin and destitute of cilia. The wall of each plate is continuous with the wall of the plate that lies in front of it, with the wall of the plate that lies behind it, and with the plate on the other side of the gill that lies opposite to it. Near the border furthest from the suspensory membrane, the opposing walls of the two series of gill plates are separated so as to form a large blood-space (fig. 53, *bs.*), that runs the whole length of the gill. This space is continued as a narrow slit to the base of the suspensory membrane. Thus the blood-space in the suspensory membrane is in direct communication with the blood-space of each plate, and in the gill the blood is free to flow from one part to another.

The chitinous framework consists of a bridged trough that occupies the bottom and part of the sides of the blood-space that lies between the two series of plates, and of two series of side spouts that project into the plates on the two sides, and lie in contact with the thickened epithelium. Although the chitinous framework is arranged as a system of troughs and spouts that, from their position, must be filled with blood, they are probably not directly concerned in the circulation of the blood.

Between the chitinous trough and the suspensory membrane there is a small bundle of muscle-fibres that is continued the whole length of the gill (fig. 53, *lm.*). This bundle lies in the open part of the chitinous trough, and probably corresponds to the large bundle that occupies a similar position in the gill of Yoldia (text-fig. U, *llm.*). A second longitudinal bundle of muscles is found in the gill of Yoldia (*ulm.*), but this does not seem to be present in this species. A few of the muscle-fibres in the suspensory membrane seem to be continued into the plates. They are not numerous, and they have not been carefully followed. The gill of this species is so small that it is not favourable for the determination of minute details.

The gills probably act as respiratory organs, but their small size, together with the blood-supply of other parts, makes it seem probable that other organs, such as the mantle and the palps, are also concerned in respiration. The opaque character of the shells of adult animals makes it quite impossible to observe the normal movements of the gills. They can be seen to move slightly, however, and it seems probable that the suspensory membranes contract slightly at intervals. Such movements would be useful in causing movements in the contained blood, but they are not sufficient to cause strong currents of water. The shape of the gills is not such as would make them efficient pumping organs. (Compare fig. 53 and text-fig U.) Inasmuch as these animals live entirely covered by mud, the production of strong currents of water could not be beneficial. As the animal wanders around in the mud the fæces naturally drop out of the open mantle chamber.

It would be a matter of some interest if the exact relationship of the gills of Nucula and Yoldia could be determined. It would seem to be a comparatively easy task to account for the changes in the shape and structure of the gill of Yoldia if we were to start with a gill such as has been described for Nucula. The habits of Yoldia are such as to render the formation of strong currents of water absolutely necessary, for otherwise the mantle chamber would become clogged with fæces and dirt. The gill of Yoldia might have been perfected for pumping water from a Nucula-like gill. It would, however, be equally easy to account for the reverse modifications when we consider what the formation of strong currents of water by an animal entirely covered by a soft, slimy mud would mean. If we follow the generally accepted theory of the gill, the former change would seem more likely than the latter, though it is quite possible that nothing like a direct change from one to the other has taken place. The generally accepted theory of the gill has grown up as the result of structural and embryological considerations, and but scant attention has been given to probable modifications for the special purposes of the animals. Until we have much more detailed knowledge regarding the habits of most of the Lamellibranchs that have plate gills, and of some of the supposed near relatives of these Lamellibranchs, it seems to me that we lack the necessary data to give the derivation of the gill with anything like accuracy. There is much in the structure and embryology of Nucula that points to a generalised type, and in this much it seems natural to look at the gills as primitive; but the gills of Yoldia—its undoubted near relative—are so remarkably well adapted for the performance of a special function, that it hardly seems safe to regard them as slightly modified gills until there are more careful observations on the habits of the other forms.

I recognise fully the mass of evidence in favor of the primitive form of the plate-like gill. My only plea is for caution.

HYPOBRANCHIAL GLANDS.

The epithelium on the inside of the posterior end of each lobe of the mantle, and on the outer side of a corresponding portion of the suspensory membrane of each gill, is glandular, and has been termed the hypobranchial gland. When these glands are present in Lamellibranchs, their secretions seem to correspond very closely to mucus, and they are generally referred to as mucous glands. During the greater part of the year the hypobranchial glands of both sexes of Nucula delphinodonta are rather small and inconspicuous. They contain rounded or oblong masses of a refractive material that takes no stain. The cells themselves are small, and do not seem to be secreting actively. The hypobranchial glands of specimens of males seem to have the appearance that has been described, no matter what time of the year they are collected. As the breeding season approaches, the hypobranchial glands of the females become greatly distended with secretions. The rounded or oblong masses that are common at other seasons of the year are now seldom found, and the cells are packed full of rather large granules. Immediately after the brood-sac is formed, the cells of the hypobranchial glands appear shrunken and free from granules, and the glands have the appearance of having discharged their secretions. After examining a large number of specimens, I have become convinced that the hypobranchial glands furnish nearly all of the material from which the brood-sacs are formed. Specimens kept in aquaria do not form brood-sacs, and accordingly the processes of their formation have not been observed, but it seems probable that the secretions from the glands are passed posteriorly by cilia on the mantle, and probably swelled out into a bubble by the respiratory current of water. While the material is still soft it adheres to the foreign bodies with which it comes in contact.

Well developed hypobranchial glands are present in only a limited number of Lamellibranchs, and their special function is hard to determine. It is interesting to find that they are concerned in the formation of the brood-sacs in this species, but this is the first instance that has been reported where such a sac is formed. It may be that other forms that possess especially large hypobranchial glands will be found to form similar brood-sacs, but this will not hold true for all. Nucula proxima has rather large hypobranchial glands, and I find that it does not form brood-sacs. Such a case as this, where it is known that brood-sacs are not formed, seems to indicate either that the glands have some function to perform other than providing the material for the formation of brood-sacs, and that Nucula delphinodonta has adapted them to this purpose; that they are retained from forms that originally formed brood-sacs, in which case we must suppose that the ancestors of all forms that possess hypobranchial glands formed brood-sacs; or that in forms where brood-sacs are not formed the glands are, when present, mere vestiges, and are not now functional.

The latter explanation seems unlikely, as the glands of Nucula proxima are better developed than vestiges are likely to be. If the second explanation is accepted, we must regard the rearing of embryos in brood-sacs as more primitive, for this group at least, than throwing the eggs in the water where the embryos have to take care of themselves. From the standpoint of specialisation this seems to be very unlikely, and the fact that the embryos of Nucula delphinodonta possess tests that seem to serve no purpose, while similar tests function as organs for locomotion in other forms, points clearly to a condition when all of these embryos depended on their own activities for protection. It seems most likely that Nucula delphinodonta has made use of already existing glands to furnish the secretions for the formation of its brood-sacs, and that they may have other functions to perform.

PERICARDIUM.

A short time before the shell-gland begins to fold at the sides to form the lobes of the mantle, a space appears between the stomodæum and the gut, and a little later a space begins to form between the shell-gland and the gut (fig. 24). These two spaces are separated by the gut, but in preserved material they are frequently connected around the sides of the gut. When these connections may be due to shrinkage caused by the treatment with preservatives, it seems more likely that the spaces are normally connected with each other. It is just possible that these spaces may be traced back in their formation to the blastocœle, but it is more probable that the blastocœle entirely disappears, and that they represent a schizocœle. At first the space ventral to the gut is larger than that dorsal to it, but the latter grows as the mantle arches dorsally, and the ventral space remains practically unchanged.

As the foot begins to take form the ventral space becomes quite small, and about the same time that the embryo sheds its test it disappears altogether. A short time before the test is shed the dorsal space reaches its greatest size (figs. 25 and 26). About the time that the test cells begin to break apart, the stomach is carried dorsally some distance into this space (fig. 34). Two fibres, that in shape suggest muscle-fibres, extend from the anterior end of the stomach to the mantle. Their position suggests that they may aid in moving the stomach dorsally, but of this I have no proof. As the stomach moves dorsally they become shorter and thicker, but there is no evidence that they are moving factors. Until casting is completed, the apical plate and the stomodæum lie between the edges of the shell-valves, and keep them from being closed. When they are removed, the contraction of the adductor muscle closes the shell, and the body, which has until now been lying between gaping valves, is made to change its shape and position. The stomach and liver pouches are forced into the dorsal space until the dorsal end of the stomach comes in contact with the mantle.

This divides the space into anterior and posterior parts (fig. 35). There is no longer room for the liver pouches to retain their form and position, and as the body continues to move dorsally they are flattened out and soon go to pieces (fig. 36). Most of the cells that formerly composed their walls become scattered and rounded, and the anterior space becomes entirely filled (fig. 39). The posterior space, somewhat diminished in size, persists, and finally becomes the pericardium (figs. 40 and 41). The pericardial space is not smooth as it has been necessary to represent it in the figures. Mesoderm cells project into it from the surrounding tissue, and others lie comparatively free within it. As yet it lies almost wholly dorsal to the intestine, but just before the heart is formed it is extended beneath the intestine, and begins to have a rather definite epithelial lining. The epithelial lining seems to be formed by the change in shape and position of cells in the immediate vicinity. I find no indication that the pericardium originates as a pair of pouches, as has been described by Ziegler for Cyclas cornea (20).

VASCULAR SYSTEM.

Small connected cavities are present throughout the body from an early time, but a true vascular system, with a heart and anything like a definite circulation, is not to be distinguished until much later, and a closed system of vessels with capillaries is never present.

The heart is formed about the time that the gill becomes well divided into two lobes, or just before the third lobe is formed. It seems to be formed by the hollowing out of a strand of mesoderm that stretches across the pericardial cavity. I have seen nothing that would indicate that the heart has a double origin, as Ziegler has described for Cyclas cornea (20). Mesoderm cells in the pericardial cavity and along its walls arrange themselves to form a strand that becomes hollow and begins to pulsate. From the first appearance of its cavity the heart surrounds the intestine (figs. 41 and 67). Most specimens show the heart collapsed with its walls in contact with the intestine, but some specimens have it distended with blood. In all cases it is easy to determine that the heart is perforated by the intestine, but it is especially evident in specimens where the heart is distended. In most of these cases the intestine lies nearer the ventral than the dorsal wall of the heart, and in many cases it lies directly in contact with this wall. At this stage the heart is not separated into auricles and ventricle (fig. 67, *h.*). It is in the form of a bent spindle, the two ends of which communicate with the blood-spaces of the gill. The larger median portion arches dorsally and surrounds the intestine. Anterior and posterior aortæ leave the heart, but no attempt has been made to follow them, until the adult stage is reached.

For a considerable time after its formation there is no appreciable change in the heart. About the time that the eighth pair of gill plates are formed it begins to be separated into ventricles and auricles. The auricles are at first very small and narrow. They extend only a short distance from each gill, and are separated from the ventricle by slight constrictions. There has been no change in the relative positions of the heart and intestine. At a slightly later stage, when the gill has about ten pairs of plates, the ventricle of the heart begins to change its shape. This seems to be due to the growth of the kidneys, which push anteriorly ventral to the pericardium. As the kidneys grow, the two sides of the heart are pushed dorsally, while the middle part of its ventral wall is held in its original position by the intestine. In this way the ventral wall is pulled out into a sort of trough in which the intestine lies (fig. 68, *h.*). Continued growth deepens the trough until it is considerably deeper than the intestine is wide. The heart gradually closes in, dorsal to the intestine, at the anterior and posterior ends of the trough, until it becomes free from the intestine, and lies dorsal to it (fig. 69). This is a very slow process, and is not completed until after the animal has reached sexual maturity.[1]

The adult heart consists of a ventricle and a pair of auricles, separated from each other by constrictions that are much deeper on the dorsal than on the ventral surface (fig. 69, *h.*). The openings between the auricles and the ventricle are so small that they must be quite obliterated during contraction. A band of muscle occurs near the end of each auricle, that keeps the blood from flowing back into the spaces of the gills. Each auricle is somewhat conical, small where it joins the gill, and considerably enlarged at the end next to the ventricle. The ventricle is swollen next to the auricles, and flattened over the intestine. The swollen ends of the auricles and the corresponding swellings the ventricle make right and left enlargements that superficially might be mistaken for two hearts.

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[1] Every specimen of Nucula proxima that I have examined has its heart perforated by the intestine. The specimens are all of good size, and many of them are the same ones from which I obtained eggs and sperm.

A blood-vessel leaves the anterior end of the ventricle on the left side of the intestine, and not in contact with it. Another blood-vessel leaves the posterior end of the ventricle above the intestine and in contact with it. The anterior vessel is somewhat larger than the other. It runs forward over the dorsal end of the stomach and sends branches to the liver and genital organs, to the stomach and loops of the intestine, to the foot, to the labial palps, and to the anterior portions of the lobes of the mantle. The vessel that leaves the ventricle posteriorly is at first dorsal to the intestine, but it soon becomes ventral to it, and is distributed to the posterior part of the body.

All of the blood-channels seem to end in rather large connected spaces, that ramify throughout the body. The course of the blood cannot be traced in these spaces. The blood-spaces of the foot, beside providing for the ordinary blood-supply, serve as reservoirs in which blood can be forced to extend the foot. By suppressing some channels and squeezing blood into others different results may be obtained. Blood must undergo respiratory changes in the gills, the mantle lobes, and the palps.

The opinions of writers on Lamellibranch morphology, regarding the primitive form and position of the heart, are very different. Milne-Edwards (10) thought that the double appearance of the heart of Nucula and Arca pointed toward a primitive condition in which the heart was double. Thiele (19), basing his conclusions on Ziegler's observations on the formation of the heart of Cyclas, holds that the heart was probably originally a double organ, and that upon uniting in the median line it has taken up the various positions in regard to the intestine. Grobben (5) considers the single heart primitive, and thinks that the double condition is the result of changes in the position of retractor muscles. Pelseneer (13) and others, depending largely upon the position of the heart in Nucula and Arca, have considered the dorsal position of the heart to be the primitive position. Stempell (17) rightly holds that the ventral position of the heart of Malletia chilensis destroys the foundation of Pelseneer's reasoning, inasmuch as Nucula and Malletia are closely related forms. Stempell apparently considers the perforated heart to be the most primitive. From this position the heart may become dorsal or ventral to the intestine by a comparatively simple process.

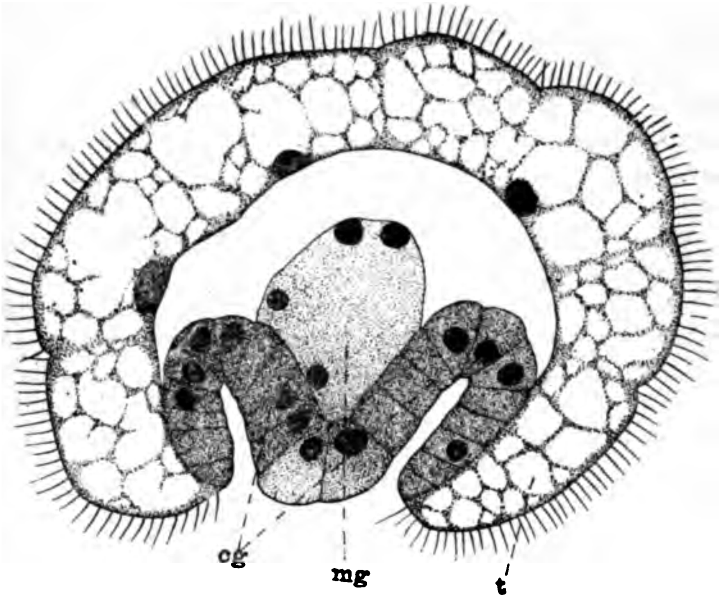
The development of the heart of Nucula seems to indicate that the perforated heart is more primitive than the dorsal heart in this group. While, as Stempell holds, it seems most reasonable to consider a perforated heart that may become either dorsal or ventral by comparatively simple changes as more primitive than either a dorsally or a ventrally placed heart—where, in order to reach the opposite extreme, the heart would have to enclose the intestine, and then become free on the other side,—there is still nothing to prove that the ventral position of the heart is not primitive. The development of the heart of Malletia would accordingly be of considerable interest.

As neither the pericardium nor the heart of this Lamellibranch seems to be formed as a paired structure, there is nothing here to further the view of Thiele (19) that the position of the heart in regard to the intestine depends simply upon the position of two lateral hearts, that may, as a matter of convenience, fuse dorsally, ventrally, or around the intestine.

NERVOUS SYSTEM.

The cerebral ganglia are formed in direct contact with the apical plate. The cells from which they originate can first be distinguished as a group soon after the surface cells that form the test become ciliated (fig. 15, *cg.*). They frequently remain as surface cells for some time, and they doubtless originate as surface cells in all cases. The group of cells is not distinctly paired, and does not invaginate as it does in Yoldia. Each cell becomes much larger at the inner end than at the end that comes to the surface. Although a test cell lies between the cerebral ganglia and the apical plate they still remain in contact beneath this cell. Little change occurs in the appearance, size, or position of the cerebral ganglia until the test is cast away, and until then no other part of the nervous system can be distinguished.

When the test-cells break apart and accumulate near the anterior end of the embryo (fig. 34) a portion of the body of the embryo is carried dorsally at the expense of the large dorsal space. This dorsal movement includes the cerebral ganglia (*cg.*). When casting is completed, and the valves of the shell are closed, a further dorsal movement occurs, that results in the filling of the greater part of the dorsal space. This movement places the cerebral ganglia in position posterior to the anterior adductor muscle (figs. 35 and 36, *cg.*). The foot now begins to grow quite rapidly, and the pedal and visceral ganglia begin to form (fig. 36, *pg.* and *vg.*). Both pairs of these ganglia are formed as thickenings of the surface ectoderm. The thickenings that give rise to the pedal ganglia begin to form first, but both pairs of ganglia are in process of formation at the same time. Owing to the character of the embryonic tissue it is very difficult to determine how the commissures that connect the ganglia arise. They are first found very close to the surface, almost, if not quite, in contact with the ectoderm. Later they sink deeper into the body. The cerebro-visceral commissures are quite thick, and differ from the cerebro-pedal commissures in



TEXT-FIG. V.—Transverse section of a forty-five hour embryo of Yoldia limatula, taken through the cerebral pouches. *cg.* Cerebral pouches. *mg.* Anterior wall of the mid-gut. *t.* Test.

having much the same structure as the ganglia themselves. In the earlier stages I have been able to demonstrate only a single cerebral origin for each cerebro-pedal commissure. This may be due to the difficulty of tracing commissures in embryonic tissue. Later stages show two separate origins very distinctly.

The double origin of the cerebro-pedal commissures has been regarded by Pelseneer (13) as an indication of the presence of cerebral and pleural ganglia in each anterior nerve-mass. Furthermore, Pelseneer and others find that each mass is divided by a constriction into two rather distinct parts. I have not been able to satisfy myself that there is a distinct separation into cerebral and pleural ganglia, either in this or the other forms that I have studied.

The cerebral and pedal ganglia are about equal in size, but they differ in shape (fig. 48). The visceral ganglia are smaller than the cerebral ganglia, but compare pretty well with them in shape. Each cerebral ganglion is large at its anterior end, and tapers posteriorly into the cerebro-visceral commissure. The commissure that connects the two cerebral ganglia is a broad, somewhat flattened band, that passes between the œsophagus and the anterior adductor muscle, and joins their anterior ends. The cerebral ganglia give rise to a number of nerves. A large nerve leaves the ventral side of each near its anterior end, passes ventrally along the posterior and ventral surfaces of the anterior adductor muscle, to which it sends branches, and is distributed to the anterior and ventral portions of the corresponding lobe of the mantle. Just posterior to the origin of the pallial nerve, and a little closer to the median line, another nerve, about equal to the pallial nerve in size, leaves each cerebral ganglion. This nerve follows along the fold of the tissue that suspends the labial palps and is continued into the palp appendage. Other nerves from these ganglia are distributed to the visceral mass and to the dorsal portions of the foot muscles. Posterior and still further toward the median line than the palp nerve, the two portions of each cerebro-pedal commissure leave each cerebral ganglion, one a little anterior and ventral to the other. The two portions run posteriorly a short distance, and join to form a single commissure that is continued to the pedal ganglion of the same side. A nerve leaves each cerebro-pedal commissure dorsal to the corresponding otocyst, and is continued to it. This nerve is generally supposed to have its origin in the cerebral ganglion, and the angle at which it issues from the commissure indicates that this is probably the case. The otocystic nerve is about equal in size to the posterior division of the cerebro-pedal commissure. Stempell (18) finds that each otocystic nerve of Solemya togata leaves the cerebral ganglion direct, and runs an independent course to the otocyst. He also finds that each cerebro-pedal commissure leaves the cerebral ganglion as a single strand. He thinks that this is a double commissure, because it receives fibres from what he considers cerebral and pleural ganglia.

It seems more likely to me that the nervous systems of all Mollusca have been derived from some such a generalized type as is found in Chiton, and that each class has developed ganglia according to its needs, than that the ancestors of Lamellibranchs possessed the comparatively complex system of ganglia found in Gastropods. If this is true, it is easy to understand why Gastropods with their complicated head apparatus should develop ganglia for which Lamellibranchs have no need. Accordingly the necessity to homologize all of the ganglia in the two classes disappears.

In most Lamellibranchs the otocystic nerves spring from the cerebro-pedal commissures, and they are supposed to originate in the cerebral ganglia. In Solemya togata, Stempell finds that the otocystic nerves leave the cerebral ganglia direct, and are not included in the cerebro-pedal commissures in any part of their length. Is it not possible that the posterior root of the cerebro-pedal commissure, in forms where there are two roots, is the central end of the otocystic nerve?

The pedal ganglia (fig. 48, *pg.*) are rounded and nearly equal to the cerebral ganglia in size. They lie close together, and they are connected by a moderately large commissure. The nerves from the pedal ganglia supply the muscles of the foot. They need no special mention.

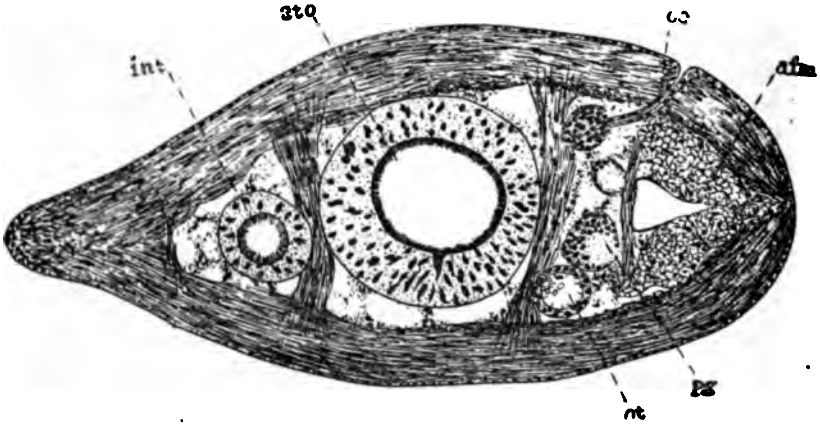
The visceral ganglia (fig. 48, *vg.*) are the smallest of the three pairs of ganglia. In shape they resemble the cerebral ganglia, but they are turned in the opposite direction. Each visceral ganglion is elongated, and gradually tapers anteriorly into the cerebro-visceral commissure. The two ganglia lie far apart, and are connected near their posterior ends by a long and rather thick commissure. A rather large nerve leaves the posterior end of each ganglion, runs posteriorly ventral to the posterior adductor muscle, and, besides giving branches to this muscle, supplies the posterior and ventral portions of the corresponding lobe of the mantle. Anterior and ventral to the posterior pallial nerves another rather large nerve leaves each ganglion. This nerve runs along the inner side of the suspensory membrane of the corresponding gill nearly to its posterior end.

OTOCYSTS.

The otocysts are formed soon after the embryo sheds its test. They originate as invaginations in the body-wall, a little posterior and dorsal to the pedal ganglia. The invaginations deepen and close over to form what seem to be closed sacs, that soon come to lie near the pedal ganglia in the interior of the foot. As in the case of Yoldia, these sacs are apparently entirely closed. Soon after the otocysts are formed, before the gills acquire their second lobes, otoliths appear. The otoliths have the appearance of little crystalline fragments, but I am inclined to think that they are formed in the otocysts, and are not introduced through the otocystic canals, as has been held by some writers. The particles seem to be too large to have been introduced through canals that, at this stage, I am unable to find. Again, the otocysts never seem to contain diatoms. Diatoms are very abundant in the brood-sacs in which the embryos are carried, and form a large part of the animal's food. Many of them are well shaped to pass through small openings, and one would expect to find them occasionally in the otocysts, if the contained material consists of foreign bodies that have gained access through the otocystic canals.

About the time that the gills acquire their sixth pair of plates the otocysts can be seen to be connected with the surface of the foot (figs. 46 and 64,*ot.*). At first the connection seems to be solid, but a little later openings can be traced from the otocysts to the exterior. These tubes, the otocystic canals, are quite slender near the otocysts, but widen toward the surface of the foot. From each otocyst the canal passes anteriorly, laterally, and a little dorsally to open to the exterior (figs. 46 and 64,*ot.*).

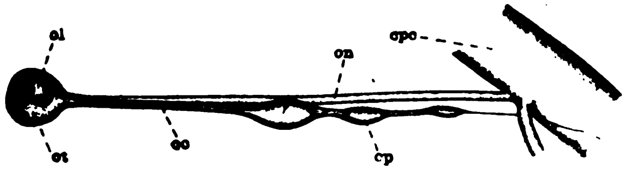
The position of the external opening is not just what might be expected if the otocystic canals are remnants of the invaginations that formed the otocysts. The otocysts are formed just posterior and a little dorsal to the pedal ganglia. As they develop, they sink into the interior of the foot and become permanently settled near the ganglia at points nearly opposite their points of origin. As the same relation between organs in his region is retained during the whole of the development, there is no reason to think that growth is more from one side than from another. If, then, the otocystic canals are remnants of the original invaginations, we might expect them to run almost perpendicular to the surface instead of opening so far anterior and dorsal. It might be thought that the development of the anterior foot muscles has crowded the stomach, ganglia, and otocysts posteriorly, and caused the otocystic canals to take up this position, but reference to fig. 64 will show that before these muscles become very large the otocystic canals open further toward the anterior than when these muscles become highly developed (text-fig. W). This seems to show that the muscles, as they develop, project anteriorly, and do not affect the organs lying behind them.



TEXT-FIG. W.—Horizontal section of the foot of an adult Nucula delphinodonta. The otocystic canals leave the dorsal side of the otocysts, so that in this section only the dorsal wall of the otocyst is seen on the side where the canal is present. *afm.* Anterior foot muscle. *int.* Intestine. *oc.* Otocystic canal. *ot.* Otocyst. *pg.* Pedal ganglion. *sto.* stomach.

In a former publication (1) I have described the imperfect otocystic canals of Yoldia limatula. The canals are short and do not reach the surface of the foot. Frequently a number of closed pouches are connected with the end of each otocystic canal by a strand of fibrous material (text-fig. X). Stempell reports that the otocystic canals of Leda pella are very rudimentary. He has never been able to trace them with certainty to the surface skin (17). The conditions illustrated by these two forms can easily be explained as the result of degeneration, but there is no direct evidence that this is the case. If the canals are not remnants of the original invaginations, the imperfect canals may be structures that have never been perfect canals, or they may indicate the degeneration of canals that have at some time been perfect.

The nerve-supply of the otocysts has been discussed in connection with the nervous system. It seems possible that the dorsal roots of the cerebro-pedal commissures may be the central ends of the otocystic nerves.



TEXT-FIG. X.—Otocyst of Yoldia limatula. *cpc.* Cerebro-pedal commissure. *oc.* Otocystic canal. *ol.* Otolith. *on.* Otocystic nerve. *op.* Otocystic pouch. *ot.* Otocyst.

MUSCULAR SYSTEM.

For convenience in treating the subject the muscles may be grouped into those concerned in shutting the shell, in moving the foot, in propelling blood, in retracting the margins of the mantle, in retracting the palp appendages, and in raising the gills. Beside these muscles, there are many scattered and interlacing fibres that are concerned in making many of the movements.

The anterior adductor muscle (figs. 25 and 36, *aa.*) is formed somewhat earlier than the posterior adductor muscle, and throughout life the former is larger than the latter (fig. 48). When the anterior adductor muscle is first formed (fig. 25, *aa.*), it occupies a position at the anterior end of the dorsal space, very near the apical plate. Soon after the test is shed, it becomes surrounded by tissue that is drawn up around it (figs. 35 and 39, *aa.*). The posterior adductor muscle is formed soon after the test is shed (fig. 39, *pa.*). It lies ventral to the intestine, and posterior to the visceral ganglia, and from its first appearance is surrounded by other tissue.

In the adult the adductors are attached to the shell, with their dorsal borders very near the ends of the rows of teeth. The function of these muscles is simply to close the shell. The contraction of the muscles, and the consequent closing of the shell, compresses an elastic pad known as the cartilage, that lies in the cartilage pit. As soon as the adductor muscles relax, the expansion of this piece of cartilage opens the shell. The epidermis is not thickened to form a prominent external ligament.

The foot is attached to the shell by three pairs of well developed foot muscles, and by a number of fibres that form a more or less connected series on each side, ventral to the genital organ and liver. Of the three pairs of foot muscles, one is posterior and two are anterior. The posterior muscles are inserted on the shell along the bases of the teeth, anterior and dorsal to the posterior adductor muscle. They extend anteriorly and ventrally along the sides of the foot, and form the strong retractors of the foot. The two pairs of anterior foot muscles are attached to the shell close together, along the bases of the teeth, posterior and dorsal to the anterior adductor muscle. In distribution, the anterior pair of these muscles corresponds to the two anterior pairs in Yoldia. They spread out along the sides of the foot, and are distributed to its posterior and ventral portions. The more posterior of the two pairs of muscles passes between the pair just mentioned, and is distributed to the anterior and ventral portions of the foot.

All of these muscles are closely bound together by their own fibres and by interlacing fibres, so that many movements occur that cannot be explained by direct pulls of one or more muscles. It should be remembered that the attachments of the fibres are all along the sides of the foot, and that many, if not most of the muscle-fibres, pull from one part of the body-wall to another, without changing the relation of the body to the shell. Thus the muscular side flaps of the foot can be spread apart after the animal has been removed from the shell.

Between the muscles, loose connective tissue and large blood-spaces occur. Many of the movements, especially those that result in the protrusion of the foot, seem to depend on the action of muscles on the fluids of the body, more especially upon the blood contained in the spaces of the foot. By obliterating some channels and forcing blood into others, different results may be obtained.

The muscle-fibres that are attached to the shell along the ventral border of the genital mass and liver are distributed to the body-wall. They are not as numerous as they are in Yoldia. I have found no indication of a special muscle at the posterior end of each series, as is the case with Yoldia (3).

The heart is largely made up of interlacing muscle-fibres. Each auricle is separated from the ventricle by a constriction (figs. 68 and 69, *h.*). It seems probable that, when the ventricle begins to contract, the contraction of the muscles in these constrictions closes the openings between the ventricle and the auricles so that the blood cannot flow back into them. Where the auricles join the blood-spaces of the gills and mantle lobes, the muscles probably act in the same way.

There are some muscle-fibres in the suspensory membranes of the gills that probably contract at intervals. The opaque shells make it impossible to watch the movements of the gills, but it will be seen that such movements as are made must force some of the blood out of the blood-spaces of the suspensory membranes. The movements are not enough to form strong currents of water, such as are formed by Yoldia (1).

The margins of the lobes of the mantles are never protruded far beyond the margins of the valves of the shell, and the pallial muscles are accordingly not excessively developed.

Each of the large palp appendages is supplied with a rather large muscle that is continued into it from the body-wall. It occupies the ventral (morphologically outer) side of the appendage (fig. 66, *lm.*), and is continued to its tip. This muscle serves to retract the appendage. Its position in the appendage is such that when the appendage is strongly retracted it is curled as shown in fig. 48. The muscle seems to be homologous with fibres that extend into the membrane that suspends the palps from the body-wall.

EXCRETORY ORGANS.

Just before embryos reach the stage where the second gill filaments begin to flatten, preparatory to forming the third gill filaments, a pair of narrow tubes appear just anterior to the visceral ganglia and ventral to the pericardium. The two tubes touch each other on the median line of the body, but their cavities do not seem to communicate. Laterally they are extended to the surface of the body, where they open into the mantle chamber. This is the earliest stage in which I have been able to distinguish the kidneys. I have not succeeded in determining whether the external openings are present from the beginning, or whether they are formed later. I am inclined toward the view that the kidneys are mesodermal in their origin; but this view is based simply on the length and narrowness of the tubes when they can first be distinguished. They may be formed as invaginations from the surface.

The cells forming the walls of the kidneys soon become large and vacuolated. This character is retained throughout the life of the animal, and makes the tracing of their cavities in some places a very difficult matter. Near the outer end of each kidney the cells are smaller, and the lumen is more easily traced. As the kidneys grow, they extend anteriorly and crowd dorsally beneath the pericardium and heart. As growth continues they become bent into loops, and numerous side pouches are formed.

Although much time has been spent in trying to find the inner, pericardial openings, of the kidneys, I have not succeeded in placing them. Cavities leading from the pericardium have frequently been traced nearly to the kidneys, but the vacuolated condition of the cells that compose their walls makes it very difficult to trace cavities with accuracy. I have no reason to suppose that the pericardial openings do not exist. I have simply been unable to find them.

In the adult, the ducts of the genital organs pass close to the lateral extremities of the pericardium. Near its end each duct turns toward the median line, meets the outer end of the kidney on the same side of the body, and opens with it into the mantle chamber. This connection is easy to demonstrate. Whether the genital ducts also communicate with the pericardium, or with the inner ends of the kidneys, I am not prepared to say.

GENITAL ORGANS.

The genital organs appear after the animal has become adult in most other respects. Each genital organ consists, at first, of a short and rather narrow tube that lies close to the pericardium, for the most part in contact with it. Whether this tube originates from the pericardium, or whether it is formed in some other way, has not been determined. The genital organs grow rapidly, and extend anteriorly and dorsally over and among the lobules of the liver, which are now very numerous. Soon the eggs and sperm begin to be formed, and the sexes can be distinguished. The eggs are few in number, but they are large and brown. The sperm are very numerous, of moderate size, and pale yellow. These colours are imparted to the genital organs. As their products begin to mature, the genital organs become very extensive and crowd between and around other organs, until all available space is filled.

The genital ducts of the adult, as in the young, connect with the outer ends of the kidneys, and with them open into the mantle chamber.

SUMMARY.

The young embryos of Nucula delphinodonta and Yoldia limatula resemble each other in most respects. They differ considerably in appearance, because of the difference in the size and distribution of the surface cilia. In the case of Yoldia the apical cilia are long and bunched together, and the cilia on the three intermediate rows of test-cells are collected into bands (text-fig. F). In Nucula delphinodonta all of the cilia on the surface of the embryo are short and evenly scattered (text-fig. E). The embryos of Yoldia swim freely in the water, and have to depend on their own activities for safety. The embryos of Nucula delphinodonta develop in a protecting brood-sac (fig. 1). It is to the advantage of these embryos to remain in the brood-sac, so active locomotion would not only be of no value, but it would be a positive danger. The possession of a test that is not functional as an organ of locomotion probably indicates that the embryos of the ancestors of Nucula delphinodonta were free-swimming. They then probably corresponded closely in appearance to the embryos of Yoldia limatula and Nucula proxima, both of which have the apical tuft and the bands of cilia.

The presence of a separate anal opening in the test, an extensive apical plate, and the formation of the cerebral ganglia without invaginations (fig. 24), are points in which Nucula delphinodonta differs from Yoldia. Nucula delphinodonta sheds its test when the foot is very immature.

The development of many of the organs of Yoldia has not been traced. The following is a brief review of the organs of Nucula delphinodonta.

Test.—The test consists of five rows of flattened cells, that together cover the greater portion of the body of the embryo. The cilia on the test are short and evenly distributed. The size and distribution of the cilia are probably the result of the protection afforded the developing embryo by the brood-sac. The test is finally thrown away. It is probably homologous to the velum of most Lamellibranch embryos. (See pp. 23-26, and figs. 11, 24, 25, 34, and 35.)

Apical Plate.—The apical plate is quite extensive, and bears short diffuse cilia that resemble the cilia on the test cells. The size of the apical cilia is probably also the result of the protection afforded the developing embryo by the brood-sac. The apical plate is thrown away with the test. (See pp. 26 and 27, and figs. 11 and 24.)

Shell.—The shell begins to form some time before the test is shed. The prodissoconch has a rounded outline and a short straight hinge-line. The adult shell is very robust. (See pp. 27 and 28, and figs. 20, 36, 50, and 51.)

Mantle.—The mantle lobes are formed by the growth and folding of the shell-gland. There are no tentacles on the margins of the mantle, and no siphons are formed. (See p. 29, and figs. 8, 17, 20, 48, and 69.)

Foot.—The foot is formed by the growth of tissue that, at first, lies between the stomodæum and the gut. At the time the test is shed it is very small and cannot be moved. The side flaps are developed as the result of unequal growth of the ventral side of the foot. The foot is a remarkably good burrowing organ, and it seems never to be used in creeping. (See pp. 30-33, and figs. 25, 28, 34, 36, 39, 40, 41, 48, 49, and 69.)

Byssal Gland.—The byssal gland is formed as an invagination on the ventral surface of the foot soon after the test is shed. It becomes very extensive, but in the adult is quite small. It seems never to form fibres. (See p. 33 and 34, and figs. 39, 40, 41, 45, and 48.)

Alimentary Canal.—The primitive gut is formed by the separation and division of cells on one side of the embryo. It is carried further into the interior by the addition of cells around the blastopore. These cells form the stomodæum. Later the gut grows posteriorly, beneath the shell-gland, and forms the stomach and intestine. The anus opens into the mantle chamber near the anal pore in the test. The future shape of the intestine seems to depend upon the position of certain organs during its elongation. (See pp. 34-39, and figs. 8, 9, 11, 15, 24, 25, 34, 36, 40, 45, 46, 47, and 48, and text-figs. M to S.)

Labial Palps.—The labial palps are marked out as patches of cilia about the time that the third lobe of the gill begins to form (fig. 41). The ciliated patches along the sides of the body are bent so as to form grooves (fig. 62, *lp.*) ; the dorsal portions of the patches form the outer palps, and the ventral portions the inner palps. The palp appendages are formed by unequal growth of the posterior portion of the outer palps, and each corresponds morphologically to a pair of ridges with a groove between them. They can be extended beyond the margins of the shell, and they are used as food collectors. (See pp. 39-43, and figs. 41, 45, 47, 48, 54, 55, 56, 57, 58, 59, 60, 62, and 66.)

Gills.—The gills are formed as folds on the inner sides of the lobes of the mantle. The folds form lobes that grow to form filaments and finally plates. The inner plates are formed first. The outer plates are formed by growth at the bases of the inner plates. A study of their development throws no light on the phylogeny of the gills. (See pp. 43-49, and figs. 39, 40, 41, 45, 48, 52, and 53.)

Hypobranchial Glands.—The hypobranchial glands are formed about the time that the animals become sexually mature. They seem to furnish the secretions from which the brood-sac is formed, and they may have other functions. (See pp. 49 and 50.)

Pericardium.—The pericardium is a remnant of a cavity that probable represents a schizocœle. Its epithelial lining seems to be formed by the rearrangement of mesodermal cells. (See pp. 50-52, and figs. 24, 26, 28, 34, 35, 36, 39, 41, and 48.)

Vascular System.—The heart is formed as a mesodermal strand that stretches across the pericardium from one side to the other. There is no indication that it is formed by the fusion of either a pair of pouches or two masses of cells. It seems to be single in its origin. It is formed around the intestine, but later becomes free and dorsal to it. This seems to show that for this group, at least, the dorsal position of the heart as found in the adult is not primitive. The vascular system consists largely of spaces that occur in all parts of the body. (See pp. 52-55 and figs. 41, 48, 67, 68, and 69.)

Nervous System.—The cerebral and pedal ganglia are about equal in size, and the visceral ganglia are considerably smaller. The cerebro-visceral commissures are very large, and contain many scattered nuclei. The cerebro-pedal commissures show ordinary structure. It is suggested that the smaller, dorsal roots of the cerebro-pedal commissures may be the central ends of the otocystic nerves. (See pp. 55-59, and figs. 24, 34, 36, 40, 46, and 48.)

Otocysts.—The otocysts are formed as invaginations from the body-wall soon after the test is shed. They seem to be entirely closed off, but canals connecting them with the surface are present in the adult. The otoliths are irregular bodies, but they are probably formed in the otocysts themselves. (See pp. 59-61. and figs. 40, 46, 48, and 64, and text-fig. W.)
377, and figs. 40, 46, 48, and 64, and text-fig. W.)

Muscular System.—The muscular system is well developed, and resembles the muscular system of Yoldia in most respects. The extensive attachments of the foot muscles to the dorsal portion of the shell is accounted for by the great development of these muscles. (See pp. 61-64.)

Excretory Organs.—The vacuolated character of the cells of the execretory organs makes it difficult to trace some portions of the cavities of these organs. The inner, pericardial openings, are hard to find. The outer end of each excretory organ opens into the mantle chamber, in connection with the genital duct of the same side. (See pp. 64 and 65.)

Genital Organs.—The genital organs are formed after the animal is adult in most other respects. They can first be distinguished as short tubes that lie very close to, or in contact with, the pericardium, and open into the mantle chamber in connection with the outer ends of the kidneys. The genital organs become very extensive in the adult. The sexes are separate. (See p. 65.)

Most of the work necessary for the preparation of this paper was done in the Biological Laboratory of the Johns Hopkins University. To many that are now or formerly were connected with that laboratory, and especially to Professor W. K. Brooks, I am indebted for suggestions and encouragement. I also desire to express my appreciation of the courtesies extended to me by Professor C. O. Whitman, at the Marine Biological Laboratory. I am particularly indebted to my wife, who has, among other things, performed a great share of the work connected with the care and preservation of material. Beside the work at the seashore, embryos obtained in June were kept alive in Baltimore from October 1st until January 1st, with water sent from the sea.

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Cartilage. *cg.*
port. *ec.* Ecto-
gill. *h.* Heart.
al palp. *k.* Kid-
palp. *m.* Mantle.
uter labial palp. *op.*
dductor muscle. *pap.*
scar. *pg.* Pedal gang-
modæum. *sto.* Stomach.
eeth on the shell. *v.* An
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modæum. × 275.
10.—Dorsal view of an embryo in which the test is growing over
hell-gland. The lines numbered 11, 12, and 13 indicate the planes of
ions represented in corresponding figures. × 150.

LITERATURE

1. DREW.—"Yoldia limatula," 'Memoirs from the Biol. Lab. of the Johns Hopkins Univ.,' vol. iv, No. 3, 1899.
2. DREW.—"Some Observations on the Habits, Anatomy, and Embryology of Members of the Protobranchia," 'Anat. Anz.,' Bd. xv, No. 24, 1899.
3. DREW.—"Locomotion in Solenomya and its Relatives," 'Anat. Anz.,' Bd. xvii, No. 15, 1900.
4. FORBES AND HANLEY.—'History of British Mollusca and their Shells,' 1853.
5. GROBBEN.—"Die Pericardialdrüse der Lamellibranchiaten," 'Arb. Zool. Inst. Wien,' Bd. vii, 1888.
6. JACKSON.—"Phylogeny of the Pelecypoda," 'Mem. Boston Soc. Nat. Hist.,' vol. iv, No. 8, 1890.
7. KELLOGG.—"A Contribution to our Knowledge of the Morphology of Lamellibranchiate Mollusks," 'Bull. U. S. Fish. Com.,' vol. x, 1890.
8. KOWALEVSKY.—"Étude sur l'embryogène du Dentale," 'Ann. Musée d'Hist. nat. de Marseille, Zool.,' tome i, 1883.
9. LACAZE-DUTHIERS.—"Histoire de l'organisation et du développement du Dentale," 'Ann. des Sci. Nat.,' series 4, tome vii, 1857.
10. MILNE-EDWARDS.—'Leçons sur la physiologie et l'anatomie comparée.'
11. MITSUKURI.—"On the Structure and Significance of some Aberrant Forms of Lamellibranchiate Gills," 'Quart. Journ. Micr. Sci.,' vol. xxi, 1881.
12. PATTEN.—"The Embryology of Patella," 'Arb. Zool. Inst. Univ. Wien,' Bd. vi, 1886.
13. PELSENEER.—"Contribution à l'étude des Lamellibranchs," 'Arch. de Biol.,' tome xi, 1891.
14. PELSENEER.—'Recherches morphologiques et phylogénétiques sur les Mollusques archaïques,' 1899.
15. PRUVOT.—"Sur le développement d'un Solénogastre," 'Compt. rend. Acad. Sci.,' Paris, tome cxi, 1890.
16. RICE.—"Die systematische Verwertbarkeit der Kiemen bei den Lamellibranchiaten," 'Jen. Zeit. für Naturwiss.,' Bd. xxxi, 1897.
17. STEMPELL.—"Beiträge zur Kenntniss der Nuculiden," 'Zool. Jahrb.,' Suppl. 4, Fauna Chilensis, Heft 2, 1898.
18. STEMPELL.—"Zur Anatomie von Solemya togata," 'Zool. Jahrb.,' Bd. xiii, 1899.
19. THIELE.—"Die Stammesverwandtschaft der Mollusken," 'Jen. Zeit. für Naturwiss.,' Bd. xxv, 1891.
20. ZIEGLER.—"Die Entwickelung von Cyclas cornea," 'Zeit. für wiss. Zool.,' Bd. xli, 1885.

EXPLANATION OF PLATES

Reference Letters

aa. Anterior adductor muscle. *aas*. Anterior adductor muscle-scar. *ap*. Apical plate. *bg*. Byssal gland. *bs*. Blood-space. *ca*. Cartilage. *cg*. Cerebral ganglion. *cp*. Cartilage pit. *cs*. Chitinous support. *ec*. Ectoderm. *f*. Foot. *g*. Gill. *gs*. Suspensory membrane of gill. *h*. Heart. *int*. Intestine. *ip*. Inner plate of the gill. *ilp*. Inner labial palp. *k*. Kidney. *l*. Liver. *lm*. Longitudinal muscle. *lp*. Labial palp. *m*. Mantle. *mg*. Mid-gut. *mo*. Mouth. *oes*. Œsophagus. *olp*. Outer labial palp. *op*. Outer plate of the gill. *ot*. Otocyst. *pa*. Posterior adductor muscle. *pap*. Palp appendage. *pas*. Posterior adductor muscle-scar. *pg*. Pedal ganglion. *pn*. Palp nerve. *sg*. Shell-gland. *std*. Stomodæum. *sto*. Stomach. *t*. Test. *tc*. Cavities in the mantle caused by teeth on the shell. *v*. An organ of unknown function. *vg*. Visceral ganglion. *y*. Cut wall of gill plate. *z*. Scattered cells of the disorganised liver.

PLATE 20.

FIG. 1.—Adult specimen with the brood-sac attached. The brood-sac is torn open to show the eggs inside. × 10.

FIG. 2.—Sixteen-celled stage. × 150.

FIG. 3.—Section of an embryo in the sixteen-celled stage. × 275.

FIG. 4.—Section of a later cleavage stage that corresponds to an epibolic gastrula. The asterisk (*) marks the position where the gut is formed. × 275.

FIG. 5.—An embryo that is slightly older than the one represented in section by Fig. 4. × 150.

FIG. 6.—Lateral view of an embryo in which the gut has been formed, represented as a slightly transparent object. From the study of preserved material I am inclined to think that the shell-gland does not bear cilia, but this has not been determined on living material. The line marked 7 indicates the plane in which the section, Fig. 7, was taken. × 150.

FIG. 7.—Transverse section of an embryo in the stage represented by Fig. 6. The line 7, on Fig. 6, indicates the plane of the section. × 275.

FIG. 8.—Sagittal section of an embryo in the stage represented by Fig. 6. × 275.

FIG. 9.—Sagittal section of an embryo slightly older than the embryo of which Fig. 8 is a section. It represents the beginning of the formation of the stomodæum. × 275.

FIG. 10.—Dorsal view of an embryo in which the test is growing over the shell-gland. The lines numbered 11, 12, and 13 indicate the planes of sections represented in corresponding figures. × 150.

FIG. 11.—Sagittal section of an embryo in the stage represented by Fig. 10. The line 11 on Fig. 10 indicates the plane of the section. × 275.

FIGS. 12 and 13.—Transverse sections of an embryo in the stage represented by Fig. 10. The lines 12 and 13 on Fig. 10 indicates the planes of the sections. × 275.

PLATE 21.

FIG. 14.—Lateral view of an embryo in which the test is fully formed, represented as a slightly transparent object. The lines numbered 16, 17, 18, and 19 indicate the planes of sections represented in corresponding figures. × 150.

FIG. 15.—Sagittal section of an embryo in the stage represented by Fig. 14. The anterior ends point in opposite directions in the two figures. × 275.

FIGS. 16, 17, 18, and 19.—Transverse sections of an embryo in the stage represented by Fig. 14. The lines 16, 17, 18, and 19 on Fig. 14 indicate the planes of the sections represented by these figures. × 275.

FIGS. 20, 21, and 22.—Transverse sections of an embryo older than the one represented by Fig. 14, and a little younger than the embryo represented by Fig. 23. The lines 20, 21, and 22 on Fig. 23 represent planes that correspond to these sections. × 275.

FIG. 23.—Lateral view of an embryo in which the mantle is beginning to form, represented as a slightly transparent object. The lines 20, 21, and 22 indicate the planes of sections represented in corresponding figures, but the embryo represented in Fig. 23 is slightly older than the one from which these sections were obtained. × 150.

FIG. 24.—Sagittal section of an embryo in the stage represented by Fig. 23. × 275.

FIG. 25.—Lateral view of an embryo that would soon shed its test. The test cells, indicated in outline, are very indistinct, and are not accurately drawn. Cilia have been indicated along the margins only. They cover the whole of the surface. The organs are more clearly shown than in preceding figures of embryos. They are not visible in whole mounts, but have been reconstructed from sections. The lines 27, 28, 29, 30, 31, 32, and 33 indicate the planes of sections represented by these figures. (See Plate 22.) × 150.

PLATE 22.

FIG. 26.—Sagittal section of an embryo in the stage represented by Fig. 25, Pl. 21. × 275.

FIGS. 27, 28, and 29.—Transverse section of an embryo in the stage represented by Fig. 25, Pl. 21. The lines numbered 27, 28, and 29 on Fig. 25 indicate the planes of sections represented by these figures. × 275.

FIGS. 30, 31, 32, and 33.—Horizontal sections of an embryo in the stage represented by Fig. 25, Pl. 21. The lines numbered 30, 31, 32, and 33 on Fig. 25 indicate the planes of the sections represented by these figures. × 275.

PLATE 23.

FIG. 34.—Lateral view of a reconstruction of an embryo that has just completed the first step in the process of casting. The test cells, apical plate, and stomodæum still adhere to the anterior end of the embryo. × 150.

FIG. 35.—Lateral view of a reconstruction of an embryo that has completed the process of casting. × 150.

FIG. 36.—Lateral view of a reconstruction of an embryo in which the liver pouches have begun to go to pieces. × 150.

FIG. 37.—Sagittal section of an embryo in the stage represented by Fig. 36. × 275.

FIG. 38.—Transverse section of an embryo in the stage represented by Fig. 36, taken through the stomach just posterior to the pedal ganglia. × 275.

FIG. 39.—Lateral view of a reconstruction of an embryo that is just beginning to form the gills. × 150.

FIG. 40.—Lateral view of a reconstruction of an embryo in which each gill is beginning to form two lobes. × 150.

FIG. 41.—Lateral view of a reconstruction of an embryo in which each gill is beginning to form its third lobe. × 150.

FIG. 42.—Horizontal section of an embryo in a stage represented by Fig. 40, taken through the dorsal end of the stomach and the re-forming lobes of the liver. × 200.

FIG. 43.—Horizontal section of an embryo in the stage represented by Fig. 41, taken through the dorsal end of the stomach and the re-forming lobes of the liver. × 200.

FIG. 44.—Horizontal section of an embryo in the stage represented by Fig. 46, Pl. 24, taken through the dorsal end of the stomach and the re-formed lobes of the liver. × 150.

PLATE 24.

FIG. 45.—Lateral view of a reconstruction of an embryo in which each gill has four pairs of plates. × 125.

FIG. 46.—Lateral view of a reconstruction of an embryo in which each gill has six pairs of plates. × 125.

FIG. 47.—Lateral view of a reconstruction of an embryo in which each gill has eight pairs of plates. × 110.

FIG. 48.—Lateral view of a reconstruction of an adult specimen. × 30.

FIG. 49.—Adult specimen with the foot protruded and the side flaps spread apart. × 10.

FIG. 50.—View of the inside of an adult left shell-valve. × 15.

FIG. 51.—Left shell-valve seen obliquely from the dorsal margin. × 15.

FIG. 52.—A nearly horizontal section of an embryo in the stage represented by Fig. 46, cut to show the developing outer plates of the gills. × 150.

Fig. 53.—A pair of adult gill plates. The suspensory membrane, the continuous chitinous trough, the longitudinal muscle, and the walls of the plates that join the plates next in succession have all been cut across in removing the plates from the gill. (Drawn from a study of sections.) × 250.

PLATE 25.

Figs. 54, 55, and 56.—Stages in the development of the labial palps. The palps have been carefully drawn, but for the sake of clearness they have in each case been represented with the outer palp on the right side turned away from the corresponding inner palp. The foot is represented as cut off, and the specimen is turned so that the mouth can be seen between the palps. × 125.

Fig. 57.—The posterior portions of the right outer and inner palps of an adult specimen. The two palps are represented as spread apart and placed in a position that corresponds with Fig. 56. × 65.

Figs. 58, 59, and 60.—Successive sections of the labial palps of a specimen that has six pairs of gill plates. The sections are taken transverse to the embryo. The stage is much the same as is represented by Fig. 54. Fig. 58 is near the mouth, Fig. 59 is near the posterior end of the outer palp, and Fig. 60 is posterior to the outer palp. × 150.

Fig. 61.—Transverse section of an embryo with four pairs of gill plates (see Fig. 45, Plate 24) taken through the mouth. × 200.

Fig. 62.—Transverse section of an embryo with four pairs of gill plates, taken just anterior to the stomach. × 200.

Fig. 63.—Sagittal section of the antero-dorsal portion of an embryo that has eight pairs of gill plates. × 150.

Fig. 64.—Horizontal section of the foot of an embryo that has six pairs of gill plates, taken just ventral to the mouth. × 150.

Fig. 65.—Horizontal section of the foot of an embryo that has six pairs of gill plates, taken through the mouth. × 150.

Fig. 66.—Transverse section of the palp appendage of an adult specimen. × 200.

Fig. 67.—A nearly transverse section of an embryo that has five pairs of gill plates, taken through the heart. × 200.

Fig. 68.—A diagonal section of an embryo that has nine pairs of gill plates, taken through the heart. × 90.

Fig. 69.—A diagonal section of an adult specimen, taken through the heart. × 45.

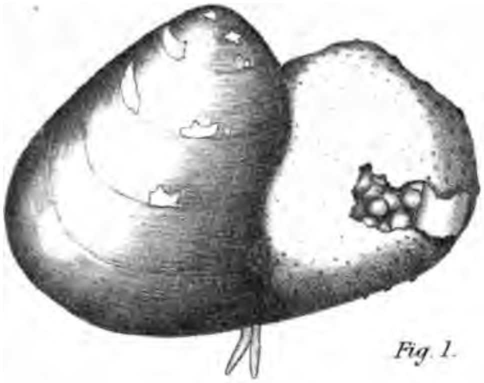
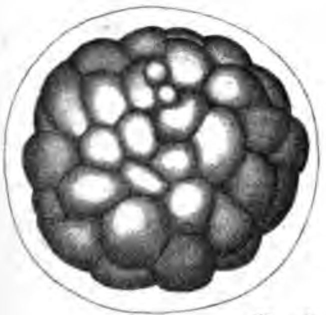


Fig. 1.

Fig. 2.



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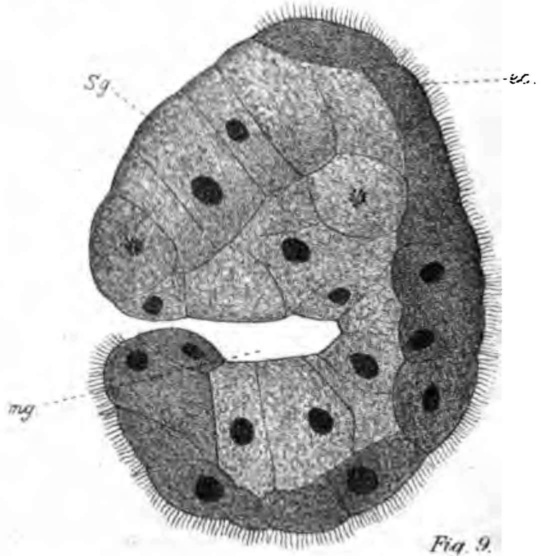

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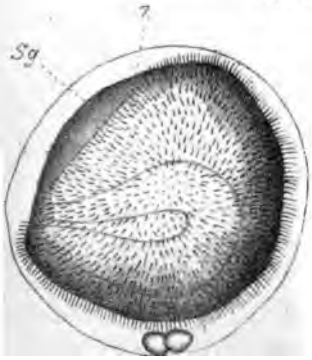

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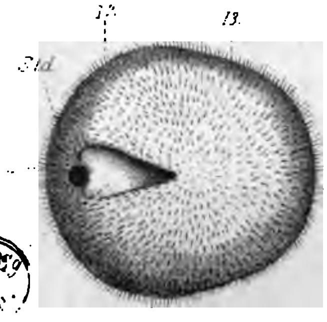

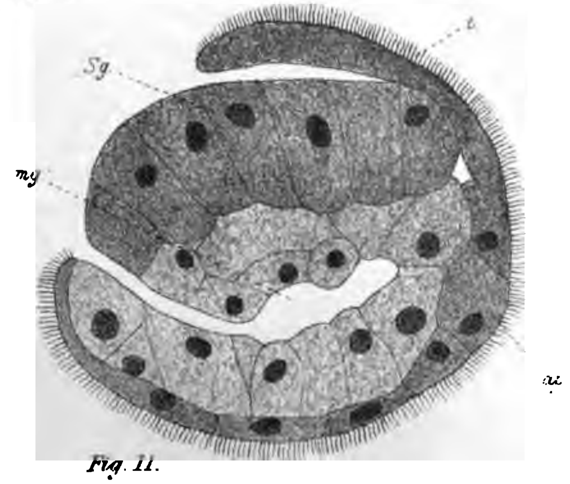

Fig. 11.

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Fig. 10.

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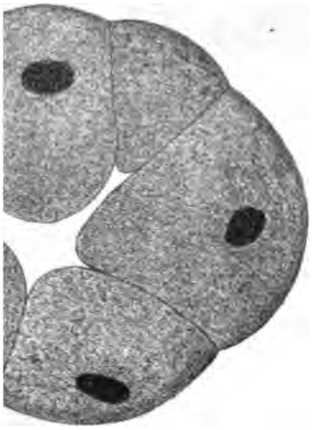

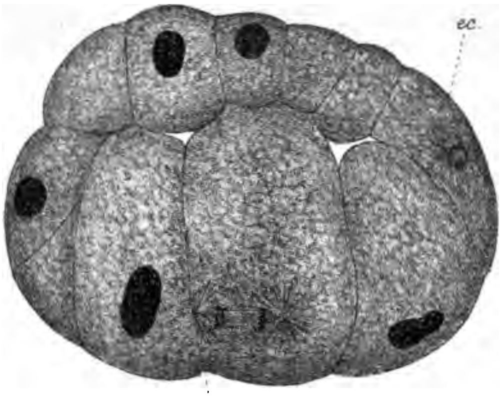

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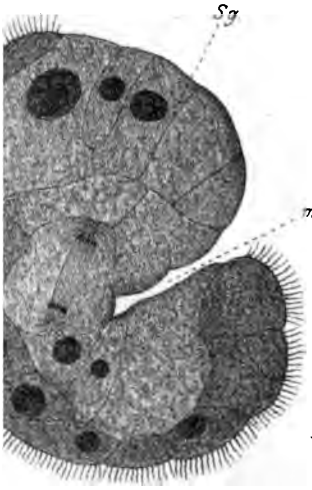

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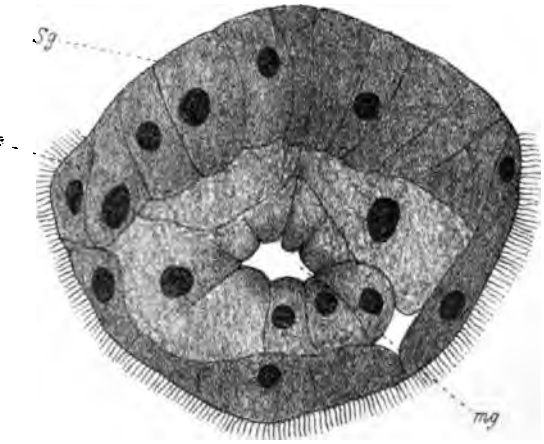

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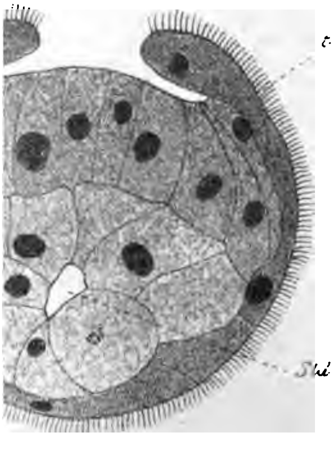

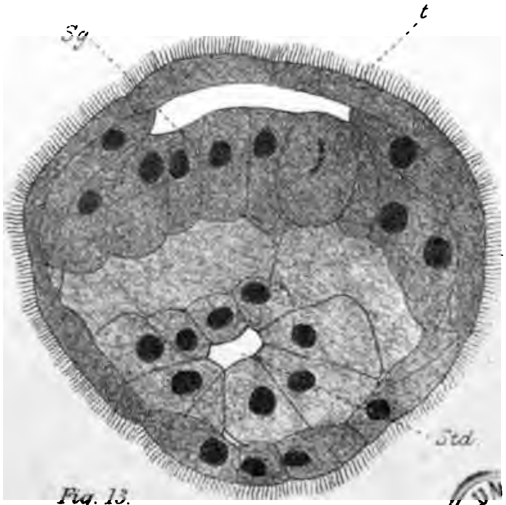

Fig. 13.

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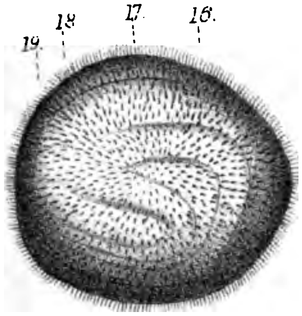
Fig. 14.



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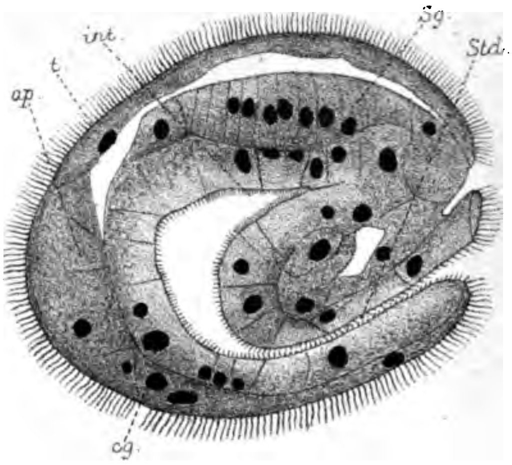

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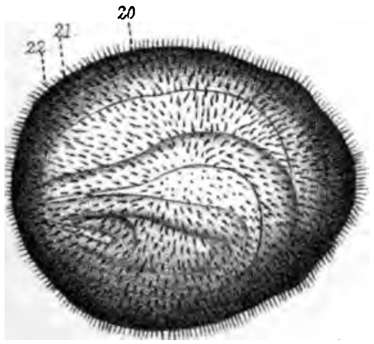

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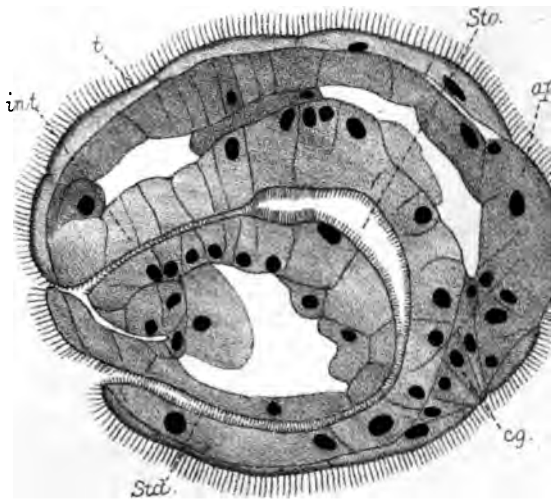

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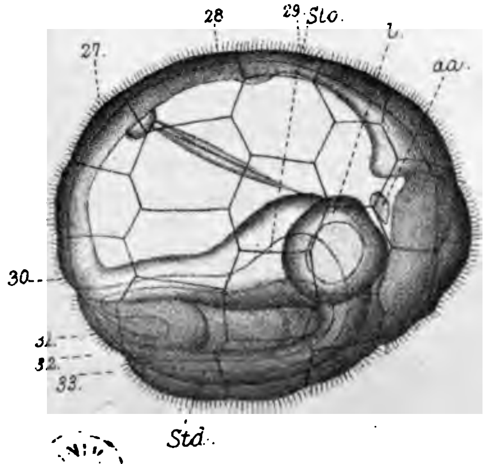

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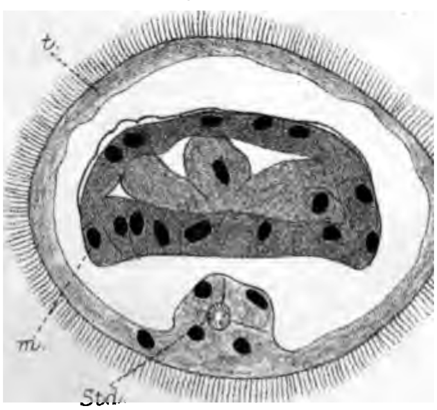

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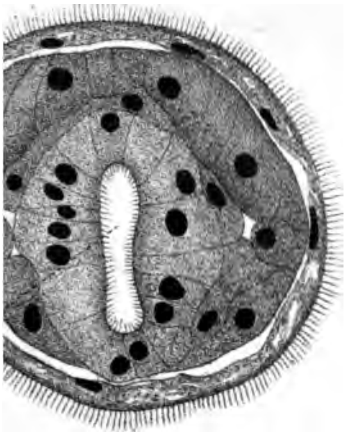
Fig. 16.



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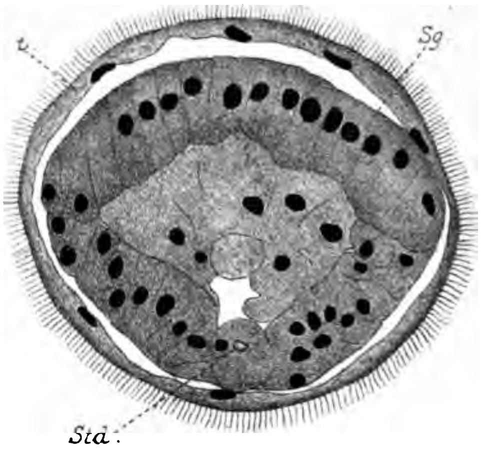

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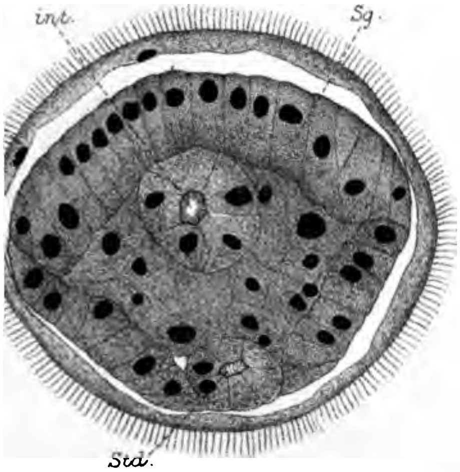

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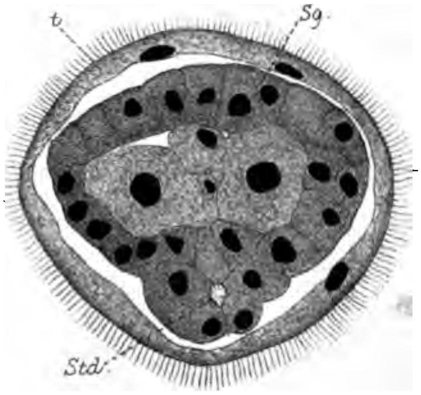

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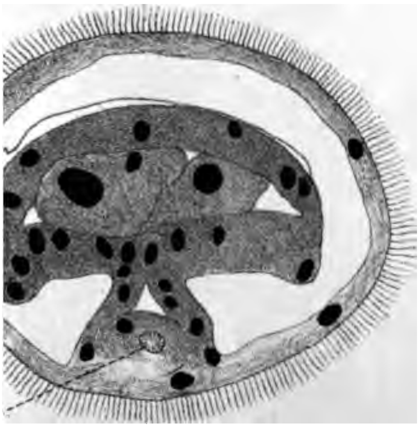

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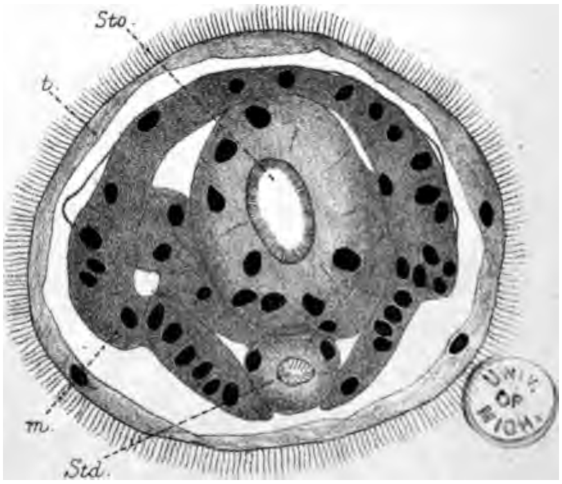

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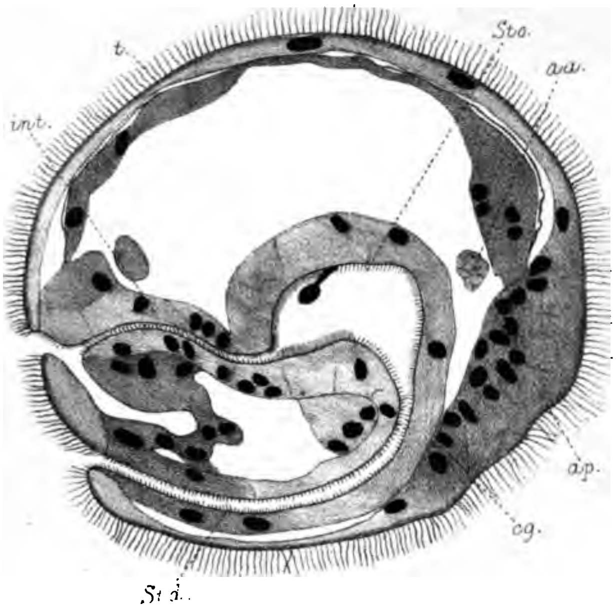

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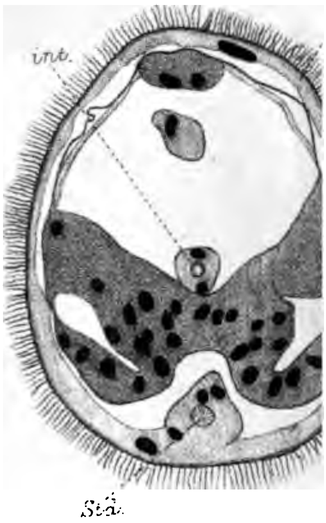

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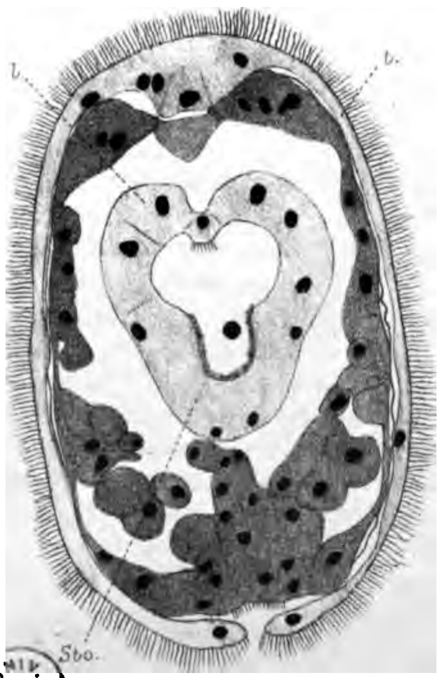

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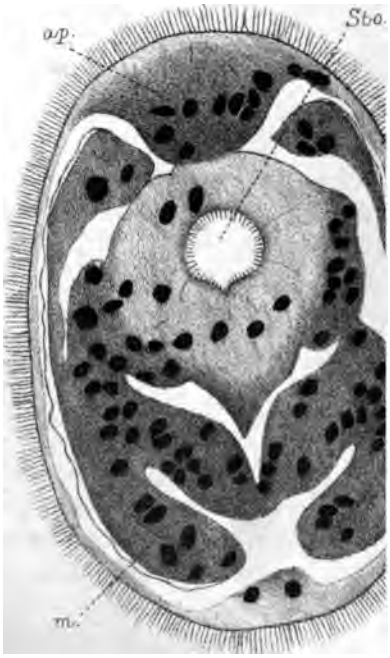

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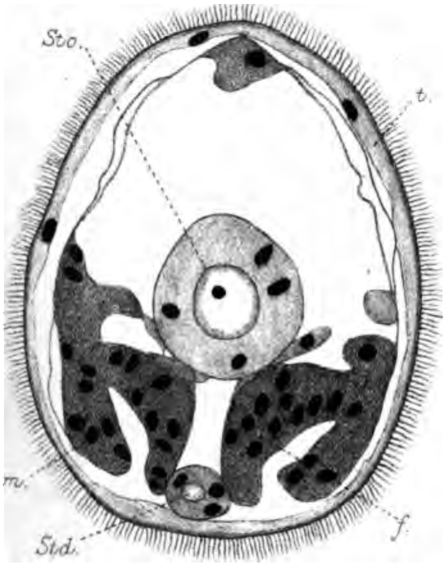

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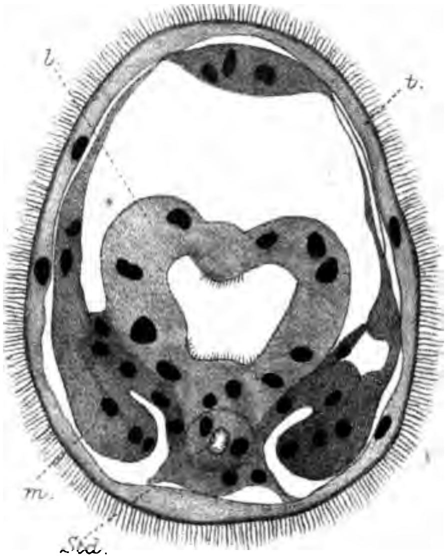

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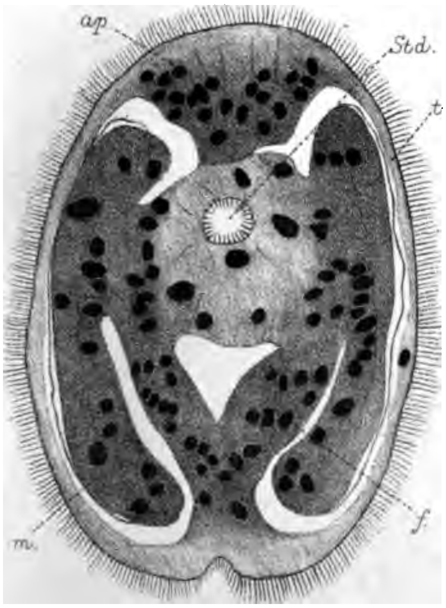

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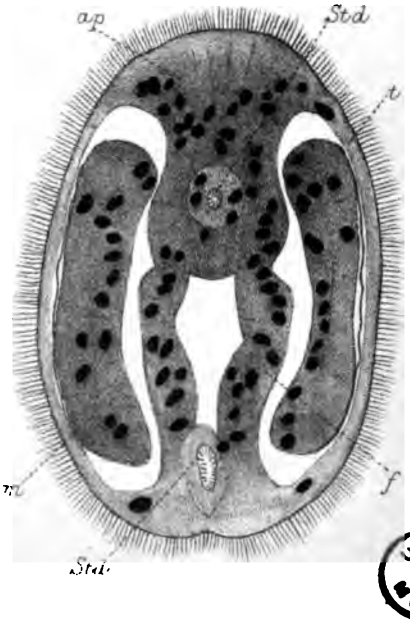

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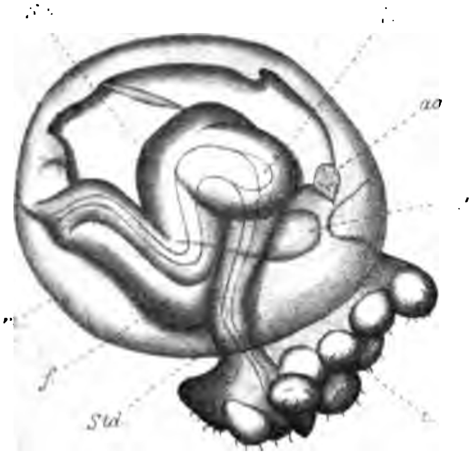

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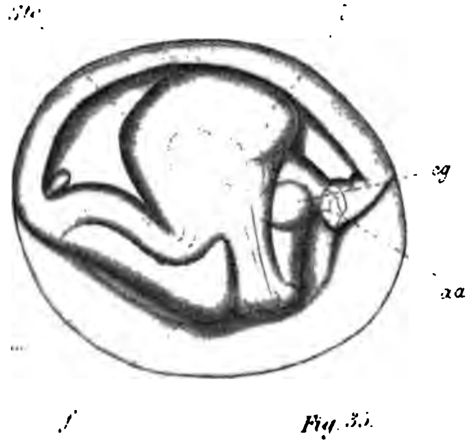

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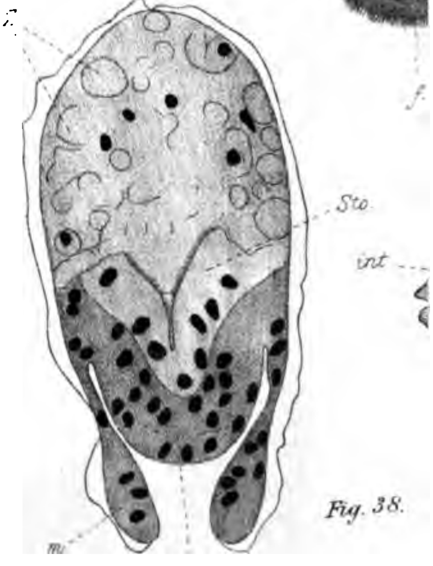

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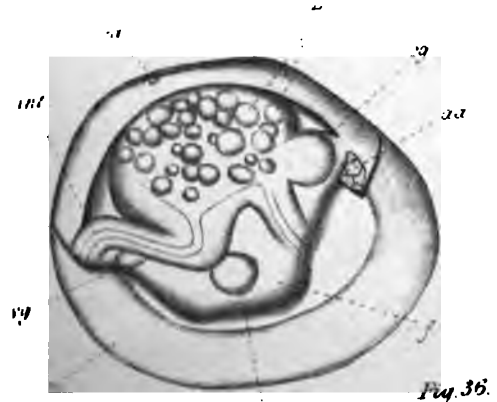

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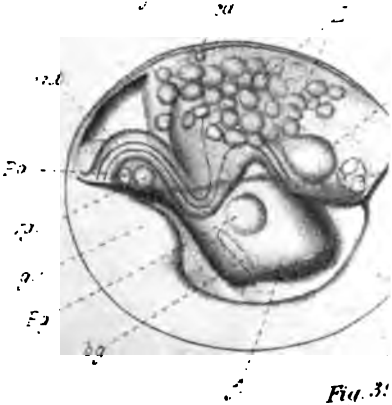

Fig. 3

Fig 37.

Fig 43.

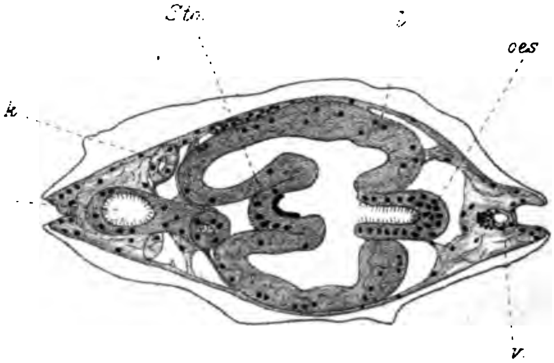

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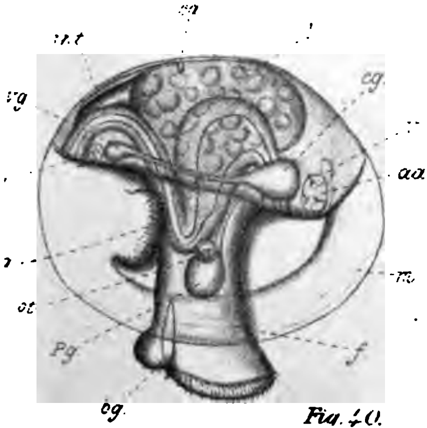
Fig. 42.



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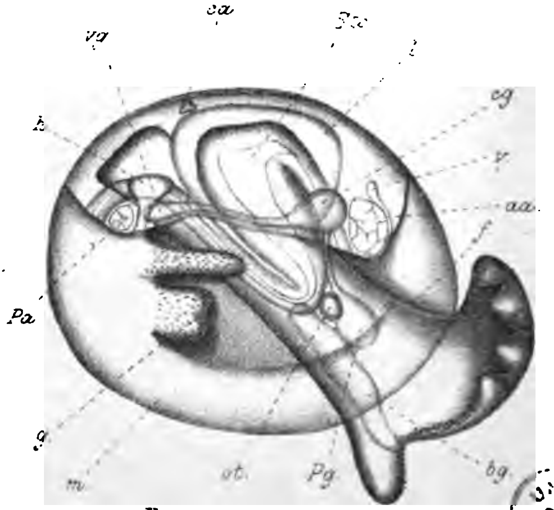

Fig 41.

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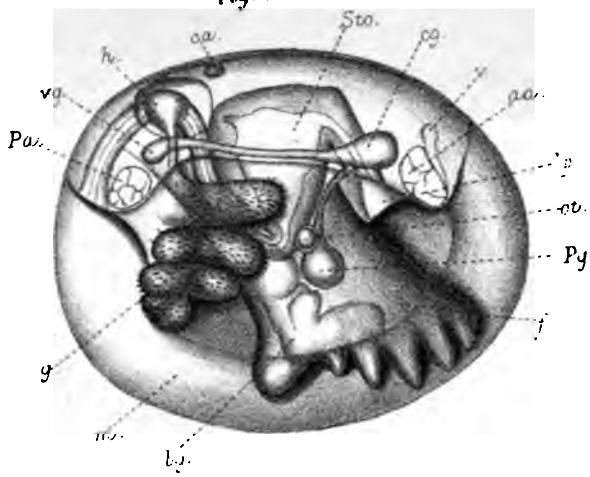
Fig. 45.



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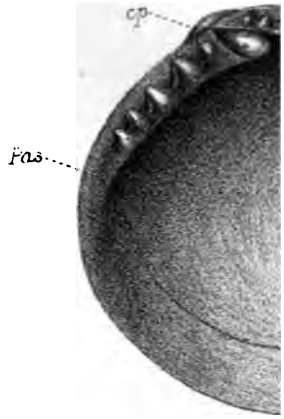

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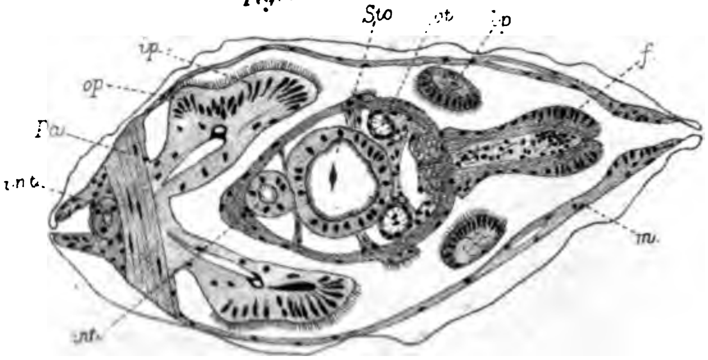

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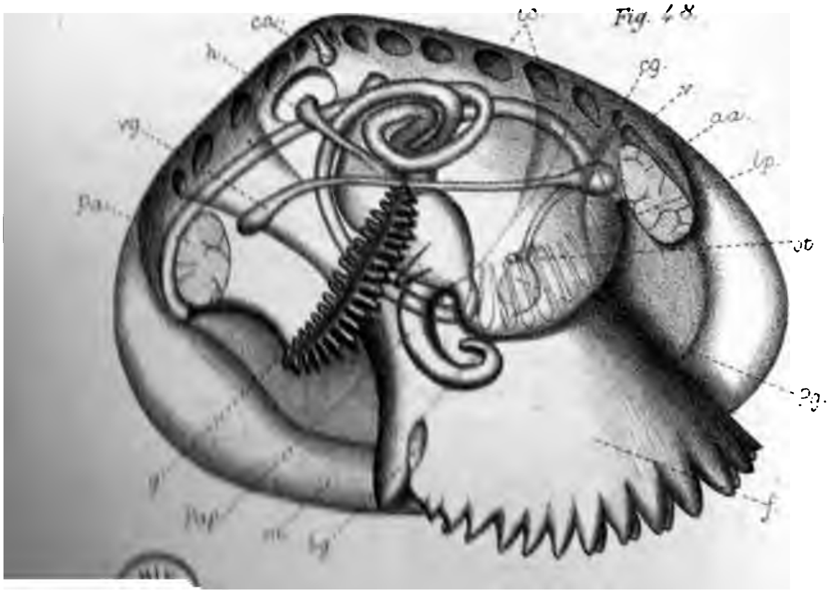

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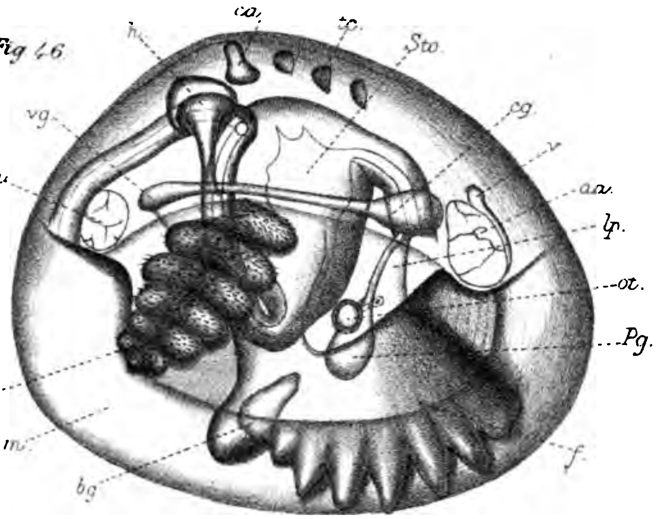

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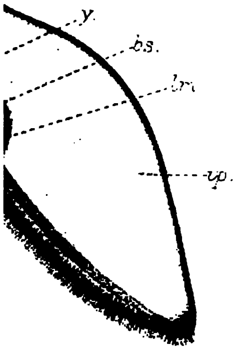

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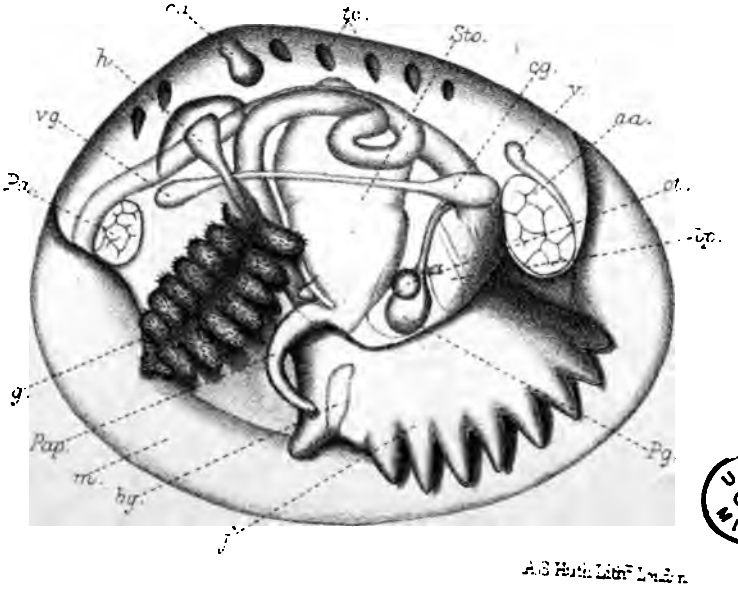

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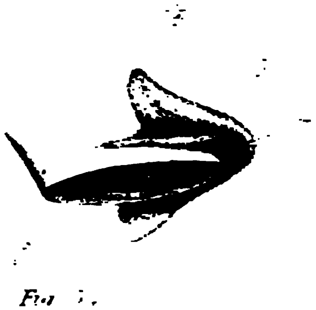

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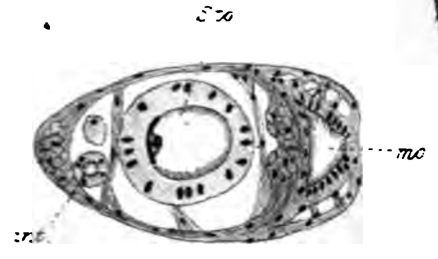

Fig. 65.

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Fig. 67

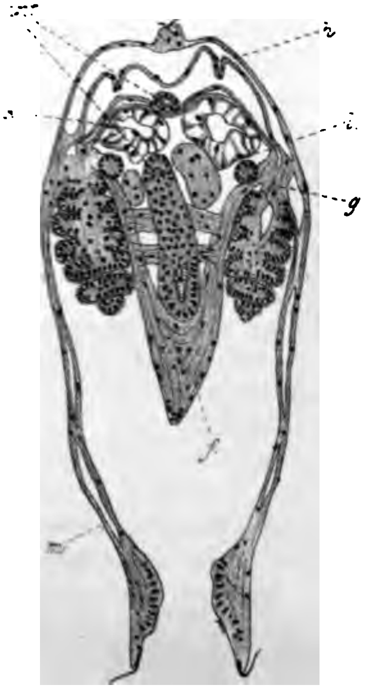

Fig. 68

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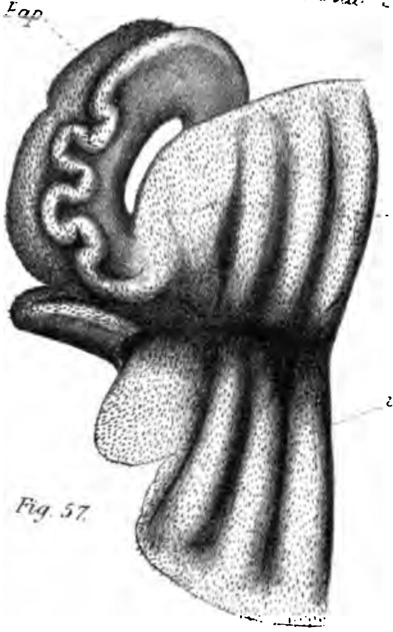
Fig. 55.



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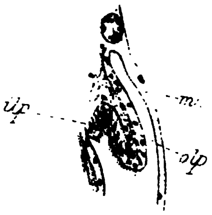

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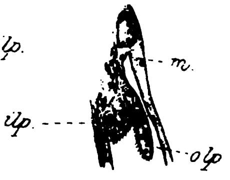

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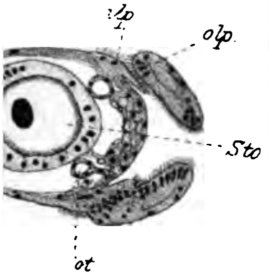

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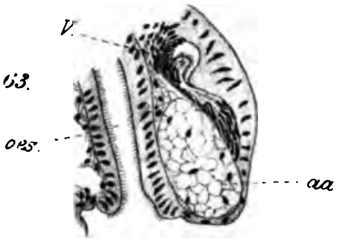

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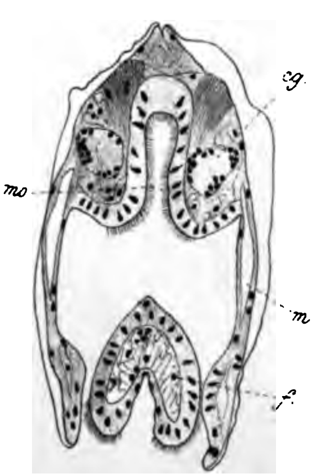

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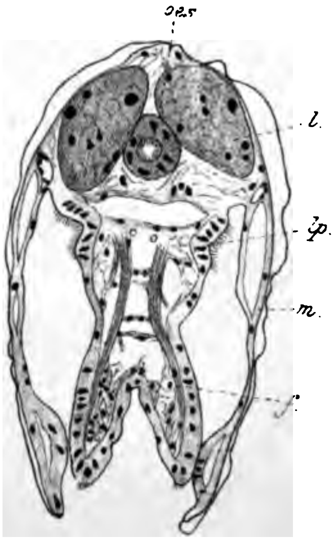

Fig. 62.

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The University of Maine Studies

No. 3

A Preliminary List of Maine Fungi

BY

PERCY LeROY RICKER, M. S.

Assistant in Biology

ORONO, MAINE
April, 1902

HISTORICAL SKETCH OF THE STUDY OF THE MAINE FLORA

While no group of Maine plants has been thoroughly investigated, our knowledge of the phanogamous plants is probably more complete than of any other group. This is due to the more general interest taken in that group, and to the efforts of Mr. M. L. Fernald of the Gray Herbarium, who has published an extended list of Maine plants.[1] A large part of our knowledge of the lower forms is due to the extensive lists of Filamentous Algæ,[2] Lichens,[3] Characeæ,[4] and several groups of Fungi[5] published by the late Professor Francis L. Harvey, of the University of Maine. Some knowledge of the Diatoms of the State has also been given us by Professor A. B. Aubert,[6] of the University of Maine. There are no published lists of other groups, but a list of about 150 species of Mosses was prepared by Mr. E. D. Merrill while in the University of Maine, and large collections of Maine Mosses are preserved in the University herbarium. Extensive collections of Liverworts have been made by Professor Harvey and his students, and specimens of them have been preserved in the University herbarium.

Rev. Joseph Blake was the first to study the Fungi of Maine. Many new and interesting forms were found by him, and several of them were described by Rev. M. J. Berkley of England, and Rev. Moses A. Curtis of North Carolina. Mr. Blake's collections were mostly made in Cumberland county and about August

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[1] Proc. Portland Soc. Nat. Hist. 2: pts. 2, 3, & 4. 1892-97.

[2] Bull. Torr. Bot. Club, 15: 155-161, 1888; 16: 181-188, 1889; 19: 118-125, 1892.

[3] Bull. Torr. Bot. Club, 21: 389-393, 1894; 23: 7-10, 1896.

[4] Bull. Torr. Bot. Club, 22: 397-398, 1895.

[5] See Harvey, F. L. in List of works and papers treating of Maine Fungi. For complete bibliography of Maine botany see Rhodora 1; 111-151, 1899.

[6] Le Diatomist 2: 150-151 & 211, 1894-95. Am. Mo. Micr. Jour. 17: 165-6, 1896.

30, 1856, his first lot of Fungi was sent to Dr. Curtis for identification. It was largely through the encouragement received from Dr. Curtis that he continued his collections in this line. Their correspondence lasted until March 23, 1861, and during this time 800 specimens of Fungi were sent Dr. Curtis for identification.[1] Notes on many of these forms were given in "Notices of North American Fungi," which were published in Grevillea.[2] Very little collecting was done in Maine by Mr. Blake after 1861, but a few specimens were picked up on his trips through Maine which lasted until 1880.

Shortly after collecting was begun in Maine by Mr. Blake, small collections were made around Portland by Mr. C. B. Fuller and Rev. E. C. Bolles. Most of their collections were sent to Dr. M. C. Cooke of England, and notices were published in Grevillea and the Proceedings of the Portland Society of Natural History.

The next botanist to give attention to these plants was the late Professor F. L. Harvey. His collections were larger and he made a more thorough study of Maine Fungi than any of his predecessors, but his University work prevented him from spending very much time on the group, and he gave very little attention to it after 1897. Most of his collections after that date, except the Myxomycetes, were turned over to the author. On this latter group he spent much of his spare time, making a very thorough study of them.

While a student in the University, Mr. E. D. Merrill made extensive collections in the vicinities of Orono and Auburn, and from these collections, together with those made by the author between 1896 and 1901, the greater part of this list has been compiled.

This list is very incomplete as collecting has been principally confined to Cumberland, Androscoggin, and Penobscot Counties, but in order to call attention to this very much neglected group, and perhaps serve to stimulate further study, it seems advisable to publish it in this condition.

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1. Dr. Curtis's correspondence with Mr. Blake has been preserved and is in the University Herbarium. It contains many interesting notes.
2. See Berkley, M. J. in list of works on Maine Fungi.

LIST OF WORKS AND PAPERS TREATING OF MAINE FUNGI

Berkley, Rev. M. J. Notices of North American Fungi, Grevillea, 1:68, 147, 1872-73; 2:7, 20, 50, 99, 100, 157, 179. 1873-74; 3:63, 100, 107, 154. 1874-75. 4:4, 51, 52, 104, 106, 157. 1875-76.

——— and Curtis, Rev. M. A., Centuries of North American Fungi. Am. Mag. Nat. Hist. Ser. 4.3: 288-293. 1859.

Cooke, M. C. Decades of Maine Fungi. Proc. Portland Soc. Nat. Hist. 1: 179-185. 1862.

——— North American Fungi. Grevillea, 5: 150-153. 1877; 11: 111. 1883.

——— Pezizæ Americanæ. Hedwigia, 14:81-85. 1875.

——— and Ellis, J. B. New Jersey Fungi. Grevillea, 5: 33. 1876. Mentions or describes four Maine species.

Ellis, J. B. New North American Fungi. Bull. Torr. Bot. Club, 8:74. 1881.

——— and Everhart, B. M. North American Phyllostictas. p. 101. 1900.

——— ——— New species of North American Fungi from various localities. Proc. Phil. Acad. Sci. 1893: 148, 160. 1894; Bull. Torr. Bot. Club, 24:475. 1897; 27: 572-573. 1900.

——— ——— Fungi Columbiani. Century XV continued by C. L. Shear. Numbers 1340, 1360, 1408, 1416, 1461, 1482.

——— ——— North American Fungi. Numbers 237, 1920, 1932, 2010, 2017, 2018, 2079, 2347, 3278, 3597.

——— ——— North American Pyrenomycetes. p. 203. 1892.

——— ——— Synopsis of North American Hypocreaceae. Jour. Mycol. 2:67, 133. 1886.

Farlow, W. G. The Gymnosporangia or Cedar-Apples of the United States. pp. 13, 27-30. 1880.

Harvey, F. L. Contributions to the Gasteromycetes of Maine. Bull. Torr. Bot. Club, 24:71-74. 1897.

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[1] This list is probably incomplete, and the author will be greatly obliged for any additions.

——— Contributions to the Myxogastres of Maine. Bull. Torr. Bot. Club, 23: 307-314. 1896; 24: 65-71. 1897; 26; 320-324. 1899.

——— Contributions to the Pyrenomycetes of Maine. Bull. Torr. Bot. Club, 23: 50-58. 1896.

——— and Knight, O. W. Cryptogams Collected near Jackman, Maine, August, 1895. Bull. Torr. Bot. Club, 24: 340-342. 1897.

Lister, A. A. Monograph of the Mycetozoa. 1895.

Macbride, T. H. The North American Slime Moulds. 1899.

Peck, C. H. Boleti of the United States. Bull. N. Y. State Museum. 8: 78. 1889.

——— New species of Fungi. Bull. Tor. Bot. Club, 22: 493. 1895; 23: 419-420. 1896; 25: 328. 1898; 26: 69-70. 1899; 27: 20-21, 611. 1900.

Robinson, B. L. Rhodora, 1: 90. 1899, mentions Ustilago violacea (P.) Fckl., as U. antherarum Fr.

Saccardo, P. A. Sylloge Fungorum. 1: 308, 355, 377. 1882; 2: add. XLI. 1883; 3: 170, 178. 1884; 4: 355. 1886; 5: 368, 448, 487. 1887; 6: 400, 793, 798. 1888; 7: 584, 1888; 8: 163, 472, 1889.

Schrenk, Herman von. Some Diseases of New England Conifers. U. S. Dept. Agr. Div. Veg. Phys. and Path. Bull. 25. 1900.

Sprague, C. J. Contributions to New England Mycology. Proc. Bost. Soc. Nat. Hist. 5: 325-331. 1856; 6: 315-321. 1859.

Thaxter, R. The Entomophthoreæ of the United States. Mem. Bost. Soc. Nat. Hist. 4: No. VI. 1888.

——— Contributions towards a monograph of the Laboulbeniaceae. Mem. Am. Acad. of Arts and Sci.; 12: No. III. 1896.

——— Preliminary diagnoses of new species of Laboulbeniaceæ. Proc. Am. Acad. of Arts and Sci. 36: No. 23. 1901.

Thaxter, R. New or Peculiar Aquatic Fungi. Bot. Gazette, 28: 480-481. 1897.

Underwood, L. M. Bull. Torr. Bot. Club, 26: 254. 1899. Describes Cantharellus multiplex.

——— On the Distribution of North American Helvellales. Minn. Bot. Studies, Bull. 39, Part 8. 1896.

A PRELIMINARY LIST OF MAINE FUNGI

The following list includes such species of Fungi as are known to be found in the State of Maine, and although necessarily incomplete, it is hoped that it will serve as a stimulus to the further collection and study of the forms belonging to this more or less obscure group. No very thorough study has been made of the Fungi of this state and it is confidently expected that further study and collection will increase this list to two or three times its present number. The state is a rich field for collecting and ought to furnish many more new and interesting forms.

With the exception of such references as have been taken from literature, most of the species here listed are known to be in some Maine collection. Those marked with an asterisk have been taken from the notes of the late Professor F. L. Harvey. Although the specimens can not now be found, there is no doubt that they are authentic. Professor Harvey lost a large part of his collection of Agaricaceæ, and a few other specimens, from the ravages of insects. Many of these specimens were determined by Professor C. H. Peck. Doubtless others have been misplaced or lost. In many cases the only specimen collected was sent away for determination, and unfortunately very few letters from his correspondents have been preserved. However, such species are indicated and it is hoped that they may be verified or collected again by some of those into whose hands this list may come.

The location of the material on which this list is based may be determined from the following statement:—

1. Species referred to in literature, a list of which has already been given, are presumably in the collections of the various authors. Specialists interested will probably know where these collections are located.

2. Species collected by the Rev. Joseph Blake are in the Blake Herbarium, now owned by the University of Maine. Determinations made by M. J. Berkley, M. A. Curtis, M. C. Cooke, and J. B. Ellis.

3. Species collected by Professor F. L. Harvey are now owned by Mr. LeRoy H. Harvey, Orono, Me. Myxomycetes verified by A. P. Morgan, T. H. Macbride, and G. A. Rex. Other species,

except those marked with an asterisk, presumably determined by Professor Harvey unless otherwise stated.

4. Species collected by various students while in the University are either in the Harvey or the University collections.

5. Species collected by Mr. E. D. Merrill, Washington, D. C., while an undergraduate and graduate student at the University of Maine, 1894-1899. Determinations by Professor Harvey unless otherwise stated.

6. Species collected by the author while an undergraduate and graduate student at the University of Maine, 1896-1901. Determinations made by the author unless otherwise stated, but only after careful microscopical examination and comparison with authentic specimens, as well as descriptions. Uredineæ all verified by Dr. J. C. Arthur. Duplicates of most of the species collected by Prof. F. L. Harvey and Rev. Jos. Blake are also in the authour's herbarium.

The credit for the foundation of this work belongs to the late Professor Harvey, and to him the author is greatly indebted for assistance and inspiration in taking up this work. He is also indebted to the following:—

To Mr. L. H. Harvey for access to his father's collection.

To Messrs. J. B. Ellis, C. H. Peck, J. C. Arthur, E. A. Burt, and W. G. Farlow for determination or verification of specimens.

To Dr. Roland Thaxter for the loan of literature.

The classification followed is that of Saccardo's Sylloge Fungorum, the genera and species being arranged alphabetically. In the case of parasitic species the hosts are given as far as possible, but in some cases the determination of the host was not made at the time of collecting and the material is such that it is impossible to make it now.

For the benefit of those who are not familiar with the lower forms of plants it may be well to indicate briefly some of the characteristics of the Fungi, giving as far as possible the common names of the various groups into which the Fungi are divided. The Fungi, popularly known under the names of moulds, mildews, smuts, rusts, toadstools, and mushrooms, are plants:—

1st. Of very simple structure.

2nd. Contain no Chlorophyll, which is the green coloring matter of the higher plants, and therefore cannot live on inorganic matter, as do other plants.

3rd. Reproduce by very minute spores instead of seeds.

It must be understood, however, that spores are not homologous with seeds. Spores are analogous with seeds and homologous with the pollen of the flower of the higher plants.

Since the Fungi are not able to live on inorganic matter, they must live as parasites on living plants or animals, or as saprophytes on decaying plants or animals. To the former class belong a large number of forms which are very injurious to cultivated and wild plants. Investigators in many of the Experiment Stations of this country have given much time to the study of these injurious Fungi, and already much has been learned regarding the life histories and the best methods of checking the ravages of these parasites.

Fungi are variously classified by different authors, but for convenience they have been divided into six classes, two of which are not usually considered as true Fungi. These classes are in turn divided into orders, and orders into families. The various classes and orders with such common names as have been applied to them may be arranged as follows:—

Class I. MYXOMYCETES (Slime moulds). Represented in Maine by one order (Myxomycetaceæ), which live mostly on rotten wood, and are very remarkable organisms. In the early stages of their life history they resemble certain of the lowest forms of animal life. In latter stages they resemble the puff-balls (Lycoperdaceæ), and were placed in that order by our early mycologists. Later they were placed in an order by themselves and placed at the foot of the vegetable kingdom. For the past few years there has been a general indisposition among both botanists and zoologists to claim them. One of the latest standard text-books on zoology[1] places them among the lowest forms of animals. On this account they have been placed first in the list. They are included because they have been pretty

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[1] Parker and Haswell, A Text-book of Zoology.

carefully studied in Maine[2] and they are usually regarded as plants.

Class II. SCHIZOMYCETES. Include the bacteria, many of which are useful to man; others produce serious diseases in man and animals, and some produce diseases in plants, as the pear blight (Micrococcus amylovorus). They are not, however, considered as true Fungi.

Class III. PHYCOMYCETES (lower or algal-fungi).

Order Mucoraceæ. Including most moulds except the ordinary green mould.

Order Peronosporaceæ.—Including "white rusts" and "downy mildews." Of considerable economic importance.

Order Saprolegniaceæ.—Aquatic moulds often parasitic on fish and causing much trouble in fish hatcheries.

Order Entomophthoraceæ.—Mostly parasitic on insects and are beneficial.

Order Chytridiaceæ.—Simple parasites affecting a few of the higher plants.

Class IV. DEUTEROMYCETES.—Commonly known as "imperfect fungi," of which there are three orders. Many of these are probably stages in the development of ascomycetous fungi. A few are of considerable economic importance; but comparatively little is known of their life histories.

Class V. ASCOMYCETES (spore-sac fungi).

Order Saccharomycetaceæ.—Yeast plants.

Order Pyrenomycetaceæ.

Family Perisporiaceæ.—Including the "powdery mildews," which are of considerable economic importance.

Family Sphaeriaceæ.—Includes the "black knot." Mostly saprophytic forms.

Family Hypocreaceæ.—Includes the ergot of grain.

Family Dothideaceæ.
Family Microthyriaceæ.
Family Lophiostomaceæ.
Family Hysteriaceæ.

Many saprophytic forms. Of little economic importance.

Family Laboulbeniaceæ.—Minute fungi found on insects. No economic importance. Their position in classification is uncertain.

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[2] By Professor F. L. Harvey.

Order Discomycetaceæ.
Family Helvellaceæ.—Fleshy fungi, some edible.
Family Pezizaceæ.
Family Dermateaceæ.
Family Bulgariaceæ.
Family Stictidaceæ.
Family Phacidiaceæ.
Family Patellariaceæ.
Cup or saucer shaped fungi, mostly fleshy; but few of economic importance. Phacidiaceae parasitic on leaves.
Family Gymnoascaceæ.—"Leaf-curl" and "plum-pockets." Of considerable economic importance.
Family Caliciaceae.—No economic importance.
Class VI. BASIDIOMYCETES.
Order Ustilaginaceæ.—Smuts, parasitic on corn and grain.
Order Uredinaceæ.—Rusts, parasitic on higher plants.
Order Hymenomycetaceæ.
Family Agaricaceæ.—Toadstools and mushrooms. Gills on the under side.
Family Polyporaceæ.—The woody or bracket fungi. Pores on the under side.
Family Hydnaceæ.—Toadstool—like forms with spines.
Family Clavariaceæ.—Club or coral like forms.
Family Thelephoraceæ.—Ear-fungi; mostly on rotten wood.
Family Tremellaceæ.—Soft, waxy or gelatinous fungi.
Order Gasteromycetaceæ.
Family Phallaceæ.—Stink-horn fungi.
Family Nidulariaceæ.—Bird's-nest fungi.
Family Lycoperdaceæ.—Puff-balls and earth-stars.

WASHINGTON, D. C., November 1, 1901.

CLASS I. MYXOMYCETAE

ORDER MYXOMYCETACEÆ

FAMILY DIDYMIACEÆ.

BADHAMIA CAPSULIFERA (Bull.) Berk. Orono, 10-1896, (O. W. Knight).

BADHAMIA FASCICULATA (Jungh.) Rost. On dead gray birch, Orono, 9-1890, (Harvey).

BADHAMIA HYALINA (Pers.) Berk. On decaying wood, Cumberland, (Blake). On decaying wood, Orono, 10-1896, (Harvey).

BADHAMIA MACROCARPA (Ces.) Rost. On logs, low ground, Orono, 10-1896, (Harvey).

BADHAMIA RUBIGINOSA (Chev.) Rost. On moss and sticks, Orono, 10-1895, (Merrill). On base of fir tree, Orono, 9-1896, (Harvey).

BADHAMIA SUBAQUILA (Macbr.) Orono, 10-1896, (Harvey). This species was first named as B. verna Rost., by A. P. Morgan, and was so given in Professor Harvey's list. Professor Macbride believes it to be a new species, and describes it as above, in his North American Slime Moulds.

BADHAMIA UTRICULOSA (Bull.) Berk. On fallen logs, Orono, 10-1896, (Harvey).

CRATERIUM LEUCOCEPHALUM (Pers.) Ditm. East Auburn, 11-1896, (Merrill).

CRATERIUM MINUTUM (Leers.) Fr. On decaying leaves. Orono, 9-1896, (Merrill). On decaying leaves, East Auburn, 7-1897, (Merrill).

FULIGO SEPTICA (Link.) Gmel. Rangeley, (Rex). Orono, 1890; Greenfield, 9-1895, (Harvey).

LEOCARPUS FRAGILIS (Dicks.) Rost. Rangeley, (Rex). Orono, 10-1896, (Harvey). East Auburn, 11-1896, (Merrill).

PHYSARUM CAESPITOSUM Schw. (*P. citrinellum Pk.*) Greenfield, 10-1895, (Harvey).

PHYSARUM CINEREUM (Batsch.) Pers. Rangeley, (Rex).

PHYSARUM CITRINUM Schum. Oldtown, 1898, (Harvey).

PHYSARUM CONTEXTUM Pers. Rangeley, (Rex). Orono; Greenfield, 10-1896, (Harvey).

PHYSARUM DIDERMA Rost. Orono, 10-1896, (Harvey).

PHYSARUM FLAVICOMUM Berk. (*P. cupripes B. & Br.*) Orono, 8-1896, (Harvey).

PHYSARUM GLOBULIFERUM (Bull.) Rost. Under bark of a standing birch, Orono, 10-1896, (Harvey). On fallen hemlock, East Auburn, 11-1896, (Merrill).

* PHYSARUM IMITANS Racib. On moss, Orono, 10-1896, (Harvey).

PHYSARUM LEUCOPHAEUM Fr. (*P. connexum Lk.*) Orono, 10-1896, Greenfield, 10-1896, (Harvey).

PHYSARUM LEUCOPS (Link.) Rost. On fallen leaves, Monmouth, 7-1897, (Merrill).

PHYSARUM MUSCORUM (A. & S.) Berk. (*Fuligo muscorum A. & S.*) Eastport, (Farlow).

PHYSARUM OBRUSSEUM (B. & C.) Rost. Orono, 1897, (Harvey).

PHYSARUM ORNATUM Peck. Orono, 10-1896, (Harvey).

PHYSARUM PENETRALE Rex. Rangeley, (Rex).

PHYSARUM PITTACINUM Ditm. East Auburn, 7-1897, (Merrill).

PHYSARUM RUFIPES (A. & S.) Morg. (*Cytidium rufipes A. & S.*) On decaying leaves, Orono, 10-1896, (Harvey). On decaying leaves, East Auburn, 11-1896, (Merrill).

PHYSARUM SINUOSUM (Bull.) Rost. Rangeley, (Rex). Monmouth, 7-1897, (Merrill).

PHYSARUM VIRESCENS Ditm. Rangeley, (Rex).

TILMADOCHE COMPACTA Wing. (*T. columbina (Berk.) Rost.*) On birch log, Oldtown, 8-1898, (Harvey).

TILMADOCHE NUTANS (Pers.) Rost. Rangeley, (Rex). Orono, 9-1896, (Harvey).

TILMADOCHE VIRIDIS (Bull.) Sacc. Rangeley, (Rex.) Orono, 9-1895, (Harvey).

FAMILY DIDYMIACEAE

CHONDRIODERMA MICHELII (Lib.) Rost. Rangeley, (Rex).

CHONDRIODERMA RADIATUM (L.) Rost. On hemlock bark, Orono, (Harvey). On hemlock bark, East Auburn, 10-1896, (Merrill). On fallen leaves, Monmouth, 7-1897, (Merrill).

CHONDRIODERMA SAUTERI Rost. Seal Harbor, (Rex).

CHONDRIODERMA SPUMARIOIDES (Fr.) Rost. On decaying leaves, East Auburn, 11-1896, (Merrill).

CHONDRIODERMA TESTACEUM (Schr.) Rost. Rangeley, (Rex). Monmouth, 7-1897, (Merrill).

DIDYMIUM CLAVUS (A. & S.) Rost. Rangeley, (Rex).

DIDYMIUM EFFUSUM (Link.) Fr. Rangeley, (Rex).

DIDYMIUM EXIMIUM Peck. Orono, 1889, (Harvey).

DIDYMIUM FARINACEUM Schrad. Rangeley, (Rex). Orono; West Sister Is., Penobscot Bay, 8-1886, (Harvey).

DIDYMIUM MICROCARPUM (Fr.) Rost. Cumberland; Wells, (Blake). Bar Harbor, (Rex).

DIDYMIUM PROXIMUM B. & C. Beech woods, Orono, 10-1896, (Harvey).

LEPIDODERMA TIGRINUM (Schrad.) Rost. In moss, on tree trunk, Orono, 10-1896, (Harvey).

FAMILY SPUMARIACEÆ.

DIACHAEA LEUCOPODA (Bull.) Rost. (*D. elegans Fr.*) Rangeley, (Rex). Monmouth, 7-1897, (Merrill).

DIACHAEA THOMASII Rex. Kittery, 8-1895, (R. Thaxter).

SPUMARIA ALBA (Bull.) DC. On moss, Pamadumcook Lake, 10-1895, (Harvey). On sticks, Orono, 10-1896, (Harvey). On grass, East Auburn, 11-1896, (Merrill). On sticks, Katahdin Iron Works, 10-1899, (Harvey)

FAMILY STEMONITACEÆ.

COMATRICHA AEQUALIS Peck. On rotten wood, Orono, 10-1896, (Ricker). On charred logs, Oldtown, 10-1897, (Harvey).

COMATRICHA FRIESIANA (DeBy.) Rost. (*C. obtusa Preuss.*) Bar Harbor, (Rex). Orono, 10-1896; Greenfield, 10-1896, (Harvey).

COMATRICHA IRREGULARIS Rex. Oldtown, 9-1895; Greenfield, 10-1896, (Harvey). East Auburn, 11-1897, (Merrill).

COMATRICHA SUKSDORFII E. & E. East Auburn, 11-1896, (Merrill).

COMATRICHA TYPHINA (Roth.) Rost. Portland, (Fuller). Grev. 5: 150. Rangeley, (Rex). Orono, (Harvey).

Lamproderma arcyrioides (Somm.) Rost. Rangeley, (Rex).

Lamproderma arcyrionema Rost. On rotten wood, Orono, 1897, (Harvey).

Lamproderma columbinum (Pers.) Rost. Greenfield, 10-1894; Orono, 10-1896, (Harvey).

Lamproderma physaroides (A. & S.) Rost. Rangeley, (Rex). Greenfield, 9-1895, (Harvey).

Lamproderma scintillans (B. & Br.) List. On decaying wood, East Auburn, 11-1896, (Merrill).

Lamproderma violaceum (Fr.) Rost. Greenfield, 10-1885; Orono, 10-1896, (Harvey).

Stemonitis ferruginea Ehrh. Rangeley, (Rex). Orono, 8-1890; Greenfield, 10-1895, (Harvey). Monmouth, 7-1897, (Merrill).

Stemonitis fusca Roth. Otisfield; Harrison, (Blake). Rangeley, (Rex). Orono; Oldtown, (Harvey).

Stemonitis herbatica Pk. On fallen tree trunks, Greenfield, 10-1895, (Harvey).

Stemonitis smithii Macbr. Greenfield, 10-1895; West Sister Is., Penobscot Bay, 8-1896, (Harvey).

FAMILY AMAUROCHAETACEÆ.

Amaurochaete atra (A. & S.) Rost. (*Reticularia atra Fr.*) Maine, (Fuller). Herb. Port. Soc. Nat. Hist.

FAMILY LICEACEÆ.

Licea minima Fr. Cumberland, (Blake). Orono, 10-1896, (Harvey).

Lindbladia effusa (Ehr.) Rost. Cumberland, (Blake). Orono, 9-1897, (Harvey). East Auburn, 7-1897, (Merrill).

Orcadella operculata Wingate. On trunks red oak, Maine, (Wingate). Proc. Phil. Acad. Sci. 1889:280.

Tubulina cylindrica (Bull.) DC. Cumberland, (Blake). Rangeley, (Rex). Orono; Greenfield; Jackman, (Harvey).

FAMILY CLATHROPTYCHIACEÆ.

Enteridium splendens Morgan. (*E. Rozeanum Wing.*) Orono, 10-1896; Greenfield; Bradley, (Harvey). East Auburn, 11-1896, (Merrill).

TRICHIA PERSIMILIS Karst. (*T. affinis DeBy., T. jackii Rost.*) Portland, Brev. 5:150. Greenfield, 9-1895, (Harvey).

TRICHIA RENIFORMIS Peck. Orono; Greenfield, 10-1896, (Harvey).

TRICHIA SCABRA Rost. Oldtown, 9-1895,; Orono, 10-1896, (Harvey).

TRICHIA SUBFUSCA Rex. Jackman, 9-1895, (Harvey).

TRICHIA VARIA Pers. Cumberland, (Blake). Rangeley, (Rex). Orono, 9-1889; Greenfield, 9-1895, (Harvey).

CLASS II. SCHIZOMYCETAE

BACILLUS SUBTILIS (Ehrenb.) Cohn. On unsterilized potatoes for cultures, Orono, 5-1900, (Ricker).

MICROCOCCUS AMYLOVORUS Burrill. On Pyrus communis, East Northport, 1894, (M. B. Whitney). Det. Harv.

SARCINA LUTEA Fluegge. On plate cultures from air, Orono, 5-1900, (Ricker).

CLASS III. PHYCOMYCETAE

ORDER MUCORACEÆ.

PHYCOMYCES NITENS (Agardh.) Kunze. On excrement of cat, Washington, 1897, (T. S. Bowen). Det. F. L. H.

RHIZOPUS NIGRICANS Ehrbg. On stale bread, Orono, (Harvey).

ORDER PERONOSPORACEÆ.

CYSTOPUS CANDIDUS (Pers.) Fr. On Dentaria diphylla, Maine, (Blake). On Capsella Bursa-pastoris, Orono, 10-1898, (Ricker).

PERONOSPORA SPARSA Berk. On Rosa sp. (cult.), in hot-house, Bangor, 4-1900, (Ricker).

PHYTOPHTHORA INFESTANS (Mont.) DeBy. On Solanum tuberosum, Orono, (Harvey). On Solanum tuberosum, Westbrook, 8-1897, (Ricker). On Lycopersicum esculentum, Machias, 7-1898, (Ricker).

PLASMOPARA VITICOLA (B. & C.) Berl. & DeToni. On Vitis riparia, Orono, 10-1900, (Ricker). On Ampelopsis quinquefolia, Orono, 10-1900, (Ricker).

ORDER SAPROLEGNIACEÆ.

GONAPODYA POLYMORPHA Thaxt. On submerged twigs, Kittery Pt., (R. Thaxter). Bot. Gaz. 1895:481.

GONAPODYA SILIQUAEFORMIS (Reinsch.) Thaxt. On decaying submerged apples, Kittery Pt., (R. Thaxter). Bot. Gaz. 1895, p. 480.

SAPROLEGNIA FERAX (Gruith.) Nees. On flies, in aquaria, Orono, 10-1897, (Ricker). On fish eggs, Monmouth, 10-1897, (Merrill).

ORDER ENTOMOPHTHORACEÆ.

EMPUSA APICULATA Thaxt. Maine, Thaxt. Entomoph. of U. S. p. 164.

EMPUSA CULICIS (A. Braun.) Wint. Maine, Thaxt. Entomoph. of U. S. p. 158.

EMPUSA FRESENII Nowak. Maine, Thaxt. Entomoph. of U. S. p. 168.

EMPUSA GRYLLI Fres. Maine, Thaxt. Entomoph. of U. S. p. 159.

EMPUSA LAGENIFORMIS Thaxt. Maine, Thaxt. Entomoph. of U. S. p. 169.

EMPUSA MUSCÆ (Fr.) Cohn. On Musa domestica, Orono, 10-1900, (Ricker).

EMPUSA PLANCHONIANA (Cornu.) Thaxt. Kittery, Thaxt. Entomoph. of U. S. p. 165.

ENTOMOPHTHORA APHIDIS Hoffm. Maine, Thaxt. Entomoph. of U. S. p. 175.

ENTOMOPHTHORA DIPTERIGENA Thaxt. Maine, Thaxt. Entomoph. of U. S. p. 179.

ENTOMOPHTHORA ECHINOSPORA Thaxt. Maine, Thaxt. Entomoph. of U. S. p. 180.

ENTOMOPHTHORA GEOMETRALIS Thaxt. Kittery, Thaxt. Entomoph. of U. S. p. 171.

ENTOMOPHTHORA OCCIDENTALIS Thaxt. Maine, Thaxt. Entomoph. of U. S. p. 171.

ENTOMOPHTHORA RHIZOSPORA Thaxt. Kitery, Thaxt. Entomoph. of U. S. p. 184.

ENTOMOPHTHORA SPHAEROSPERMA Fres. Maine, Thaxt. Entomoph. of U. S. p. 172.

ENTOMOPHTHORA TENTHREDINIUS Fres. Kittery, Thaxt. Entomoph. of U. S. p. 162.

ORDER CHYTRIDIACEÆ.

SYNCHYTRIUM DECIPIENS Farl. On Amphiocarp monoica. Orono, 7-1899, (Harvey). Det. P. L. R.

CLASS IV. DEUTEROMYCETAE.

ORDER HYPHOMYCETACEÆ.

FAMILY MUCEDINACEÆ.

ASPERGILLUS FLAVUS Lk. On rotten wood, Orono, 10-1897, (Ricker).

BOTRYOSPORIUM PULCHRUM Cda. On decaying tomato vines, Orono, 10-1898, (Ricker). Det. R. Thax.

GEOTRICHUM CANDIDUM Link. On decaying wood, Orono, 10-1896, (Harvey). Det. Ell.

GLOMERULARIA CORNI Pk. On Cornus canadensis, Orono, 5-1898, (Ricker).

MONILIA PENICELLATA E. & E. On decaying logs, Lewiston, (A. T. Jordan). Det. Ell. On decaying logs, Orono, (Harvey).

OIDIUM CHRYSANTHEMI Rbh. On Chrysanthemum sinensis. Orono, 12-1898, (Ricker).

OOSPORA SCABIES Thaxt. On Solanum tuberosum, Orono, (Harvey).

OOSPORA? Parasitic on mice, Sherman, 3-1900. Two mice were received in which one side of the head had been eaten away by the fungus, leaving a hard white granular mass. Microscopical examination showed this to be made up of short chains of spores, about one micron in diameter. These refused to yield to culture in ordinary media, and unfortunately the specimens were lost before opportunity came for further study. Cats were said to be affected with the same disease. Joseph Leidy, in Proc. Phil. Acad. Sci. 25:260-261, notes a similar disease of mice which he refers to Torula or Oidium.

OVULARIA MONILIOIDES Ell. & Mart. On Myrica gale, Sandy Bay, 8-1895, (Harvey). Det. Ell. On Myrica gale, Oldtown, 6-1898, (L. H. Harvey).

PENICILLIUM GLAUCUM Lk. On stale bread, Orono, 10-1897, (Ricker).

RAMULARIA DIERVILLÆ, Pk. On Diervilla trifida, Westbrook, 7-1897, (Ricker).

RAMULARIA MENTHICOLA Sacc. On Mentha canadensis, Orono, 8-1891, (F. P. Briggs). Det. P. L. R.

RAMULARIA PLANTAGINIS E. & M. On Plantago major, Westbrook, 8-1899, (Ricker). On Plantago major, Orono, 10-1900, (Ricker).

RAMULARIA RANUNCULI Pk. On Ranunculus acris, Orono, 10-1900, (Ricker).

RAMULARIA TARAXACI Karst. On Taraxacum officinale, Westbrook, 9-1899, (Ricker).

SPOROTRICHUM OLIVACEUM (Lk.)Fr. On decaying wood, Orono, 10-1896, (Harvey).

TRICHODERMA LIGNORUM (Tode.) Harz. On Acer rubrum, Cumberland, (Blake). On Acer rubrum, Orono, (Harvey). On Acer rubrum, Pownal, 11-1897, (Stover).

TRICHOTHECIUM ROSEUM (Pers.) Link. On dead Acer rubrum, Cumberland; Wells, (Blake). On dead Acer rubrum, Orono, 12-1887, (Harvey).

FAMILY DEMATIACEÆ.

ALTERNARIA BRASSICÆ (Berk.) Sacc. On Brassica oleracea, Cumberland, 1858, (Blake). Det. Ell.

CERCOSPORA CIRCUMSCISSA Sacc. On Prunus serotina, Westbrook, 8-1899, (Ricker).

CERCOSPORA DEPAZEOIDES (Desm.) Sacc. On Sambucus nigra, Westbrook, 7-1897, (Ricker). On Sambucus nigra, Orono, 8-1900, (L. H. Harvey).

CERCOSPORA DIERVILLÆ E. & E. sp. nov. On leaves of Diervilla trifida, Orono, 10-1900, (Ricker, No. 762). Spots circular, scattered, small (2-3 m. m.), dirty white with a red border; hyphae cespitose, tufts scattered over the spots both above and below, olive-brown, continuous or sparingly septate, 80-110x4-5 μ; conidia obclavate, olive-brown, 2-4 septate, 50-60x5-6 μ.

The tufts are not effused but scattered singly and rather sparingly and are so compact as to be easily mistaken for perithecia.

CERCOSPORA NYMPHAEACEÆ C. & E. On Nymphaea odorata, Oldtown, 9-1900, (Ricker).

CERCOSPORA PLANTAGINIS Sacc. On Plantago major, Orono. 10-1900, (Ricker).

CERCOSPORA ROSAECOLA Pass. On Rosa sp. (cult.), Westbrook, 8-1900, (Ricker). On Rosa sp. (cult.), Orono, 10-1900, (Ricker).

CERCOSPORA SQUALIDA Pk. On Clematis Virginiana, Orono, 10-1900. (Ricker).

CERCOSPORA STACHYDIS E. & E. On Stachys palustris, Twobush Is., Penobscot Bay, 8-1896, (Harvey). Det. P. L. R.

CERCOSPORA VARIA Pk. On Viburnum cassanoides, Westbrook, 7-1897, (Ricker).

CLADOSPORIUM CUBISPORUM B. &. C. Maine, (Blake). Grev. 3:107.

CLADOSPORIUM EPIPHYLLUM (Pers.) Mart. On Quercus, Portland, (Fuller). Grev. 5:152.

CLADOSPORIUM GRAMINUM Corda. On grass, Orrington, 6-1896, (Harvey).

CLADOSPORIUM HERBARUM (Pers.)Link. On dead stems and leaves, Orono, 8-1889, (Harvey). Cumberland, 9-1857; Harrison, 9-1859, (Blake).

CLADOSPORIUM TYPHARUM Desm. On Typha latifolia, Orono, 11-1900, (Ricker).

CONIOTHECIUM TORULOIDES Cda. On Salix, Cumberland, 1857; Harrison, (Blake).

FUMAGO VAGANS Pers. On decaying wood, Cumberland, (Blake).

FUSICLADIUM DENTRITICUM (Wallr.) Fckl. On Pyrus malus, Orono, 3-1896, (Harvey).

*HELMINTHOSPORIUM INCONSPICUUM BRITTANICUM Grove. On Avena stativa, Augusta, 1894, (B. W. McKeen). Det. Ell. On Avena sativa, Orono, (Harvey).

HELMINTHOSPORIUM MACROCARPUM Grev. On Alnus, North Bridgton, 9-1859, (Blake).

HELMINTHOSPORIUM OBCLAVATUM Sacc. *N. A. F. No* 2079. On decaying wood, Orono, 12-1886, (Harvey).

MACROSPORIUM CHEIRANTHI (Lib.) Fr. On dead stems, Cumberland, 1857, (Blake).

MACROSPORIUM SOLANI Ell. & Mart. On Solanum tuberosum, Orono, 8-1897, (Ricker). Det. Ell.

MYXOTRICHUM CHARTARUM Kunze. *F. Col. No.* 1360. On paper, Orono, 12-1898, (Ricker).

POLYTHRINCIUM TRIFOLII Kze. On Trifolium pratense, Harrison, 9-1859, (Blake). On Trifolium pratense, Katahdin Iron Works, 11-1898, (Ricker). On Trifolium pratense, Orono, 11-1898, (Ricker). On Trifolium repens, Westbrook, 7-1898, (Ricker).

SEPTONEMA SPILOMEUM Berk. On decaying wood, Limerick, 11-1859, (Blake).

TORULA BINALIS C. &. Ell. On decaying wood, Wells, 5-1880, (Blake).

ZYGODESMUS FUSCUS Corda. On rotten wood, Cumberland, 9-1858, (Blake). On rotten wood, Orono, 10-1895, (Harvey).

ZYGODESMUS GRANULOSUS Peck. On rotten wood, Orono, 10-1895, (Harvey). Det. Pk.

ZYGODESMUS HYDNOIDEUS B. & C. On rotten wood, Orono, 9-1896, (Harvey).

ZYGODESMUS RUBIGINOSUS Pk. On decaying bark, Orono, 10-1896, (Harvey).

FAMILY STILBACEÆ.

CERATIUM HYDNOIDES (Jacq.) A. & S. On rotten wood, Wells, 1859, (Blake). On rotten wood, Oldtown, 10-1899, (Ricker). According to our present understanding of this form, it should be placed under the Myxomycetes, as Ceratiomyxa fruticulosa (Muell.) Macbr.

HEYDENIA FUNGICOLA Pk. On Polystictus abietinus, Jackman, 8-1895, (Harvey). Det. Pk.

ISARIA CARNEA Schw. On rotten wood, Orono, 10-1896, (Harvey). Det. Pk.

ISARIA FARINOSA (Dicks.) Fr. On the ground, Cumberland, (Blake).

SPOROCYBE PERSICÆ (Schw.) Fr. On Prunus cerasus, Cumberland, (Blake).

SPOROCYBE RHOIS (B. & C.) Sacc. On Rhus typhina, Cumberland, (Blake). On Rhus typhina, Orono, 4-1900, (Ricker).

STILBUM GLOMERULISPORUM E. & E. *N. A. F. No. 3597.* On Picea nigra, Orono, 12-1896, (Harvey). Issued as above, but never described. It is doubtful if this is a Stilbum.

STILBUM VULGARE Tod. On decaying turnip, Cumberland, (Blake). On dead wood, Maine, (Sprague). Grev. 3:63.

FAMILY TUBERCULARIACEÆ.

AEGERITA CORDAE Sacc.? Orono, 10-1896, (Harvey). Doubtfully referred to this form by A. P. Morgan.

BACTRIDIUM ELLISH Berk. On rotten wood, Orono, 10-1896, (Harvey). Det. Ell.

DENDRODOCHIUM COMPRESSUM E. & E. On decaying Pine logs, Orono, 1897, (Harvey). Det. Ell.

EPICOCCUM SCABRUM Cda. On Typha latifolia, Orono, 11-1900, (Ricker). Det. Ell.

EPICOCCUM SPHAEROSPERMUM Berk. On Typha latifolia, 12-1857, (Blake).

FUSARIUM BERENICE, (B. & C.) Sacc. Parasitic in a Peziza, Harrison, 8-1858, (Blake). Parasitic in a Peziza, Orono, 10-1896, (Harvey). Det. Ell.

HYMENOPSIS TROCHILOIDES Sacc. On grass, Orrington, 6-1896, (Harvey). Det. Ell.

ILLOSPORIUM ROSEUM (Schreb.) Mart. Parasitic on a lichen, Wells, 1880, (Blake).

PERIOLA TOMENTOSA Fr. On Brassica campestris, Cumberland, (Blake).

TUBERCULARIA DUBIA Link. On Pinus, Wells, 2-1860, (Blake).

TUBERCULARIA GRANULATA Pers. On Robinia pseudacacia, Cumberland, (Blake).

TUBERCULARIA NIGRICANS (Bull.) Link. On Rubus (raspberry), Orono, 12-1889, (Harvey).

ORDER SPHAEROPSIDACEÆ.

FAMILY SPHAERIOIDACEÆ.

ACTINONEMA ROSÆ (Lib.) Fr. On Rosa (cult.), Westbrook, 8-1900, (Ricker).

APOSPHAERIA HEMISPHAERICA (A. & S.) Sacc. On Pinus, Wells, 10-1859, (Blake).

APOSPHAERIA CLYPEATA (C. & Ell.) Sacc. On dead wood, Maine, (Blake). Grev. 5:33.

APOSPHAERIA HYSTRELLA Sacc. On Pinus, Wells, (Blake).

CEUTHOSPORA SP.? On Fragaria virginiana, Orono, 10-1900, (Ricker).

CYTISPORA CARNEA E. & E. On Tilia americana, Orono, (Harvey). Det. Ell.

CYTISPORA CHRYSOSPERMA (Pers.) Fr. On Populus tremuloides, Orono, 1890, (Harvey). Det. Ell.

CYTISPORA EXASPERANS E. & E. On Acer rubrum, Orono, 1896, (Harvey). Det. Ell.

CYTISPORA FUGAX (Bull.) Fr. On Fraxinus americana, Cumberland, (Blake).

CYTISPORA LEUCOSPERMA (Pers.) Fr. On Populus, Cumberland, (Blake).

CYTOSPORA NIVEA (Hoffm.) Sacc. On Populus tremuloides, Oldtown, 9-1900, (Ricker). Det. Ell.

CYTISPORA PINASTRI Fr. On Pinusilvestris, Orono, 10-1900, (Ricker).

CYTISPORA RHUINÆ Schw. On Rhus, Maine, (Blake). Grev. 2:99. I have been unable to find any other reference to this species. There is, however, a C. rhoina Fr., On Rhus, which may be the same.

DARLUCA FILUM (Biv.) Cast. On Puccinia clintonii, Basin Mills, 5-1898, (Merrill). Det. Farl.

Dendrophoma pruinosa (Fr.) Sacc. On Fraxinus, Cumberland, 2-1859, (Blake).

Dendrophoma sambuci (B. & C.) Sacc. On Sambusus, Maine, (Blake). Grev. 2:179.

Diplodia microspora B. & C. On Philadelphus coronarius, Orono, 10-1897, (Ricker). Det. Ell.

Endobotrya elegans B. &. C. On Fagus ferruginea, Portland, (Sprague). In Blake Herb.

Hendersonia lirella Cke. On Spiraea ulmaria, Orono, 12-1887, (Harvey). Det. Ell.

Micropera drupacearum Lev. Maine, (Morse). Grev. 2:100.

Phoma acuum C. &. E. On Pinus silvestris, Orono, 10-1900. (Ricker). Det. Ell.

Phoma asteriscus Berk. On Heracleum lantanum, Orono, 8-1895, (Harvey). Det. Ell.

Phoma landeghemiæ (Nits.) Sacc. On Philadelphus coronarius, Orono, 10-1897, (Ricker). Det. Ell.

Phoma orthosticha E. & E. On Typha latifolia, Orono, 11-1899, (Ricker).

Phoma pulchella (B. & C.) Sacc. On Rhus typhina, Cumberland, (Blake).

Phoma strobiligena Desm. *F. Col. No. 1340.* On Picea excelsa, Orono, 12-1898, (Ricker). Det, Ell. On Pinus silvestris, Orono, 12-1898, (Ricker). Det. Farl.

Phyllosticta acericola C. & E. On Acer rubrum, Westbrook, 7-1899, (Ricker). On Acer rubrum, Orono, 10-1900, (Ricker).

Phyllosticta caryæ Pk. On Carya, Maine, Ellis, N. A. Phyllostictas. p. 35.

Phyllosticta decidua Ell. & Kell. On Mentha canadensis, Bradley, 10-1899, (Ricker). Det. Ell. On Mentha sativa, Westbrook, 7-1900, (Ricker).

Phyllosticta gaultheriæ, E. & E. On Gaultheria procumbens, Orono, 12-1897, (Harvey). Det. Ell.

Phyllosticta lappæ Sacc. On Arctium lappæ, 10-1900, (Ricker). Det. Ell.

Phyllosticta negundinis Sacc. & Speg. On Negundo, aceroides, Orono, 11-1900, (Ricker). Det. Ell.

Phyllosticta smilacis E. & M. On Smilax herbacea, Oldtown, 8-1899, (Harvey). Det. Ell.

Phyllosticta tinea Sacc. On Viburnum lantanoides, Orono, 5-1899, (Ricker). Det. Ell.

Rabenhorstia tiliæ Fr. On Tilia americana, Orono, 10-1896, (Ricker). Det. Ell.

Septoria acerina Pk. On Acer pennsylvanicum, Orono, 7-1899, (Harvey). Det Ell.

Septoria conspicua E. &. M. On Steironema ciliatum, Orono, 10-1900, (Ricker).

Septoria dalibardæ Pk. On Dalibarda repens, East Auburn, 7-1898, (Merrill). Det. Harv.

Septoria diervillicola E. & E. On Diervilla trifida, Westbrook, 7-1897, (Ricker). Det. Ell.

Septoria divaricata E. & E. On Phlox paniculata, Orono, 9-1897, (Ricker).

Septoria erigerontea Pk. On Erigeron, Westbrook, 8-1899, (Ricker).

Septoria grossulariæ (Lib.) West. On Ribes grossulariae, Westbrook, 8-1899, (Ricker).

Septoria increscens Pk. On Trientalis americana, Fryeburg, 8-1897, (Harvey).

Septoria lactucicola E. & M. On Lactuca integrifolia, Westbrook, 9-1898, (Ricker).

Septoria lobeliæ Pk. On Lobelia inflata, Westbrook, 8-1895, (A. H. Norton). Det. Harv.

Septoria nabali B. & C. On Prenanthes serpentaria, Westbrook, 7-1899, (Ricker).

Septoria oenotheræ West. On Oenothera fruticosa, Orono, 8-1898, (Harvey). Det. P. L. R.

Septoria pentastemonis E. &). On Pentstemon laevigatus, Brunswick, 7-1899, (Ricker).

Septoria pisi West. On Psium sativum, Orono, 10-1897, (Harvey).

Septoria polygonorum Desm. On Polygonum persicaria, East Auburn, 8-1898, (Merrill).

Septoria rhododendri Cke. On Rhododendron, Maine, (Fuller). Grev. 5:151.

SEPTORIA RUBRI West. On Rubus villosus, Brunswick, 8-1899, (Ricker).

SEPTORIA SACCHARINA E. & E. On Acer saccharinum, Orono, 7-1899, (Harvey). Det. P. L. R.

SEPTORIA SCUTELLARIÆ Thum. On Scutellaria galericulata, Brunswick, 8-1899, (Ricker).

SEPTORIA SII Rob. & Desm. On Sium cicutifolium, Westbrook, 7-1899, (Ricker).

SEPTORIA SONCHIFOLIA Cke. On Sonchus asper, Orono, 7-1899, (Harvey). Det. P. L. R.

SEPTORIA WILSONI Clint. On Chelone glabra, So. Chesterville, 7-1899, (Miss Eaton). Det. P. L. R.

SPHAEROGRAPHIUM FRAXINI (Pk.) Sacc. On Fraxinus americana, Orono, 6-1899, (Ricker).

SPHAERONEMA ACERINUM Pk. On Acer rubrum, Orono, 6-1900, (Ricker).

SPHAEROPSIS ROBINIÆ Ell. & Dearn. On Robinia pseudacacia, Cumberland, (Blake).

VERMICULARIA COPTINA Pk. On Coptis trifolia, Orono, 6-1898, (Ricker).

VERMICULARIA POLYGONATI Schw. On Polygonatum biflorium, Ea. Auburn, 7-1898, (Merrill).

FAMILY LEPTOSTROMACEÆ.

DISCOSIA ARTOCREAS (Tode.) Fr. On Betula populifolia, Cumberland, 4-1857, (Blake). On Quercus rubra, Westbrook, 7-1899, (Ricker). On Abies balsamea, Orono, 10-1900, (Ricker).

ENTOMOSPORIUM MACULATUM Lev. On Pyrus communis, Portland, 1892, (A. D. Morse). Det. Harv. On Pyrus communis, Belfast, 1894, (J. G. Brooks). Det. Harv.

LEPTOSTROMA FILICINUM Fr. On Osmunda, Harrison, 8-1858, (Blake).

LEPTOSTROMA PTERIDIS Ehrenb. On Pteris aquilina, Cumberland, 4-1857, (Blake).

LEPTOSTROMELLA ELASTICA E. & E. On Ficus elastica, (greenhouse), Orono, 9-1899, (Ricker).

LEPTOTHYRIUM POMI (Mont. & Fr.) Sacc. On Pyrus malus, Wells, (Blake). On Pyrus malus, Orono, 10-1898, (Ricker).

LEPTOTHYRIUM VULGARE (Fr).) Sacc. On dead stems, Cumberland, 4-1857, (Blake).

PIGGOTIA FRAXINI B. & C. On Fraxinus americana, Westbrook, 9-1899, (Ricker). On Fraxinus americana, Orono, 10-1900, (Ricker).

FAMILY EXCIPULACEÆ.

DINEMASPORIUM STRIGOSUM (Fr.) Sacc. On Solidago, Maine, (Blake). On Fraxinus, Wells, (Blake).

DISCELLA CARBONACEA (Fr.) B. & Br. On Salix, Cumberland, (Blake).

ORDER MELANCONIACEÆ.

CORYNEUM MICROSTICTUM B. & Br. On Rubus strigosus, Cumberland, (Blake).

CORYNEUM PULVINATUM Kunze. & Schm. So. Paris, Proc. Bost. Soc. Nat. Hist., 5:329.

GLOEOSPORIUM LINDEMUTHIANUM Sacc. & Mag. On Phaseolus vulgaris, Kennebunk, 1893, (E. T. Perkins). Det. Harv. On Phaseolus vulgaris, Westbrook, 8-1899, (Ricker).

GLOEOSPORIUM PHOMOIDES Sacc. On Lycopersicum esculentum, Orono, (Harvey).

GLOEOSPORIUM VENETUM Speg. On Rubus, Blue Hill, (H. H. Osgood). Det. Harv.

GLOEOSPORIUM VERSICOLOR B. & C. On Pyrus malus, Orono, 3-1896, (Harvey).

LIBERTELLA BETULINA Desm. On Betula populifolia, Orono, 1894, (Harvey). Det. Ell.

LIBERTELLA FAGINEA Desm. *N. A. F. No.* 3278. On Fagus ferruginea, Orono, 9-1896, (Harvey).

MARSONIA MARTINI Sacc. & Ell. On Quercus ilicifolia, Westbrook, 8-1899, (Ricker). Det. Ell.

MELANCONIUM BICOLOR Nees. On Betula populifolia, Cumberland, (Blake).

MELANCONIUM OBLONGUM Berk. On Juglans cinerea, Orono, 9-1896, (Ricker). Det. Ell.

MELANOSTROMA MINUTA Cda. On dead wood, Orono, 10-1896, (Harvey).

MYXOSPORIUM NITIDUM B. & C. On Cornus, Cumberland, 11-1857, (Blake). On Cornus, alternifolia, Katahdin Iron Works, 11-1898, (Ricker).

MYXOSPORIUM RHOIS (B. & C.) Sacc. Maine, (Blake). Grev. 2:157.

NAEMOSPORA CROCEA (Bon.) Sacc. On Betuia populifolia, Wells, 1880, (Blake).

STEGANOSPORIUM PIRIFORME (Hoffm.) Corda. On Acer rubrum, Cumberland, (Blake). On Acer rubrum, 10-1896, (Harvey).

CLASS V. ASCOMYCETAE.

ORDER SACCHAROMYCETACEÆ.

SACCHAROMYCES ROSACEUS Frankl. On plate cultures from air, Orono, 4-1900, (Ricker).

ORDER PYRENOMYCETACEÆ.

FAMILY PERISPORIACEÆ.

ASTERINA CELASTRI E. & K. On Celastrus scandens, Orono, 9-1892, (F. P. Briggs). Det. Harv. On Celastrus scandens, Westbrook, 7-1899, (Ricker).

ASTERNIA GAULTHERIÆ Curtis. On Gaultheria procumbens, Orono, 5-1898, (Ricker).

CAPNODIUM PINI B. & C. On Pinus, Diamond Cove, (Sprague). In Blake Herb.

DIMEROSPORIUM COLLINSII (Schw.) Thum. On Amelanchier canadensis, Wells, 8-1859, (Blake). On Amelanchier canadensis, Orono, 5-1897, (Merrill).

ERYSIPHE AGGREGATA (Pk.) Farl. On fertile catkins, Alnus incana, Orono, 10-1900, (Ricker).

ERYSIPHE CICHORACEARUM DC. On Aster macrophyllus, Orono, 10-1899, (Ricker).

Erysiphe communis (Wallr.) Fr. On Delphinium elatum, Cumberland, 1857, (Blake). On Pisium sativum, Orono, 8-1886, (Harvey). On Clematis virginiana, Bradley, 10-1899, (Ricker). On Ranunculus acris, Orono, 10-1900, (Ricker).

Erysiphe graminis DC. (*Oidium monilioides Lk.*) On Poa pratensis, Westbrook, 7-1900, (Ricker). On Poa pratensis, Orono, 11-1900, (Ricker).

Erysiphe phlogis Schw. On Phlox paniculata, Harrison, 9-1859, (Blake). On Phlox paniculata, Westbrook, 8-1900, (Ricker).

Eurotium herbariorum (Wigg.) Lk. On poorly dried plants, Orono, 3-1897, (Harvey).

Microsphaera dubyi Lev. On Lonicera tartarica, Orono, 10-1900, (Ricker).

Microsphaera extensa C. & P. On Quercus rubra, Orono, 9-1897, (Harvey).

Microsphaera friesii Lev. On syringa vulgaris, Orono, 9-1897, (Ricker).

Microsphaera penicillata (Wallr.) Lev. On Alnus incana, Orono, 11-1900, (Ricker).

Microsphaera russelli Clint. On Oxalis stricta, Orono, 10-1900, (Ricker).

Microsphaera vaccinii C. & P. On Vaccinium corymbosum, Jackman, 8-1895, (Harvey).

Phyllactinia suffulta (Reb.) Sacc. On Celastrus scandens, Orono, 9-1892, (F. P. Briggs). Det. Harv. On Cornus stolonifera, Orono, 10-1898, (Ricker). On Corylus rostrata, Orono, 10-1900, (Ricker).

Podosphaera minor Howe. On Spiraea salicifolia, Orono, 10-1900, (Ricker).

Podosphaera oxyacanthae (DC.) DeBy. On Prunus virginiana, Orono, (Harvey).

Scorias spongiosa (Schw.) Fr. On Alnus incana, Pea Cove, 10-1898, (Ricker).

Sphaerotheca castagnei Lev. On Bidens cernua, Oldtown, 9-1900, (Ricker).

*Sphaerotheca humuli (DC.) Burrill. Orono, (Harvey).

*Sphaerotheca mors-uvae (Schw.) B. & C. Orono, (Harvey.)

UNCINULA AMERICANA Howe. On Vitis riparia, Orono, 9-1889, (Harvey).

UNCINULA CIRCINATA C. & Pk. On Acer rubrum, Orono, 9-1889, (Harvey).

UNCINULA SALICIS (DC.) Winter. On Salix cordata, Bradley, 10-1899, (Ricker). On Salix discolor, Orono, 10-1900, (Ricker).

FAMILY SPHAERIACEÆ.

ACANTHOSTIGMA PULCHRISETUM (Pk.) Sacc. On decaying wood, Auburn, 11-1896, (Merrill). Det. Ell.

AGLAOSPORA PROFUSA (Fr.) De Not. On Robinia pseudacacia, Cumberland, (Blake).

AMPHISPHAERIA APPLANATA (Fr.) Ces. & De Not. On Pinus, Wells, (Blake).

AMPHISPHAERIA ORONOENSIS (E. & E.) Sacc. On rotten wood, Orono, 12-1886, (Harvey).

ANTHOSTOMA ELLISH Sacc. On Alnus, Wells, (Blake). Bull. Torr. Bot. Club, 8: 74.

ANTHOSTOMA MICROSPORUM Karst. On Betula, Wells, 1880, (Blake). On Alnus, Orono, 10-1896, (Harvey). Det. Ell.

BERTIA MORIFORMIS (Tode.) De Not. On Abies balsamea, Orono, 11-1895, (Harvey). On Abies balsamea, Auburn, 8-1896, (Merrill).

BOMBARDIA FASICULATA Fr. On Betula, Cumberland, 10-1858, (Blake). On rotten wood, Orono, 10-1896, (Merrill).

CALOSPHAERIA CILIATULA (Fr.) Karst. On Betula populifolia, Orono, (Harvey). Det. Ell.

CALOSPORA ACULEANS (Schw.) Sacc. On Rhus typhina, Cumberland, 12-1857, (Blake).

CERATOSTOMA SPINA (Schw.) Sacc. On Fraxinus, Cumberland, 1-1858, (Blake).

CHAETOMIUM CHARTARUM Ehrbg. On paper, Orono, 12-1898, (Ricker).

CUCURBITARIA BERBERIDIS (Pers.) Gray. On Berberis vulgaris, Wells, (Blake).

CUCURBITARIA ELONGATA (Fr.) Grev. On Pinus, Cumberland, Wells, (Blake).

CUCURBITARIA LONGITUDINALIS Pk. On Andromeda ligustrina, Wells, (Blake).

Daldinia concentrica (Bolt.) Ces. & De Not. On Fraxinus sambucifolia, Cumberland, 10-1858, (Blake). On dead limbs, Orono, 6-1898, (Ricker). On dead limbs, Ea. Auburn, 1897, (Merrill).

Daldinia vernicosa (Schw.) Ces. & De Not. On dead limbs, Orono, 10-1899, (Ricker).

Diaporthe leiphaema (Fr.) Sacc. On Alnus, Cumberland, 11-1857, (Blake).

Diaporthe salicella (Fr.) Sacc. Cumberland, (Blake). Orono, (Harvey).

Diaporthe spiculosa (A. & S.) Nits. Wells, 8-1859, (Blake).

Diaporthe syngenesia (Fr.) Fckl. On Fagus, Cumberland, (Blake).

Diatrype disciformis (Hoffm.) Fr. On Fagus ferruginea, Cumberland, (Blake).

Diatrype platystoma (Schw.) Berk. On Acer rubrum, Orono, 1892, (Harvey).

Diatrype stigma (Hoffm.) Fr. On Betula, Cumberland, 4-1857; Wells, (Blake). Auburn, 1897, (Merrill.)

Diatrypella betulina (Pk.) Sacc. *N. A. F. No.* 2347. On Betula populifolia, Orono, 9-1899, (Harvey).

*Diatrypella discoidea Cke. & Pk. Orono, 1889, (Harvey).

Diatrype nigro-annulata (Grev.) Nits. On Alnus, Cumberland, 1859, (Blake).

Diatrypella quercina (Pers.) Nits. On Quercus rubra, Harrison, 9-1859, (Blake).

Diatrypella tocciaeana subeffusa E. & E. On Alnus incana, Wells, (Blake). Journ. Mycol 4:62.

Diatrypella verruciformis (Ehrh.) Nits. On Betula, Cumberland; Wells, (Blake).

Eutypa spinosa (Pers.) Tul. On Acer, Cumberland, (Blake).

*Eutypella cerviculata (Fr.) Sacc. Orono, (Harvey).

Eutypella corynostoma (B. & Rav.) Sacc. On Acer rubrum, Orono, 7-1896, (Harvey).

Eutypella similis (Karst.) Sacc. Orono, 9-1896, (Harvey).

Fracchiaea callista B. & C. On Cornus alternifolia, Cumberland, (Blake).

GNOMONIA ERRABUNDA (Rob.) Awd. Portland, (Morse). Proc. Bost. Soc. Nat. Hist. 5:331.

GNOMONIA ULMEA (Sacc.) Thum. On Ulmus americana, Wells, 9-1859, (Blake). On Ulmus americana, Orono, (Harvey). On Ulmus americana, Westbrook, 9-1900, (Ricker).

GNOMONIA CORYLI (Batsch.) Sacc. On Corylus rostratus, Harrison, 9-1859, (Blake). On Corylus rostratus, Orono, 9-1900, (Ricker).

GNOMONIELLA FIMBRIATA (Pers.) Sacc. On Ostrya virginica, Harrison, 9-1859, (Blake).

HELMINTHOSPHAERIA CLAVARIARUM (Desm.) Fckl. On Clavaria spinulosa, Orono, 9-1895, (Harvey).

HERCOSPORA TILIACEA (Ell.) Sacc. On Tilia americana, Orono, (Harvey). Det. Ell.

HYPOXYLON COCCINEUM Bull. On Acer rubrum, Orono, 12-1887, (Harvey).

HYPOXYLON COHAERENS (Pers.) Fr. On Fagus ferruginea, Cumberland, 6-1859, (Blake). On Fagus ferruginea, Orono, (Harvey). On Fagus ferruginea, Westbrook, 5-1898, (Ricker).

HYPOXYLON ENTEROMELUM (Schw.) Berk. On Fagus ferruginea, Cumberland; Wells, (Blake).

HYPOXYLON FUSCUM (Pers.) Fr. On Alnus, Cumberland; Wells, (Blake). On Acer rubrum, Orono, (Harvey). On Acer rubrum, Westbrook, 6-1897, (Ricker).

HYPOXYLON FUSCO-PURPUREUM (Schw.) Berk. On decaying wood, Orono, 10-1895, (Harvey). Det. Pk.

HYPOXYLON GLOMIFORME B. & C. On Salix ?, Cumberland, (Blake).

HYPOXYLON MARGINATUM (Schw.) Berk. On Quercus, Maine Journ. Mycol. 4:68.

HYPOXYLON MORSEI B. & C. (*H. blakeii B. & C.*) On Betula, Wells, 4-1880, (Blake). On Alnus, Maine, (Morse). Grev. 4:51. On Salix, Cumberland, 1857, (Blake).

HYPOXYLON MULTIFORME Fr. On Betula lutea, Cumberland, 1859, (Blake). On Betula lutea, Orono, 1890, (Harvey).

HYPOXYLON PERFORATUM (Schw.) Fr. On Acer, Orono, 1-1888, (Harvey). Det. Ell.

Hypoxylon rubiginosum (Pers.) Fr. On Acer rubrum, Oldtown, 9-1897, (Harvey). On Acer rubrum, Auburn, 1897, (Merrill).

Hypoxylon turbinulatum (Schw.) Berk. On Fagus ferruginea, Oldtown, 7-1897, (Harvey).

Lasiosphaeria hirsuta (Fr.) Ces. & De Not. On dead wood, Oldtown, 8-1895, (Harvey). Det. Ell.

Lasiosphaeria mutabilis (Pers.) Fckl. On Alnus, Harrison, 8-1859, (Blake). On Quercus rubra, Wells, 9-1859, (Blake).

Lasiosphaeria ovina (Pers.) Ces. & De Not. On decaying bark, Auburn, 11-1896, (Merrill). Det. Ell. On decaying bark, Oldtown, 7-1897, (Harvey).

*Leptosphaeria comatella (C. & E.) Sacc. Cumberland, (Blake).

Leptosphaeria culmicola (Fr.) Karst. On grass, Orrington, 6-1896, (Harvey).

Leptosphaeria doliolum (Pers.) De Not. On Chenopodium album, Cumberland, (Blake). On Solidage lanceolata, Orono, 9-1899, (Ricker). Det. Ell.

Lizonia sphagni Cke. On dead Sphagnum, Maine, Grev. 18:86.

Massaria inquinans, (Tode.) Fr. On Acer, Orono, 12-1892, (Harvey).

*Massaria pupula (Fr.) Tul. Orono, (Harvey).

Massariella scoriadea (Fr.) Sacc. On Alnus, Wells, 2-1860, (Blake).

Melanconis stilbostoma (Fr.) Tul. On Pyrus malus, Cumberland; Wells, (Blake). * Orono, (Harvey).

Melanomma pulvis-pyrius (Pers.) Fckl. On Acer, Cumberland, (Blake). On decaying wood, Orono, 1896, (Harvey).

Metasphaeria sublanosa (Cke.) Sacc. On decaying wood, Oldtown, 8-1896, (Harvey). Det. Ell. On decaying wood, Auburn, 11-1896, (Merrill).

Ophiobolus porphyrogonus (Tode.) Sacc. On Acer, Cumberland, (Blake). On Acer, Orono, (Harvey).

Pleospora asparagi Rabh. On Asparagus officinalis, Wells, (Blake).

Pseudovalsa lanciformis (Fr.) Ces. & De Not. On Alnus, Cumberland; Wells, (Blake).

Quaternaria persoonii Tul. (*Valsa quaternata (Pers.) Fr.*) On Acer, Cumberland, 2-1859, (Blake). On Acer, Orono, (Harvey).

Rosellina desmazierii (B. & Br.) E. & E. On Betula lutea, Cumberland, (Blake). On decaying wood, Wells; Harrison, (Blake.)

Rosellinia subiculata (Schw.) Sacc. On decaying wood, Auburn, 11-1896, (Merrill). Det. Ell.

Rosellinia thelena (Fr.) Rabh. On dead bark, Orono, 1895, (Harvey).

Sphaerella colorata Pk. On Kalmia angustifolia, Orono, 4-1898, (Ricker).

Sphaerella fragariæ (Tul.) Sacc. (*Ramularia tulasnei Sacc.*) On Fragaria Virginiana, Orono, 6-1898, (Ricker). On Fragaria virginiana, Bradley, 10-1899, (Ricker).

Sphaerella gaultheriæ C. & P. On Gaultheria procumbens, Orono, 5-1898, (Ricker).

Sphaerella maculiformis (Pers.) Awd. On Vaccinium macrocarpon, Otisfield, 1859, (Blake). On Fraxinus, Cumberland, (Blake).

Sphaerella nebulosa (Pers.) Sacc. On Trifolium pratense, Cumberland, (Blake).

Sphaerella pachyasca Rost. On Diapensia lapponica, Mt. Katahdin, 9-1898, (Merrill).

Sphaerella paludosa E. & E. On Nuphar advena, Oldtown, 9-1900, (Ricker).

Sphaerella philochorta Cke. On grasses, Maine, Grev. 11:111.

Sphaerella smilacicola (Schw.) Cke. Maine, (Morse). Proc. Bost. Soc. Nat. Hist. 6:319.

Sphaeria coptis Schw. On Coptis trifolia, Orono, 5-1898, (Ricker).

Sphaeria obscura Schw. On Quercus rubra, Harrison, (Blake).

Sphaeria radicum Schw. On Fagus ferruginea, Cumberland, (Blake).

Sphaeria verbascicola Schw. On Verbascum thapsus, Orono, 4-1900, (Ricker).

Trichosphaeria flavida E. & E. On rotten wood, Orono, 8-1896, (Harvey). Det. Ell.

Ustulina vulgaris Tul. On Quercus, Wells, 11-1880, (Blake). On Quercus, Ea. Auburn, 11-1896, (Merrill). On Quercus, Oldtown, 11-1896, (Harvey).

Valsa abietis Fr. On Abies balsamea, Orono, 9-1897, (Harvey).

Valsa alni Pk. On Alnus, Wells, 1880; Cumberland, (Blake).

Valsa ambiens (Pers.) Fr. On Pyrus malus, Wells, 4-1880, (Blake). On Pyrus malus, Orono, 1895, (Harvey).

Valsa colliculus (Wormsk.) Cke. On Abies balsamea, Cumberland, 10-1857, (Blake). On Pinus, Wells, (Blake).

*Valsa deformis (Fr.) Cke. Orono, (Harvey).

*Valsa modesta (Schw.) Cke. Cumberland, (Blake).

Valsa nivea (Hoffm.) Fr. On Populus tremuloides, Wells, 9-1880, (Blake).

*Valsa rufescens (Schw.) E. & E. Cumberland, (Blake).

Valsa salicina (Pers.) Fr. Cumberland, (Blake).

*Valsa truncata C. & Pk. Wells, (Blake).

Valsaria quadrata (Schw.) Sacc. On Quercus, Harrison, 10-1878; Wells, 1880, (Blake). On Acer, Orono, 12-1887, (Harvey).

*Venturia compacta Pk. Orono, (Harvey).

Venturia ditricha (Fr.) Karst. On Betula populifolia, Orono, 4-1900, (Ricker).

Venturia pulchella C. & Pk. On Cassandra calyculata, Sebago Lake, 7-1897, (Ricker). On Cassandra calyculata, Bangor Bog, 5-1900, (Stover).

Xylaria clavulata (Schw.) B. & C. On dead scale insect (Lecanium), on Fraxinus americana, Orono, 6-1899, (Stover).

Xylaria corniformis Fr. On ground in woods, Oldtown, 10-1899, (Ricker). Det. Ell.

Xylaria filiformis (A. & S.) Fr. On dead limbs, Ea. Auburn, 1896, (Merrill). Det. Ell.

Xylaria polymorpha (Pers.) Grev. On Acer, Cumberland, (Blake). Brunswick, (Kate Furbish). On Acer, Westbrook, 7-1899, (Ricker).

FAMILY HYPOCREACEÆ.

CHILONECTRIA CUCURBITULA Sacc. On Acer, Orono, 8-1896, (Harvey).

CLAVICEPS PURPUREA (Fr.) Tul. On Calamagrostis canadensis, Orono, 8-1892, (Harvey). On Secale cereale, Westbrook, 8-1897, (Ricker).

CORDYCEPS MILITARIS (L.) Sacc. Cumberland, (Blake).

CORDYCEPS NIGRICEPS Pk. Saco (C. L. Fox.) Bull. Torr. Bot. Club, 27:20.

CORDYCEPS OPHIOGLOSSOIDES (Ehrh.) Link. Cumberland, (Blake).

EPICHLOE TYPHINA (Pers.) Tul. On Phleum pratense, Orono, 7-1890, (Harvey).

GIBBERELLA PULICARIS (Fr.) Sacc. On Philadelphus coronarius, Cumberland, (Blake).

HYPOCREA CONTORTA (Schw.) B. & C. On Alnus, Cumberland, 2-1859, (Blake.)

HYPOCREA GELATINOSA (Tode.) Fr. On decaying wood, Orono, 9-1896, (Harvey).

HYPOCREA RICHARDSONII B. & Mont. On Populus, Cumberland, 12-1857, (Blake). On Populus tremuloids, Orono, 5-1898, (Harvey).

HYPOCREA RUFA (Pers.) Fr. On decaying wood, Cumberland, (Blake). On decaying wood, Oldtown, 8-1895, (Harvey).

HYPOCREA TUBERIFORMIS B. & Rav. On decaying wood, Ea. Auburn, 7-1896, (Merrill). Det. Ell.

HYPOCRELLA HYPOXYLON (Pk.) Sacc. On grass stems, Maine Journ. Mycol. 2:67.

HYPOMYCES CANDICANS Plowr. On Spumaria alba, Orono, 10-1896, (Harvey). Det. Ell.

HYPOMYCES INAEQUALIS Pk. On stem of an Agaric, Maine. Bull. Torr. Bot. Club, 25:328.

HYPOMYCES LACTIFLUORUM (Schw.) Tul. On Lactarius, Wells, 1880, (Blake). On Lactarius, Orono, (Harvey).

HYPOMYCES ROSELLUS (A. & S.) Tul. On decaying wood, Orono, 1896, (Harvey). Det. Ell.

HYPOMYCES VIOLACEUS (Fr.) Tul. On Fuligo septica, Greenfield, 8-1895, (Harvey). Det. Pk.

MELANOSPORA CHIONEA (Fr.) Cda. Auburn, 1896, (Merrill.)

NECTRIA CINNABARINA (Tode.) Fr. (*Tubercularia vulgaris Tode.*) On decaying wood, Yarmouth, 11-1857, (Blake). On Robinia pseudacacia, Orono, (Harvey). On Philadelphus coronarius, Orono, 11-1897, (Ricker).

NECTRIA COCCINEA (Pers.) Fr. On Polyporus, Cumberland, (Blake).

NECTRIA CUCURBITULA (Tode.) Fr. On Pinus, Wells, (Blake). On Abies balsamea, Westbrook, 7-1897, (Ricker). On Abies balsamea, Pea Cove, 10-1898, (Ricker).

NECTRIA DISPERSA C. & E. Maine, (Blake). Grev. 5:33.

NECTRIA EPISPHAERIA (Tode.) Fr. On Hypoxylon, Maine, (Sprague). In Blake Herb. On Hypoxylon, Auburn, 1896, (Merrill). On Hypoxylon, Orono, 1897, (Harvey).

NECTRIA SAMBUCI E. & E. On Sambucus, Orono, 1897, (Harvey). On Sambucus, Ea. Auburn, 1897, (Merrill).

NECTRIA VULPINA Cke. On decaying wood, Oldtown, 8-1895, (Harvey).

FAMILY DOTHIDEACEÆ.

DOTHIDELLA BETULINA (Fr.) Sacc. On Betula populifolia, Harrison, 9-1859, (Blake).

DOTHIDELLA KALMIÆ (Pk.) Sacc. On Kalmia glauca, Bangor Bog, 5-1899, (Merrill).

PHYLLACHORA CARICIS (Fr.) Sacc. On Carex pedunculata, Orono, 6-1896, (Harvey).

PHYLLACHORA GRAMINIS (Pers.) Fckl. On Phleum pratense, Orono, 10-1895, (Harvey). On Danthonia spicata, Orono, 10-1895, (Harvey). On Muhlenbergia sylvatica, Westbrook, 9-1899, (Ricker).

PHYLLACHORA OXALINA E. & E. On Oxalis strictia, Orono, 10-1900, (Ricker).

PHYLLACHORA PTERIDIS (Reb.) Fckl. On Pteris aquilina, Mt Desert, (J. H. Redfield). On Pteris aquilina, Orono, (Harvey).

PHYLLACHORA TRIFOLII (Pers.) Fckl. On Trifolium repens, Harrison, 9-1859, (Blake). On Trifolium pratense, Orono, 9-1898, (Ricker).

PHYLLACHORA ULMI (Duv.) Fckl. Harrison, (Blake).

PLOWRIGHTIA MORBOSA (Schw.) Sacc. On Prunus pennsylvanica, Orono, (Harvey). On Prunus pennsylvanica, Westbrook, 7-1898, (Ricker).

PLOWRIGHTIA RIBESIA (Pers.) Sacc. On Ribes rubrum, Cumberland, (Blake). On Ribes rubrum, Orono, 1896, (Harvey).

FAMILY MICROTHYRIACEÆ.

MICROTHYRIUM MICROSCOPICUM Desm. On Fraxinus, Cumberland, 1857, (Blake).

FAMILY LOPHIOSTOMACEÆ.

*LOPHIDIUM COMPRESSUM (Pers.) Sacc. Cumberland, (Blake).

FAMILY HYSTERIACEÆ.

ANGELINIA RUFESCENS (Schw.) Duby. On decaying wood, Orono, 9-1896, (Harvey). Det. Ell.

DICHAENA FAGINEA Fr. On Fagus ferruginea, Cumberland, (Blake). On Fagus ferruginea, Orono, 9-1897, (Harvey).

GLONIUM LINEARE (Fr.) De Not. On Pyrus malus, Wells, 2-1860, (Blake).

HYPODERMA COMMUNE (Fr.) Duby. On Aralia spinosa, Oldtown, 8-1899, (Ricker).

HYSTERIUM PULICARE Pers. On Acer, Cumberland, 2-1859, (Blake). On Acer rubrum, Ea. Auburn, 8-1897, (Merrill).

HYSTEROGRAPHIUM FRAXINI (Pers.) De Not. On Fraxinus, Cumberland, (Blake).

HYSTEROGRAPHIUM VULVATUM (Schw.) Rehm. On bark, Ea. Auburn, 1896, (Merrill). Det. Ell.

*LOPHODERMIUM ARUNDINACEUM CARICINUM (Rob.) E. & E. Orrington, 6-1896, (Harvey).

LOPHODERMIUM ARUNDINACEUM CULMIGENUM (Fr.) Fckl. On grass culms, Wells, (Blake). On grass culms, Orono, (Harvey).

LOPHODERMIUM JUNIPERINUM (Fr.) De Not. On Juniperus, Portland, (Fuller). Grev. 5:153.

LOPHODERMIUM PINASTRI (Schrad.) Chev. On Pinus strobus, Cumberland, (Blake). On Pinus strobus, Orono, 5-1898. (Ricker). On Picea nigra, Orono, 1-1899, (Ricker). On Thuja occidentalis, Orono, 12-1900, (Ricker).

FAMILY LABOULBENIACEÆ.

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CAMPTOMYCES MELANOPUS Thaxt. York, Thaxt. Lab. p. 275.

CANTHAROMYCES PUSILLUS Thaxt. York, Thaxt. Lab. p. 273.

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CERATOMYCES CONTORTUS Thaxt. Kittery Pt., Thaxt. Lab. p. 379.

CERATOMYCES FILIFORMIS Thaxt. Kittery Pt., Thaxt. Lab. p. 376.

CERATOMYCES FURCATUS Thaxt. Kittery Pt., Thaxt. Lab. p. 379.

CERATOMYCES HUMILIS Thaxt. Kittery Pt., Thaxt. Lab. p. 380.

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DICHOMYCES INAEQUALIS Thaxt. Kittery Pt., Thaxt. Lab. p. 283.

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LABOULBENIA HARPALI Thaxt. Kittery, Thaxt. Proc. Am. Acad. Arts and Sci. 24:13.

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STIGMATOMYCES PURPUREUS Thaxt. Kittery Pt., Thaxt. Proc. Am. Acad. Arts and Sci. 36:405.

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TETRATOMYCES BREVICAULIS Thaxt. Kittery Pt., Thaxt. Lab. p. 357.

TETRATOMYCES MIRIFICUS Thaxt. Maine, Thaxt. Lab. p. 355.

ZODIOMYCES VERTICELLARIUS Thaxt. York, Thaxt. Lab. p. 372.

ORDER DISCOMYCETACEÆ.

FAMILY HELVELLACEÆ.

GEOGLOSSUM DIFFORME Fr. On the ground, Otisfield, 8-1858, (Blake).

GEOGLOSSUM HIRSUTUM Pers. On the ground, Cumberland, (Blake). In Sphagnum bog, Orono, 9-1896, (O. W. Knight).

*GEOGLOSSUM OPHIOGLOSSOIDES (L.) Sacc. Orono, (Harvey).

GEOGLOSSUM PECKIANUM Cke. On the ground in woods, Brownfield, 9-1896, (Merrill). Det. Pk.

GYROMITRA ESCULENTA (Pers.) Fr. On the ground, Orono, 5-1898, (Ricker).

HELVELLA INFULA Schaeff. On the ground in woods, Orono, 9-1897, (Harvey).

HELVELLA LACUNOSA Afz. So. Paris, Proc. Bost. Soc. Nat. Hist. 5:330.

HELVELLA MACROPUS (Pers.) Karst. On the ground, Harrison, 8-1858, (Blake). On decaying logs, Cumberland, 8-1858, (Blake). On decaying logs, Pea Cove, 10-1898, (Harvey).

HELVELLA MONACHELLA (Scop.) Fr. On the ground in woods, Harrison, 8-1858, (Blake).

HELVELLA NIGRA Pk. On ashes of an old camp-fire, shore Basin Lake, Mt. Katahdin, (altitude 2500 feet), 9-1898, (Harvey).

LEPTOGLOSSUM LUTEUM (Pk.) Sacc. On the ground in woods, Brownfield, 7-1896, (Merrill).

MITRULA PHALLOIDES (Bull.) Chev. On leaves in wet places, Cumberland, 1859, (Blake). On leaves in wet places, Wells, 1880, (Blake). On leaves in wet places, So. Lagrange, 7-1897, (Harvey).

MITRULA VITELLINA (Bres.) Sacc. In the woods under trees, Orono, 10-1888, (Harvey).

*MITRULA VITELLINA IRREGULARIS Pk. Orono, 10-1896, (Harvey).

MORCHELLA ESCULENTA (L.) Pers. On the ground in woods, Chebeague Is., Casco Bay, (Fuller). On the ground in woods, Livermore Falls, (Kate Furbish). On the ground in woods, Westbrook, 6-1898, (Ricker).

SPATHULARIA CLAVATA (Schaeff.) Sacc. On the ground in woods, Orono, 8-1896, (Harvey). On the ground in woods, Monmouth, 1897, (Merrill).

FAMILY PEZIZACEÆ.

BELONIDIUM AURELIA (Pers.) De Not. On decaying logs, Ea. Auburn, 9-1896, (Merrill).

CHLOROSPLENIUM AERUGINOSUM (Oeder.) De Not. On decaying logs, Wells, 1880, (Blake). On decaying logs, Orono, 9-1897, (Ricker). On decaying logs, Auburn, (Merrill).

CHLOROSPLENIUM VERSIFORME (Pers.) Karst. On Acer, Harrison, 8-1859, (Blake).

Dasyscypha agassizii (B. & C.) Sacc. On Abies balsamea, Orono, 10-1896, (Harvey). On Abies balsamea, Westbrook, 9-1898, (Ricker).

Dasyscypha bicolor (Bull.) Fckl. On dead twigs, Maine, Grev. 3:154.

Dasyscypha calycinia (Schum.) Fckl. On Abies, Orono, 10-1896, (Harvey).

Dasyscypha cerina (Pers.) Fckl. Portland, (Fuller). In Herb. Port. Soc. Nat. Hist.

Dasyscypha ellisiana (Rehm.) Sacc. On Pinus rigida, Westbrook, 4-1899, (Ricker). Det. Ell.

*Dasyscypha hyalina (Phill.) Sacc. Orono, 1890, (Harvey).

*Dasyscypha nivea (Hedw.) Sacc. Orono, 1890, (Harvey).

Geopyxis nebulosa Cke. On decaying logs, Oldtown, 8-1895, (Harvey).

*Geopyxis pallidula C. & Pk. Orono, 1896, (Harvey).

Geopyxis pulchra Ger. On the ground, Orono, 5-1895, (G. Haley).

Helotium citrinum (Hedw.) Fr. On decaying logs, Cumberland, (Blake). On decaying logs, Orono, 10-1896, (Harvey). On decaying logs, Katahdin Iron Works, 11-1898, (Ricker).

Helotium confluens Schw. On decaying logs, Wells, 5-1880, (Blake).

Helotium herbarum (Pers.) Fr. On Quercus, Harrison, 9-1859, (Blake). On Rubus, Wells, 1880, (Blake).

Lachnea erinaceus Schw. On decaying logs, Orono, 12-1887, (Harvey).

Lachnea hemisphaerica Wigg. On decaying logs, Cumberland, 8-1858, (Blake). On decaying logs, Orono, 9-1896, (Harvey).

Lachnea scutellata Linn. On decaying logs, Cumberland, (Blake). On decaying logs, Orono, 9-1886, (Harvey). On decaying logs, Westbrook, 7-1897, (Ricker).

*Lachnella corticalis (Pers.) Fr. Orono, 1890, (Harvey).

Mollisia cinerea (Batsch.) Karst. On decaying logs, Orono, 9-1896, (Harvey). Det. Morg.

Mollisia discolor (Mont.) Phill. On Ulmus, Cumberland, 10-1858, (Blake).

PEZIZA AURANTIA Pers. On decaying logs, Harrison, (Blake). On the ground, Orono, (Harvey).

PEZIZA BADIA Pers. Orono, 8-1887, (Harvey).

PEZIZA BAUERANA Cooke. On an old water tank, Orono, 6-1890, (Harvey).

PEZIZA COCHLEATA L. On the ground, Cumberland, 1857, (Blake). On the ground, Wells, 1880, (Blake).

PEZIZA ODORATA Pk. On the ground, Orono, 6-1896, (Harvey).

PEZIZELLA REGALIS (C. & E.) Sacc. On bark of decaying trees, Orono, 10-1888, (Harvey).

PEZIZELLA VULGARIS (Fr.) Sacc. On Pinus, Wells, 1880, (Blake).

PHAEOPEZIZA RETIDERMA (Cke.) Sacc. On Ground, Portland, (Fuller). In Herb. Port. Soc. Nat. Hist.

PHAEOPEZIZA SCABROSA (Cke.) Sacc. Portland, (Bolles.) Sacc. Syll. Fung. 8: 472.

*PHIALEA VIRGULTORUM (Vahl.) Sacc. Orono, 1890, (Harvey).

PLECTANIA HIRTIPES Cooke. Maine, (Bolles). In Sacc. Syll. 8:163.

PSEUDOPLECTANIA NIGRELLA Pers. On the ground, Orono, 5-1898, (Ricker). Det. Farl.

PSILOPEZIA BABINGTONII Berk. On decaying logs, Pownal, 7-1897, (Stover). Det. Ell.

PYRONEMA HAEMASTIGMA (Hedw.) Fr. On decaying logs, Wells, 1880, (Blake).

*PYRENOPEZIZA NERVISEQUIA (Pers.) Sacc. Portland, (Bolles).

SCLEROTINIA INCONDITA Ell.? On leaves in wet places, Orono, 5-1899, (Ricker).

FAMILY DERMATEACEÆ.

*CENANGELLA RAVENELII (Berk.) Sacc. Orono, 1889, (Harvey).

CENANGIUM ABIETIS (Pers.) Rehm. On Pinus, Wells, (Blake). On Pinus, Orono, 12-1887, (Harvey).

CENANGIUM ABIETIS STROBILINUM A. & S. *F. Col. No. 1416.* On Picea excelsa, Orono, 4-1899, (Ricker). Det. Ell.

CENANGIUM FURFURACEUM (Roth.) De Not. On Alnus, Orono, 8-1897, (Harvey).

CENANGIUM POPULNEUM (Pers.) Rehm. On Populus tremuloides, Orono, 5-1898, (Ricker).

CENANGIUM PRUNASTRI (Pers.) Fr. On Acer, Cumberland, 3-1859, (Blake).

CENANGIUM PULVERACEUM (A. & S.) Fr. On decaying logs, Orono, 1890, (Harvey). On decaying logs, Auburn, 1896, (Merrill).

CENANGIUM PUNCTOIDEUM (Cke.) Sacc. Maine, (Blake). Grev. 5:33.

CENANGIUM STICTUM (B. & C.) Sacc. Maine, (Morse.). Grev. 4:4.

CENANGIUM TUBERCULIFORME E. & E. On Alnus, Orono, 8-1896, (Harvey). Det. Ell.

DERMATEA CERASI (Pers.) Fr. On Prunus pennsylvanica, Mt. Katahdin, 4-1856, (Blake). On Prunus pennsylvanica, Westbrook, 5-1898, (Ricker).

DERMATEA FUSISPORA E. & E. On Betula, Orono, 1892, (Harvey). Det. Ell.

TYMPANIS ALNEA (Pers.) Fr. On Alnus, Cumberland, 2-1859, (Blake). On Alnus incana, Orono, 9-1899, (Ricker).

TYMPANIS CONSPERSA Fr. On Populus, Harrison, 9-1859, (Blake). On Populus, Orono, 10-1890, (Harvey). On Populus, Westbrook, 12-1897, (Ricker).

TYMPANIS LARICINA (Fckl.) Sacc. On Abies nigra, Auburn, 1-1897, (Merrill). Det. Ell.

URNULA CRATERIUM (Schw.) Fr. On the ground, Livermore Falls, 1891, (Kate Furbish). Det. Harv.

FAMILY BULGARIACEÆ.

AGYRIUM RUFUM Pers. Fr. On Pinus, Wells, 1880, (Blake).

BULGARIA INQUINANS (Pers.) Fr. On Acer saccharinum, Cumberland, 1857, (Blake). On Ulmus americana, Westbrook, 9-1898, (Ricker).

BULGARIA RUFA Schw. On Betula populifolia, Orono, 12-1887, (Harvey).

CORYNE SARCOIDES (Jacq.) Tul. On Acer, Cumberland, 1856, (Blake).

CORYNE URNALIS (Nyl.) Sacc. On decaying logs, Orono, 10-1888, (Harvey).

LEOTIA CHLOROCEPHALA Schw. On the ground, Harrison, 8-1858, (Blake). On the ground, Orono, (Harvey).

LEOTIA LUBRICA (Scop.) Pers. On the ground, Harrison, 8-1858, (Blake).

LEOTIA VISCOSA Fr. On the ground, Orono, 8-1887, (Harvey).

OMBROPHILA ENTEROCHROMA (Pk.) Sacc. On Thuja occidentalis, Pea Cove, 10-1898, (Ricker). On Thuja occidentalis, Orono, 10-1900, (Ricker).

ORBILIA CHRYSOCOMA (Bull.) Sacc. On decaying wood, Oldtown, 7-1897, (Harvey).

ORBILIA COCCINELLA (Somm.) Karst. Orono, (Harvey). Det. Morg.

ORBILIA VINOSA (A. & S.) Karst. On decaying wood, Orono, 10-1895, (Harvey). Det. Pk.

FAMILY STICTIDACEÆ.

PROPOLIS FAGINEA (Schrad.) Karst. On decaying wood, Orono, 10-1895, (Harvey). Det. Pk.

STICTIS RADIATA (L.) Pers. On decaying logs, Orono, 10-1895, (Harvey).

XYLOGRAMMA HYSTERINUM (Fr.) Rehm. On Abies balsamea, Wells, 1860, (Blake).

FAMILY PHACIDIACEÆ.

COCCOMYCES DENTATUS (K. & Schum.) Sacc. On Quercus rubra, Wells, 5-1880, (Blake). On Betula, Orono, 10-1898, (Harvey).

COCCOMYCES PINI (A. & S.) Karst. On Pinus strobus, Orono, (Harvey). On Pinus strobus, Westbrook, 7-1899, (Ricker).

PHACIDIUM SALICINUM Fckl. On Salix, Orono, (Harvey).

PHACIDIUM VACCINII Fr. On Arctostaphylos uva-ursi, Wells, 5-1880, (Blake).

RHYTISMA ACERINUM Pers. On Acer dasycarpum, Orono, 9-1897, (Ricker). On Acer rubrum, 9-1900, (Ricker).

RHYTISMA ANDROMEDÆ (Pers.) Fr. On Andromeda polyfolia, Bangor Bog, 5-1899, (Merrill).

RHYTISMA BLAKEI M. A. Curtis in Blake Herb. On Rubus hispidus, Kennebunk, 5-1857, (Blake). There is some doubt as to whether the fungus to which this name has been applied is really a Rhytisma or not.

RHYTISMA DECOLORANS Fr. On Andromeda ligustrina, Cumberland, 9-1858, (Blake).

RHYTISMA ILICIS-CANADENSIS Schw. On Nemopanthes fasicularis, Orono, 1893, (Harvey). On Nemopanthes fasicularis, Mt. Katahdin, 9-1898, (Merrill).

RHYTISMA PRINI Schw. On Ilex verticellata, Wells, 8-1859, (Blake). On Ilex verticellata, Orono, 10-1898, (Ricker).

RHYTISMA PUNCTATUM (Pers.) Fr. On Acer spicatum, Katahdin Iron Works, 11-1898, (Ricker).

RHYTISMA SALICINUM (Pers.) Fr. On Salix herbacea, Mt. Katahdin, 9-1898, (Merrill). On Salix cordata, Bradley, 10-1899, (Ricker).

RHYTISMA SOLIDAGINIS Schw. On Solidago lanceolata, Cumberland, (Blake). On Solidago lanceolata, Auburn, (Merrill). On Solidago lanceolate, Orono, (Harvey).

RHYTISMA VACCINII Fr. On Vaccinium, Wells, 1859, (Blake).

FAMILY PATELLARIACEÆ.

BLITRYDIUM CUCURBITARIA (Cooke.) Sacc. On Ulmus americana, Orland, 7-1897, (Merrill). Det. Ell.

DURELLA COMPRESSA (Pers.) Tul. On Fagus ferruginea, Cumberland, 12-1857, (Blake).

KARSCHIA LIGNYOTA (Fr.) Sacc. On Ulmus americana, Orono, 10-1897, (Harvey).

LECANIDION FUSCO-ATRUM Rehm. On Pinus, Wells, (Blake).

TRYBLIDIOPSIS PINASTRI (Pers.) Karst. On Pinus strobus, Cumberland, 2-1858, (Blake). On Pinus silvestris, Orono, 10-1900, (Ricker).

FAMILY GYMNOASCACEÆ.

EXOASCUS ALNI-INCANAE Kuhn. On Alnus incana, Westbrook, 7-1900, (Ricker). On Alnus incana, Orono, 10-1900, (Ricker).

FAMILY CALICIACEÆ.

CALICIOPSIS ELLISII Sacc. On Polyporus, Cumberland, (Blake.)

CALICIOPSIS PINEA Pk. On Pinus strobus, Orono, 10-1896, (Harvey). Det. Pk.

CALICIUM CURTUM Turn. & Borr. On decaying wood, Wells, (Blake).

CALICIUM TIGILLARE (B. & Br.) Sacc. On Polyporus pergamenus, Westbrook, 5-1898, (Ricker). Det. Ell.

EMBOLUS OCHREATUS (De Not.) Sacc. Greenfield, 9-1895, (Harvey). Det. Pk.

CLASS VI. BASIDIOMYCETAE.

ORDER USTILAGINACEÆ.

ENTYLOMA COMPOSITARUM Farl. On Aster novi-belgii, Peaks Is., 10-1899, (W. A. Getchell). In Bot. Gaz. 19:187.

ENTYLOMA LOBELIAE Farl. Maine, (Farlow). Crypt. Flora. White Mts. p. 238.

GRAPHIOLA PHOENECIS (Moug.) Poit. On Phoenix dactylifera, Bangor, 3-1899, (Ricker). In a greenhouse.

USTILAGO ANOMALA Kunze. On Polygonum convolvulus, Fryeburg, 8-1899, (Harvey).

USTILAGO AVENÆ (Pers.) Jens. On Avena sativa, Cumberland, 1857, (Blake). On Avena sativa, Westbrook, 8-1900, (Ricker).

USTILAGO CARICIS (Pers.) Fckl. On Carex pedunculata, Clifton, 6-1896, (Harvey). On Carex pedunculata, Orono, 7-1896, (Harvey).

USTILAGO HORDEI (Pers.) Kell. & Sw. On Hordeum sativum, Orono, 8-1890, (Harvey).

USTILAGO MAYDIS (DC.) Cda. On Zea mays, Wells, 8-1859, (Blake). On Zea mays, Orono, (Harvey).

USTILAGO VIOLACEA (Pers.) Fckl. On Arenaria groenlandica, Saddleback, Mt. 8-1897, (Fernald).

ORDER UREDINACEÆ.

AECIDIUM ASTERUM Schw. On Aster, Westbrook, (Bolles). Proc. Port. Soc. Nat. Hist. 1:181.

AECIDIUM CLEMATIDIS DC. On Clematis virginiana, Orono, 7-1899, (Harvey). Det. P. L. R.

Aecidium elatinum A. & S. On Abies balsamea, Wells, 1880, (Blake).

Aecidium grossulariæ Schum. On Ribes prostratum, Orono, 5-1898, (Ricker). On Ribes floridum, Orono, 6-1900, (Ricker.)

Aecidium hydnoideum, B. & C. On Dirca palustris, Winthrop, 6-1857, (Blake).

Aecidium hypericatum Schw. On Hypericum perforatum, Westbrook, (Bolles). Proc. Port. Soc. Nat. Hist. 1 :181.

Aecidium mariæ-wilsoni Pk. On Viola cucullata, Harrison, 6-1881, (Blake).

Aecidium oenotheræ Mont. On Oenothera biennis, Basin Mills, 5-1899, (Ricker).

Calyptospora goeppertiana J. Kuehn. On Vaccinium vitis-idaea, Clifton, 6-1896, (Harvey). On Vaccinium vitis-idaea, Mt. Katahdin, 8-1898, (Merrill).

Chrysomyxa albida Kuehn. On Rubus villosus, Wells, 9-1883, (Blake).

Chrysomyxa pirolæ (DC.) Rost. On Pyrola rotundifolia, Biddeford, 5-1859, (Blake). On Pyrola rotundifolia, Orono, 5-1892, (Harvey).

Coleosporium solidaginis (Schw.) Thum. On Solidago, Cumberland, 9-1857, (Blake). On Solidago canadensis, Bradley, 10-1899, (Ricker). On Aster lindleyanus, Orono, 10-1900, (Ricker).

Cronartium asclepiadeum (Willd.) Fr. *F. Col. No. 1482.* On Myrica gale, Orono, 10-1900, (Ricker).

Gymnosporangium clavariiforme (Jacq.) Rees. On Juniperus communis, Portland, (Fuller). Farl. Gymnosp. p. 13.

Gymnosporangium clavipes C. & Pk. On Juniperus virginiana, Orono, 11-1900, (Ricker).

Gymnosporangium juniperinum, (L.) Fr. On Juniperus virginiana, Cumberland, 1859, (Blake).

Gymnosporangium sabinæ (Dicks.) Wint. On Pyrus communis, Westbrook, (Bolles).

Melampsora farinosa (Pers.) Schroet. On Salix, Orono, (Harvey). On Salix cordata, Auburn, 7-1896, (Merrill).

MELAMPSORA POPULINA (Jacq.) Lev. On Populus tremuloides, Orono, 9-1897, (Merrill). On Populus monilifera, Orono, 9-1898, (Ricker).

MELAMPSORA VITELLINAE (DC.) Thum. On Salix lucida, Orono, 10-1900, (Ricker).

PHRAGMIDIUM POTENTILLÆ (Pers.) Karst. On Potentilla canadensis, Orono, 5-1898. (Ricker). On Potentilla canadensis, Westbrook, 6-1900, (Ricker).

PHRAGMIDIUM RUBI-IDAEI (DC.) Karst. On Rubus, Westbrook, (Bolles). Proc. Port. Soc. Nat. Hist. 1 :185.

PHRAGMIDIUM SUBCORTICIUM (Schrank.) Wint. On Rosa, Westbrook, (Bolles). Proc. Port. Soc. Nat. Hist. 1 :181.

PUCCINIA ANEMONES-VIRGINIANÆ Schw. On Anemone virginiana, Cumberland, (Blake).

PUCCINIA ANGUSTATA Pk. On Scirpus eriophorum, Orono, 9-1895, (Harvey). Det. Arth. On Scirpus eriophorum, Westbrook, 8-1899, (Ricker).

PUCCINIA ARENARIÆ (Schum.) Schroet. Portland, (Fuller). Grev. 5 :152.

PUCCINIA ASPARAGI DC. On Asparagus officinalis, Orono, 7-1898, (Harvey).

PUCCINIA ASTERIS Duby. On Aster, Harrison, 8-1859, (Blake). On Aster macrophylla, Jackman, 8-1895, (Harvey). On Aster macrophylla, Westbrook, 7-1898, (Ricker).

PUCCINIA CARICIS (Schum.) Reb. On Carex retrorsa, Orono, 10-1895, (Harvey). On Carex rostrata, Orono, 10-1895, (Harvey). On Carex crinita, Westbrook, 8-1899, (Ricker). On Carex bromoides, Orono, 10-1899, (Harvey).

PUCCINIA CIRCAEÆ Pers. On Circaea alpina, Cumberland, 8-1857, (Blake). On Circaea lutetiana, Ea. Auburn, 7-1896, (Merrill). On Circaea lutetiana, Sebago Lake, 7-1898, (Ricker).

PUCCINIA CLINTONII Pk. On Pedicularis canadensis, Basin Mills, 5-1898, (Merrill).

PUCCINIA CORONATA Cda. On Rhamnus, Maine, Proc. Port. Soc. Nat. Hist. 1 :180.

PUCCINIA GRAMINIS Pers. On Berberis vulgaris, Cumberland, (Blake). On Triticum sativum, Westbrook, 9-1899, (Ricker).

PUCCINIA HELIANTHI Schw. On Helianthus tuberosus, Auburn, 9-1898, (Merrill).

PUCCINIA HIERACII (Schum.) Mart. On Solidago, Maine, (Sprague). In Blake Herb.

PUCCINIA JUNCI (Str.) Wint. On Juncus, Westbrook, (Fuller). Grev. 5:152.

PUCCINIA MALVACEARUM Mont. On Althaea rosea, Augusta, 8-1898, (B. W. McKeen). Det. P. L. R.

PUCCINIA MENTHÆ AMERICANA Burr. *F. Col. No. 1461.* On Mentha Canadensis, Bradley, 10-1899, (Ricker).

PUCCINIA ORNATA A. & H. On Rumex brittanica, Oldtown, 9-1900, (Ricker). Det. Arth. On Rumex brittanica, Orono, 10-1900, (Ricker). On Rumex brittanica, Long Is., Casco Bay, (A. B. Seymour).

PUCCINIA PERIDERMIOSPORA (E. & T.) Arth. On Spartina cynosuroides, Orono, 10-1900, (Ricker). Det. Arth.

PUCCINIA POLYGONI Pers. On Polygonum amphibium, Harrison, 9-1859, (Blake). On Polygonum muhlenbergii, Orono, 10-1900, (Ricker).

PUCCINIA PORPHYROGENITA Curt. On Cornus canadensis, Bradley, 7-1890, (Harvey).

PUCCINIA PYROLÆ Cke. On Polygala, Cape Elizabeth, (Bolles). Proc. Port. Soc. Nat. Hist. 1:183. Cooke gives the host as Pyrola, but it should probably be Polygala paucifolia.

PUCCINIA RUBIGO-VERA (DC.) Wint. On Triticum vulgare, Cumberland, (Blake). On Secale cereale, Orono, (Harvey).

PUCCINIA SUAVEOLENS (Pers.) Rostr. On Cnicus arvensis, Orono, 10-1900, (Ricker).

PUCCINIA TARAXACI Plowr. On Taraxacum officinale, Orono, 10-1898, (Ricker).

PUCCINIA THALICTRI Chev. On Thalictrum, Portland, (Fuller). Grev. 5:152.

PUCCINIA VIOLÆ (Schum.) DC. On Viola rontundifolia, Bradley, 7-1890, (Harvey). On Viola blanda renifolia, Orono, 6-1896, (Merrill).

ROESTELIA AURANTIACA Pk. On Amelanchier canadensis, Wells, 1880, (Blake). On Amelanchier canadensis, Orono, 8-1897, (Harvey). On Amelanchier canadensis, Falmouth Foreside, 8-1901, (Ricker). On Crataegus macrantha, Falmouth Foreside, 8-1901, (Ricker).

ROESTELIA CORNUTA (Gmel.) Fr. On Pyrus americana, Mt. Desert Is., 9-1897, (J. C. Arthur).

ROESTELIA LACERATA (Sow.) Fr. On Crataegus, Westbrook, (Bolles). Proc. Port. Soc. Nat. Hist. 1 :180. On Pyrus americana, New Portland, 6-1857, (Blake).

TRIPHRAGMIUM CLAVELLOSUM Berk. On Aralia nudicaulis, Bradley, 7-1890, (Harvey). On Aralia nudicaulis, Westbrook, 7-1898, (Ricker).

UREDO CAEOMA NITENS Schw. On Rubus villosus, Orono, 6-1898, (Ricker).

UREDO CASSANDRÆ Pk. & Cl. On Cassandra calyculata, Harrison, 6-1881, (Blake). Det. Arth.

UREDO IRIDICOLA Pk. On Iris versicolor, Bradley, 10-1899, (Ricker).

UREDO LEDICOLA Pk. On Ledum latifolium, Orono, 6-1899, (Harvey).

UREDO POLYPODII (Pers.) DC. On Osmunda cinnamomea, Wells, 8-1859, (Blake).

UROMYCES APPENDICULATUS (P.) Lev. On Phaseolus vulgaris, Orono, 7-1899, (Harvey).

UROMYCES ASCLEPIADIS Cke. On Asclepias, Cape Elizabeth, (Fuller). Grev. 5 :152.

UROMYCES CALADII (Schw.) Farl. On Arisaema triphyllum, Basin Mills, 5-1899, (Ricker).

UROMYCES CARYOPHYLLINUS (Schrank.) Schroet. On Dianthus caryophyllus, Orono, 12-1898, (Ricker). In a greenhouse.

UROMYCES GERANII (DC.) Otth. & Wartm. On Geranium, Westbrook, (Bolles).

UROMYCES HYPERICI (Schw.) Curt. On Hypericum perforatum, Cape Elizabeth, 9-1859, (Blake). On Hypericum mutilum, Bradley, 10-1899, (Ricker).

UROMYCES JUNCI (Desm.) Tul. On Juncus tenuis, Orono, (Harvey).

UROMYCES LILII Clint. On Lilium canadense, Bradley, 7-1899, (Harvey).

UROMYCES PIRIFORMIS Cke. On Acorus calamus, Orono, 9-1897, (Harvey).

UROMYCES TRIFOLII (Hedw.) Lev. On Trifolium pratense, Auburn, (Merrill). On Trifolium pratense, Orono, 11-1898, (Harvey).

ORDER HYMENOMYCETACEÆ.

FAMILY AGARICACEÆ.

AGARICUS CAMPESTER Linn. Orono, (Harvey).

AMANITA FROSTIANA Pk. Orono, 8-1887, (Harvey).

*AMANITA MONTICULOSA B. & C. Cumberland, (Blake).

AMANITA MUSCARIA Linn. Cumberland, 8-1855, (Blake). Orono, 9-1900, (Ricker).

AMANITA PHALLOIDES Fr. Orono, 8-1896, (Harvey).

*AMANITA SPRETA Pk. Wells, (Blake).

ANTHRACOPHYLLUM NIGRITA (Lev.) Kalchbr. Eastport, (Farlow). Bull. Bussey Inst., 1:436, as Xerotus nigrita Lev.

ARMILLARIA MELLEA Vahl. Orono, 10-1895, (Harvey).

CANTHARELLUS AURANTIACUS Fr. Oldtown, 8-1896, (Harvey).

CANTHARELLUS CIBARIUS Fr. Harrison, 8-1859, (Blake). Orono, 8-1896, (Harvey).

CANTHARELLUS DICHOTOMUS Pk. Orono, 9-1896, (Harvey).

CANTHARELLUS FLOCCOSUS Schw. *N. A. F. No. 1920.* Orono, 8-1887, (Harvey).

CANTHARELLUS INFUNDIBULIFORMIS (Scop.) Fr. Orono, 8-1896, (Harvey). Det. Pk.

CANTHARELLUS INFUNDIBULIFORMIS SUBCINEREUS Pk. Orono, 10-1896, (Harvey). Det. Pk.

CANTHARELLUS MULTIPLEX Underwood. Seal Harbor, 8-1898, Bull. Torr. Bot. Club, 26:254.

CANTHARELLUS PRINCEPS B. & C. Maine, (Sprague). In Sacc. Syll. 5:487.

CANTHARELLUS TUBAEFORMIS Fr. Cumberland, (Blake).

CLAUDOPUS NIDULANS (Pers.) Pk. On Fagus ferruginea, Pea Cove, 10-1898, (Ricker). Det. Burt.

CLAUDOPUS VARIABILIS Pers. Cumberland, (Blake).

CLITOCYBE ALBISSIMA Pk. Orono, 10-1895, (Harvey).

CLITOCYBE CANDICANS Pers. Orono, 9-1898, (Harvey).

Clitocybe laccata Scop. Orono, 8-1887, (Harvey).

Clitocybe nebularis Batsch. Cumberland, 8-1855, (Blake).

Clitocybe ochro-purpurea Berk. Orono, 8-1895, (Harvey).

Clitocybe phyllophylla Fr. Orono, 10-1895, (Harvey).

Clitocybe trullisata Ellis. Wells, (Blake).

Clitopilus abortivus B. & C. Orono, 10-1898, (Ricker).

Clitopilus caepitosus Pk. Orono, 9-1890, (Harvey).

Clitopilus noveboracensis Pk. Oldtown, 8-1895, (Harvey).

Collybia abundans Pk. Orono, 8-1896, (Harvey).

Collybia acervata Fr. Orono, 9-1897, (Harvey). Det. Pk.

Collybia butyracea Bull. Westbrook, 8-1898, (Ricker). Det. Pk.

Collybia cirrata Schum. Orono, 8-1897, (Harvey). Det. Pk.

Collybia confluens Pers. Orono, 8-1893, (Harvey). Pea Cove, 10-1898, (Ricker).

Collybia dryophilla Bull. Orono, 10-1895, (Harvey). Det. Pk.

Collybia fuliginella Pk. Bradley, 9-1897, (Harvey).

Collybia maculata A. & S. Orono, 8-1896, (Harvey).

Collybia radicata Rehl. Orono, 1897, (Harvey).

Collybia tuberosa Bull. Maine, Proc. Bost. Soc. Nat. Hist. 6:316.

Collybia volutipes Curt. Orono, 8-1897, (Harvey). Det. Pk.

Coprinus atramentarius silvestris Pk. Orono, 10-1895, (Harvey). Det. Pk.

Coprinus fimentarius Fr. Cumberland, (Blake).

Coprinus plicatilis (Curt.) Fr. Cumberland, (Blake). Patten, 8-1898, (Harvey).

Cortinarius albo-violaceus (Pers.) Fr. Orono, (Harvey).

Cortinarius armillatus (A. & S.) Fr. Orono, 9-1897, (Harvey).

Cortinarius cinnamemous (Linn.) Fr. Orono, 8-1897, (Harvey).

CORTINARIUS CINNAMOMEUS SEMISANGUINEUS Fr. Orono, 1896, (Harvey).

CORTINARIUS SPILOMEUS Fr. Orono, 9-1896, (Harvey).

*CORTINARIUS TORVUS Fr. Orono, (Harvey).

CORTINARIUS VIOLACEUS (Linn.) Fr. North-west carry, 8-1897, (Harvey).

*CREPIDOTUS APPLANATUS Pers. Orono, (Harvey).

CREPIDOTUS VERSUTUS Pk. Westbrook, 8-1893, (Ricker).

ENTOLOMA GRAYANUM Pk. Orono, 9-1892, (Harvey).

FLAMMULA ALNICOLA Fr. Brunswick, (Kate Furbish).

FLAMMULA FLAVIDA Pers. Cumberland, (Blake).

*FLAMMULA SPUMOSA Fr. Orono, 9-1896, (Harvey).

GALERA LATERITIA Fr. Orono, 7-1897, (Harvey). Westbrook, 7-1898, (Ricker).

GALERA TENERA Schaeff. Orono, 6-1897, (Harvey).

HYGROPHORUS BOREALIS Pk. Orono, 9-1897, (Harvey).

*HYGROPHORUS CANTHARELLUS Schw. Orono, (Harvey).

HYGROPHORUS CHRYSODON (Batsch.) Fr. Orono, 10-1897, (Ricker).

HYGROPHORUS CINNABARINUS Schw. So. Paris, Proc. Bost. Soc. Nat. Hist. 5:326.

HYGROPHORUS CONICUS (Scop.) Fr. Orono, 9-1897, (Harvey).

HYGROPHORUS FLAVO-DISCUS Frost. Brunswick, 1896, (Kate Furbish).

HYGROPHORUS FULIGINEUS Frost. Orono, 10-1898, (Ricker).

HYGROPHORUS MINIATUS Fr. Orono, (Harvey).

HYGROPHORUS PARVULUS Pk. Greenville, 9-1896, (Harvey). Det. Pk.

HYGROPHORUS PUNICEUS Fr. Orono, 8-1895, (Harvey).

HYPHOLOMA CANDOLLEANUM Fr. Cumberland, (Blake).

HYPHOLOMA EPIXANTHUM Fr. Cumberland, 11-1855, (Blake).

HYPHOLOMA INCERTUM, Pk. Orono, 7-1896, (Harvey).

HYPHOLOMA SUBLATERIUM Schaeff. Cumberland, 10-1858, (Blake). Orono, (Harvey).

INOCYBE GEOPHILA Sowerb. Orono, 9-1897, (Harvey).

*INOCYBE LANGUINOSA Bull. Orono, (Harvey).

LACTARIUS AFFINIS Pk. Orono, (Harvey).

LACTARIUS AQUIFLUUS Pk. Orono, (Harvey).

LACTARIUS CAMPHORATUS (Bull.) Fr. Wells, 8-1880, (Blake). Orono, (Harvey).

LACTARIUS CILICIOIDES Fr. Orono, 10-1900, (Ricker). Det. Pk.

*LACTARIUS CINEREUS Pk. Orono, (Harvey).

*LACTARIUS DECEPTIVUS Pk. Orono, (Harvey).

*LACTARIUS DELICIOSUS (Linn.) Fr. Orono, (Harvey).

*LACTARIUS GRISEUS Pk. Orono, (Harvey).

LACTARIUS HYGROPHOROIDES B. & C. Maine, (Sprague). In Sacc. Syll. 5:448.

*LACTARIUS HYSGINUS Fr. Orono, (Harvey).

*LACTARIUS INSULUS Fr. Orono, 1896, (Harvey).

LACTARIUS LIGNYOTUS Fr. Westbrook, 7-1898, (Ricker).

LACTARIUS PICINUS Fr. ? Cumberland, 10-1858, (Blake).

LACTARIUS SUBDULCIS (Bull.) Fr. Orono, 10-1895, (Harvey). Det. Pk.

*LACTARIUS THEJOGANUS (Bull.) Fr. Orono, (Harvey).

*LACTARIUS UVIDUS Fr. Orono, (Harvey).

*LACTARIUS VELLERUS Fr. Orono, (Harvey).

*LACTARIUS VOLEMUS Fr. Orono, (Harvey).

LEPTINUS COCHLEATUS Fr. Wells, 9-1859, (Blake).

*LENTINUS HAEMATOPUS Berk. Orono, 10-1895, (Harvey).

LENTINUS LECOMTEI Fr. Cumberland, 7-1858, (Blake). Oldtown, 8-1896, (Harvey).

LENTINUS LEPIDEUS Fr. Orono, 10-1896, (Harvey).

LENZITES BETULINA (Linn.) Fr. Cumberland, 11-1857, (Blake). *Orono, (Harvey).

LENZITES COOKEI Berk. Orono, (Harvey).

LENZITES CRATAEGI Berk. Otisfield; Cumberland, (Blake). Pea Cove, 10-1898, (Ricker).

LENZITES KLOTZSCHII Berk. Cumberland; Otisfield, (Blake).

LENZITES SEPIARIA Fr. Cumberland, (Blake). Orono, (Harvey).

LEPIOTA MASTOIDEA Fr. Cumberland, 1859, (Blake).

*LEPIOTA METULISPORA Berk. & Br. Orono, 10-1895, (Harvey).

Lepiota procera Scop. Fryeburg, 8-1899, (Harvey).

Leptonia aethiops Fr. Orono, 8-1897, (Harvey).

Marasmius androsaceus (Linn.) Fr. Wells, 6-1860, (Blake).

*Marasmius anomalus Pk. Orono, (Harvey).

Marasmius campanulatus Pk. Westbrook, 8-1899. (Ricker). Det. Pk.

Marasmius filipes Pk. Orono, 10-1895, (Harvey). Sebago Lake, 7-1898, (Ricker).

Marasmius glabellus Pk. Wells, 9-1881, (Blake).

Marasmius oreades Fr. Cumberland, (Blake).

Marasmius perforans Fr. Cumberland, (Blake).

Marasmius polyphyllus Pk. Orono, 1896, (Harvey).

*Marasmius preacutus Ell. Orono, (Harvey).

Marasmius rotula (Scop.) Fr. Cumberland, (Blake). Orono, (Harvey).

Marasmius scordonius Fr. Orono, 10-1895, (Harvey). Det. Pk.

Mycena corticola Schum. Orono, 8-1887, (Harvey).

Mycena epipterygia Scop. Cumberland, 11-1857, (Blake). Orono, 8-1887, (Harvey). Det. Pk.

Mycena galericulata Scop. Orono, 10-1888, (Harvey).

*Naucoria pediades Fr. Orono, (Harvey).

Naucoria semiorbicularis Bull. Wells, 9-1859, (Blake). Orono, 6-1896, (Harvey).

Omphalia campanella Batsch. Orono, (Harvey).

Omphalia fibula Bull. Orono, 8-1887, (Harvey).

Omphalia gerardiana Pk. Orono, 9-1896, (Harvey). Det. Pk.

Omphalia sphagnicola Berk. Orono, 7-1898, (Harvey).

Panaeolus campanulatus Linn. Cumberland, 11-1857, (Blake). Orono, 7-1897, (Harvey).

Panaeolus papilionaceus Fr. Cumberland, 7-1858, (Blake).

Panus conchatus Fr. Cumberland, 8-1858, (Blake). Harrison, 9-1859, (Blake).

Panus operculatus B. & C. *N. A. F. No. 2010.* Orono, 8-1886, (Harvey). Westbrook, 2-1895, (Ricker).

PANUS SALICINUS Pk. Cumberland, (Blake). *Orono, (Harvey).

PANUS STYPTICUS (Bull.) Fr. Cumberland, 11-1855, (Blake). Orono, 8-1887, (Harvey).

PHOLIOTA MUTABILIS Schaeff. Cumberland, (Blake).

PHOLIOTA SQUARROSA Mull. Orono, 10-1895, (Harvey).

PHOLIOTA UNICOLOR Vahl. Orono, 10-1895, (Harvey).

PLEUROTUS ALGIDUS Fr. Cumberland, 11-1857, (Blake).

PLEUROTUS APPLICATUS Batsch. Cumberland, 10-1858, (Blake). Orono, 10-1896, (Ricker). Det. Ell.

PLEUROTUS BLAKEII B. & C. Cumberland, 11-1857, (Blake).

PLEUROTUS CANDIDISSIMUS B. & C. Orono, 10-1895, (Harvey).

PLEUROTUS MITIS Pers. Cumberland, 11-1857. (Blake). Wells, 9-1890, (Blake).

PLEUROTUS NIGER Schw. Harrison, 9-1857, (Blake).

PLEUROTUS OSTREATUS Jacq. Jackman, 8-1895, (Harvey). Pea Cove, 10-1898, (Harvey).

PLEUROTUS PORRIGENS Pers. Orono, 10-1895, (Harvey).

PLEUROTUS SALIGNUS Schrad. Cumberland, 11-1857, (Blake).

PLEUROTUS SEROTINUS Schrad. Orono, 10-1896, (Harvey).

PLEUROTUS STRIATULUS Fr. Damariscotta Mills, 11-1896, (Harvey). Orono, (Harvey).

PLEUROTUS ULMARIUS Bull. Brunswick, (Kate Furbish).

PSILOCYBE FOENISECII Pers. Orono, 7-1896, (Harvey). Det. Pk.

PSILOCYBE SPADICEA Fr. Cumberland, (Blake).

RUSSULA ALUTACEA Fr. Wells, 8-1880, (Blake). Orono, 8-1887, (Harvey).

*RUSSULA ATRO-PURPUREA Pk. Greenville, 8-1895, (Harvey).

RUSSULA DECOLORANS Fr. Orono, 9-1897, (Harvey).

RUSSULA FOETENS (Pers.) Fr. Cumberland, 8-1855, (Blake).

*RUSSULA INTEGRA (Linn.) Fr. Orono, (Harvey).

*RUSSULA PURPURINA Quel. Orono, 10-1895, (Harvey).

SCHIZOPHYLLUM COMMUNE Fr. On Thuja occidentalis and Salix lucida, Orono, 5-1897; Westbrook, 9-1900, (Ricker).

*STROPHARIA HOWEANA Pk. Orono, 10-1895, (Harvey).

*STROPHARIA SEMIGLOBATA Batsch. Orono, (Harvey).

*TRICHOLOMA ALBUM Schaeff. Orono, 10-1895, (Harvey).

TRICHOLOMA DAVISIAE Pk. Falmouth, Bull. Torr. Bot. Club, 27:611.

TRICHOLOMA DECOROSUM Pk. Orono, 10-1895, (Harvey).

TRICHOLOMA HUMILE BULBOSUM Pk. var. nov. Orono, 10-1900, (Ricker). Differs from the species in that the stem has a bulbous base.

TRICHOLOMA LACUNOSA Pk. Orono, 10-1898, (Harvey).

TRICHOLOMA MICROSPORUM Ell. Orono, 8-1887, (Harvey).

*TRICHOLOMA MICULATUM Fr. Yarmouth, (Blake).

TRICHOLOMA SUBACUTUM, 9-1897, (Harvey). Orono, 9-1897, (Ricker).

TRICHOLOMA VACCINUM Pers. Greenfield, 9-1895, (Harvey).

TROGIA ALNI Pk. *N. A. F. No. 2017.* Orono, 10-1896, (Harvey). Westbrook, 9-1898, (Ricker).

TROGIA CRISPA (Pers.) Fr. Cumberland, 11-1857, (Blake). Orono, 10-1898, (Ricker).

FAMILY POLYPORACEÆ.

*BOLETINUS PICTUS Pk. Orono, (Harvey).

*BOLETINUS CLAVIPES Opat. Orono, (Harvey).

BOLETUS GRANULATUS L. Orono, 10-1900, (Ricker).

BOLETUS AMERICANUS Pk. Orono, (Harvey).

*BOLETUS CHROMAPES Frost. Orono, (Harvey).

BOLETUS CLINTONIANUS Pk. Orono, 10-1898, (Harvey).

BOLETUS DECIPIENS Pk. Wells, (Blake).

*BOLETUS FLAVUS Wither. Wells, (Blake).

BOLETUS LUTEUS Linn. Orono, 9-1897, (Harvey).

BOLETUS PALUSTER Pk. *N. A. F. No. 1932.* Orono, 9-1887, (Harvey).

*BOLETUS SCABER Fr. Orono, (Harvey).

BOLETUS SPADICEUS Schaeff. Cumberland, (Blake).

*BOLETUS SPECTABILIS Pk. Orono, (Harvey).

BOLETUS SUBLUTEUS Pk. Orono, 10-1900, (Ricker). Det. Pk.

BOLETUS SUBTOMENTOSUS L. Kennebunk, (Blake).

BOLETUS VARIEGATUS Swartz. Otisfield, (Blake).

DAEDALEA CONFRAGOSA Pers. On Acer, Otisfield, 8-1858, (Blake). On Quercus rubra, 5-1897, Orono, (Ricker).

Daedalea unicolor (Bull.) Fr. On Betula. Cumberland. (Blake). On Betula, Pemadomcook Lake, 10-1896. (Harvey).

Favolus alutaceus B. & Mont. On Quercus. Portland, (Fuller). Grev. 5:150.

Favolus boucheanus Klotzsch. On Fagus ferruginea. Cumberland, (Blake). On Fagus ferruginea. Harrison. 8-1858. (Blake.)

Flavolus europaeus Fr. On Fagus ferruginea. Oldtown, 10-1899, (Ricker).

Fomes applanatus (Pers.) Wallr. Cumberland. (Blake). Orono, 10-1896, (Ricker).

Fomes carneus Nees. On Picea nigra. Jackman. 9-1895, (Harvey). On Picea nigra, Orono, 10-1896. (Ricker).

Fomes connatus Fr. On Acer rubrum. Orland, 1897; Orono, 1897, (Merrill).

Fomes fomentarius (Linn.) Fr. Cumberland, (Blake). On Fagus ferruginea, Orono, 10-1896, (Ricker).

Fomes igniarius (Linn.) Fr. ? On Pyrus malus, Orono, (Harvey).

Fomes lucidus (Leys.) Fr. Cumberland, (Blake). On Pinus, Westbrook, 2-1895; Orono, 9-1896, (Ricker).

Fomes nigricans Fr. Orono, 9-1896, (Ricker).

Fomes obliquus (Pers.) Fr. On Alnus serrulatus, Orono, 9-1896, (Ricker).

Fomes pinicola Fr. On Pinus strobus, Orono, 9-1896, (Ricker).

Fomes salicinus (Pers.) Fr. On Betula lutea, Orono, 9-1896, (Ricker).

Fomes scutellatus Schw. On Alnus, Cumberland, 2-1859, (Blake). On Alnus, Orono, (Harvey).

*Fomes volvatus Pk. Orono, (Harvey).

Gloeoporus conchoides Mont. Cumberland; Harrison, 10-1881, (Blake).

Merulius corium Fr. Maine, (Morse), Grev. 1:68.

Merulius haedinus B. & C. On Alnus, Harrison, 9-1876; Wells, (Blake).

Merulius lacrymans (Jacq.) Fr. Portland, (Morse). In Herb. Port. Soc. Nat. Hist. On the ground, Orono, 9-1895, (Harvey).

Merulius tremellosus Schrad. On Tsuga canadensis, Cumberland, (Blake). On Tsuga canadensis, Orono, 10-1886, (Harvey).

Polyporus admirabilis Pk. On Pyrus malus, Riverside, Bull. Torr. Bot. Club, 26: 69.

Polyporus adustus (Willd.) Fr. On Acer, Orono, 5-1897, (Ricker). On Acer, Auburn, (Merrill).

Polyporus albellus Pk. Orono, (Harvey).

Polyporus arcularius (Batsch). Fr. On Alnus, Cumberland, (Blake).

Polyporus benzoinus (Wahl.) Fr. On Tsuga canadensis, Greenfield, 1894, (Harvey).

Polyporus betulinus Fr. On Betula populifolia, Orono, (Harvey). On Betula populifolia, Westbrook, 2-1895, (Ricker).

Polyporus borealis (Wahlbg.) Fr. *Mt. Katahdin, 9-1898, (Harvey). On Fagus ferruginea, Pea Cove, 10-1898, (Ricker). Det. Farl.

Polyporus brumalis (Pers.) Fr. On Betula, Cumberland, (Blake). On Betula, Orono, 12-1897, (Harvey).

Polyporus caesius (Schrad.) Fr. On Tsuga canadensis, Greenfield, 10-1894, (Harvey).

Polyporus chioneus Fr. Orono, 11-1892, (Harvey).

Polyporus elegans (Bull.) Fr. On Betula, Cumberland, 7-1858, (Blake). On Fagus ferruginea, Orono, 10-1896, (Ricker).

Polyporus lacteus Fr. On Acer, Cumberland, (Blake). On Alnus, Harrison, 8-1858, (Blake).

Polyporus picipes Fr. On fallen trees, Orono, 10-1896, (Harvey).

Polyporus pubescens (Schum.) Fr. On fallen trees, Orono, (Harvey).

Polyporus resinosus (Schrad.) Fr. On Abies balsamea, Greenfield, 1893, (Harvey). On Abies balsamea, Pea Cove, 10-1898, (Ricker).

Polyporus resinisus incurvus Pk. On Acer, Orono, 1896, (Harvey).

Polyporus schweinitzii Fr. On the ground, Orono, 10-1897, (Ricker).

Polyporus spumeus (Sow.) Fr. On Tsuga Canadensis, Orono, 1895, (Harvey).

Polyporus squamosus (Huds.) Fr. Portland, (Sprague). Proc. Bost. Soc. Nat. Hist. 5: 326.

Polyporus sulphureus (Bull.) Fr. On Quercus, Monmouth, 7-1897; Bradley, 10-1897, (Merrill).

Polyporus varius Fr. Orono, 1897, (Harvey).

Polyporus weinmanni Fr. On Pinus, Orono, 10-1896; N. W. Carry, 8-1897, (Harvey).

Polystictus abietinus Fr. On Abies balsamea, Cumberland, 11-1857, (Blake). On Abies balsamea, Orono, (Harvey).

Polystictus aureo-nitens Pat. & Pk. On Betula populifolia, Auburn, 10-1896, (Merrill). On Alnus, Pea Cove, 10-1898, (Ricker).

Polystictus cinnamomeus Jacq. Bank of Wissattaquoik River, 9-1897, (Harvey).

Polystictus circinatus Fr. On fallen trees, N. W. Carry, (Harvey).

Polystictus conchifer Schw. On Ulmus americana, Orono, 1890, (Harvey). On Ulmus americana, Auburn, 1897, (Merrill).

Polystictus hirsutus Fr. On fallen trees, Cumberland, (Blake). On Fagus ferruginea, Durham, 12-1896, (Stover).

Polystictus oblectans Berk. On the ground, Orono, 8-1897, (Harvey).

Polystictus perennis (Linn.) Fr. Cumberland, (Blake). Orono, (Harvey).

Polystictus pergamenus Fr. On Populus, Harrison, (Blake). On Betula papyrifera, Westbrook, 2-1895, (Ricker).

Polystictus piceinus Pk. On Abies balsamea, Orono, (Harvey). On Abies balsamea, Durham, 1-1897, (Stover).

Polyporus pseudopergamenus Thum. Orono, (Harvey).

Polystictus radiatus (Sow.) Fr. On Fagus ferruginea, Bradley, 10-1900, (Ricker).

Polystictus versicolor (Linn.) Fr. On fallen trees, Cumberland, (Blake). On fallen trees, Orono, 9-1896, (Ricker).

Polystictus virgineus Schw. Portland, (Sprague). In Blake Herb. On Alnus, Ea. Auburn, 1896, (Merrill).

Polystictus zonatus Fr. On fallen trees, Orono, (Harvey).

Poria attenuata Pk. On Pinus, Jackman, 9-1895, (Harvey). Det. Pk.

*Poria calcea Schw. Cumberland, (Blake).

Poria contigua (Pers.) Fr. On fallen trees, Wells, (Blake).

Poria farinellus Fr. On Pinus, Maine, (Blake). Herb. Harv, Univ.

Poria ferruginosa (Schrad.) Fr. On Betula, Cumberland, 4-1859, (Blake). On Acer, Orono, 10-1895, (Harvey).

Poria inermis E. & E. On Prunus, Durham, 12-1897, (Stover).

Poria mucida (Pers.) Fr. On Pine boards, Wells, (Blake).

Poria nitida A. & S. On Fraxinus, Pownal, 4-1897, (Stover).

*Poria sinuosa Fr. Orono, 1890, (Harvey).

Poria subacida Pk. On dead wood, Orono, 1890, (Harvey). On dead wood N. W. Carry, 10-1897, (Harvey).

Poria vaporaria Fr. On Andromeda ligustrina, Wells, 8-1859, (Blake). On Abies balsamea, Cumberland, 11-1857, (Blake). On Abies balsamea, Orono, 10-1896, (Harvey).

Poria violacea Fr. On Pinus, Orono; Oldtown, 10-1895, (Harvey).

Poria vulgaris, Fr. Cumberland, (Blake).

Solenia anomala (Pers.) Fr. On Prunus, Orono, 1892, (Harvey).

Solenia fasciculata Pers. On rotten wood, Jackman, 9-1895, (Harvey).

Solenia ochracea Hoffm. On Salix, Cumberland, 11-1876, (Blake). On Tilia americana, Orono, 12-1887, (Harvey).

Solenia villosa Fr. On decaying logs, Cumberland, (Blake). On decaying logs, Orono, (Harvey).

Trametes cinnabarina (Jacq.) Wint. On fallen trees, Cumberland, (Blake). On Fagus ferruginea, Orono, 5-1897, (Ricker).

Trametes indora Fr. On Pinus, Orono, 1890, (Harvey).

Trametes mollis Fr. On Salix, Harrison, 9-1859, (Blake). On Acer pennsylvanicum, Greenville, 8-1895, (Harvey).

Trametes sauveolens (Linn.) Fr. On Betula, Bradley, 1896, (Harvey). On Salix, Damariscotta Mills, 12-1896, (Harvey).

FAMILY HYDNACEÆ.

CALDESIELLA FERRUGINOSA (Fr.) Sacc. On Ulmus americana, Cumberland (Blake). On Ostrya virginica, Harrison, 9-1859, (Blake).

GRANDINIA CORRUGATA Fr. On Alnus, Orono, 10-1892, (Harvey).

GRANDINIA GRANULOSA Fr. Cumberland, (Blake).

HYDNUM AURISCALPIUM Linn. *F. Col. No. 1408.* On Pinus silvestris, Orono, 12-1897, (Ricker).

HYDNUM CAPUT-URSI Fr. Lunksoos Camp, 9-1898, (Harvey).

HYDNUM CORALLOIDES Scop. On Fagus ferruginea, Pea Cove, 10-1898, (Harvey).

HYDNUM CROCEUM (Schw.) Fr. On decaying logs, Orono, 10-1892, (Harvey).

*HYDNUM DELICTABILE Pk. Orono, 1896, (Harvey).

HYDNUM FENNICUM Karst. On the ground, Orono, 1896, (Harvey).

HYDNUM FERRUGINEUM Fr. On the ground, Cumberland, (Blake). On the ground, Orono, 8-1895, (Harvey).

HYDNUM FUSCO-ATRUM Fr. On Alnus, Cumberland, (Blake). (Blake).

HYDNUM GRAVEOLENS Delast. Peaks Is., Casco Bay, (Fuller). In Herb. Port. Soc. Nat. Hist.

HYDNUM IMBRICATUM Linn. Orono, 8-1887; Oldtown, 9-1896, (Harvey).

HYDNUM MUCIDUM Pers. On Pyrus malus, Wells, 10-1859, (Blake).

HYDNUM OCHRACEUM Pers. On Fagus, Cumberland, 1858, (Blake). On Alnus, Harrison, 9-1876, (Blake).

HYDNUM PITHYOPHILUM B. & C. On Pinus, Wells, (Blake).

HYDNUM REPANDUM Linn. On the ground, Cumberland, (Blake). On the ground, Orono, 8-1896, (Harvey).

HYDNUM SEPTENTRIONALE Fr. Orono, 1891, (Harvey).

HYDNUM SUAVEOLENS CAERULEUM Horn. On the ground, Orono, 10-1896, (Ricker).

HYDNUM ZONATUM Batsch. On the ground, Cumberland, (Blake). On the ground, Orono, 9-1896, (Harvey).

IRPEX CINNAMOMEUS Fr. Orono, 10-1892, (Harvey).

IRPEX FUSCO-VIOLACEUS (Schrad.) Fr. Orono, 9-1896, (Harvey).

IRPEX LACTEUS Fr. On Betula, Orono, 1897, (Harvey).

IRPEX MOLLIS B. & C. On Tsuga Canadensis, Westbrook, 12-1895, (Ricker).

IRPEX OBLIQUUS (Schrad.) Fr. Durham, 1897, (Stover).

IRPEX RIMOSUS Pk. Orono, (Harvey).

IRPEX SINUOSUS Fr. Cumberland, (Blake). Pea Cove, 10-1898, (Ricker).

KNEIFFIA SETIGERA Fr. Wells, 1880, (Blake). On Alnus incana, Orono, 8-1898, (Ricker).

MUCRONELLA AGGREGATA Fr. Orono, 10-1895, (Harvey).

ODONTIA FIMBRIATA Pers. Ea. Auburn, 1896, (Merrill).

PHLEBIA MERISMOIDES Fr. Maine, (Fuller). Herb. Port. Soc. Nat. Hist.

PHLEBIA RADIATA Fr. Cumberland, (Blake). Orono, 9-1887, (Harvey).

TREMELLODON GELATINOSUM (Scop.) Pers. On Tsuga canadensis, Cumberland, 9-1858, (Blake). On rotten wood, Pea Cove, 10-1898, (Ricker).

FAMILY CLAVARIACEÆ.

CALOCERA CORNEA Fr. On Alnus, Cumberland, (Blake). On Pinus strobus, Westbrook, 8-1900, (Ricker).

*CALOCERA VISCOSA (Pers.) Fr. Orono, (Harvey).

CLAVARIA ABIETINA Pers. Greenfield, 8-1895, (Harvey).

CLAVARIA AUREA Schaeff. Orono, 8-1896, (Harvey).

CLAVARIA BOTRYTES Pers. Cumberland, (Blake).

CLAVARIA CINEREA Bull. Pea Cove, 10-1898, (Ricker).

CLAVARIA CONTORTA Holmsk. Cumberland, 11-1857, (Blake).

CLAVARIA CRISPULA Fr. Maine, (Sprague). Grev. 2:7.

CLAVARIA CRISTATA Pers. Harrison, 8-1858, (Blake). Orono, 8-1887, (Harvey).

CLAVARIA FISTULOSA Fr. ? Cumberland, 11-1857, (Blake).

CLAVARIA FORMOSA Pers. Orono, 9-1897, (Harvey).

CLAVARIA FRAGILIS Holmsk. Harrison, 2-1858, (Blake).

CLAVARIA FUSIFORMIS Sowerb. Orono, 10-1887, (Harvey). Westbrook, 8-1899, (Ricker).

Clavaria gracilis Pers. Greenville, 8-1895, (Harvey).

Clavaria harveyi Pk. Orono, 8-1887, (Harvey).

Clavaria inaequalis Mull. Cumberland, (Blake). Greenville, 8-1895, (Harvey).

Clavaria ligula Fr. Cumberland, 8-1858, (Blake). Orono, 10-1898, (Ricker).

Clavaria mucida Pers. Orono, (Harvey). Det. Ell.

Clavaria pistillaris Linn. Westbrook, 9-1900, (Ricker). Det. Ell.

Clavaria platyclada Pk. Maine, Bull. Torr. Bot. Club, 23:419.

Clavaria pulchra Pk. Orono, 8-1896, (Harvey).

Clavaria spinulosa Pers. Orono, 9-1895, (Harvey).

Clavaria stricta Pers. Greenfield, 10-1894, (Harvey).

Clavaria subtilis Pers. Maine, (Sprague). In Blake Herb.

Lachnocladium micheneri B. & C. Orono, 10-1896, (Harvey).

Physalacria inflata Pk. Greenville 8-1895, (Harvey).

FAMILY THELEPHORACEÆ.

Corticium alutarium B. & C. Harrison, 9-1859, (Blake).

Corticium amorphum (Pers.) Fr. Cumberland, (Blake). Pea Cove, 10-1898, (Ricker).

Corticium auberianum Mont. On Alnus, Cumberland, (Blake).

*Corticium caeruleum (Schrad.) Fr. Orono, (Harvey).

Corticium effuscatum C. & E. Orono, 9-1895, (Harvey). Auburn, 8-1896, (Merrill).

Corticium incarnatum (Pers.) Fr. Cumberland; Wells, 1880, (Blake). Orono, 12-1896, (Harvey).

Corticium lacteum Fr. Orono, 10-1896, (Harvey).

Corticium lanosum E. & E. Orono, 10-1896, (Harvey).

Corticium leve Pers. Cumberland, (Blake). Orono, 10-1895, (Harvey).

*Corticium lilacino-fuscum B. & C. Cumberland, (Blake).

Corticium lilacinum Schroet. Cumberland, 11-1857, (Blake).

Corticium oakesii B. & C. Cumberland, (Blake). Auburn, 8-1896, (Merrill)

Corticium pinicolum Tul. Orono, 10-1895, (Harvey).

*Corticium polygonium Pers. Orono, 1889, (Harvey).

Corticium rubro-canum Thum. Orono, (Harvey).

Corticium salicinum Fr. On Salix discolor, Orono, 10-1900, (Ricker).

Corticium scutellare B. & C. Orono, 9-1897, (Harvey).

Corticium sub-aurantiacum Pk. Orono, 10-1895, (Harvey).

Corticium sub-giganteum Berk. Wells, 1880, (Blake). Orono, 12-1887, (Blake).

Craterellus clavatus (Pers.) Fr. Maine, (Sprague). Grev. 1:147.

Craterellus cornucopioides (L.) Fr. Cumberland, Harrison, 8-1858, (Blake).

Craterellus dubius Pk. Greenfield, 8-1896, (Harvey).

Cyphella fasciculata B. & C. Mt. Katahdin, 7-1856, (Blake).

Cyphella pezizoides Zopf. On Tilia americana, Orono, 1890, (Harvey). On Philadelphus coronarius, Orono, 10-1896, (Ricker).

Cyphella ravenelii Sacc. On Alnus serrulata, Wells, 9-1859, (Blake). On Alnus serrulata, Orono, 5-1898, (Ricker).

Hymenochaete agglutinans Ell. Orono, 1887, (Harvey).

Hymenochaete corrugata (Fr.) Lev. Orono, 12-1897, (Harvey).

Hymenochaete rubiginosa (Schr.) Lev. Cumberland; Wells, (Blake). On Acer rubrum, Orono, 4-1898, (Ricker).

Hymenochaete tabacina (Sow.) Lev. Wells, 1880, (Blake). Westbrook, 2-1895, (Ricker).

Peniophora cinerea (Fr.) Cke. On Picea nigra, Westbrook, 5-1898, (Ricker). Det. Ell.

Stereum bicolor (Pers.) Fr. Harrison, 10-1881, (Blake). Orono, 10-1895, (Harvey).

Stereum complicatum Fr. On Fagus ferruginea, Cumberland, 11-1857, (Blake).

Stereum fasciatum Schw. Harrison, 8-1858, (Blake).

Stereum frustulosum (Pers.) Fr. Harrison, (Blake). Ea. Auburn, 1896, (Merrill).

Stereum hirsutum (W.) Fr. Wells, (Blake). On Betula, Westbrook, 5-1898, (Ricker).

Stereum imbricata (Schw.) Lev. On Pinus, Wells, 1880, (Blake).

Stereum micheneri B. & C. Maine, (Morse). In Blake Herb.

Stereum ochraceo-flavum Schw. On Betula populifolia, Orono, 4-1898, (Ricker).

Stereum pini Fr. ? On Pinus, Wells, (Blake).

Stereum pulverulentum Pk. On Betula papyrifera, Orono, 10-1892, (Harvey).

Stereum purpureum Pers. *N. A. F. No. 2013.* Orono, 1897, (Harvey).

Stereum radiatum Pk. Orono, 10-1895, (Harvey).

Stereum sericeum Schw. Auburn, 1897, (Merrill).

Stereum striatum Fr. Westbrook, 6-1897, (Ricker). Pea Cove, 10-1898, (Ricker).

Stereum tuberculosum Fr. (*S. rugosum Auct. plus Amer. not Fr.*) Orono, 10-1896, (Harvey). Det. Burt.

Thelephora caryophyllea (Schaeff.) Pers. Cumberland, 9-1858, (Blake).

Thelephora fimbriata (Schw.) Fr. Portland, (Fuller). In Herb. Port. Soc. Nat. Hist.

Thelephora laciniata Pers. On Pinus Strobus, Wells, 2-1860, (Blake). On Pinus Strobus, Orono, 10-1900, (Ricker).

Thelephora palmata (Scop.) Fr. Orono, 11-1896, (Merrill).

Thelephora pedicellata Schw. Orono, 10-1896, (Harvey).

Thelephora schweinitzii Pk. Harrison, 8-1858, (Blake). Orono, 9-1896, (Harvey).

Thelephora terrestris Ehrh. Cumberland, (Blake).

FAMILY TREMELLACEÆ.

Craterocolla rubella Pers. Orono, 10-1896, (Harvey). Westbrook, 9-1898, (Ricker).

Dacryomyces deliquescens (Bull.) Dub. Portland, (Fuller). Grev. 5:150. Wells, 1880, (Blake).

Dacryomyces stillatus Nees. Harrison, 9-1859, Cumberland, (Blake).

*DITIOLA RADICATA (A. & S. Fr. Orono, 1890, (Harvey).

EXIDIA ALBIDA (Huds.) Bref. Cumberland, 3-1859, (Blake). Orono, 10-1896, (Harvey).

EXIDIA GLANDULOSA (Bull.) Fr. On Alnus incana, Westbrook, 2-1895, (Ricker). On Alnus incana, Orono, 9-1896, (Ricker).

*EXIDIA RECISA Fr. Portland, (Bolles).

GUEPINIA SPATHULARIA (Schw.) Fr. On Betula lutea, Pownal, 8-1897, (Stover). On Betula lutea, Pea Cove, 10-1898, (Ricker).

HIRNEOLA AURICULA-JUDAE (L.) Berk. Cumberland, (Blake). Orono, 1891, (Harvey).

NÆMATELIA ENCEPHALA (Willd.) Fr. Maine, (Fuller). Grev. 2:20.

NÆMATELIA NUCLEATA (Schw.) Fr. Cumberland, (Blake). Orono, 12-1887, (Harvey).

TREMELLA AURANTIA Fr. Wells, (Blake). Orono, (Harvey).

*TREMELLA COLORATA Pk. Orono, (Harvey).

*TREMELLA ENACTA B. & C. Orono, (Harvey).

*TREMELLA FRONDOSA Fr. Orono, (Harvey).

*TREMELLA LUTESCENS Pers. Orono, (Harvey).

TREMELLA MESENTERICA Retz. Wells, (Blake). On Tsuga canadensis, Cumberland, 1857, (Blake).

TREMELLA SARCOIDES (Dicks.) Fr. Orono, 1890, (Harvey).

*TREMELLA STIPTATA Pk. Orono, (Harvey).

ULOCOLLA FOLIACEA (Pers.) Bref. Cumberland, (Blake). Pea Cove, 10-1898, (Ricker).

ORDER GASTEROMYCETACEÆ.

FAMILY PHALLACEÆ.

MUTINUS BREVIS B. & C. Orono, 8-1896, (Harvey).

PHALLUS DAEMONUM Rumph. Orono, 9-1894, (Harvey).

PHALLUS IMPUDICUS Linn. Orono, 9-1896, (Harvey).

FAMILY NIDULARIACEAE.

CRUCIBULUM VULGARE Tul. Cumberland, 8-1858, (Blake). Machias, 8-1897, (Ricker). Orono, 4-1899, (Ricker).

CYATHUS STERCOREUS (Schw.) De Ton. Cumberland, 1858, (Blake). Orono, 10-1900, (Ricker).

CYATHUS STRIATUS (Huds.) Hoffm. Orono, 9-1890, (Harvey).

NIDULARIA PULVINATA (Schw.) Fr. Orono, (Harvey).

SPHÆROBOLUS STELLATUS Tod. Orono, (Harvey).

*SPHÆROBOLUS TUBEROSUS Fr. Orono, (Harvey).

FAMILY LYCOPERDACEÆ.

BOVISTA CIRCUMSCISSA B. & C. Cumberland, (Blake).

BOVISTA PILA B. & C. Jackman, 9-1895, (Harvey). Orono, 4-1898, (Ricker).

*BOVISTA PLUMBEA Pers. Orono, (Harvey).

CALVATIA CYATHIFORME (Bosc.) Morg. Orono, 8-1896, (Harvey).

GEASTER HYGROMETRICUS Pers. Wells, 9-1859, (Blake).

*LYCOPERDON ASTEROSPERMUM D. & M. Orono, (Harvey).

LYCOPERDON BOVISTA Linn. Maine Herb. Bost. Soc. Nat. Hist.

LYCOPERDON CURTISII Berk. Orono, (Harvey).

LYCOPERDON PUSILLUM Batsch. Cumberland, (Blake). Orono, (Harvey).

LYCOPERDON GEMMATUM Batsch. Harrison, 8-1858, (Blake). Orono, (Harvey).

LYCOPERDON GLABELLUM Pk. Orono, 1896, (Harvey).

LYCOPERDON MOLLE Pers. Orono, 9-1896, (Harvey).

LYCOPERDON PEDICELLATUM Pk. Orono, (Harvey).

LYCOPERDON PIRIFORME Schaeff. Cumberland, (Blake). Orono, (Harvey).

*LYCOPERDON SUBINCARNATUM Pk. Greenville. 8-1895, (Harvey).

LYCOPERDON TURNERI E. & E. Orono, (Harvey).

LYCOPERDON WRIGHTII B. & C. Orono, (Harvey).

LYCOPERDON WRIGHTII SEPARANS Pk. Orono, (Harvey).

SCLERODERMA VULGARE Hornen. Cumberland, 9-1877, (Blake). Orono, (Harvey).

SUMMARY.

	Genera.	Species.
Myxomycetaceæ:		
Physaraceæ	6	32
Didymiaceæ	3	13
Spumariaceæ	2	3
Stemonitaceæ	3	15
Amaurochetaceæ	1	1
Liceacoæ	4	4
Clathroptychiaceæ	1	1
Cribrariaceæ	2	6
Reticulariaceæ	1	1
Perichænaceæ	1	3
Arcyriaceæ	5	13
Trichiaceæ	4	19
Schizomycetaceæ	3	3
Mucoraceæ	2	2
Peronosporaceæ	4	4
Saprolegniaceæ	2	3
Entomophthoraceæ	2	15
Chytridiaceæ	1	1
Hyphomycetaceæ:		
Mucedinaceæ	12	16
Dematiaceæ	13	30
Stilbaceæ	5	8
Tuberculariaceæ	9	12
Sphaeropsidaceæ:		
Sphærioidaceæ	17	61
Leptostromaceæ	6	8
Excipulaceæ	2	2
Melanconiaceæ	9	16
Saccharomycetaceæ	1	1
Pyrenomycetaceæ:		
Perisporiaceæ	11	26
Sphæriaceæ	44	107
Hypocreaceæ	10	25

Pyrenomycetaceæ:	Genera.	Species.
Dothideaceæ	3	10
Microthyriaceæ	1	1
Lophiostomaceæ	1	1
Hysteriaceæ	7	11
Laboulbeniaceæ	17	60
Discomycetacoæ:		
Helvellaceæ	7	16
Pezizaceæ	17	37
Dermateaceæ	5	16
Bulgariaceæ	6	12
Stictidaceæ	3	3
Phacidiaceæ	3	14
Patellariaceæ	5	5
Gymnoascaceæ	1	1
Caliciaceæ	3	5
Ustilaginaceæ	3	8
Uredinaceæ	13	67
Hymenomycetaceæ:		
Agaricaceæ	37	165
Polyporaceæ	12	96
Hydnaceæ	9	33
Clavariaceæ	4	26
Thelepheraceæ	7	50
Tremellaceæ	9	20
Gasteromycetaceæ:		
Phallaceæ	2	3
Nidulariaceæ	4	6
Lycopordaceæ	5	19
	370	1136

Orders	17
Families	45
Genera	370
Species	1136

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ERRATA.

The distance separating the publisher, editor and author made it impossible for the author to see all of the proofs, so there are several mistakes in the list. Those noted are as follows:

Page 8, line 3, from the bottom and elsewhere, for *Berkley* read *Berkeley*.
Page 12, line 16, omit parenthesis from Macbr.
Page 24, line 17, for *ellish* read *ellisii*.
Page 25, line 8 from bottom, for *Pinusilvestris* read *Pinus silvestris*.
Page 26, line 3, for *Sambusus* read *Sambucus*.
Page 27, line 8 from bottom, for) read *E*.
Page 28, line 1, for *rubri* read *rubi*.
Page 30, line 2, omit comma after Cornus.
Page 31, line 17, for *syringa* read *Syringa*.
Page 32, line 17, for *ellish* read *ellisii*.
Page 38, line 20, for *tremuloids* read *tremuloides*.
Page 49, line 2 from bottom, for *ellish* read *ellisii*.
Page 53, line 6 from bottom, for *rontundifolia* read *rotundifolia*.
Page 68, line 7 from bottom, for *leve* read *læve*.
Page 68, line 2 from bottom, for *oakesh* read *oakesii*.

The University of Maine Studies

No. 4

A Catalogue and Bibliography of the Odonata (Dragon-flies) of Maine,

With an Annotated List of their Collectors

BY

FRANCES LEROY HARVEY

Professor of Natural History

ORONO, MAINE
August, 1902

Most of the papers left by the late Professor Harvey have been published in the *Entomological News*. The local interest attaching to this paper made its publication in Maine desirable. The proof has been read by L. H. Harvey, of the class of 1901.

A CATALOGUE AND BIBLIOGRAPHY OF THE ODONATA (DRAGON-FLIES) OF MAINE, WITH AN ANNOTATED LIST OF THEIR COLLECTORS

SUBFAMILY I. CALOPTERYGINÆ.

1. CALOPTERYX LEACH.

1. *Calopteryx maculata* Beauv.
   Maine (Proc. B. S. N. H. 15: 273; no authority, but probably Packard); Manchester (Miss Wadsworth); Orono, Bradley, S. Lagrange, Foxcroft, N. E. Carry (Harvey); Farmington (Miss Furbish); Mt. Desert (Bullock).
2. *C. aequabilis* Say.
   Maine (Proc. B. S. N. H. 15: 274, no authority); Orono, Bradley, S. Lagrange, Foxcroft (Harvey); Manchester (Miss Wadsworth).

2. HETÆRINA HAGEN.

3. *Hetærina Americana* Fabr.
   Norway (Smith); Bradley, 1897, Auburn, 1898 (Merrill); Winslow, 1899 (Hitchings); Chemo Mills (Harvey).

SUBFAMILY II. AGRIONINÆ.

3. LESTES LEACH.

4. *Lestes congener* Hagen.
   Orono, 1899; N. W. Carry, 1898 (Harvey); Manchester 1898 (Miss Wadsworth).
5. *L. unguiculatus* Hagen.
   Orono, N. W. Carry (Harvey); Manchester (Miss Wadsworth); York Harbor (Moore).
6. *L. uncatus* Kirby.
   Orono (Bartle & F. L. Harvey); Manchester (Miss Wadsworth).

7. *L. disjunctus* Selys.
   Manchester (Miss Wadsworth); Orono, Fryeburg (Harvey).

8. *L. forcipatus* Rambur.
   Orono, Fryeburg (Harvey); Manchester (Miss Wadsworth).

9. *L. rectangularis* Say.
   Orono, Fryeburg (Harvey); Manchester (Miss Wadsworth).

10. *L. vigilax* Selys.
    Manchester, (Miss Wadsworth); Fryeburg (Harvey).

11. *L. inequalis* Walsh.
    Orono, Bradley (Harvey); Manchester (Miss Wadsworth).

4. ARGIA RAMBUR.

12. *Argia putrida* Hagen.
    Orono and many other localities (Harvey). Manchester (Miss Wadsworth).

13. *A. violacea* Hagen.
    Orono, Bradley, etc. (Harvey); Manchester (Miss Wadsworth; Mt. Desert (Bullock).

14. *A. apicalis* Say.
    Orono, (Harvey).

5. ERYTHROMMA CHARPENTIER.

15. *Erythromma conditum* Hagen,
    Manchester (Miss W.); Bradley & Orono (Harvey).

6. NEHALENNIA SELYS.

16. *Nehalennia irene,* Hagen.
    Maine (Packard); Manchester (Miss Wadsworth); Orono, Fryeburg (Harvey); York Harbor (Moore).

17. *N. posita* Hagen,
    Orono, Penobscot River 1897 (Bartle Harvey).

7. AMPHIAGRION SELYS.

18. *Amphiagrion saucium* Burmeister.
    Maine (Packard); Manchester (Miss Wadsworth); Orono (Bartle Harvey); Bradley (Harvey).

8. ENALLAGMA CHARPENTIER.

19. *Enallagma civile* Hagen.
Orono (Harvey) ; Manchester (Miss Wadsworth) ; York Harbor (Moore).

20. *E. ebrium* Hagen,
Manchester (Miss Wadsworth).

21. *E. cyathigerum* Charp., race annexum Hagen,
Manchester (Miss Wadsworth).

22. *E. Calverti*, Morse,
Orono 1897 (Florence Harvey) ; 1898 (Harvey).

23. *E. Hageni* Walsh,
Orono, Fryeburg (Harvey) ; Manchester (Miss Wadsworth) ; Mt. Desert (Bullock) ; York Harbor (Moore).

24. *E. geminatum* Kellicott,
Bradley, Chemo Mills (Harvey).

25. *E. signatum* Hagen,
Bradley (Harvey) ; Manchester Miss Wadsworth).

26. *E. pollutum* Hagen,
Chemo stream, Bradley (Harvey) ; Manchester (Miss Wadsworth).

27. *E. exsulans* Hagen.
Manchester, 1891 (Miss Wadsworth) ; Orono, 1898 (Harvey).

9. ISCHNURA CHARPENTIER.

28. *Ischnura verticalis* Say.
Maine, 1836 (Randall ; Proc. B. S. N. H. 15 : 276) Orono, Fryeburg (Harvey) ; Manchester (Miss Wadsworth) ; Mt. Desert (Bullock) ; York Harbor (Moore).

29. *I. Ramburii* Selys.
Manchester (Miss Wadsworth).

10. ANOMALAGRION SELYS.

30. *Anomalgrion hastatum* Say.
Maine. Hagen's synopsis p. 77 (Packard). Has not been re-discovered.

SUBFAMILY III. GOMPHINÆ.

11. HAGENIUS SELYS.

31. *Hagenius brevistylus* Selys.
Bradley, Orono, Greenfield, N. E. Carry (Harvey); Manchester (Miss Wadsworth).

12. OPHIOGOMPHUS SELYS.

32. *Ophiogomphus rupinsulensis* Walsh.
Maine (Packard, Proc. Acad. Nat. Sci. Phila. 1862, p. 388. Also by Morrison, teste Selys 1878).
33. *O. aspersus* Morse.
Russell Stream, Aug. 1899 (Harvey).
34. *O. carolus* Needham.
Orono ♀ (Florence Harvey) ♂ (Ned Mansfield); Greenfield, Bradley (Harvey).
35. *O. mainensis* Packard.
Maine (Packard. Proc. Ent. Soc. Phila. 1863, p. 255).
36. *O. anomalus* Harvey.
Orono (Harvey).
37. *O. johannus* Needham.
Chemo Mill, Bradley, 1899 (Harvey).

13. GOMPHUS LEACH.

38. *Gomphus nævius* Hagen.
Chemo Stream, Bradley, a single ♀ 1890, (Harvey); 1897-9 Many males and a few females (F. L. & Bartle Harvey).
39. *G. parvulus*. Selys.
Maine (Hag. Syn. Odon. of Am. p. 46, 1875; no authority); Manchester (Miss Wadsworth).
40. *G. abbreviatus* Hagen.
Orono (Harvey); Manchester (Miss Wadsworth, teste P. P. Calvert).
41. *G. brevis* Selys.
Orono (Harvey).
42. *G. exilis* Selys.
Orono (Harvey); Manchester (Miss Wadsworth); Mt. Desert (Bullock).

43. *G. spicatus* Selys.
S. Lagrange, Orono, Oldtown (Harvey); Manchester (Miss Wadsworth).

44. *G. Scudderi* Selys.
Russell stream near N. E. Carry, one male, 1897, many males and females, Aug. 25-29, 1899 (Harvey).

14. DROMOGOMPHUS SELYS.

45. *Dromogomphus spinosus,* Selys.
Manchester (Miss Wadsworth); Old Hown, Pushaw Pond, Aug. 16, 1898, a single ♂ (Harvey).

SUBFAMILY IV. CORDULEGASTERINÆ.

15. CORDULEGASTER LEACH.

46. *Cordulegaster maculatus* Selys,
Greenfield, Orono (Harvey); Manchester (Miss Wadsworth).

47. *C. Sayi,* Selys.
Portland (Packard, Hag. Syn. O. of A. p. 50, 1875).

48. *C. diastatops* Selys.
Manchester (Miss Wadsworth); Orono, Greenfield, Bradley (Harvey).

49. *C.* (Taeniogaster) *obliquus,* Say.
Orono, Me. (Packard, see Proc. B. S. N. H. 16: 356); Manchester (Miss Wadsworth); Orono & Bradley (Harvey).

SUBFAMILY V. AESCHINÆ.

16. EPIAESHNA SELYS.

50. *Epiaeschna heros* Fabricius.
Maine (Proc. B. S. N. H. 15: 272, no authority); 1899 (Harvey).

17. BOYERIA MCLACHLAN.

51. *Boyeria vinosa* Say.
Maine (Proc. B. S. N. H. 15: 272, no authority); Orono, Greenfield, N. E. Carry, etc. (Harvey); Manchester (Miss Wadsworth).

18. GOMPHÆSCHNA SELYS.

52. *Gomphæschna furcillata* Say.
Manchester (Miss Wadsworth).

19. BASIÆSCHNA SELYS.

53. *Basiæschna Janata* Say.
Orono, Bradley (Harvey); Manchester (Miss Wadsworth).

20. ÆSCHNA FABRICIUS.

54. *Æschna juncea* var *verticalis* Hagen.
Maine (Smith? Hagen's Syn. Od. of A. p. 34); Manchester (Miss Wadsworth); Orono, Bradley (Harvey).

55. *Æ. clepsydra* Say.
Maine (Proc. B. S. N. H. 15: 271, 1873, no authority). Orono, S. Lagrange in ponds, Bradley, Greenfield, etc. (Harvey).

56. *Æ constricta* Say.
Maine (Smith? Synopsis Od. of A. Hagen p. 34); Manchester (Miss Wadsworth); Orono, N. E. Carry, Kineo, Fryeburg, etc. (Harvey).

21. ANAX LEACH.

57. *Anax junius* Drury.
Orono (Harvey); Manchester (Miss Wadsworth).

SUBFAMILY VI. CORDULINÆ.

22. DIDYMOPS RAMBUR.

58. *Didymops transversa* Say.
Manchester (Miss Wadsworth); Orono (Harvey).

23. MACROMIA RAMBUR.

59. *Macromia illinoensis* Walsh.
Manchester (Miss Wadsworth); Orono, Bradley (Harvey).

24. CORDULIA LEACH.

60. *Cordulia shurtleffi* Scudd.
Orono (Bartle Harvey); Bradley (Harvey).

25. EPICORDULIA SELYS.

61. *Epicordulia princeps* Hagen.
Manchester (Miss Wadsworth).

26. TETRAGONEURIA HAGEN.

62. *Tetragoneuria cynosura* Say.
Maine (Hag. Syn. O. of A. 1875, p. 60, no authority) ; Bradley (Harvey) ; Manchester (Miss Wadsworth).

63. *T. spinigera* Selys.
Manchester (Miss Wadsworth) ; Bradley (Harvey).

64. *T. semiaquea* Burmeister.
Manchester (Miss Wadsworth) ; Mt. Desert (Bullock).

27. NEUROCORDULIA SELYS.

65. *Neurocordulia uhleri* Selys.
Orono (Packard, Hag. Syn. O. of A. 1875, p. 61) ; Orono Harvey) ; Manchester (Miss Wadsworth).

66. *N. obsoleta* Say.
Manchester, July 5th (Miss Wadsworth).

67. *N. yamaskanensis* Provancher.
Orono, 1898 ♂ (L. H. Harvey) ; ♀(Harvey), several in 1899 (Harvey).

28. SOMATOCHLORA SELYS.

68. *Somatochlora elongata* Scudd.
Coast of Maine at sea (Harvey).

69. *S.* elongata var. *minor* Calvert.
Over Penobscot River, Orono, Bradley (Harvey).

70. *S. linearis* Hagen, (Probably).
Manchester, July 27, 1897 (Miss Wadsworth).

71. *S. forcipata* Scudd.
Maine (Randall, 1836. Proc. B. S. N. H. 15 : 268) ; Orono, Bradley (Harvey) ; Manchester (Miss Wadsworth).

72. *S. septentrionalis* Hagen.
Orono, 6-18-1898 (Bartle Harvey). Over swamp.

73. *S. walshii* Scudd.
Manchester (Miss Wadsworth) ; Orono (L. H. Harvey) ; Bradley (Harvey).

74. *S. lepida* Selys.
Portland (Jones and probably Randall. Proc. B. S. N. H. 15: 270); Greenfield, Bradley, Orono (Harvey); Manchester (Miss Wadsworth).

75. *S. libera* Selys.
Orono (Bartle Harvey); Greenfield (Harvey); Manchester (Miss Wadsworth).

SUBFAMILY VII. LIBELLULINÆ.

29. LIBELLULA LINNE.

76. *Libellula exusta* Say.
Norway (Smith. Hag. Syn. O. of A. 1875 p. 69). Manchester (Miss Wadsworth).

77. *L. incesta* Hagen.
Manchester (Miss Wadsworth).

78. *L. 4-maculata* Linné.
Manchester (Miss Wadsworth); Orono, Bradley (Harvey); Mt. Desert (Bullock) Miller) (var. pranubila Newman. Orono (Harvey).

79. *L. pulchella* Drury.
Brunswick (Proc. B. S. N. H. 16: 367); Orono, Bradley (Harvey); Manchester (Miss Wadsworth).

80. *L. semifasciata* Burmeister.
Manchester (Miss Wadsworth); Orono, June 1898 (Harvey).

30. PLATHEMIS HAGEN.

81. *Plathemis trimaculata* De Geer.
Maine (Hag. Syn. O. of A. 1875 p. 67, no authority); Orono, Bradley (Harvey); Manchested (Wiss Wadsworth); Mt. Desert (Bullock); Bar Harbor (Miller).

31. NANNOTHEMIS BRAUER.

82. *Nannothemis bella* Uhler.
Maine (Packard); Mt. Desert (Bullock).

32. CELITHEMIS HAGEN.

83. *Celithemis ornata* Rambur.
Manchester (Miss Wadsworth); Bradley (Bartle Harvey).

84. *C. elisa* Hagen.
Bradley (Harvey); Manchester (Miss Wadsworth); Mt. Desert (Bullock).

33. LEUCORHINIA BRITTINGER.

85. *Leucorhinia intacta* Hagen.
Orono, Bradley (Harvey); Manchester (Miss Wadsworth).

86. *L. hudsonica* Selys.
Oldtown, Orono (Harvey).

87. *L. proxima* Calvert.
Manchester (Miss Wadsworth); Old Town, Orono (Harvey).

88. *L. frigida* Hagen.
Bradley (Harvey & Bartle Harvey); Mt. Desert (Bullock).

89. *L. glacialis.*
Orono, Bradley, Chemo Stream (Harvey).

34. SYMPETRUM NEWMAN.

90. *Sympetrum rubicundulum* Say.
Maine (Proc. B. S. N. H. 15: 267, no authority); Manchester (Miss Wadsworth); N. W. Carry, South Lagrange, Greenfield, Bradley, Orono, Fryeburg, etc. (Harvey); York Harbor (Moore).
Greenfield, Bradley, Orono, Fryeburg, etc. (Harvey); York Harbor (Moore).

91. *S. obstrusum* Hagen.
York Harbor (Moore); Fryeburg (Harvey).

92. *S. semicinctum* Say.
Maine (Randall. Proc. B. S. N. H. 15: 267); Orono, Bradley (Harvey); Manchester (Miss Wadsworth); York Harbor (Moore).

93. *S. vicinum* Hagen.
Brunswick (Packard Hag. Syn. O. of A. p. 80); Manchester (Miss Wadsworth); Orono, Bradley, Fryeburg (Harvey); York Harbor (Moore).

94. *S. costiferum* Uhler.
Maine (Hag. Syn. O. of A. p. 81, no authority): Orono, Bradley (Harvey); Manchester (Miss Wadsworth); York Harbor (Moore).

BIBLIOGRAPHY.

BULLOCK, DAVID JAYNE.

1. Notes on Mt. Desert Dragon-flies. Ent. News, 2: 93. 1891.

CALVERT, PHILIP P.

1. Notes on N. Am. Odonata. Trans. Am. Ent. Soc. 17: 33-40. 1890. Maine species collected by Miss Wadsworth at Manchester are considered.
2. Data on the Distribution of Dragon-flies (Odonata) I. Ent. News, 5: October, 1894. Mentions papers on Odonates by Miss Wadsworth, and Mr. D. J. Bullock, F. L. Harvey, besides giving lists of species collected at Mt. Desert by Bullock, and at York Harbor by J. P. Moore.
3. Catalogue of the Odonata of the Vicinity of Phila., Pa. Trans. Am. Ent. Soc. 20: 1893. Maine species mentioned for geographical distribution.

HAGEN, HERMAN A.

1. Synopsis of the Neuroptera of North America, Smithsonian Institution, Washington, D. C. 1861. Mentions species collected in Maine by Prof. A. S. Packard.
2. On the Neuroptera in Harris' Collection. Proc. Bost. Soc. Nat. Hist., 15: 1873. Ten species from Maine are mentioned, three of which are credited to John Witt Randall, one to K. T. Jones, and the others are without authority.
3. Odonate Fauna of Georgia. Proc. Bost. Soc. Nat. Hist., 16: 1874. Two Maine species mentioned, one credited to Packard and the other without authority.
4. Synopsis of the Odonata of America. Proc. Bost. Soc. Nat. Hist. 18: 20-96, 1875. Twenty-one species are mentioned including several recorded in previous papers. For several species only the State is given and for all no authority. Orono, Brunswick, Norway, and Portland are localities mentioned and would suggest Packard, Smith, Jones, Morse, and probably Randall as the collectors.

5. Synopsis of the Odonata of North America No. I. Psyche, 5: 241. 1889. Two Maine species mentioned.
6. Synopsis of the Odonate Genus Leucorhinia Britt. Trans. Am. Ent. Soc. 22: 229-230. 1890. Two Maine species mentioned in notes by Mr. Calvert.
7. Notes and Descriptions of some North American Libellulina. Psyche 5: 383. 1890. One species from Maine mentioned as collected by Smith or L. Agassiz.

HARVEY, FRANCIS LEROY.

1. A contribution to the Odonata of Maine. Ent. News, 2: 50, 73. 1891.
2. Contributions to the Odonata of Maine—II. Ent. News, 3: 91, 116. 1892.
3. Contributions to the Odonata of Maine—III. Ent. News, 9: 59, 85. 1898.
4. Contributions to the Odonata of Maine—IV. Ent. News, 12: 1901.

KIRBY, W. F.

1. A Synonymic Catalogue of Odonata or Dragon-flies, London, 1890. Mentions some species from Maine.

WADSWORTH, MISS MATTIE.

1. List of the Dragon-flies (Odonata) taken at Manchester, Kennebec Co., Me., in 1888 and 1889. Ent. News. 1: 36, 55. 1890.
2. Additions and Corrections to the above. Ent. News, 2: 11. 1891.
3. Second Additions and corrections to the above. Ent. News 3: 8. 1892.
4. Third Additions to the above. Ent. News 9: 111. 1898.
5. Fourth Addition to the above. Ent. News. ix, p. 111, 1898.

WALSH, BENJAMIN D.

1. Observations on certain N. A. Neuroptera by H. Hagen, M. D. Translated from the original French MS and published by permission of the author with notes and descriptions of about twenty new N. A. species of Pseudoneuroptera. Proc. Ent. Soc. Phila., 2: 107-272. 1863 *Ophiogomphus Mainensis,* Packard described p. 255.

Collectors of Maine Odonates.

Randall, Dr. John Witt. Earliest collector of insects in Maine, 1836-40. Specimens sent to Thomas W. Harris and credited to Randall in his MS catalogue. He collected coleoptera mostly, but also insects of other orders, including a few Odonates. He published a paper "Description of New Coleoptera from Maine." (Bost. Jour. Nat. Hist. Vol. 2.)

Packard, Prof. Alpheus Spring. Began gathering insects in Maine when only 16 years old; collected during his college course 1858-61, and until 1864 at Brunswick mostly. Also at Orono and in Northern Maine while on the Geological Survey, August and September 1861. Collected in all orders. Uhler named his Odonates. Specimens went first to the Peabody Academy of Science and afterwards to the Cambridge Museum. Author of many articles bearing upon the Insects of Maine.

Morse, Prof. Edward Sylvester. Collected in the vicinity of Portland, Maine from 1856-62 in all orders. Specimens went to Museum of Comparative Zoology, Cambridge, Mass.

Smith, Prof. S. I. Made large collections in all orders at Norway, Maine. His specimens are now in the Museum of Comparative Zoology, Cambridge, Mass. Prof. Smith is the author of a paper, "Orthoptera of Maine." published in the Proc. Portland Soc'y Nat. Hist. Vol. I.

Agassiz, Prof. Louis. Is credited with an Odonate collected at Bethel, Maine.

Verrill, Prof. A. E. May have collected insects in Maine at Norway between 1858-61; if so, they probably went to the Cambridge Museum.

Jones, Thomas K., Portland. An amateur collector particularly of beetles. He donated a fine collection of Maine beetles to the Portland Society of Natural History. The present secretary writes, "They have gone the way of all insect collections not having daily care." Odonates were collected somewhat and the specimens, we think, went to the Cambridge Museum, as Mr. Jones is mentioned by Dr. Hagen. Mr. Jones is a sign painter by trade and has collected insects many years. Has been an active member of the Portland Society of Natural History and once its secretary.

Morrison, H. K. Is credited with collecting *Ophiogomphus rapinsulensis* in Maine. (See Selys Quatriemes Additions au Synopsis des Gomphines, Brussels, 1878: 50.)

Fernald, Prof. C. H. Orono and vicinity, while connected with the Maine State College from 1871-86. Specimens in collection of University of Maine, as reported by the present writer in Entomological News, are without collector's name, but we presume were collected by Prof. Fernald or his pupils.

Wadsworth, Mattie E. Manchester, Kennebec Co. from 1890 to date. Results published in Entomological News. (See Bibliography).

Harvey, Prof. F. L. Orono, Me. and various localities in the Penobscot valley 1886-1899. Results published in Entomological News. (see Bibliography.)

Moore, Dr. J. Percy. Instructor of Zoology, University of Pennsylvania, Philadelphia. Collected at York Harbor, Maine, in summer of 1890. Specimens given to Mr. P. P. Calvert and reported by him in Ent. News. 5: 242. 1894. (See Bibliography).

Bullock, David Jayne. Lives (1901) in Philadelphia, Pa. Collected in vicinity of Bar Harbor, in 1890. Specimens reported by collector.

Specimens collected in 1891 were reported by Mr. P. P. Calvert in Ent. News, 5: 242, 1894. (See Bibliography.)

Collections made by the following persons have been examined by the writer and reported by him: Mr. and Mrs. Anson Allen, Orono; Miss Kate Furbish, Rangeley region; Mr. E. D. Merrill, Auburn, Monmouth and Orono; P. L. Ricker, Westbrook; LeRoy H. Harvey, Bartle F. Harvey, Miss Florence Harvey, and Willis L. Harvey, Orono, Bradley, Greenfield, and other localities in the Penobscot valley.

We know of Maine Odonates in the collections of other Entomologists of the state, but have not examined them critically. Miss Mattie Wadsworth, David Jayne Bullock and the writer are the only collectors of Odonates of Maine who have published their results.

The University of Maine Studies

No. 5

A Study of the Physiographic Ecology of Mount Ktaadn, Maine

BY

LEROY HARRIS HARVEY, B. S. (1901)
Professor of Biology in Morningside College
Sioux City, Iowa

ORONO, MAINE
December, 1903.

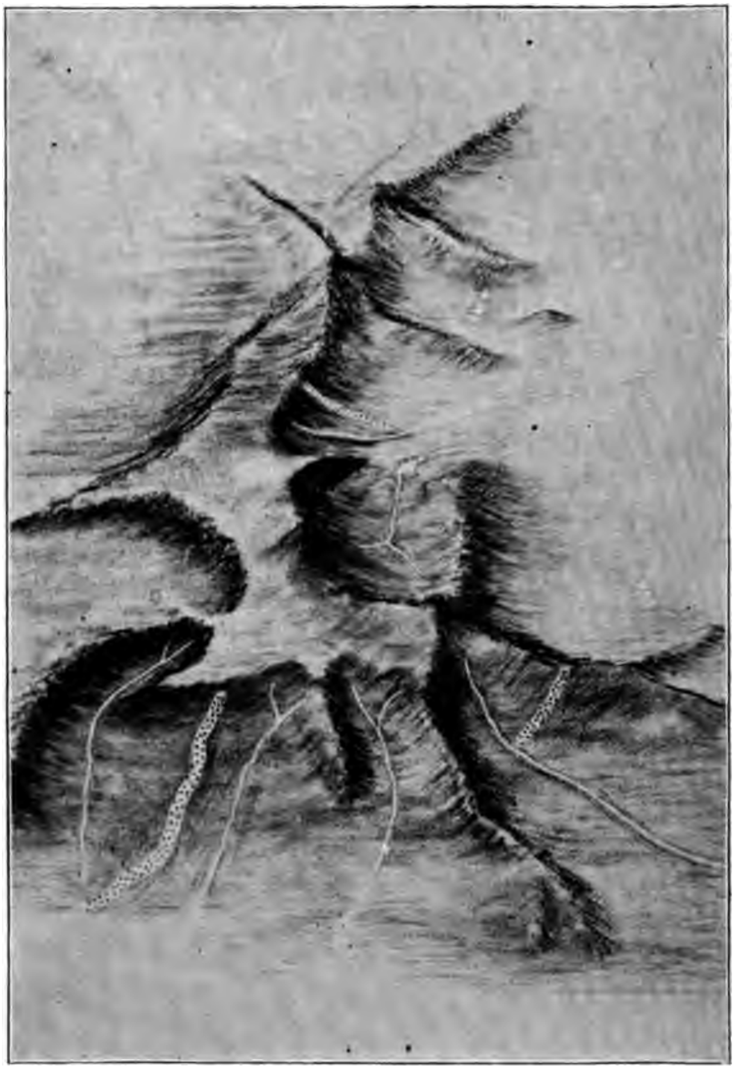

Figure 1. Relief map of Mt. Ktaadn, illustrating the topography of the upper 2,000 feet. The view point is from the south. The clear lines represent streams, the dotted lines land slides, and small clear spaces lakes. Further description in text.

A STUDY OF THE PHYSIOGRAPHIC ECOLOGY OF MOUNT KTAADN,* MAINE.

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*In the spelling of this name Mr. Harvey has followed J. Hammond Trumbull, William Willis and C. E. Potter, authorities on the Abscalka language; also Thoreau, Dr. Chas. F. Jackson, and others.

From the White Mountains, on the eastern borders of New Hampshire, a mountain system traverses the State of Maine in a northeastern direction terminating in Mars Hill on the eastern boundaries of Aroostook county near the St. John's river. This system, presumably archean in age, has many notable interruptions and is represented now and then merely by widely distant hills and low peaks. From its southwest extremity in the White Mountains, of which Mount Washington (6,300 feet) is the highest peak, the elevation decreases toward the Kennebec river where the first appreciable break in the system occurs. Here the range gives way to an extensive stretch of low hills and broad swells reaching nearly to the eastern border of the State. From out this plain occasional high peaks arise, such as Mount Kineo on the eastern margin of Moosehead lake. In Piscataquis county the range assumes again a mountain character in Mt. Spencer and, increasing higher and higher toward the northeast, has its grand culmination in that majestic peak, Ktaadn. Again decreasing in elevation, the range continues its northeastern direction; Chase mountain in Piscataquis and Mar's Hill in Aroostook being the only two remaining peaks of prominence.

Ktaadn is a lonely mountain, rising with its foothills from an almost level plain which extends unbroken for miles to the south, west and north. Rising thus, in such a bold, abrupt manner, to an altitude of 5,216 feet above sea level and being the highest and most northerly peak[1] of any consequence in this northeast extension of the Appalachian chain, it is obviously exposed to all possible climatic vicissitudes and naturally becomes the most ideal place in the State for the study of alpine conditions, climatic influences, timber lines, ecological adaptions to alpine conditions, and the dynamics of mountain societies.

Though Ktaadn has been the goal of several botanical expeditions, extending over a period of some sixty-six years,[1] the flora has been treated wholly from the taxonomic and floristic aspect.

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[1] Mt. Ktaadn lies 161 miles to the northeast of Mt. Washington in Lat. 45°, 03', 40", thus being 1°, 37', 15", approximately 112 miles, farther north.

[1] The first botanical records are those made by Prof. J. W. Bailey in the Am. Jour. Sci. 32: 20-34. 1837. The mountain was described as early as 1804 by Chas. Turner, Jr., of Boston. "His account is preserved in the collections of the Mass. Hist. Society."

Exception might be made, however, of Dr. Harshberger's popular account[2] of the ecology of the mountain.

[2] Harshberger, J. W. A botanical ascent of Mount Ktaadn, Me. Plant World 5: 21-29. 1902.

The material for the present paper has been gathered from two visits to the mountain. The first made in 1898 during the last two weeks in September; the second in 1902 extending over the last two weeks in August.

The conclusions which the writer ventures are presented with the hope of exciting further ecological study in addition to purely floristic work upon the mountain. The conclusions drawn are given tentatively, but the writer fully believes that similar studies of the Mount Ktaadn flora, as well as of other alpine and alpestine regions would yield excellent results.

The author wishes to here express his obligation to Dr. Henry C. Cowles for many valuable criticisms and suggestions, Miss Nettie B. Dickson for the relief map of the mountain, and to Mr. John Thompson for figures 1, 7, and 10.

II. TOPOGRAPHY AND PHYSICAL GEOGRAPHY.

No attempt will be made to give a detailed description of the topography and physical geography of the mountain, for this has been thoroughly done by Hamlin,[1] Tarr,[2] and others to whose accounts the reader is referred. Only those facts will be presented which lend themselves to a better appreciation of the physiographic conditions bearing pertinently upon an ecological discussion. The writer has drawn very freely from the above articles. Subsequent reference, in this description, to the general features of the mountain will be rendered more intelligible by a study of the accompanying relief map (Plate I).

Mt. Ktaadn and its foot-hills constitute a continuous granite area eruptive through a vast region of stratified rock which forms even the lower slopes of the mountain itself. Though of the same range, Ktaadn is quite distinct as a mountain. To the south, east and west, stretches a vast plain whose elevation can scarcely be more than 550 feet above sea level. From this low

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[1] Hamlin, C. E. Observations upon the physical geography and geology of Mount Ktaadn. Bull. Mus. Comp. Zoo. Harvard. 7: 206-223. 1881.

[2] Tarr, R. S. Glaciation of Mount Ktaadn. Bull. Geol. Soc. Am. 11: 433-448 1900.

extended expanse the mountain rises, not at first abruptly, but for miles by moderate gradations up to approximately one-half its altitude,—about 2,200 feet on the south side, and 2,900 feet on the east. To the East Branch of the Penobscot, 23 miles due east, there is from the South basin a gradient of more than 100 feet to the mile. From this gradual rise the upper half of the mountain rears itself abruptly, bounded by bare, precipitous cliffs and steep declivities sustaining vegetation.

These sharp declivities and precipitous walls terminate above in a narrow ridge or crest which bears the highest peaks and gives the mountain its general outline. From the lower slopes of this crest the various spurs arise. In shape the crest presents a striking resemblance to a gigantic fish hook with its bowl opening to the northeast. The shank, formed by the crest of the North mountain and the Northern ridge, curves strongly toward the northeast. The bowl and barb are represented by the Great Basin and Pomola respectively.

Along the southern base of the bowl, upon the peak-bearing crest, arise the two chief prominences of Ktaadn. They are less than 500 yards apart and differ in altitude some 15 or 20 feet. The two peaks are known respectively as the East and West peaks, the latter being the higher with an altitude of 5,215 feet, as determined by Prof. Fernald.[1] "Directly beneath the east peak (5,200 feet), shoots off to the southeast the longest of all the spurs, (the southeast spur) which, narrow above, widens greatly toward its foot." Beyond the peaks, a narrow much serrated crest, the outer limb of our hook, swings shortly northward forming toward its point, "first, the little tower-like peak known as the 'Chimney,' and then, across a narrow, square-cut notch, the peak, Pomola."

Pomola (4,819 feet) has a wide, convex northern face sloping off gradually with a precipitous foot to the floor of the south basin 1,900 feet below. In subsequent reference to Pomola this entire eastern limb of the mountain is to be understood. "Eastward from Pomola projects a narrow sharp ridged spur, the 'Horseback.' Towards its extremity, the 'Horseback' forks, and sends off to the northeast a lower, flat-backed spur." On the southern flank of this "Horseback" is the east slide.

[1] Fernald, M. C. Bangor Daily Whig and Courier, November 9, 1894.

Against the western limb of the bowl, and a few hundred feet below the crest, abuts the "tableland," an almost absolutely plane surface, inclined to the northwest at an angle of from five to seven degrees, and having a length of a mile and a half, and an area of more than five hundred acres. This "tableland" is bounded by a sharp brow from which extend several spurs. The South spur, a short, blunt projection widened at its tip, arises a few hundred yards west of West peak and runs slightly southeastward. The Southwest spur, a long, narrow ridge, has its origin at the southwest corner of the "tableland" and, bending sharply, runs a few degrees south of southwest. Midway between these two spurs and about a half mile below the brow is the head of the southwest slide.

From the West peak there is a sharp descent northward and westward, into which the "tableland" merges, down to the level of 4,250 feet; here, with the table land, it passes into the lowest part of the Central mountain, termed the "saddle." Northward from the saddle there gradually arises a rounded knob, the first North peak (4,700). By a moderate depression of the crest, this peak is separated from a second similar one, slightly lower and three-fourths of a mile farther to the northeast. Approximately one-half mile beyond along the crest is a third minor peak, some seventy-five feet lower than the first. The "saddle" thus naturally divides the peaks into two groups, known respectively as the North and South mountains.

From the First and Second North peaks two sharp, narrow spurs extend eastward enclosing the North basin. (Fig. 1). This basin, opening slightly south of east, resembles in shape the capital letter U. At the mouth, midway between the tips of the two spurs, is a knoll rising 50 feet, perhaps, above the floor of the basin proper (3,700 feet). About a mile long and half a mile wide it has an area of approximately 320 acres. In its floor are two small morainic ponds.

Between the more southern of these two spurs and the point of Pomola is enclosed the bowl of the hook, the great basin, (3,000 feet) which forms a vast amphitheatre. Viewed from above this basin bears a striking resemblance to an old volcanic crater. Approximately stated this great cirque is "from summit to summit east and west two and a half miles by a mile and a half from north to south" giving it an area of 2,240 acres.

From the southern end of the "saddle" a short spur juts out into the great basin which, with Pomola, encloses a second smaller amphitheatre, the South basin. In its floor (3,000 feet) lies Chimney pond (2,928 feet or 2,287 feet below West peak). The well nigh vertical walls of this basin terminate above in the crest which forms the heel of the hook and bears the "Chimney," Pomola, and the East and West peaks.

Beyond the peaks of the North mountain, the crest continues as the Northern spur extending some three miles to the northeast at a lower level (4,500 feet) and then drops abruptly. Russell mountain lies just beyond its tip.

The gradual slope directly west from the [illegible] peak shortly passes into the Northwest spur which [illegible] some three-fourths of a mile to the northwest at an approximate level of 4,400 feet. Between this spur and the walls of the Northern ridge, which here extend nearly north, is included the Northwest basin. The writer has recently described this basin and for details the reader is referred to this description.[1] Only the salient points will be repeated here. In general form the North west basin suggests the capital letter V with [illegible] base slightly rounded, and with a very broad gateway opening to the northwest into the valley of the Middle Wissattaquoik. Its eastern arm is formed by the precipitous west wall of the Northern ridge while the wooded north slope of the Northwest spur makes the other arm of our capital letter. By the confluence of these two arms as they join the North mountain, the rounded base of our letter is formed. The floor of this basin is virtually a shelf cut from the Northwest spur, apparently by glacial action. It has an altitude of 2,940 feet, 50 feet lower than South basin; and varies in width from 200 to 250 yards. From this shelf a precipitous descent of 250 feet leads to the valley proper below.

Nestled at the base of the Northwest spur and on the shelf described above, are four small ponds, evidently morainic in origin. Lake Cowles (2,938 feet) the largest and most western is about five acres in extent. Davis pond, next in size, less than

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[1] **Harvey, LeRoy H., An ecological excursion to Mount Ktaadn. Rhodora 5: 42-46. 1903.**

2 acres, occupies the eastern extremity of the shelf. Between these lie the two other ponds each less than half an acre in extent. The outlets of these ponds join sooner or later and empty as a common stream into the Middle Wissattaquoik some four miles down the valley. Rising up from, and occupying a large part of, the shelf are two *roches moutonnées* which with their flat tops and precipitous sides bespeak unmistakably a glacial origin.

The mountain then as an entirety is a long (9 miles), narrow, fish-hook-shaped, serrated crest, bristling with peaks and divided by the low Central mountain, the "saddle," into the North and South mountains from which jut out spurs in all directions, enclosing several well defined basins and preventing every conceivable exposure. A multitude of local conditions which large[illegible] the development of the varied plant physiogno[illegible] slopes is [illegible] produced.

III. The Geology.

The entire mountain from the lowest point in which rock has been found in situ is, as noted above, composed of granite. Two varieties are very evident, especially so in the great basin; a gray, which composes the lower two-thirds of the basin walls, and a red, out of which the East and West peaks, Pomola, the Chimney, the North peaks, and the serrated crest are formed. This line of demarkation is not one of general distinctness, yet the main fact, as outlined above, still holds. From analyses[1] made by Dr. Wadsworth of Harvard, I take an example of each of the varieties:

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[1] Hamlin, C. E. Op. cit.

No. 3.—A gray granite, composed of feldspar, quartz, and biotite. The feldspar is of two kinds: a grayish-white variety with a pinkish tinge, is the most abundant, while subordinate to it occurs a milk-white striated feldspar. The powder of the rock is magnetic. Microscopic examination shows it to be composed of orthoclase, much decomposed, and plagioclase, slightly altered, quartz, biotite, and magnetite. This gray variety is generally very solid and occurs but rarely in process of disintegration.

No. 23.—A brownish red granite of similar composition with the preceding. Feldspars colored pink and greenish white.

Calcite and a greenish talcose mineral occur as alteration products. In their section the feldspar is seen to be greatly altered. The biotite is partly decomposed. Dr. Wadsworth, however, regards these two varieties as parts of the same formation. This specimen was taken from the very crest and like all the rest of the top of the mountain is so decomposed as to yield readily to the hammer.

The lower two-thirds of the walls of the great basin, including approximately the upper limit of the gray variety, is "arranged (on the western side) in concentric sheets that dip west at an angle varying from 45° to 60°." On the southern wall the concentric layers dip north often at angles greater than 60°. The red granite caps these concentric sheets. Upon weathering it splits into blocks more or less regular in form which strongly resemble "courses of cyclopean, but crumbling masonry." So friable is this rock that it readily crumbles under the slightest weight, giving rise to a residual granitic soil, the only original soil of the mountain.

"The forms which the several parts of the mountain now present, and the condition of their surfaces, are largely due to the original structure and mode of weathering that characterize the rocks. As the highly inclined concentric sheets in the basin walls break away, and fall upon the talus below, other faces of equal inclination are exposed; while the red granite of the higher parts, deprived of support, in turn gives way, and thus the steepness of the walls is maintained." Similar explanation applies to precipitous faces upon other parts of the mountain.

That part of the crest between East peak and Chimney owes its form and preservation to the circumstance that the modified red granite which makes it up divides in weathering into plates which, when undisturbed stand vertically on edge * * * * a mere blade of rock from one to two feet wide, having upon one side the yawning gulf of the basin (South basin) and on the other cliffs too steep for climbing." These plates "vary in thickness from an inch, or less, to upwards of a foot." When they loosen, under frost action, and crash down the cliffs on either side, the plates remaining constitute the ever narrowing and lowering crest. Between East and West peaks the rock plates stand across the ridge at various angles. Loosened by frost the plates fall from the perpendicular, and the ridge bristles with these oblique projecting plates presenting "a savage and chaotic desolation that is probably without parallel in eastern North America."

The very diverse conditions of surface upon the other summits are due largely to simple differences in firmness of the constituent rock. "Thus, parts made up of the more friable red granite (not dividing into plates) are covered with small sized fragments, rounded by decay. These assume, over wide stretches, the size and almost the arrangement of cobble paving stones and in a few places the aspect of gravelled areas." Such conditions prevail particularly upon the slopes of the northern summits.

"Again, the middle of the northward slope, between the Tableland and the Saddle, is piled with blocks of the firmer red granite, riven from the mass beneath, of size so great as to render travel over them extremely difficult. The tableland is in parts smoothed by a covering of wholly disintegrated material, but in general is strewn with tabular blocks that increase upwards toward West Peak in size and number."

"The slopes south from the two chief peaks are covered with loose, angular, often tabular fragments, as far down as the (so called) tree-line, which is everywhere very low, leaving an unusual amount of naked rock above." "The whole rock surface of the mountain has been so shattered by frost action that only on faces of cliffs too steep to admit of an accumulation of detritus is rock to be found in situ."

The structure then of the red granite, which makes up the upper 700 feet of the mountain, has determined a variety of savage conditions from a blade-like crest to long slopes covered with huge angular or tabular blocks or fields of cobble stones. These conditions are all very significant in their bearing upon timber lines and the genetic development of plant societies upon the higher slopes.

IV. THE ORIGIN OF THE MT. KTAADN FLORA.

In studying the flora of North America the identity of plants on isolated mountain summits and regions far to the north is a noticeable fact. The floras of Mt. Washington, Ktaadn, Labrador, and east Arctic America, localities widely separated by miles of lowland, impassable barriers for Arctic plants, are possessed of alpine species quite identical. These facts of discontinuous distribution of mountain forms and their strong Arctic affinities, many identical species recurring far to the north, demand an explanation since continuous distribution is the common condition. We are indebted to Prof. Asa Gray for an explanation of this interesting phenomenon, and the following paragraphs are largely adaptations of his views to the case of Mt. Ktaadn.

In the Pliocene epoch, in pre-glacial times, it is presumable that a quite homogeneous and uniformly distributed flora encircled the polar zone, there being then a postulated north polar land connection continuous around the globe. Destroyed by some great land movement, presumably toward the close of the Pliocene, only isolated islands, Greenland, Iceland, and others, now remain to mark its probable former course.

With the inauguration of the Pleistocene epoch great changes, cumulative from the Pliocene, came about. Huge masses of snow and ice, accumulated to the north and extended southward. The cause of this accumulation, made possible by the lowering of the temperature, is referred by Scott[1] to an epeirogenic movement in northern North America, and the polar zone. Dr. Chamberlin,[2] on the other hand, ascribes its cause to the gradual depletion of CO_2 from the atmosphere by organic and inorganic agencies, thus reducing the CO_2 blanket of the earth and facilitating radiation until the temperature became so lowered that ice accumulation ensued. Whatever the theory of the cause, the fact of glaciation remains the same. With the advent of ice accumulation and refrigeration, this uniformly distributed Arctic flora was driven southward in every longitude, retreating from the ever advancing ice sheet. Our temperate flora was likewise forced southward or exterminated by the glacial advance and by the fleeing Arctic species. From this general consideration of glaciation, we may now pass to its effect upon New England and in particular Ktaadn.

We have seen that as refrigeration progressed in the polar zone the Arctic flora travelled to the southward, closely

[1] Scott, W. B. An introduction to Geology. New York. 1899, p 524.

[2] Chamberlin, T. C. A group of hypotheses bearing on climatic changes Jour. Geo. 7: 653-683. 1897.

followed by an Arctic ice cap which, according to the Canadian glaciologists, originated in North America from three distinct centers of maximum accumulation and flowed outwards in all directions. "One of these centers of maximum accumulation and distribution lay to the north of the St. Lawrence river, and on the highlands of Labrador, sending its ice-mantle southward over the Maritime Provinces, New England, and the Middle States, as far west as the Mississippi river." This ice sheet is known as the Laurentide glacier.

As this Laurentide ice-sheet advanced conditions of extreme cold were felt far beyond its edge. Thus the loftier mountains of New England, Washington and Ktaadn, feeling its chilling influence, became centers of ice accumulation. These mountain floras were consequently early forced down the mountain slopes into the plains below, uniting with the migrating Arctic forms from the far north. The nature of those pre-glacial alpine species is mere conjecture. However, they, as well as the accompanying lowland forms, doubtless exerted a modifying influence on the Arctic species. Yet the fact of their migration in unison precludes any marked modification of their mutual relations.

From these mountain centers, as general glaciation advanced, extensive ice-sheets flowed out in all directions, coalescing with each other and finally with the Laurentide glacier, and, united, advanced over New England even to the sea. This ice sheet was thousands of feet in thickness at its maximum, no mountain peaks, with possibly the exception of Mt. Washington, rising above the vast *mer de glace*. Before this all life retreated, many species of plants doubtless to the sea and extermination. This advance continued; the ice-sheet reaching at its greatest development to latitude 40°, about the middle of New Jersey. At this time our Arctic flora was doubtless enjoying a congenial climate along the Gulf.

After an extended period of this general glaciation, warmth gradually returned, according to Prof. Chamberlin, by the re-establishment of the CO_2 blanket, thus restricting radiation. With this return the ice-sheet gradually retreated, closely followed by the Arctic life. This retreat in New England was presumably one of continuity, yet in Wisconsin there is strong evidence of five glacial and four interglacial stages, representing periods of advance and retreat respectively. As the glacier dwindled, some of the New England peaks, such as Washington and Ktaadn, soon projected above the surface. When sufficient area was thus exposed, the accumulation of snowfields was again permitted, and valley glaciers descended from the mountain tops. In other words, following the withdrawal of the great continental glacier, there came a period of glaciation. The northward migrating flora was now met by these local ice sheets and temporarily retarded. The continued shrinkage of these large centers finally gave rise to coalescing valley glaciers; again permitting the northward advance of plants toward these centers of local glaciation.

In this advance, most naturally, the Arctic forms were the pioneers, following closely the melting ice front and obtaining a foothold wherever morainic soil was exposed. This advance was, as pointed out above, in unison and was also one of latitudinal zonation; the temperate plants, following closely the progression of the Arctic forms. As the coalescing valley glaciers gave way to isolated ones, the migrating Arctic species came to the lowlands about these high peaks. As the snows melted above, and as these now isolated valley glaciers retreated in their cirques, a separation in the previously compact Arctic flora took place. Some individuals pursued the receding snows up the mountain slopes, occupying every inch of exposed ground, while the main line of migration continued northward with the ever shrinking glacier. As amelioration progressed and the valley glaciers melted these Arctic forms ascended still higher. The main body of migrants pushed onward in its northward journey; while mingled temperate and pre-glacial alpine forms, on the approach of normal climatic conditions, came to occupy the intervening space between the mountains. Thus we have Arctic products isolated upon Ktaadn.

When these Arctic species began their mountain ascent they were, because of migration in unison, practically unmodified and identical with their northward journeying brethren, which, as complete warmth returned, had once more come to occupy the Arctics. As they ascended, unlike the compact body migrating northward, they were subject to modifying influences in such factors as the co-mingling with pre-glacial alpine forms, seeking their original habitats, and new alpine climatic conditions, Again, it is not to be presumed that identical species ascended mountain peaks widely separated. We thus readily interpret any varietal, specific, or even generic peculiarities which may exist upon any mountain. However, the majority of Arctic and alpine forms have, through the fixity of the specific type, come down to us unchanged from glacial times. But we must not neglect the possibility of subsequent distribution from a center as the factor in maintaining this specific identity in Arctic and alpine species. *Lycopodium Selago* is identical the world over in Arctic and Alpine habitats. This identity may be due not to the fixity of the specific type, for in Alpine conditions it has been subjected to the modifying influences noted above, but to the fact of frequent introduction, by wind dispersal, of individuals of the specific type derived from the Arctic centers by distribution, and the consequent commingling.

The flora of Mt. Ktaadn is then glacial in origin, being isolated, as a glacial relict, by the northward retreat of the continental ice sheet. We may now examine in particular its genesis upon the mountain. We have seen that, as the isolated valley glaciers, such as those occupying the North, South, and Northwest basins, retreated before the increasing warmth, Arctic plants approached the mountain base, and, as this local recession continued, the flora arrived at the base of Ktaadn.[1]

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[1] With the establishment of the isolated valley glaciers, it is quite probable that the higher peaks of the mountain arose as menataks above the local glacier; and with the ever increasing exposure must have formed a foot hold for these Arctic forms. It seems more probable, however, that the principal encroachment was from base to summit.

The first forms to reach the mountain were, in all probability, lichens of the crustaceous type, such as *Buellia geographica,* which found ready foothold on the increasing exposure of granitic rock. Following closely the ascent of the pioneer lichen society was that of the reindeer-iceland-moss combination, encirling the mountain as a basal zone and ascending as the pioneer society advanced. Encroaching upon this zone from below came that of the Alpine tundra, extending out into the lowlands, followed in turn by the *Krummholz* and passing gradually into the *Picea-Abies* forest which doubtless covered the entire southern part of the State at this time. Beyond, to the south, lay a wide belt of the white pine, and in turn beyond it came the deciduous forest. Encroachment of one zone upon another above has been continuous, societies gradually ascending, resulting in the present distribution of plant societies upon the mountain. It is obvious that this encroachment was one of horizontal zonation but for any one place it is a story of vertical succession. This progression will be considered in the section upon plant societies.

The place where this isolated Arctic flora first encroached upon the mountain is an interesting point of conjecture. From the retarding effect of the basin glaciers, the very favorable opportunity on the gentler incline of the stoss side of the mountain, and the greater sun exposure, it would seem probable that the first advance was from the southwest and west. This idea would seem to be confirmed in the present distribution of the spruce and fir. Their higher ascent on this side, their apparently greater age on the south and west slopes, and the advance of the *Krummholz* from this section, all indicate more favorable conditions, past and present, on this part of the mountain. As to the east side of the mountain, and in particular the basins, it seems very evident, from the present conditions, that the Great basin was the first to be claimed by the plant migrants, and that the North basin (Fig. 1) resisted this encroachment for a much longer time. In fact, presenting as it does a desolation simulated only on the highest slopes, it would seem that the disappearance of the valley glacier from this basin was comparatively recent.

V. FACTORS.

If a bird's eye view be taken from the summit of the mountain a varied panoramic picture greets the eye. A vast forest, coniferous in places, deciduous in others, dotted here and there by sphagnum bogs and a multitude of lakes whose shores are fringed with meadows, extends for miles, an unbroken landscape feature. If the mountain is now considered in particular, one sees in contrast, bare exposed rocks, mats of appressed growth, scrubby forest forms, and alpestrine meadows. That there are at least two distinct sets of causes operating in this region is very obvious. One determines the general plant physiognomy; the other controls the local aspect. One determines the coniferous forest; the other controls the formation of the alpestrine meadow and the Alpine-Tundra.

The question now most naturally presents itself: why in one place do we have the forest and in another its entire absence? Why is the coniferous forest dominant here, and the deciduous there? The present condition of these various plant societies is evidently the resultant of the inter-action of a complex of natural agencies operating upon them. Hence an interpretation of these conditions will largely depend upon an understanding of these determining factors. For convenience of discussion they may be treated under four heads, climatic, edaphic, biotic, and historical.

A. CLIMATIC FACTORS.

The factors to be treated under this head are composite and inclusive in nature. Of these temperature and moisture are, perhaps, the most important. A general survey of our entire country shows us a central prairie region bordered east and west by forest formations. The Atlantic and Middle States present a forest because the resultant of these factors produces a condition congenial to forest development. For similar reasons the Pacific coast is dominated by a vast coniferous belt. The absence of these favorable forest developmental conditions in the middle west, results in a climatic prairie formation.

Within this great Eastern forest we find a varied physiognomy. The Central states are dominated by a deciduous forest, while the extreme Northern states are coniferous in aspect. These differences are likewise climatically determined, being due to a different adjustment of the determining forces which vary in different latitudes. Such homogeneous plant groupings are known as climatic formations.

The Ktaadn region lies within the Northern Pine Belt of Sargent,[1] the boreal of Merriam,[2] the black spruce-fir balsam combination being the climatic mesophytic type. The entire absence of temperature and rainfall readings in this region makes a discussion of the climatology impossible, but a general consid-

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[1] **Sargent, C. S.** Tenth Census Rpt. 9: 494. 1880.

[2] **Merriam, C. H.** The geographic distribution of life in North America. Rpt. Smith. Inst. 1891: 365-415.

eration has shown us that the interaction of these complex agencies has probably determined the coniferous nature of this forest.

In contradistinction to these comprehensive and far-reaching climatic factors, are those which are decidedly local in their effects. Mount Ktaadn presents within itself a varied physiognomy. The Alpine-Tundra, the heath, the cliff bogs, the *Krummholz,* and the alpestrine meadow are but phases resulting from the local influence of the several co-operating factors. Yet these many and distinctive plant societies are all within the same climatic formation. Rising as Ktaadn does, from an extensive lowland, it introduces abnormal climatic conditions for this region. Its height brings about new relations as to exposure, light, moisture, wind, and temperature which are superimposed upon the normal climate of the region. We may expect then the physiognomy of these mountain societies to be in direct response to the resultant of the imposed conditions.

In the section of this paper devoted to the origin of the Ktaadn flora, we recognized and commented upon the strong resemblance our mountain flora bears to that of regions far to the north, but at that time offered no suggestion as to why this isolated Arctic flora had been able to so successfully sustain itself there. We have upon Ktaadn a flora which is probably much like the climax type of Labrador and Arctic North America but which is here, as noted above, largely determined by local climatic conditions; that is we have repeated in a local way upon high mountain peaks the far-reaching climatic conditions of regions farther to the north. Or, in other words, a mountain repeats altitudinally conditions latitudinally true of more Arctic regions. In concluding this general discussion, it may be well again to emphasize the existence of a local climate as well as a general one; the former condition is strikingly exemplified upon high mountains.

These local climatic factors are several: heat, light, and wind may be mentioned as the most significant. Operating through space they act directly upon the aerial parts of plants through the atmospheric medium which surrounds them. Other parts are affected indirectly, as will be brought out in the following discussion. We may treat these factors under two heads, radiant energy and wind.

(a)—*Radiant Energy.* The ultimate source of all our energy is the sun. It manifests itself upon the earth as ether vibrations which give rise in our bodies to the sensations of light and heat depending only upon their rate of vibration. With the plant, however, it is simply a difference in energy, not sensation. So closely are these two factors related that it is almost impossible to differentiate their effects. However, light would seem to be the more important, controlling as it does one of the vital processes, photosynthesis. Ascending the mountain the atmosphere becomes rarer, hence the intensity of the light proportionally greater as higher altitudes are reached. Plants able to withstand this greater intensity must possess protective structures. They have become "light loving" species, as expressed by authors. It would seem more pertinent, however, to designate them as light enduring forms. The absence of broad leaved species, the high development of cutinization, and palisade structures may be, in part, responses to this high light intensity.

Closely related to the function of photosynthesis, is that of transpiration or water loss. Both these functions are largely dependent upon the stomata for their efficiency, at least in the alpine forms under consideration. The stomata are primarily paths of gaseous exchange, but are also the canals of water loss. The latter necessarily occurs where wet membranes are exposed to an atmosphere of less diffusive tension. The amount of transpiration is dependent in part upon the aperture of the stomata, which is in turn dependent upon the light intensity, the temperature of the air and its relative humidity. This transpiration loss is vital in the economy of plant life and especially is this true of alpine regions where the absorption, due to the low temperature of the soil, is at a minimum and the transpiration, on account of the high wind velocity, greatly augmented; it should be said, however, that some experiments seem to show lessened transpiration in alpine regions.

In response to these precarious conditions we find protective adaptations which tend to mitigate the harmful effects which might otherwise arise. Whether they have been developed primarily in relation to light or to transpiration is of course problematical, yet the fact that the same ecological adaptations exist where the light condition is normal (the sphagnum bog) but the ratio of transpiration to absorption is high, would tend to favor the latter view. Further discussion of high transpiration and its resulting protective adaptations may be more advantageously considered under wind, and will be reserved for that section.

With the increased light intensity also goes an abnormal temperature relation, varying greatly from that of the surrounding region. It is a point of common knowledge that with an increase of elevation there is a corresponding decrease in temperature, depending upon the increasing ease of radiation as the atmospheric density decreases. No systematic temperature observations have ever been made upon the mountain. The United States Weather Bureau has, however, had from 1870 to 1892, a station upon Mt. Washington at an altitude of 6,279 feet. Tables of the maximum and minimum temperatures for a series of years compiled from the annual report of the chief signal officer, are very instructive and may be considered quite representative of the conditions upon Ktaadn.

*TABLE I—MAXIMUM TEMPERATURE.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1873...	0.	-5.	0.	.6	10.	15.	17.2	13.9	13.9	14.4	1.1	3.3
1874..........	5.	2.8	3.3	4.4	15.	16.1	.....	....	16.1	6.1	4.4	1.1
1875..........	1.7	2.8	2.2	2.2	15.	15.6	12.8	15.6	16.7	5.	1.7	4.4
1876..........	5.	1.1	5.6	6.1	11.7	18.9	17.8	22.2	14.4	8.9	5.6	-5.6
1877..........	-2.2	1.7	2.2	5.	12.8	16.1	16.1	17.2	15.6	13.9	3.3	3.9
1878..........	.6	.6	1.1	7.2	14.4	21.7	20.	15.6	16.7	12.2	2.8	1.1
1879	-3.3	-10.6	1.7	5.6	16.7	21.1	15.	16.4	15.6	12.2	6.7	4.4
1880..........	4.4	1.7	2.8	4.4	16.1	15.	16.7	18.9	18.3	10.	8.3	-.6
1881...... ...	-3.9	2.2	1.7	5.6	16.1	20.6	22.2	19.4	17.5	12.2	8.5	4.8
1882..........	1.1	1.6	2.6	2.3	7.5	17.2	15.6	18.6	13.6	14.4	6.8	0.
1883	3.3	6.1	1.7	10.	16.3	18.6	15.8	14.6	15.6	12.5	7.8	2.9
1884....	2.2	3.9	5.3	7.3	12.8	19.4	19.3	18.3	17.2	13.6	2.8	6.1
1885...	2.8	0.	-2.2	13.3	16.7	17.2	20.6	16.7	12.8	12.2	10.6	5.6
1886...	2.8	5.	5.	11.1	9.4	14.4	19.4	20.6	16.7	9.4	7.2	0.
Total mean.	1.4	.9	2.3	6.1	12.6	17.6	17.7	17.5	15.	11.2	5.5	2.2

*TABLE II—MINIMUM TEMPERATURE.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1873..........	-25.	-20.5	-18.3	-10.	-7.8	-2.8	.55	-.55	-7.8	-13.3	-30.	-27.8
1874..........	-45.4	-33.3	-35.	-27.8	-20.5	-6.7	-.55	-2.2	-5.	-12.8	-27.2	-26.7
1875...... ...	-50.8	-37.2	-32.7	-26.1	-73.3	-7.2	0.	-2.2	-9.4	-15.5	-37.2	-40.
1876	-34.4	-43.6	-31.7	-17.8	-13.9	0.	0.	-6.7	-6.1	-15.	-23.3	-43.6
1877...... .. .	-37.8	-26.7	-29.4	-15.	-11.7	-3.9	4.4	1.1	-6.7	-11.1	-18.3	-25.
1878..........	-37.2	-27.2	-27.6	-9.4	-10.5	-9.4	1.6	1.6	-10.	-12.2	-23.3	-26.1
1879...	-33.9	-30.5	-23.1	-21.7	-10.5	-9.4	0.	-.55	-11.7	-17.8	-28.9	-32.2
1880......	-28.4	-32.8	-25.	- 24.4	-18.3	-1.1	-.55	-2.8	-5.4	-15.5	-26.7	-33.3
1881.........	-34.4	-37.8	-22.2	-27.2	-13.3	-8.8	0.	1.7	-2.2	-19.4	-26.4	-29.
1882..........	-39.4	-29.	-28.5	-25.1	-15.5	-5.7	-1.7	-3.3	-8.3	-12.2	-21.7	-31.7
1883..... ...	-33.9	-33.5	-36.7	-23.3	-12.6	-6.3	-2.2	-6.4	-9.6	-14.4	-27.	-41.8
1884...... ...	-33.9	-34.4	-32.2	-16.8	-10.8	-2.9	-1.1	-5.8	-10.2	-15.2	-22.6	-43.9
1885..........	-58.	-38.9	-54.4	-23.3	-18.3	-9.4	1.7	-5.	-10.5	-12.2	-14.4	-26.7
1886......... .	-28.3	-39.4	-28.3	-16.7	-7.8	-4.4	-2.2	-2.2	-11.7	-18.3	-18.9	-31.7
Total mean.	-36.9	-33.2	-30.4	-19.7	-13.2	-5.5	-.05	-2.4	-8.1	-14.7	-24.9	-32.9

*The readings are in centigrade.

(b)—*Wind.* The influence of wind upon vegetation is great and manifests itself in a variety of effects. Indirectly, plant life is influenced by the wind in furthering dissemination and facilitating anemophilous pollination. While more directly the external form, internal structure, and vital processes may be greatly modified and disturbed by the mechanical impact on the one hand and the desiccating effects concomitant with high wind velocity and extreme exposure on the other. The extent of these influences is largely dependent upon two conditions; the plant's exposure and the strength and prevalence of the wind. These two conditions exist in a superlative degree upon mountains and are proportionally great as the altitude increases. As the action of wind induces a complex of consequences in plants, it will be well to discuss the various effects independently.

The study of seed dispersal has two aspects: the pure ecological standpoint dealing with varied adaptive structures facilitating seed dissemination, and the floristic phases treating of questions of origin and present distribution. The large per cent (about 30%) of the flora possessed of adaptations furthering wind dispersal is at least deserving of passing notice.

Wind is a factor not to be underestimated in its relation to pollination. Though many insects abound even to the summit they are presumably of little significance in entomophilous pollination, belonging as they do to groups whose members aid only slightly if at all in pollen transportation. Further, the majority of forms are strongly anemophilous. The great efficiency of the wind in the formation, as well as the dispersal, of seed is to be properly accorded in the consideration of any alpine flora.

The most evident wind effect upon plants is the modification of morphological form. Though formerly controverted, it now seems well established that this influence is partly mechanical and largely due to the force of impact of the wind blast. It directly follows that the extent of this modification varies with exposure and the velocity and constancy of the wind. We may expect to find then upon Ktaadn drastic evidence of wind influence upon external form. As one ascends the slopes he passes successively from forest trees which clothe the plain below through those whose branches just overtop his head, those that are shoulder-high, those that are knee-high, and at last he remarks at finding himself walking upon the crowns of trees which lie prostrate beneath his feet upon the higher slopes. This diminution in size, with the increased altitude, is accompanied by a no less marked effect on form. The scrubby, scraggly, gnarled, knotted, and twisted character of the trees is most striking. To this condition of morphological modification the Germans have applied the term *Krummholz*. The *Krummholz* covers the north basin, the higher slopes, and a greater part of the "tableland" and "saddle," extending far up toward the North and South peaks. (Figs. 2, 3). Its gnarled, scraggy, and interlacing branches make it an almost impenetrable mass.

So closely wind trimmed is this growth of spruce and fir that its surface presents an almost level green. If one approaches the "saddle" from the east slope a much different impression is conveyed than if his first view is obtained from the west. If viewed from the east a striking condition presents itself. Residual granitic soil, bare rocks and boulders, the alpine mat, prostrate firs and spruces, and the *Krummholz* in receding succession from the brow of the slope confront one. (Fig. 4). Passing back into the *Krummholz* these much dwarfed trees gradually attain a greater height, ascending gently to the leeward until at the west bow of the saddle they reach about one-fifth their normal height.

This gradual and successive extension in height is due to the increased protection afforded by each succeeding tree, the inclined plane rising to the leeward. But if, on the other hand, the approach is from the west, (Fig. 4) not this heath-like condition, but a diminutive forest confronts one, and he is not aware that conditions other than those exist upon the saddle.

If attention is now focussed upon a single tree far to the windward, the direct effects of the wind become still more obvious. The very general inclination of the crowns to the leeward shows strongly their tendency to conform to the direction of the prevailing wind. In extreme cases the entire crown is to the leeward of the trunk which may itself be inclined at no gentle angle, in many cases lying even prostrate. The straggling nature of the trees and the great number of dead branches in the crowns are also characteristic features.

A closer examination reveals another striking fact. The trunks themselves in cross section have an ellipsoidal tendency with the longer axis lying parallel to the direction of the prevailing wind. The high development of bark and the small diameter and great age are but other evidences of this same factor. We thus see that a high and constant wind not only defines the whole landscape but determines the individual plant form as well. The modification of internal structure resulting from the mechanical impact of the wind is evidenced in the great increase of mechanical tissue; and it is to this increase that the trunk owes its ellipsoidal form, mechanical tissue developing only abnormally where the stimulus of the strain is focused, obviously on the leeward side perpendicular to the wind impact.

The influence of wind upon transpiration though not the most evident is by far the most significant. Other things equal, the rate of transpiration is dependent upon the difference in diffusion tension of water vapor within and without the plant body. The desiccating influence of a wind blast is well known and needs but to be recalled in this connection. This desiccating effect, along with the constant replacement of the atmospheric environment, reduces the external diffusion to a minimum, thus augmenting transpiration greatly beyond its normal amount. Furthermore, during winter, the resting periods of plants, the wind reaches its highest velocity (see Table III) thus keeping the peaks and higher slopes bare a large part of the time and reducing the available moisture in the soil to a minimum. Coincident with this maximum wind velocity are the minima of precipitation and temperature. (See Tables II and V). It likewise dries the plant itself, even thawing the frozen sap, thereby increasing the transpiration at a time when this excessive drain can least well be met, concomitant as it is with a period when absorption, because of the dryness of the soil and its low temperature, is highly impaired if not entirely prevented. We have thus a condition of excessive transpiration and diminished absorption. In other words, the ratio of transpiration to absorption is at a maximum. The existence of this high transpiration ratio throughout the year and its accentuated value during the resting period produces a condition very precarious to plant life.

*TABLE III—WIND VELOCITY IN MILES PER HOUR.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1881..........	130	110	132	120	78	94	60	90	90	165	108	170
1882..........	126	120	118	120	100	95	92	80	113	100	98	116
1883..........	152	126	150	88	96	128	80	94	108	94	100	132
1884..........	130	130	122	92	100	74	96	88	96	92	128	96
1885..........	120	108	128	90	98	100	96	92	90	94	95	96
1886..........	122	138	115	110	88	94	84	88	100	89	99	100
Total mean.	130	122	127	103	93	86	85	89	99	105	105	118

* Data from Mt. Washington.

It is not surprising in view of this great desiccation and high transpiration ratio, to find that alpine plants have suffered adaptive modifications which tend to mitigate these harmful effects. The excessive development of cutin in epidermal layers, producing the sclerophyll type of leaf, high development of the tomentose character in several species, absence of dorsal stomata, reduction in the number of ventral stomata, the reduction in number and size of transpiring surfaces, and the cespitose habit of growth are all evidences of protective adaptations and adaptations without which this mountain flora would be unable to withstand the adverse conditions of its environment.

B. EDAPHIC FACTORS.

Soil factors operate upon plants, not through the atmosphere but through the substratum in which they live. The soil being an anchorage as well as a source of food materials, its importance becomes at once very apparent. Schimper has considered the influence of soil and its properties so significant in the determination of the local distribution of plant societies that he has designated those societies so determined edaphic formations and the soil and its properties edaphic factors.

The soil and its influence has long been a subject of interest and investigation. As early as 1836 Unger[1] studied its chemical nature, deciding that it was the all important factor in soil influence upon plant distribution. On the other hand Thurmann[1] in 1849 became the sponsor of the physical theory of soils as influencing the distribution of plant societies. From its variety of nature, and physical properties, the soil invites a variety of conditions in regard to food, heat, and moisture content. Of these factors it is perhaps the last whose influence is predominant in determining the physiognomy of plant societies. Upon this basis, the water content of the soil, Thurmann (1849) proposed a classification which was more fully developed later (1896) by Warming,[2] who divided plant societies into three classes, hydrophytes, mesophytes, and xerophytes, those plants inhabiting respectively soils rich, medium, and poor in moisture.

The source of soil water is primarily the rainfall of the region. Though we have no readings from Ktaadn, data from Mt. Washington can not fail to be pertinent. High as these mountains are they intercept moisture-laden clouds and precipitation is almost daily (see Table IV) and frequently excessive. A high precipitation is the result. (Cf. Tables V and VI).

TABLE IV—RAINY DAYS.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total per cent.
1884....	16	22	20	12	19	13	22	16	17	22	18	22	57.1
1835....	22	9	13	17	14	15	20	20	13	12	20	22	53.8
1886....	20	11	21	11	13	18	15	14	16	17	19	20	53.
Total mean	19	14	18	13	15	15	19	17	15	17	19	21	54.6

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[1] Unger F. Uber den Einfluss des Bodens auf die Vertheilung des Geachse.—Vienne 1836. Review. Ann. Sci. Nat. 8: II, 75-93. 1837.

[1] Thurman Jules. Essai phytostatique—quant a l'influence des roches sous-jacents. Paris, 1849. Review. Ann. Sci. Nat. 12: III, 335-343. 1849.

[2] Warming, E., Okologische Pflazen geographie. Knoblanch translation, p.116 Berlin, 1896.

TABLE V—PRECIPITATION IN INCHES.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1873....	3.39	5.2	5 81	2.72	4.55	3.2	13.54	5.81	13.66	9.23	5.5	5.95	78.56
1874....	4.4	2.47	6.71	5.74	6.53	13.44	7.97	9.51	5.52	2.96	2.34	3.07	70.66
1875....	1.82	1.	2.13	2.	2.5	6.83	7.4	7.95	11.34	6.3	2.67	3.84	55.78
1876....	2.8	3.5	6.21	3.12	7.83	9.32	14.51	2.2	14.89	3.21	3.49	6.48	77.56
1877....	2.06	.33	11.64	3.4	3.72	8.78	11.27	11.11	2.79	7.75	17.55	6.01	86.41
1878....	8.54	5.88	10.66	23.41	9.28	7.67	11.	11.35	7.37	5.78	4.78	8.77	114.49
1879....	7.13	7.01	7.51	6.79	4.4	11.84	10.23	9.55	6.53	5.03	9.53	5.56	91.11
1880....	4.24	2.56	4.87	3.47	5.51	5.86	7.24	5.82	15.23	7.96	9.37	7.80	79.93
1881....	3.94	6.62	8.51	5.08	12.5	7.03	9.93	11.96	6.13	18.38	15.10	15.15	120.33
1382....	7.20	5 94	14.52	11.20	8.91	11.4	10.03	2.81	13.32	6.19	3.25	2.64	97.41
1883....	4.16	5.65	4.18	6.29	9.10	11.30	11.14	6.66	6.9	5.55	3.72	2.66	76.71
1884....	2.45	7.55	4.16	3.29	9.54	8.08	2.39	8.63	7.58	12.91	7.99	4.7	100.78
1885....	5.49	1.87	.95	2.66	2.29	11.34	11.34	14.26	5.56	11.11	6.67	4.83	78.37
1886....	4.5	9.03	3.11	3.36	3.25	6.07	6.3	8.34	8.52	5.09	6.48	3.10	64.03
Total mean	4.46	4.40	6.50	5.88	6.43	8.72	11.08	8.10	8.95	7.68	6.96	5.61	85.15

TABLE VI—TOTAL MEAN PRECIPITATION AT ORONO. ALT. 150ft.

Year.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
1868-1900..	4.37	4.15	4.24	2.82	3.64	3.62	3.33	3.57	3.35	4.07	4.44	3.73	45.33

A study of these tables brings out several important facts. It will be noticed that the greatest rainfall is coincident with the growing period, June-September, a fact very significant in the development of the flora. Upon this and its daily distribution is the presence of the mesophytic undergrowth, which extends far up toward the limits of the *Krummholz,* only explainable. While the precipitation is frequent and high, its retention is by no means complete. The thin residual soil, allowing the water to soon reach the underlying granite, permits a rapid drainage. The thick Alpine-Tundra topographical irregularities, and many adaptations for water retention in the lichens and mosses however raise this retention ratio. Yet, all in all, it is the frequency of precipitation rather than amount that determines the mesophytic effect.

C. BIOTIC FACTORS.

A general survey of the plant world convinces us of an internal and mortal combat. We see from purely physical reasons that no two plants can occupy identical soil at the same time. From this necessarily arises a struggle for supremacy of position leading to a more favorable life relation. This struggle for existence is threefold. It may take place between individuals of the same species, between individuals of different species, and thirdly between plant societies. The line along which two societies meet is pronouncedly that of greatest aggression and struggle. It is along this tension line that the ecologist finds his most interesting study. For it is here, above all other places, that he may analyze the influencing factors and study the encroachment of one society upon another. Where the conditions for life are most favorable, the struggle of society with society, species with species, and individual with individual is the most severe and the tension line becomes the battlefield of mortal combat.

The influence of animals upon the plant life here is at a minimum. The absence of man and the slight effect of the winter grazing of droves of caribou, which come from the north to feed upon the lichens and heaths laid bare upon the higher slopes, leaves the flora of the mountain in a delightfully primeval state.

D. THE HISTORICAL FACTOR.

This factor deals with and involves a question of time. Hence it gives us a conception of movement and of change, for we recognize that our world is not one of statics but of dynamics. Nothing is fixed; all is movement. There is a continual and progressive change in the physiography of any region, a destructive and constructive cycle, tearing down there, building here. This progressive introduction of new physiographical conditions has brought about a corresponding succession of plant societies, a thing which must inevitably follow. This succession may of course be either progressive or retrogressive. Hence we have a continual readjustment of plant societies. Considered geologically all this movement has its temporary end, the pene plain for the land, the climax mesophytic forest for the plant society. I say temporary end, for epeirogenic or orogenic movements would rejuvenate the physiography and bring about a readjustment of the plant societies and inaugurate the redevelopment of the climax forest. It is evident then that the stage in the plant cycle at any one period is directly dependent upon the then existing physiographic stage.

The purely geological phase of this factor must not be neglected. If we speak of the physiographic factor in terms of years, so must we speak of the geological in centuries, embracing vast periods of time. It is in the latter phase of this historical factor that we have found the origin of the Ktaadn flora.

Having discussed the various factors instrumental in the determination of the plant aspect of the mountain, we may now take up in detail the study of the many plant societies which give it its characteristic tone. But as we pass to this treatment let us have clearly in mind that it is to the interaction of these complex climatic, edaphic, biotic and historical factors that the mountain presents its varied plant physiognomy.

VI. The Plant Societies.

The study of the historical factor and the origin of the Ktaadn flora showed that the life of the plant covering of Ktaadn has been one of progressive dynamics. Further, the plant societies, as they are seen there to-day, represent the various and successive steps of this horizontal development. For any one place, however, the story has been one of vertical succession. So by the one the other may be interpreted. It is the object of this section of the paper to trace the genetic development of these plant societies in so far as it is possible.

A. ROCK SOCIETIES.

In the discussion of the physiography of the mountain it was noted that Ktaadn is one solid mass of granite. With such a vast rock exposure, it offers an admirable opportunity for the genetic study of this type of society. It is on the higher peaks, the crest, and the upper talus slopes, where vegetation has yet been unable to encroach, that we may best study the pioneer plant society.

(a). *The Crustaceous Lichen Society.* Along the crest, where frost action splits the red granite into vast blocks which, losing their perpendicularity, still remain as oblique projecting plates in chaotic desolation, we find the bare rocks with only a crustaceous lichen covering. The most abundant and pioneer form is *Buellia geographica,* of universal distribution. With its yellowish-green cast it gives a tone most lurid to the vast talus slopes and weathered crest. The growth of *Buellia,* as well as other forms, is centripetal and as the lichen expands in circumference it dies behind at the center, becoming black. There are several other less prominent associated forms.

Beginning in small patches these crustaceous lichens expand into mats and mats into islands as it were. Finally uniting they may cover entire boulders. Needing no soil the crustaceous lichen is essentially a lithophyte. To fit it to this extremely xerophytic and precarious life, it must first be able to form an attachment to the rock upon which it lives and secondly it must have ability to obtain food from its rock substratum the air. By means of holdfasts its position is secured. From rain and drainage various compounds may be absorbed. Again the symbiosis of fungus and alga in the lichen perhaps fits it as a pioneer form. Finally the ability to dry up and suffer no injury, reviving with the next rain, admirably fits the lichen to its xerolithophytic life. Several foliaceous forms may accompany this crustaceous covering. *Umbilicarias* are not uncommon even at the very summit, yet they never become conspicuously prominent. Upon this lichen mat, and even upon the bare rocks, occur several species of lithophytic mosses. *Andreæa petrophila, Rhacomitrium sudeticum* and *R. aciculare* may be mentioned.

The wash, decay, and disintegration from the lichen-moss-mat lodging in angles where rocks adjoin, in cracks, crevices, or niches, gradually form a slight soil and prepare the way for plants whose demands are higher. To this organic decay must be added the more efficient weathering which so disintegrates the granite that it often crumbles beneath the feet. Under the action of these two forces a residual soil is soon formed and new plants make their appearance.

(b). *The Reindeer-Iceland Moss Society.* In these rock angles and cracks, only a very shallow soil having accumulated, the fructicose lichens now appear. As pure growths they never form mats of large extent for, having no means of secure attachment, they are easily dislodged by heavy winds and rains and washed away. So the excessive development of this society as such is retarded. *Cladonia rangiferina, C. rangiferina alpestris,* and *Cetraria isandica* may be mentioned as the characteristic components. With them are associated several less prominent forms. *Cladonia cristatella* may be noted. Several mosses may also attain prominence in this society. *Bazzania trilobata* is not an uncommon form, frequently forming extensive patches.

This mat once established becomes a center of accumulation, retaining the detritus of wash and erosion as well as that of local plant decay which is not a little, for these lichens and mosses grow above, dying down behind in a manner not unlike that of *Sphagnum.* Very soon a sufficient soil exists and still higher ecological forms have their introduction.

(c). *The Alpine Tundra.* With the accumulation of soil the food material becomes greater and of a higher nature. The grasses and sedges first appear and, spreading with their interlacing roots, soon make the precarious lichen-moss mat a fixity. *Hierochloë alpina, Agrostis rubra, Deschampsia flexuosa, Carex vulgaris hyperborea, C. canescens alpicola,* and *Juncus trifidus* are perhaps the most characteristic of these forms, pioneers of the Alpine Tundra. Many less prominent forms are associated. By the coalescence of mats a turf is formed. Some of the lichens still persist but have been largly forced out. Many mosses are also common at this stage, probably as pioneers rather than relicts of a former stage. *Polytrichum juniperinum* and *Mielichhoferia nitida elongata* form dense isolated patches, while *Polytrichum commune* and *P. Ohioensis* are more ubiquitous forms.

With the grasses and sedges, possibly earlier, appear *Lycopodium Selago, L. annotinum pungens, Arenaria grœnlandica,* and *Potentilla tridentata.* Edaphic conditions seem to largely determine the nature of the pioneer forms. *Prenanthes trifoliolata, P. Bootii, Solidago macrophylla,* and *Scirpus cæspitosus* are associated forms less common but not rare.

The heaths follow next. *Empetrum nigrum, Vaccinium Vitis-Idæa, V. pennsylvanicum angustifolium, V. uliginosum, Diapensia lapponica* are among the pioneers. *Ledum latifolium, Kalmia angustifolia, Kalmia glauca, Arctostaphylos alpina,* and *Rhododendron lapponicum* are of less frequency but are associated forms. Of more local occurrence are *Bryanthus taxifolius, Loiseleuria procumbens,* and *Cassiope hypnoides* being largely restricted to the lower slopes.

The Alpine Tundra mat (Figs. 2, 3) is widely distributed, covering more than one-half the upper part of the mountain. (Fig. 2). On the crest, summits, and table-land it reaches perhaps its highest and most characteristic development, yet it extends down upon the "saddle," spurs and higher slopes, and is in a very characteristic state upon the floor of the North basin, for reasons which have been sufficiently set forth above in our discussion of the origin of the flora. Its composition is not uniform, varying much in its species with edaphic conditions. In one place *Vaccinium Vitis-Idæa* is dominant, *Diapensia lapponica* characterizes the alpine mat in another, *Arctostaphylos* in another, *Ledum latifolium* in still another, while still again the mat may be almost wholly peopled by *Juncus trifidus* and the heaths conspicuously absent.

Along the brow of the "tableland," "saddle," and various spurs a very different condition exists and consequently the plant succession is modified. Here disintegration is rapid and drainage excessive. For several feet, in places yards, back from the brow a gravelly granitic soil of four or five inches in depth is destitute of vegetation. The crustaceous lichen stage is absent, as are also the fruticose forms which are excluded on account of their inability to take root and hold their position. The conditions then for plant life are very severe and only particularly adapted forms are enabled to withstand these strenuous conditions. *Arenaria grœnlandica* with its multitudinous rootlets and branching habit, *Solidago virgaurea alpina* and *Potentilla tridentata*, similarly provided, are pioneers upon this very xerophytic habitat. *Diapensia lapponica,* with its cushion habit, is also a pioneer and reaches here its greatest development, being characteristic of this stage. *Salix uva-ursi, Rhododendron lapponicum, Arctostaphylos alpina* follow closely upon *Diapensia* forming almost a definite zone. These forms, on passing back from the brow, soon give rise to a definite mat in which occurs *Vaccinium uliginosum* which latter becomes here the character plant of the Alpine Tundra. It is accompanied by *Empetrum nigrum, Ledum latifolium, Kalmia glauca,* and *K. angustifolia.* Several grasses and carices, *Juncus trifidus* and *Scirpus cæspitosus* now appear and, with several mosses, make the Alpine Tundra complete. It was noticeable that as the mat developed *Diapensia* gradually disappeared, being entirely absent when it reached its characteristic development.

(d). *The Krummholz.* With the formation of a sufficient humus to support higher forms, trees encroach upon the Alpine mat. *Betula papyrifera minor* and *B. glandulosa* are the first to make their appearances. They show a high development of the *Krummholz* habit, lying prostrate upon the mat. Locally *Larix americana* and *Juniperus communis nana* are the pioneers, especially is this true upon the spurs. Following these pioneers comes the Picea-Abies combination. Islands of spruce and fir deploy as advance guards of the forest proper (Fig. 2). Which of these two trees is the pioneer, that is the more xerophytic, is problematical. The evidence is contradictory. Three possible theories may be presented: 1. *Picea* is the xerophytic pioneer, followed by *Abies* as the conditions become more and more mesophytic. The evidence from the Great basin, North basin, and clearing societies would favor this idea. 2. *Abies* may be the more xerophytic. This idea finds little support except in places where *Abies* is the dominant species. 3. Neither is to be considered as the pioneer. It is more a question of preoccupation. The first to appear stays and there is no question of succession. This theory seems to explain very satisfactorily all conditions, especially that on the "tableland" and "saddle," where we find *Picea* dominating in one place and *Abies* in another.

At the present time the *Krummholz* forest covers the upper slopes of the various spurs, a greater part of the "tableland," practically all of the "saddle," and extends far up toward the summits, scattered trees being noted within a hundred feet of the top (Figs. 2, 3). It is then only a question of time when the entire mountain, where physically possible, may be forest clad. That is, this possibility is not climatically excluded but only edaphically retarded.

The composition of the *Krummholz* is most astonishing. Associated with the *Picea* and *Abies* are *Betula papyrifera cordifolia, Pyrus americana,* and *Amelanchier oligocarpa.* On the forest floor *Cornus canadensis, Chiogenes serpyllifolia, Coptis trifolia, Linnæa borealis, Maianthemum canadense, Clintonia borealis, Trientalis americana, Oxalis acetosella, Gaultheria procumbens, Moneses grandiflora, Listera cordata, Aspidium spinulosum dilatatum, Streptopus roseus, Aster macrophyllus, Carex trisperma, Hylocomium splendens, Hypnum crista-castrensis, H. Schreberi,* and *Dicranum* all abound and in rich profusion. These forms, and many others which might be mentioned, are all common to the climax mesophytic forest of the region. Further, most of these forms are characteristic of the mesophytic forest of low altitudes. It seems then that the *Krummholz* forest is almost as mesophytic as the Picea-Abies combination of the Great basin and surrounding country, which very evidently is the climatic mesophytic forest of this district. The nature of this forest will be referred to a later discussion.

In other words, no true alpine conditions or climatic timber lines exist upon Ktaadn. The first is probably excluded by the excessive moisture, its happy distribution, and abundant retention, making the alpine conditions quite mesophytic. The so called timber line, a popular rather than scientific delimitation, is purely physical and not a climatic demarkation.

The conditions along the tension line between the *Krummholz* and the Alpine-Tundra are very suggestive. As the forest advances and takes possession of the mat, many forms are driven out, presumably by light starvation. Other forms are better able to adapt themselves and so remain as relicts of the Alpine mat.

Among these relict forms in the *Krummholz* may be mentioned *Vaccinium pennsylvanicum angustifolium, V. uliginosum, V. Vitis-Idæa, Kalmia angustifolia, K. glauca,* and *Ledum latifolium.* But as the forest advances and the conditions become mesophytic, these relicts gradually disappear, forced out by the other forms better adapted to the new conditions of soil and decreasing light supply beneath the canopy of thickly and almost impenetrably woven branches of spruce and fir.

Of the forest itself it is not the trees which first encroach upon the alpine mat, but rather the lower forms which, pushing out gradually advance the tension line before the forest which closely follows. This advance zone is never very conspicuous, but among its members *Cornus canadensis, Maianthemum canadense, Coptis trifolia,* and *Linnæa borealis* may be mentioned.

The North Basin. Under this discussion of the *Krummholz* it may be advantageous to introduce the conditions as they exist in the North basin. This amphitheatre of over 320 acres presents an appearance even more xerophytic and alpine than some of the upper limits of the mountain itself. A great morainic dump of granite boulders, forming kettles, completes the picture of chaotic desolation. All this is in vivid contrast with the Great basin whose altitude it approximates and which supports a well developed *Picea-Abies* mesophytic forest. The Alpine-Tundra here reaches an extreme yet characteristic development, the stages of succession being practically identical with those of the crest and summits. Here the *Krummholz* also reaches an excessive development, lying in most places perfectly prostrate and gnarled and twisted to a high degree. *Picea* is noticeably predominant, *Abies* being conspicuously absent.

At the mouth of the basin, as described above, is a moraine of medium size. The Alpine-Tundra mat and the prostrate *Krummholz* cover its northwestern side. The opposite face fronting southward is, on the other hand, well clothed by a *Picea-Abies* forest. Why has this basin and its slopes this extreme xerophytic condition? It will be recalled that in the discussion of the origin of the place it was stated that this basin with others was the seat of local valley glaciers, and a theory advanced suggesting that the North basin was perhaps the last to see glacial recession, hence the last to become vegetated. The highly alpine condition of this basin is then perhaps due not to climatic causes but to the recent disappearance of the local glacier retained within its walls. It is only a question of time when the record of glaciation in this basin will be deeply hidden by a *Picea-Abies* mesophytic forest as it is in the South basin to-day.

(e). *The Picea-Abies Forest.* The theory has been advanced that the *Krummholz* is a mesaphytic combination and the evidence has been drawn from the *Picea-Abies* forest of the region. It may be well now to speak of this forest more in detail. In our discussion of climatic factors we have noticed that this combination, the resultant of a complex of factors, is the climax mesophytic forest type of this region. The principal trees are the black spruce, *Picea nigra*, and the fir-balsam, *Abies balsamea*, which form the forest stand. Associated, but largely confined to water courses, are *Betula papyrifera cordifolia*, and *Alnus viridis* which form threads of light green woven into the darker shade of the coniferous forest. The arbor-vitae, *Thuya occidentalis*, occurs sparingly along water courses at the outer border of the Great basin. It was recorded at an altitude of 2,8[illegible] feet.

The forest floor is covered with a dense and continuous mat of mosses consisting not of a multiplication of species but chiefly of three forms, *Hypnum Schreberi, H. crista-castrensis*, and *Hylocomium splendens* which recur continually in this thick moss carpet, covering rocks and logs alike with an uninterrupted mat of green. In this carpet also occur several liverworts, *Ptilidium ciliare* and *Bazzania trilobata* being the most prominent. On exposed rocks Dicranums are not uncommon. Through this moss carpet, arising from the rich humus below, extends a variety of forms. *Pyrus americana, Amelanchier oligocarpa*, and *nemopanthes fascicularis* are prominent, the abundance of seedlings of the former being especially noticeable. Other less common shrubs are: *Ribes prostratum, Viburnum pauciflorum* and *Aralia nudicaulis*. *Taxus canadensis* occurs abundantly and in its characteristic habit of growth. Other forms, which with the moss carpet constitute the forest floor, are: *Oxalis acetosella, Coptis trifolia, Maianthemum canadense,* *Cornus canadensis, Trientalis americana, Streptopus roseus, S. amplexifolius, Vaccinium canadense, Clintonia borealis, Lycopodium lucidulum, Phegopteris polypodioides, P. Dryopteris, Listera cordata, Moneses grandiflora, Goodyera tesselata,* and an abundance of *Monotropa uniflora* and *M. Hypopitys,* giving these woods a very mesophytic aspect.

This mesophytic forest covers the Great basin, South basin, the Northwest basin, most of the outer slopes and ridges, and extends far out into the lowlands about the mountain. Ascending the basins, the trees gradually become smaller until at the base of the last long precipitous ascent, the walls proper of the basins, there is an apparent tree line which skirts the base; especially is this noticeable in the Great basin. (Fig. 5). This "timber-line," so called, is more apparent than real and has its only delimitation in large trees. The walls of these basins are much subjected to slides of rock and gravel, and snow in spring, which rush down the slopes and strike at the base with tremendous force. In this plunge these avalanches sweep all before them being checked only by the larger trees at the base. The multitudinous repetition of these slides has thus formed a line of trees which represent not a climatic but an avalanche timber-line. Trees soon appear on these slides and within a few years they become reforested. The birch, *Betula papyrifera cordifolia,* is the most abundant on the slope trees. It seems, on account of its flexibility, particularly adapted to this precarious slope life. This very property of bending without breaking doubtless explains its predominance as a slope form. Mixed with it is the alder, *Alnus viridis,* and frequent spruce and fir. These trees form a continuous forest growth with the mesophytic forest of the lowlands and, gradually diminishing in size, extend up to the "tableland" and "saddle," there joining the *Krummholz* and reaching far up toward the summit. Most of the spurs, notably the Northern ridge, are also covered by this forest. Where slides are rare the composition is largely spruce and fir and would never suggest a timber-line, for the decrease in size is gradual. This same apparent "timber-line" exists upon the western and southwestern slopes. Harshburger[1] states that this timber-line is here at 3,700 feet and so maps it in a very diagramic way. Williams[2] says the timber-line barely averages 3,100 feet in the great basin and 2,200 on the southern slopes; he adds: "this last being partly due, however, to their excessive steepness."

It would appear from the above discussion that this so-called "timber-line" is more apparent than real and has no relation to climatic conditions, as most writers have implied, but is largely determined by the steepness and the resulting avalanches on the slopes and is in reality the limit of large trees. It was shown above that the limit of the *Krummholz* upon the upper slopes was not climatic but that the question of time and edaphic conditions had alone retarded its further advancement. There is then no true climatic timber-line upon Ktaadn any more than upon the other mountains of Maine, Black Cap, Waldo, Desert, and others of far lower altitudes, and it is largely the element of time that retards the forestation of the very summit.

(f). *The Roches Moutonées Society.* In the Northwest basin are two rock hills rising some 20-25 feet above the general level of the shelf. With their sloping sides and flat glaciated tops they present a plant society most unique. Bare in places, they are almost entirely covered with a typical heath formation. The drainage is excessive and the conditions extremely xerophytic. The flat tops are dominated by *Kalmia angustifolia, Cassandra calyculata,* and *Ledum latifolium.* It bears a most striking resemblance to an old sphagnum bog. In places tussocks of sphagnum appear and associated with it is *Vaccinium Vitis-Idæa. Cladonia rangiferina,* and its less common variety *alpestris* are abundant. Around bare rocks *Vaccinium uliginosum* abounds. Little remains to tell of the early stages of this unique association. It is however clear that it has passed through the crustaceous-lichen and reindeer moss stages. The heath stage corresponds in sequence to that of the Alpine-Tundra which for some reason has failed to develop here.

Covering the steep sides of those *roches moutonnées* and the basin in general, is the mesophytic *Picea-Abies* forest with its

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[1] Op. cit.

[2] Williams, E. F. Floras of Mt. Washington and Mt. Ktaadn. Rhodora 3: 1600 65. 1902.

characteristic undergrowth. Advancing from the edge of this forest to the flat glaciated tops are islands of *Krummholz* spruce and fir with single trees beyond. In several places the heath is thus completely spanned. The fusion of these islands makes the destruction of this heath in the near future a certainty. Why this rock society is so extremely xerophytic, perhaps even more so than the summits, can perhaps be explained by no other reason than by its excessive dryness due to an almost perfect drainage. There is also little retention of water, and humus accumulation is necessarily slow. These conditions all contribute to extreme xerophytism at first, but once a soil is formed succession will follow as rapidly as upon the mountain.

B. THE ALPESTRINE MEADOW SOCIETIES.

This plant society furnishes one of the strongest evidences of the edaphic theory that has ever come under the writer's observation. On a substratum, otherwise very xerophytic and which would normally support an Alpine-Tundra society, occurs, by virtue of its location and exposure, a mesophytic Alpestrine meadow society. Situated at the base of the dripping west walls of the North basin, and so presenting a warm south and southeastern exposure, it possesses in these two conditions edaphic factors which determine its existence.

Passing out from the base of the cliff, several well defined plant zones are successively traversed. Situated at the base of a precipitous cliff and upon a sharp talus slope the soil is largely accumulated from the slopes above. By snow-slides and heavy rains a residual soil of gravel and humus is washed down and forms the substratum for these plant societies. Three very distinct stages or zones appear to-day. By a study of this horizontal zonation we may arrive at an understanding of the vertical succession.

(a). *The Pioneer Stage.* Upon the first accumulation of soil which lodges in cracks, crevices, gorges, on miniature shelves, and at the base of the dripping walls, *Scirpus cæspitosus* first makes its appearance, and often becomes very abundant. *Campanula rotundifolia,* forming vast beds, follows *Scirpus.* With it is associated *Solidago Virgaurea alpina.* (Fig. 6).

Potentilla tridentata next appears to work its way into this society. *Potentilla fruticosa* is often associated, but never abundantly enough to be dominant. *Arenaria grœnlandica, Carex scirpoidea, Luzula spadicae melanocarpa, L. spicata* and *Juncus articulatus* are less prominent but normally associated forms. This plant covering though sparce now acts as a retainer of soil and humus washed from above and also adds to it by its own decay. A humus and a power of hygroscopicity soon develop sufficiently to support a less xerophytic society and the next stage soon follows.

(b). *The Meadow Stage.* Determined by the increasing water content of the substratum the meadow encroaches with rapidity upon the pioneer society. In many places the meadow has entirely replaced it extending up to the very base of the walls themselves (Fig. 6). It is thus that the stage once dominant is now being gradually replaced by another of a higher ecological type: a more successful society in the struggle for existence. At the foot of the southwest wall of the Northwest basin the pioneer society is a feature of the past, the Alpestrine meadow entirely skirting the dripping face of this precipitous wall.

Among the first meadow forms to appear in the pioneer society are *Castilleja pallida, Prenanthes trifoliolata, Aster acuminatus, A. radula, A. umbellatus*, and *Anaphalis margaritacea.* Several of the grasses now appear. *Calamagrostis canadensis, C. Langsdorfii*, and *Bromus ciliatus* occur in great profusion, *Glyceria nervata, Agropyaum violaceum*, and *Agrostis rubra* are also common. With these grasses are associated *Heracleum lanatum, Habenaria dilatata, Arnica Chamissonis, Viola blanda, V. canina*, and *Solidago macrophylla.* As a whole this society presents a striking meadow aspect, and one which appears quite out of keeping with the surroundings. This society is quite extensive, occurring wherever these conditions are repeated. Here and in the Northwest basin, however, it reaches its typical development. In this meadow society accumulation from wash and decay are continually in progress. With fit conditions we have the advent of another society.

(c). *The Shrub Stage.* With higher food demands this stage follows only when, as in our lowland natural meadows, these conditions are fulfilled. In several places this stage has quite replaced the meadow, extending up to the very base of the cliff. The first form to appear in the meadow is *Diervilla trifida* which later becomes the character shrub of this stage. *Spiræa salicifolia latifolia* follows, often becoming very abundant. Associated but secondary forms are: *Rubus strigosus, R. canadensis, Lonicera cærulea,* and *Ribes prostratum. Alnus viridis* soon makes its appearance and becomes the dominant bush. With it are *Cornus stolonifera, Nemopanthes fascicularis, Amelanchier oligocarpa, Prunus virginiana, P. pennsylvanica* and *Pyrus americana.* With these shrubs is associated a mesophytic undergrowth. *Phegopteris Dryopteris, Asplenium filix-foemina,* and *Aspidium spinulosum dilatatum* all occur in greatest profusion. Associated forms are *Streptopus roseus, S. amplexifolius, Clintonia borealis, Trientalis americana, Coptis trifolia, Galium triflorum, Viola blanda, and V. canina.* These forms precede the mesophytic forest which encroaches below. This latter society has been discussed above and need only be mentioned here. One fact seems very evident; whatever the pioneer stage, the ultimate is the climax forest of this region.

C. THE POND-BOG SOCIETIES.

The scene of general and local glaciations, the environs of the mountains are dotted with ponds whose origin is unquestionably morainic. A marked variation in size and depth presents a variety of conditions which closely control the plant life of these upland ponds. The low mean temperature of the water and the destructive spring freshets preclude an abundant acquatic vegetation in those ponds, Cowles, Davis, and Chimney, which are situated at the base of the slopes and receive the brunt of these spring devastations. In the ponds this zone is the mesophytic climax forest. Sometimes an interremoved from these destructive agents, a slight aquatic vegetation sustains itself.

(a). *The Pond Societies.* The shores of these ponds are rock strewn and slope off to some depth. A narrow zone of alder and birch, *Alnus viridis* and *Betula papyrifera cordifolia,* fringe the ponds, coming in many localities to the waters edge. Behind vening zone of amphibious forms borders the water's edge. Again a heath formation may fringe the shores. Some of the ponds, located several miles from the mountain, are bordered by a bog-like zone in which *Cassandra calyculata, Kalmia angustifolia, Ledum latifolium, Myrica Gale, Sphagnum* in profusion, *Drosera rotundifolia, Sarracenia purpurea,* and *Pellia epiphylla* abound. The presence of this sphagnum bog flora, characteristic with the exception of *Pellia,* under such excellent conditions of drainage, would seem to have its explanation in a temperature factor, as suggested by Kihlman[1] and not by the accumulation of humus acids as Schimper claims.[2] Similar short features obtain at Davis and the two small ponds of the Northwest basin.

Lake Cowles shows perhaps the highest development of an aquatic flora, yet it is much limited as to species and individuals. In the shallow water of the rocky shores grow *Isoetes heterospora,* its highest and most northern station, *Isoetes echinospora Braunii, Potamogeton confervoides, Lobelia Dortmanni, Zizania sp., Nuphar odorata minor,* and *Nymphæa Kalmianum.* These forms are never in enough abundance to be a potent factor in the life history of the pond.

Chimney pond, on the other hand, has, as far as the writer was able to observe, no acquatics yet it is bordered by an interesting zone of amphibious forms. Among these may be noted *Pellia epiphylla* which covers all available space at the water's edge. *Scirpus cæspitosus, Carex saxatilis,* and *Carex scabrata. Sphagnum* is present, but occupies a zone farther from the water's edge. In this fringing meadow-like zone also occurs *Vaccinium oxycoccus, Kalmia glauca, Aster radula, A. acuminatus* and several species of violets. Intermediate between this zone and the mesophytic forest occurs a belt of *Spiræa salicifolia latifolia* and *Alnus viridis.* The life history of these ponds is doomed to be

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[1] Kihlman, A. O. Pflanzen biologische studien aus Russich-Lappland, acta. soc. pro Fauna et Flora Fennica 6: 1890—abstract Flora 75.

[2] Schimper, A. F. W. Pflanzen geographie auf Physiologische Grundlage. Jena 1898.

long, leading doubtless to the sphagnum bog. Their destruction will be largely due to detritus washed from above.

A small pond in the Northwest basin, situated at the base of heavily wooded slopes, and receiving some residuum, is now nearing its temporary climax. Its life history will be comparatively short, leading to a small natural meadow. The shores are now bordered with a fast encroaching meadow, and similar islands almost spanning the pond make its future very evident. Upon the islands spruces have already appeared. In this meadow society grow *Scirpus cæspitosus, Carex rigida Bigelovii, Aster radula, Aster umbellatus, Lycopodium inundatum,* and many other less prominent forms.

(b) *The Sphagnum Bog Society.* In the great basin, near the outlet of Lower Basin pond, is located a small sphagnum bog. In a deep morainic depression, and isolated from the receipt of much detritus, its life history has doubtless been of great length. With the exception of a few open spots (Fig. 9) the once rocky shored pond is completely captured by sphagnum and its associated forms. By a study of these open places we are able in a measure to interpret the past order of succession, for we have here in miniature what presumably took place in the bog as a whole. The *Sphagnum* advances from the edge, dying down below. As it grows above it continually opens the way for further encroachment. The opening is finally spanned and a soil is formed. Upon this *Scheuchzeria palustris* appears, even before the substratum reaches the surface. As the soil reaches the surface *Drosera rotundifolia* and *D. longifolia* come in. As the *Sphagnum* continues its growth and the condition becomes drier *Sarracenia purpurea* appears. Associated with it are *Vaccinium oxycoccus* and *Smilacina trifolia.* With still drier conditions *Eriophorum gracile, Carex trisperma,* and the characteristic *Carex pauciflorum* become constituents of the bog flora. The heaths next appear. *Cassandra calyculata, Kalmia angustifolia, Kalmia glauca,* and *Ledum latifolium* are abundant, occurring in the order named. With these, *Pyrus arbutifolia* and *Viburnum cassinoides* are common. Other forms whose place in this succession was undeterminable but which are very significant are *Empetrum nigrum, Vaccinium uliginosum,* and *V. Vitis-Idaea.*

Upon the bog, trees now make their encroachment. *Picea nigra* is the pioneer. Associated with it, but coming later and less abundantly, are *Thuya occidentalis* and *Larix Americana.* In places this advancing forest zone is strongly *Thuya* and seems to be associated with the old rocky inlet. The remaining four-fifths of this border zone is dominantly *Picea.* When this zone closes in upon the bog, as it already has for some distance, the conditions within are constantly made more and more mesophytic and we have a mesophytic undergrowth advancing from the surrounding mesophytic climax forest. Among these mesophytic forms which closely follow the advance of the spruce are *Coptis trifolia, Trientalis americana, Clintonia borealis, Cornus canadensis, Chiogenes serpyllifolia, Trillium undulatum,* and *Osmunda cinnamomea.* The characteristic mesophytic shrubs *Nemopanthes fascicularis* and *Amelanchier oligocarpa* are also present.

The entire absence in the bog of orchids such as *Calopogon pulchellus, Arethusa bulbosa, Pogonia ophioglossoides,* and *Habenaria hyperborea,* so characteristic of sphagnum bogs of lower altitudes in Maine, seems a peculiar fact of distribution. Isolation has doubtless precluded their appearance.

The future of this bog is very evident. With the continual advance of the mesophytic forest, the bog will gradually disappear and the climax forest will one day blot out its history.

The strong mountain affinities of this bog flora may be now noticed. The possession, in common with the mountain flora, of the majority of the typical bog forms, especially *Vaccinium uliginosum, V. Vitis-Idaea,* and *Empetrum nigrum,* would seem to strongly indicate an identity of physiological conditions and suggest a common cause. We have already shown that the vegetation of the higher slopes was probably subjected to a high "transpiration ratio" due to a minimized absorption and an accentuated transpiraton. Similarly this high "transpiration ratio" exists in the bog and in the Arctics, and in all these varied habitats there is a striking identity not only specifically but ecologically, thus demonstrating the physiological similarity of these habitats. Such soils are said to be physiologically dry, in other words xerophytic.

The exact cause of the low absorption in the sphagnum bog is yet problematical. Two theories are in vogue. Schimper claims[1] that the lack of drainage and aeration causes the abundant accumulations of humus and humic acids. These act upon the roots inhibiting absorptive power. Similarly these acids preclude nitrifying bacteria, thus making the soil poor in nitrogen. In all the absorption is reduced to a minimum.

The other theory, advanced by Kihlman[1] and applied to the sphagnum bog by Ganong,[2] would refer the cause of low absorption to the low temperature, making this strong ecological and specific resemblance of Arctics, mountains, and sphagnum bogs due to an identical factor. A set of readings by the writer substantiate the latter theory. We have also shown in some preliminary experiments that the low temperature of the bog is sufficient to reduce the absorption to a minimum.

The striking Arctic and Alpine affinity of the sphagnum bog and the border flora of mountain ponds, as noted above, leads to a very significant consideration, the question of their origin. It has been shown above that the Alpine flora is glacial in origin. In view of this fact and the floral similarity between the above plant associations and the Arctics, we are led to suggest a similar explanation. Whether these ponds have received their border floras through local and valley glaciation and avalanche action or by general glaciation, is of course entirely problematical. The former mode would, however, seem more probable and must, at least, have been a source of subsequent introduction of the Arctic-Alpine forms.

This hypothesis may be extended to extra montane ponds; in these, however, general glaciation must have been the source of this relict flora. Such a condition as described for Sandy Stream pond might well be taken as an example of the initial stages of such a plant society. The centripetal encroachment of this border zone would eventually develop a typical sphagnum bog, not unlike the one described above and quite identical with

[1] Op. cit.

[1] Opp. cit.

[2] Ganong, W. F. Upon raised peat bogs in the province of New Brunswick. Trans. Roy. Soc. Canada 3: II, 131-163. 1897.

a multitude of others scattered over the New England States. If we hold to the glacial relict theory to explain the Arctic affinity of the sphagnum bog flora, we are frequently confronted with this condition: that ponds presumably similar, i. e. glacial, and synchronous in origin, in the same region and subjected to identical general influences, have passed through the natural meadow on the one hand and the sphagnum bog on the other. It has been shown above that a difference in the duration of the life history may be called upon to explain this seeming contradiction. We must presume, however, the initial stage in both classes of ponds to have been similar if not quite identical to the condition characteristic, to-day, of the shores of Sandy Stream pond. The divergence was subsequent to the pioneer stage.

A rapid development, a short life history, made possible by the relatively quick distruction of a pond, favors the introduction of forms, which, in the struggle for existence crowd out the glacial relicts and result in a natural meadow. A slow succession, an extended life history, for opposite reasons, supports the development and extension of the glacial relicts and the consequential formation of the sphagnum bog.

VII. CONCLUSIONS.

In the preceding discussion we have traced the origin and genetic development of the Ktaadn flora and studied the various factors operative in determining the present plant physiognomy. An attempt has been made to show that the accepted principles of physiographic ecology hold in general in Alpine as well as in lowland regions. The discussion has necessarily been rather general; but it is hoped that it will lay the foundation for further and more critical study along similar lines. While most of the ideas presented are not new, some of them, perhaps, appear in a new relation and others, so far as the writer is aware, have here their first expression. The conclusions of the study may be summarized as follows:

1. The flora of Mt. Ktaadn is glacial in origin, adventive from Arctic Eastern Europe, by way of a former land connection, through Iceland, Greenland, and Arctic Eastern America.

2. The flora is determined by local climatic conditions repre-

senting not only ecologically but specifically the climatic societies of regions far to the north.

3. This striking ecological and specific similarity of the floras of high mountains, the Arctics, sphagnum bogs and borders of cold ponds, is probably caused by a physiological identity of the various habitats, a physiologically dry soil, a xerophytic soil. Such habitats are characterized by a high transpiration-ratio due to an identical cause, minimized absorption, probably determined, in part at least, by the retardative effect of low temperature.

4. The *Krummholz* of the "tableland," "saddle" and upper slopes is a depauperate mesophytic forest determined by the high precipitation, its happy distribution, and abundant retention.

5. There is no true climatic timber-line upon Ktaadn. The demarkation between Alpine-Tundra and *Krummholz* forest upon the higher slopes is merely edaphic. At the base of the precipitous lower slopes the so-called "timber-line" is in reality an avalanche line.

6. The length of the life history of a pond determines its temporary climax; if short the natural meadow, if long the sphagnum bog is the result.

7. Whatever the pioneer stage and the order and rate of succession, all the plant societies are progressing toward a common end, the *Picea-Abies* combination, the climax mesophytic forest of the region.

8. The glacial relict theory may be extended to account for the Arctic affinity of the sphagnum bog flora of extra montane pounds; while in local and valley glaciation may be sought the origin of the Arctic-Alpine flora which borders the shores of ponds and forms the sphagnum bogs within the Mt. Ktaadn region.

BIBLIOGRAPHY.

Aubert, A. B. Diatomées du Mount Ktaadn. Le Diatomiste *2:* 211. 1895.

Bailey, J. W. Account of an Excursion to Mt. Katahdin in Maine. Am. Jour. Sci. *32:* 20-34. 1837.

Briggs, F. P. Plants Collected at Mt. Ktaadn, Me. Torr. Bul. *19:* 333-336. 1892.

Chamberlin, T. C. A Group of Hypotheses bearing on Climatic Changes. Jour. Geo. *7:* 653-683. 1897.

Churchill, J. R. A Botanical Excursion to Mt. Katahdin. Rhodora *3:* 147-160. 1901.

Collins, J. F. Notes on the Bryophytes of Maine II. Katahdin Mosses. Rhodora *3:* 181-184. 1902.

Cowles, H. C. The Physiographic Ecology of Chicago and Vicinity. Bot. Gaz. *31:* 73-108, 145-182. 1901.

Cowles, H. C. The Influence of Underlying Rocks on the Character of the Vegetation. Bul. Am. Bur. Geog. *2:* 1-26. 1901.

Darwin, C. R. The Origin of Species. *2:* 151.

De Laski, J. Glacial Action on Mount Ktahdin. Am. Jour. Sci. *3:* III, 27-31. 1872.

Fernald, M. C. Bangor Daily Whig and Courier. Nov. 9, 1874.

Fernald, M. L. Vascular Plants of Mt. Katahdin. Rhodora *3:* 166-177. 1902.

Ganong, W. F. Upon Raised Peat Bogs in the Province of New Brunswick. Trans. Roy. Soc. Canada. *3:* II, 131-163. 1897.

Gray, Asa. The Flora of Japan. Scientific Papers *2:* 125. 1889.

Hamlin, C. E. Observations upon the Physical Geography and Geology of Mount Ktaadn. Bull. Mus. Comp. Zoo. Harvard *7:* 206-223. 1881.

Harvey, LeRoy H. An Ecological Excursion to Mt. Ktaadn. Plant World *5:* 226. 1902.

Harvey, Leroy H. An Ecological Excursion to Mt. Ktaadn. Rhodora *5:* 41-52. 1903.

Harshberger, J. W. A Botanical Ascent of Mt. Ktaadn, Me. Plant World *5:* 21-29. 1902.

Hitchcock, C. H. Geology of Maine. Sixth Annual Rept. Me. Bd. Agri. 1861.

Hitchcock, C. H. Canadian Plants Naturalized on Mt. Washington. Geo. of N. H. *1:* 572. 1874.

Hitchcock, C. H. List of Plants found in New Hampshire only on Alpine Summits. Geo. of N. H. *1:* 569. 1874.

Hooker, J. D. Outlines of the Distribution of Arctic Plants. Trans. Linn. Soc. Lond. (B) *23:* 251-348. 1861.

Kennedy, G. G., and Collins, J. F. Bryophytes of Mt. Katahdin. Rhodora *3:* 177-181. 1902.

Merriam, C. H. The Geographic Distribution of Life in North America. Rept. Smith. Inst. *1891:* 365-415.

Merrill, E. D. Notes on Maine Plants. Rhodora *1:* 185. 1899.

Sargent, C. S. Tenth Census Rpt. *9:* 494. 1880.

Schimper, A. F. W. Pflanzengeographie auf Physiologische Grundlage. Jena. 1898.

Scott, W. B. An Introduction to Geology. New York. 1898.

Scribner, F. L. Mt. Katahdin and its Flora. Bot. Gaz. *17:* 46-54. 1885.

Tarr, R. S. Glaciation of Mt. Ktaadn. Bul. Geol. Soc. Am. *11:* 433-448. 1900.

Thurmann, J. Essai phytostatique applique au Jura et aux contrées voisine ou étude de la despersion des plantes vasculaires envisagée principalment quant a l'influence des roches sous-jacent. Paris. 1849. Review Ann. Sci. Nat. *12:* III, 335-343. 1849.

Unger, F. Uber den Einfluss des Bodens auf die Vertheilung des Gewaechse nachgwilsen inden Vegetation des nordoesthlichen Tyrols. Vienne. 1836. Review—Martins—Ann. Sci. Nat. *8:* II, 75-93. 1837.

Upham. Glaciation of Mountains in New England and New York. Am. Geo. *4:* 165, 205. 1889.

Warming, E. Okologische Pflanzengeographie. Knoblauch translation. Berlin. 1896.

Whitford, H. N. The Genetic Development of the Forests of Northern Michigan. Bot. Gaz. *31:* 289-325. 1901.

Williams, E. F. Floras of Mt. Washington and Mt. Ktaadn. Rhodora *3:* 177-181. 1902.

Willis, B. Climate and Carbonic Acid. Pop. Sci. Mo. *1901:* 242-256.

EXPLANATION OF PLATES.

Fig. 1. Relief drawing of Mount Ktaadn as seen from the south.

Fig. 2. A view on the "Saddle" showing the Alpine-Tundra in the foreground and the *Krummholz* islands beyond. The height of the trees is shown by the camera case standing upon the crown of a prostrate spruce. The xerophytic structure of the *Krummholz* is clearly shown. The rocks rising through the mat are covered with lichens.

Fig. 3. The "Saddle," North Mountain, and the Northern Ridge beyond from the north slope of West peak. The covering of the Central Mountain by the *Krummholz,* its extension far up toward the northern summits, and its encroachment upon the Alpine-Tundra, are clearly shown. The conditions along the east brow of the "Saddle" are to be noted (cf. Fig. 2).

Fig. 4. General view on the "Saddle" showing the extension of the *Krummholz* passing without interruption down the west slope. View looking northwest from north slope of West peak. The point of the Northern Ridge is seen at the right and the Sourdnahunk Mountains beyond.

Fig. 5. "Avalanche-timber-line" at the base of the precipitous east wall of the South Basin. Chimney Pond in foreground.

Reprinted from Rhodora *3:* 1902.

Fig. 6. At the base of the northeast wall of the North Basin are seen the Alpestrine meadow societies. At the right is the "pioneer-stage" in which *Campanula rotundifolia* is dominant. At the left is the "meadow-stage" which follows the pioneer society. It has here reached up to the very base of the dripping walls.

FIGURE 4

FIGURE 5.

FIGURE 6.

The University of Maine Studies

No. 6

The Habits, Anatomy, and Embryology of the Giant Scallop, (Pecten tenuicostatus, Mighels)

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ORONO, MAINE
September, 1906

THE GIANT SCALLOP (*Pecten tenuicostatus*, Mighels.)

Most of the material upon which these observations were made was secured near Bass Harbor, Mount Desert Island, Maine, during the summer of 1901. Scallops in that region are fairly abundant but are now for the most part confined to water 40 fathoms or more in depth and are accordingly only to be obtained by dredging.

The scallop industry of Maine has undergone some changes since the appearance of Smith's (28) paper in 1889, but on the whole the changes are not very important. Some of the beds have run out so they are not profitable to work, and others have been discovered. Most of the good beds are now in water of from 40 to 60 fathoms and the scallops are somewhat smaller than in former years but the methods of catching them do not seem to have changed much.

The majority of lamellibranchs are adapted for burrowing more or less in mud or sand, are elongated, a shape that makes burrowing easy, and are provided with two adductor muscles for closing the shell, a desirable number for a shell and body of this shape. Such animals usually move very slowly, by thrusting the foot out into the mud, swelling its end to form an anchor, and then drawing the shell with the inclosed body to the position of the anchored foot. The shell may, or may not be capable of closing tightly, this being dependent in part upon how deep the animal burrows, and accordingly how well it is protected by the overlying mud, and in part by other conditions. Such forms, when disturbed, usually close the shell rather slowly and keep it closed until probable danger is past.

It is common for lamellibranchs that live in or about the mud or sand to make use of a current of water, which they throw from the shell by rather suddenly closing the shell, to free the mantle chamber of the dirt that gains entrance. The ability to form a strong current is much better developed in some forms than in others, the difference apparently depending upon the ease with which dirt can be dislodged. Thus in the fresh-water mussel which lives near the surface of the mud, with at least a portion of the shell valves protruding above the surface, the current produced is not nearly so strong as in the case of the soft-shelled clam, Mya arenaria, which lives deeply buried in the mud where the dirt that gains entrance has to be elevated some distance, and where mud in suspension, caused by waves and tidal currents combined, is frequently considerable.

Many forms of lamellibranchs when put into aquaria may move some distance along the bottom by thus squirting water from the shell. This is true with Yoldia, Angulus, Mya and a large number of other forms, and at least one form, Solenomya, (6) swims freely in the water by producing a somewhat similar current of water. As such a current [illegible] is primarily of service in cleaning the mantle chamber and [illegible] used habitually for locomotion by only a few forms, [illegible] quite possible that those forms that do use it for locomotion may have simply perfected an already existing mechanism primarily designed for another purpose.

Pecten is one of the ablest swimmers among lamellibranchs. The whole structure of the animal is modified for this purpose. The valves have become rounded in outline, flattened, and comparatively light. The anterior adductor muscle has been lost, and the posterior adductor muscle, which is very powerful, is situated near the middle of the body. The cartilage has become well developed so the shell may be opened quickly when the muscle relaxes, and the hinge line is straight so there may be no unnecessary strains in opening and in closing the shell. Each gill is attached by one lamella only, so water in the temporary cloacal chamber may be thrown out without injuring the gills, and the gills and margins of the mantle are provided with muscles to withdraw them from the margins of the shell when the shell is closed. Furthermore the margins of the mantle are provided with in-folded ridges and with circular muscles so it is possible to direct the current of water which issues from the shell in the required direction.

That Pecten makes use of its ability to swim in escaping from its enemies no one can doubt who has seen the shallow water species, Pecten irradians, scatter when disturbed. How it becomes acquainted with the presence of enemies is more a matter of surmise than of experiment. That the tentacles are exceedingly sensitive to touch is well known, and they may be of great service in detecting disturbances in the water. That the eyes are physically optical instruments that may produce distinct images there is every reason to believe, but it seems to be difficult to get responses from specimens in aquaria that are without question due to the sense of vision. No experiments definitely to test their sense of vision have been devised, but it is very probable that the eyes are important organs in detecting the approach of enemies in shallow water where light is sufficient. The shallow water scallop is known to migrate between shallow and deeper water at different seasons of the year. Whether the migration is due [illegible]rch for food, temperature of the water, enemies, or locat[illegible]pawning, or to a combination of factors, is not known. The [illegible]llops seem to shift their position from time to time, b[illegible] always remain in comparatively deep water, the move[illegible] not be accounted for by either a change in temperature [illegible] spawning. It is most likely due to either continued disturbances by dredging, or enemies, or to lack of food. The latter is the usual reason assigned.

It is not entirely certain what relationship Pecten bears to the usual form of lamellibranch as regards positions of parts. In lamellibranchs that are supplied with two practically equal adductor muscles, a line connecting the two adductors runs nearly lengthwise of the animal. In such a case the hinge line is more or less dorsal, one end is anterior, and the other posterior. When one of the muscles disappears, as is the case with Pecten, one of the landmarks disappears and it becomes more difficult to locate the direction of parts. Inasmuch as the hinge line is usually dorsal, it is very natural to look at the hinge line of this form as dorsal, and for matters of description it is convenient to so consider it. If, however, the position that the anterior adductor would have occupied, had it been retained, be considered, the position of the mouth, foot and heart indicate that it would have to be placed much nearer the hinge line than the present position of the posterior adductor muscle, the muscle that is retained. If this is the case, it becomes evident that the loss of the anterior adductor muscle has been accompanied by a general reduction of the anterior part of the body, so a large part of the body of Pecten is to be considered morphologically posterior. This supposition seems to be borne out by the nervous system, and the vascular system of the mantle, as well as by the extent and position of organs. In most forms the margin of each lobe of the mantle is supplied with a posterior and an anterior pallial nerve of approximately equal size. These nerves supply the muscles and sense organs of the margins, and, in many forms at least, unite with each other so they form a continuous connection between the cerebral and the visceral ganglia. In Pecten, not only is this the case, but the nerve in the margin of the mantle is joined at intervals for nearly its whole length by nerves from the visceral ganglia (fig. 15). On the other hand, it is joined only in the region of the anterior ear by nerves from the cerebral ganglia. The visceral ganglia are the important ganglia of the animal, and both the cerebral and pedal ganglia are greatly reduced.

The blood is supplied to the mantle very largely by the posterior pallial arteries (fig. 9). The anterior pallial arteries are comparatively small, and while they are connected with the posterior pallial arteries, the size and character of the vessels indicates that the junction is probably very near the anterior wing.

Considering everything, it seems likely that the longitudinal axis of the body could be morphologically represented by a line drawn from near the hinge extremity of the anterior ear to the middle of the adductor muscle, and that a very small portion of the scallop is anterior.

The only portion of the scallop that is eaten is the adductor muscle, which is proportionately very large but certainly forms less than one-half of the bulk of the soft parts of the animal. There seems to be no good reason why the remainder of the animal should not be eaten. The margins of the mantle are rather tough but not more so than the neck (siphons) of the soft shelled clam. The probable reason that all but the muscle of the scallop is discarded, while in other forms the whole body is eaten, is that in the scallop many portions are highly colored. The visceral mass of the female is bright pink and the margins of the mantle are usually very conspicuously colored with yellows, browns, and black. Although such colors are not considered to be objectionable in many foods, they are not the usual colors for " shell-fish " and accordingly are looked upon with disfavor.

SHELL.

All members of the genus Pecten are provided with shells of a very characteristic shape. The shells are rounded, inequivalved and eared; the hinge line is straight and runs the length of the margin formed by the ears, is not provided with teeth or with a conspicuous hinge ligament and is provided with a large cartilage that is placed immediately between the beaks of the two valves.

All of the members of the genus have somewhat similar habits, are provided with numerous sense organs and are capable of swimming by clapping the shell valves together. A very heavy shell, massive teeth, or a small cartilage would not be adapted for swimming in this manner, where lightness and speed of movement are essential. A rounded outline is consistent with such progression, and the presence of numerous sense organs is important, for these animals live in positions unusually exposed to the attacks of enemies.

The shell of this particular species (figs. 1 to 7) is somewhat longer than wide and rather flat. The dimensions of a good sized specimen may be given as length 7 inches, width 6½ inches and thickness 1½ inches. The proportional thickness differs more than the other two dimensions, varying from a little under 1½ inches to a little over 1¾ inches in specimens corresponding to the other dimensions given. The two valves are of about the same weight, but the right valve, that on which the animal habitually lies, is much flatter than the left (fig. 19), lighter in color and has a rather prominent rounded notch where the anterior wing joins the main body of the shell (fig. 4). I have been unable to satisfy myself as to the function performed by this notch. The sense tentacles on the mantle margin opposite the notch are somewhat longer than those adjacent, but I have been unable to determine that they have a special function or that they are specially advantageously placed.

The outer surfaces of the valves (figs. 1 to 4), are marked by fine ridges and grooves that radiate from the beaks to the margin, and by rather prominent lines of growth that run out along the hinge line. Not all of the radial markings start from the beak but new ones are added at intervals so that the number remains approximately from 30 to 35 per inch on any portion of the surface. The lines generally have a somewhat wavy or zigzag course. Those on the upper, left valve, are more rounded and prominent than those on the under, probably because of the difference in wear in the two cases. The wear is further indicated by the fact that the markings may be nearly or quite obliterated on the most convex portion of the lower valve.

The lines of growth are visible as very fine lines all over the surface, but are much more prominent in some places than others. The larger ones may appear as ridges, which would seem to indicate that marginal growth occasionally stops as the shell thickens along a line, or they may appear as a series of rather jagged depressions that indicate where the old margins have been broken. These latter markings are rather more abundant on the lower than on the upper valve. Their relative abundance compared to the shells of other lamellibranchs is easily accounted for by the use to which the shell is put in swimming and as the upper valve usually extends over the margin of the lower (fig. 19) each blow when the valves are clapped together would be directed by the more solid inner portion of the upper valve directly onto the margin of the lower valve, thus being more likely to break off small bits from it.

The outer surface of the shell, especially of the upper valve, seems to be more than ordinarily subject to the attacks of the boring sponge, Cliona sulphurea, which frequently riddles the shell so that hardly a trace of the original surface is left (fig. 3). The reasons for the attacks on this shell more than on the shells of other mollusks found in the region is probably due to the fact that this animal does not burrow and that the shell is not provided with anything like an adequate cuticle, a layer that could not be formed because the enlarged margin of the mantle must necessarily be withdrawn far into the shell whenever the valves are brought together. The borings of the sponge frequently weaken the shells decidedly and it is not uncommon to find borings that come so near the inner surface that light may readily be seen through them, but I have never found actual perforation of the shells. It seems probable that the secretion from the sponge that acts in dissolving the shell soaks through the shell sufficiently to stimulate the mantle to renewed secretion of shell substance before the perforations are actually complete. This is indicated by the fact that shells that are badly attacked are quite universally thicker in these places than those that are not so badly attacked, and that their inner surfaces are likely to be roughened (fig. 7). The meaning of the roughened appearance is especially striking if shells that are bored only in patches are examined. In such cases the end of each of the deep burrows is marked on the inner surface of the shell by a rounded elevation, each of which reminds one at first sight of a minute pearl that has become fastened to the shell, and partially covered up by later secretions of nacre.

The markings on the inner surface of the shell are much more distinct in some individuals than in others and they differ somewhat on the two valves.

The adductor muscle scar is quite large and fairly distinct, and is placed somewhere near the center of the shell, a little nearer the posterior than the anterior border. The scar is much larger on the left (fig. 5), than in the right valve (fig. 6), where it is distinctly double, consisting of a large rounded anterior portion, (pas.) and a small somewhat crescent shaped posterior portion (pas'.). The scars usually form depressions, but sometimes elevatons, on the inner surface of the shell, and are more or less distinctly marked by lines that indicate the larger bundles into which the muscle is divided.

The foot retractor muscle is attached to the left valve of the shell along the dorsal border of the adductor muscle, just anterior to the upper end of the posterior crescent shaped portion, and the scar is not distinguishable from the scar of the adductor muscle.

The mantle is very firmly attached to each valve along a rather broad and indistinct pallial line, (pl.) that is very far removed from the margin of the shell. The muscles attached along the greater portion of this line radiate toward the free edge of the mantle. The margin of the mantle is also well supplied with circular muscles that, near the hinge line, are collected into large bundles and attached to the shell, (aps. and pps.). The scars on the shell caused by the attachment of these muscles are somewhat larger and more distinct posteriorly than anteriorly.

Immediately beneath the scars of the adductor muscle there is frequently to be seen an indistinct line that marks the attachment of the muscles by which the gills are elevated (fig. 7, sms.)

The inner surface of the shell is sometimes quite smooth, in which case fine radiating lines, possibly corresponding to the radial pallial muscles, may sometimes be seen running from the pallial line toward the free margins of the shell. It more frequently happens, however, that the inner surface of the shell is roughened. These roughenings are no doubt always due to the secretion of nacre caused by irritation, probably sometimes due to the boring sponges before mentioned, but also to other causes. Not infrequently the inner surface of the shell is marked by minute elevations each of which has a dark spot at its tip. In such shells it has frequently been noticed that the mantle is spotted as if diseased but whether the spots are due to parasites as was determined by Jameson (13) has not been determined, neither has the relationship of the spots on the mantle to the spots on the shell been determind.

Pearls are sometimes very numerous, several dozen having been taken from a single shell. When these become attached to the inner surface of the shell, they give it a very rough appearance.

This inner surface of the shell is further frequently marked by dark streaks and blotches that are usually caused by worms and other marine animals that inhabit the holes that have been formed by the boring sponges.

The structure of the shell does not correspond to the structure of a large majority of mollusk shells. Most shells are composed of a nacreous inside layer, a prismatic middle layer and an outside cuticle. In this form, and this holds true for the other scallops that I have examined, only the nacreous layer seems to be present. I have not been able to find a trace of either of the other layers in the sections that I have made, but the shell is so brittle that it is hard to grind satisfactory sections. A cuticular gland is present along the margins of the mantle (fig. 26, cgl.), and in this gland fragments of a weak layer that no doubt is cuticle is present but the frequent removal of the mantle margin far into the interior of the shell would seriously interfere with the formation of a continuous cuticle. As might be expected in an animal where so large a portion of the mantle is movable, the nacre is not formed of such uniform delicate layers as are found in some shells. Layers are present but the carbonate of lime seems to have become partly crystalized and the layers interrupted in places.

The shell material may vary in color considerably in individuals, or in the same individual, but this seems to be a variation in the nacre and not caused by the presence of other layers. The variation is especially well marked in the smaller more southern scallop, Pecten irradians, where the outer portions of each of the ridges that are so prominent in this species is deeply colored while the inner surface of the ridges and the portions forming the valleys between the ridges are white. It all seems to correspond in structure to nacre however.

The valves are attached to each other along the hinge line by a very weak ligament which represents a modification of a cuticle that serves simply to hold the two valves together along this line. Near the middle of the hinge line, just beneath the beaks, there is in each valve a deep and broad somewhat triangular depression that in old shells opens quite broadly on the hinge line. This depression, (fig. 5, cp.) forms the cartilage pit, into which is set the end of an elastic pad, the so-called cartilage, (fig. 10, c.) which is a modification of the ligament.

When the adductor muscle contracts and the valves are drawn together, this pad of cartilage is compressed and serves, when the muscle relaxes, to separate the valves again. The cartilage is composed of the same material as the enlarged elastic ligaments of such forms as the fresh-water mussels, and no doubt they have had a common origin. They both serve to open the shell by their elasticity, in the one case by expanding after being compressed and in the other by contracting after being stretched.

MANTLE.

The inside of each valve of the shell is lined by a thin fold of tissue, a mantle lobe (fig. 10, m.). The mantle lobes are united to each other along the hinge line and anteriorly and posteriorly for a space that practically corresponds to the width of the ears of the shell.

With the exception of the free borders of the mantle, each lobe consists of a very thin membrane that is closely applied to the inner surface of the shell which it entirely covers in the living extended animal. In specimens that have been disturbed so the shell valves are closed together, the margins of the mantle lobes are drawn far back into the shell so there may be a strip of three-quarters of an inch or more of the inner border of each shell valve that is left uncovered. This retraction of the mantle is necessary in order that the thickened and highly modified margins of the mantle may not be injured by the closing of the shell.

Each mantle lobe is free from the rest of the body except where it covers and is fused with the adductor muscle and digestive gland, where it is joined by the posterior border of each of the outer labial palps, and where it is joined by the membranes that support the gills.

The formation of the shell is due entirely to the secretion of materials by the mantle. The nacre, which forms the inner surface and most, if not the entire thickness of the shell is secreted by the whole of the applied surface of the mantle and in healthy perfect shells is quite smooth and white. As it is constantly being added to, it is thicker in old than in young shells and in the older part of the shell, toward the middle of the hinge than elsewhere. Certain portions of the mantle, as that along the margins between the pallial lines and the free borders, and in the region of the hinge line and wings, are more active than others in secreting nacre. In these regions the epithelium on the shell side of the mantle is composed of especially large apparently actively secreting cells, while the remainder of the surface is composed of small less active cells. This arrangement is in accord with the especially thick portion of the shell along the hinge line including the ears, and with the fact that the margins of the valves are thicker than would otherwise be expected.

If a prismatic layer is present it must be secreted by the extreme margin of the mantle but there is nothing in the appearance of the epethelium of this region that would indicate that it has a different function than that a little further removed from the margin.

A gland for the formation of the cuticle occupies a grove along the margin of the mantle, (fig. 26, cgl.) and fragments of a thin and apparently not very tough cuticle may nearly always be seen in it attached at the inner end of the gland to the epethelium that secretes it, but the withdrawal of the mantle margins far into the shell when the shell is closed must interfere with the formation of anything like a continuous cuticle. The ligament and cartilage are both present, although the former is quite thin, and may be looked upon as modifications of the cuticle. They are secreted by adjacent portions of the mantle.

The free margin of each lobe is very muscular, is abundantly supplied with organs in the form of tactile tentacles and eyes, and is provided with a large flattened ridge that is turned away from the shell valve on which the mantle lobe rests (figs. 10, 19, 20, and 26). The ridges on the two mantle lobes may be brought into contact with each other at any or all points along the margin, when the shell valves are slightly separated and thus regulate the currents of water formed by the cilia on the gills, or in swimming.

The muscles of the mantle, (figs. 16 and 26) may be grouped as the radial pallial, which are attached to the shell at the pallial lines and radiate out toward the margins, the circular pallial which are very strong, attached to the shell valves near the hinge line and run along the borders of the mantle, the muscles of the pallial ridge that are largely circular but contain also radial muscles connected with the radial muscles that have been referred to, and the suspensory muscles of the gills which are really continuation of a fold of the mantle and are attached to the shell valves between the pallial scars and the adductor muscle scars. All but the last group of these muscles, which will be described in connection with the gills, are confined to the borders of the mantle and, together with the infolded ridge, sense organs and pigmentation of this region, form a thickened portion that is very striking in appearance when compared with similar parts of most other forms.

The radial muscles are much longer and more powerful in the region opposite the hinge line than elsewhere and have for their chief function the withdrawal of the mantle margins into the shell in order that the margins may not be injured in closing the shell, which is closed both rapidly and powerfully, especially when the animal is swimming. The radial muscles of the infolded ridge are continuous with these muscles and serve to contract the width of the ridge or to extend the ridge out in the same plane with the rest of the mantle, that is to extend it out of the shell. This is no doubt done in conjunction with relaxing the circular muscles of the ridge, and extending the margin by blood pressure.

The circular pallial muscles of each mantle lobe form a very strong band that is attached to the corresponding shell valve anteriorly and posteriorly just beneath the ridge along the hinge line, at the dorsal ends of the pallial lines. They are spread out between the attachment of the radial muscles and the margins of the mantle lobes but are strongest some distance away from the attachment of the radial muscles and they nearly or quite disappear before the pallial nerve is reached. They serve as constrictors that are important in withdrawing the margins into the shell. In this they act in conjunction with the radial muscles. Their attachment to the shell along the dorsal limits of the pallial line suggests that they may be regarded as extended, modified radial muscles of this region of the mantle.

The circular muscles of the infolded ridges are connected with this band especially near the hinge line. Here the circular muscles become continuous with the other circular muscles. This leaves the dorsal inch and a half or two inches of the ridges both anteriorly and posteriorly without well developed circular muscles. The radial muscles of the ridges of these regions are also poorly developed so there is but little independent movement of the ridges near the hinge line. It is interesting to notice further that the tentacles on the ridges are not developed in this region and that with the exception of the extreme dorsal margin, the parts covered by the ears, the eyes are absent or very few in number. The circular muscles of the ridges are important in adjusting the positions of the ridges to each other and thus in regulating the currents of water in respiration and feeding, and in swimming.

The sense organs of the mantle are of two distinct kinds, tactile tentacles and eyes. The tentacles are distributed in two bands along the margin of each lobe (figs. 10 and 20). The largest forms a broad band, several tentacles deep that runs along the inner face of the margin of each lobe slightly removed from the extreme edge, about where the base of the infolded ridge joins the lobe. The tentacles in this ridge vary greatly in size, those placed farthest from the margin usually being the largest and those next to the free margins being smallest (fig. 26). Along the borders of the ears of the shell the tentacles are somewhat longer and more slender than elsewhere, and they are perhaps longest near the notch at the base of the anterior ear. A large individual may possess several thousand tentacles for there are from 75 to 100 on an inch of border.

The other band runs along the face of the ridge near its free border. In appearance these tentacles correspond to those of the other band, but they are not nearly as numerous and are not as large as the largest in the other band. They are most abundant in the portion farthest removed from the hinge line and are not found on the portions adjacent to the hinge.

All of the tentacles of both bands are capable of being greatly lengthened so they sometimes form a fringe along the border, an inch or more in length. When the animal is disturbed they are immediately withdrawn and form conical projections hardly more than a sixteenth of an inch in length for the largest.

The structure of the tentacles will be considered under the head of sense organs.

The eyes are placed along the margin of the larger band of tentacles, on the side that is turned away from the free border of the lobe of the mantle. They form a single scattered row in which they are set at irregular intervals but fairly close together. They are most abundant along the border farthest from the hinge and are absent or very few in number for an interval near the ears of the shell both anteriorly and posteriorly. In the space covered by the ears a few eyes are present. In all there are frequently as many as one hundred on each of the lobes of the mantle. Their size even in old individuals is noticeably unequal and they are not arranged in any order of size. As there are many more eyes in large than in small individuals, new ones must be added during the growth of the animal and their size may be an indication of their age. If this is true, new eyes are not added in accordance with any plan but make their appearance as spaces for them occur. The outer ends of the stalks on which the eyes are set are deeply pigmented with black or brown pigment, and the eyes themselves are blue and exceedingly brilliant. The structure of the eyes will be considered under the head of sense organs.

The mantle margins, including the infolded ridges and tentacles, are usually highly pigmented. Yellow and brown, either light or so dark as to approach black, are conspicuous in this pigmentation. Sometimes the margins are nearly of the same color throughout their extent but they are frequently blotched with different colors and with different shades of the same color arranged in irregular patterns so that with the infolded ridges, the tentacles and the brilliant eyes, the margins make very striking objects. What purpose the brilliant pigmentation may serve I cannot say. Perhaps they are not as conspicuous among the yellow incrusting sponges and the other variously colored incrusting growths among which they live. Living in deep water as the animal does, these are matters that are not easily studied.

The distribution of nerves and blood vessels in the mantle will be described in the general consideration of the nervous system and the vascular system of the animal.

VISCERAL MASS AND FOOT.

It will hardly be necessary to describe the general shape and positions of these portions of the animal as reference to figures will make the relation of parts much clearer than description (figs. 11 and 12). It will be noticed that the portion containing the digestive gland or liver, and the reproductive portion of the viscera are not broadly connected, and that the foot is placed anterior to the heart and ventral to the connecting portion.

This arrangement is such that the large adductor muscle is pretty well inclosed, there being only a small postero-ventral portion of the muscle that is not surrounded by the other organs.

The portion near the hinge consists almost entirely of the digestive gland, commonly called the liver, with the œsophagus, stomach and first part of the intestine inclosed in it. During the season of reproduction, a thin layer of gonads extends over its surfaces laterally as well as anteriorly and posteriorly. The portion ventral to the foot consists almost entirely of the gonads with the coils of the intestines running through them. The foot is largely muscle with a rather extensive byssal gland inclosed in it. The liver region extends from valve to valve of the shell and is covered closely with a very thin portion of the mantle. The reproductive portion and foot are comparatively narrow and are suspended between the gills, being supported in large part by the adductor muscle. These portions do not occupy a position midway between the two valves but are nearer the right than the left valve.

The foot is a comparatively slender, roughly cylindrical organ somewhat larger where it is attached to the body than elsewhere, cleft at its free end, so it may be spread to form a " sole " as in Nucula and Yoldia, and showing the large opening of the byssal gland to the right of the middle line, on the ventral surface somewhat behind the sole (fig. 8).

The foot has lost its symmetry, being twisted so the ventral surface is directed somewhat toward the right valve. It seems to be in a large measure a degenerate organ that is practically of no service as an organ of locomotion. The animal depends upon swimming by clapping the shell valves together to change position. The foot may however be greatly extended and thrust between the valves of the shell. When protruded it leaves the shell just ventral to the notch at the base of the anterior ear, and may be moved from place to place. The flaps on the sides of the foot are moveable and are frequently separated somewhat but there is no such active movement as in Yoldia (6) or other forms with this type of foot, with which I am acquainted. In the species under consideration I have never seen the foot protrude far out of the shell and have never seen the animal attach itself with a byssus.

Individuals of the smaller species, Pectens irradians, do attach themselves with a byssus and I have no reason to doubt that individuals of this species attach themselves. An individual of Pecten irradians placed in a glass dish of sea water will sometimes protrude its foot from the shell, apply it closely to the bottom of the dish and after a short time slowly withdraw it, leaving a rather broad band of slightly yellowish material attached to the glass and connected with the foot at the byssal gland. This is not composed of small tough threads as in the mussels Mytilus and Modiola, but it may be sufficiently tough to support the weight of the animal if, after a few minutes, the dish is carefully turned over. The animals seem never to remain attached for long periods, but after a few hours at most the attachment is dropped at the byssal gland. Whether this is passive or due to a sudden strain caused by forcing strong currents of water from the shell as in swimming has not been observed.

As in other lamellibranchs the foot is largely composed of crossing muscle fibres that by individual or combined action may press upon blood that may be confined in a rather large blood space in the foot and so cause the elastic foot to be extended. The foot is attached to the shell by a single retractor muscle which runs along the dorsal portion of the foot posteriorly, dorsal to the posterior adductor muscle, to be inserted on the left shell valve at about the point where the adductor muscle is separated into two parts (fig. 10, fm.). This muscle extends along the dorsal border of the foot and is about equally in evidence on its right and left sides. Above the opening of the byssal gland, which lies somewhat to the right of the median line on the ventral side, the muscle loses its individuality and becomes merged with the general foot muscles. It leaves the foot along the median line flattens a little and gradually runs over on the left side to be attached to the left shell valve. Why the right muscle should have degenerated is not clear but the position, attached to the left shell valve, which is uppermost, gives the muscle a straighter pull when the foot is attached to the bottom by the byssus than would be the case if the right muscle had persisted instead.

The byssal gland is quite extensive and not only permeates a considerable portion of the foot but extends some distance dorsally and posteriorly ventral to the retractor muscle of the foot. It is a racemose gland of the usual character.

ALIMENTARY CANAL.

The œsophagus is rather short and extends from the mouth, which lies beneath the anterior protruding portion of the liver, to the antero-dorsal portion of the stomach. The stomach fig. 12, s.), is fairly large and receives two large ducts from the liver which surrounds it. The openings of these ducts into the stomach are so large as to form two latteral diverticula of the stomach into which the smaller ducts from the liver empty. The portion of the alimentary canal that extends from the rounded stomach to near the posterior portion of the body is of greater diameter than the remaining portion and resembles in microscopic appearance the stomach rather than the intestine. A portion of the lining epithelium of this and of the lower end of the stomach resembles that usually concerned in the formation of a crystalline style. While a definite, well formed rod-like style, such as is so well formed in the soft clam, Mya, is not present, a large quantity of mucous is secreted. This mucous entangles the food that is swallowed and very likely performs the same function that is performed by the dissolving of the crystalline style which Kellogg (14) with much reason thinks may be to keep the cilia of the alimentary canal from forcing the food through the canal before it has had time to digest.

The remaining portion of the alimentary canal, is of about even diameter throughout its length and is lined by epithelium of the character ordinarily found in this portion in lamellibranchs. It is a ciliated epithelium, the cells of which stain deeply and probably have some secretory function. Undoubtedly the chief reason for having the canal so elongated is to give time and surface for absorbing digested food.

The position of the loops of the intestine are shown in figure 12, i, and needs no special description. It is worth noticing that the loops are practically in the same position in Pecten irradians, the only other species of scallop that I have examined. In the figure given by Pelseneer, which is copied in Parker &

Haswell's Text-Book of Zoology, page 648, the reverse loop of the intestine in the posterior portion of the visceral mass is not given. This may not be present in the species figured, but it seems quite possible that it might have been overlooked in dissections as the backward turn is so abrupt and takes place so near the other portion of the intestine. After running dorsally nearly to the hinge line, the intestine bends rather abruptly postero-ventrally, perforates the ventricle of the heart, and terminates posterior to the adductor muscle. The last inch or more of the intestine protrudes from the general body and ends in a dorsal turn that directs the fæces toward the edge of the shell in the same direction that is taken by the excurrent stream of water that is coming from the gills. It is important that the fæces should be voided, as they are, where they may be promptly removed by the current of water coming from the gills.

Throughout the length of the alimentary canal its epithelium is ciliated and movements of its contents are dependent upon the action of the cilia. The general movements caused by the muscles of the body wall may have some effect, but there is no special muscular provision to aid in the movement of ingested material.

The muscles covering the pericardium are continued down over the otherwise free extremity of the intestine and may have the action of a sphincter but in the living individuals and in the sections examined, the lumen of the intestine seems to be quite as unobstructed in this region as in other regions.

LABIAL PALPS.

These organs are essentially lips and have for their chief, if not their only, function the conducting of food into the mouth. There is as in other forms a pair of palps on each side of the body. The palps on one side of the body are connected with those of the other above and below the mouth so they resemble large drawn out lips with the upper lip of each side covering the under lip of the corresponding side so their inner surfaces, that is the surfaces continuous with the epithenium of the œsophagus, are applied to each other. In many kinds of lamellibranchs the palps consist of inconspicuous smooth flaps of tissue that have their inner or opposed surfaces thrown into series of ridges and grooves which are densely ciliated. In this form, (figs. 10 and 12, lp.) the portions of the palps that lie along the sides of the body are of this character but the portions above and below the mouth are ruffled so they form a large conspicuous mass that entirely conceals the mouth. What purpose is served by this ruffled portion that would not be served as well by the simpler arrangement has not been determined.

Both palps are free only along their ventral borders. The outer palps, which correspond to the upper lips, are united to the body wall above the mouth and along their dorsal borders. The inner palps, which correspond to the lower lip, are united to the body wall below the mouth along their dorsal borders and have their inner surfaces continuous with the inner surfaces of the outer palps. Their posterior borders, which are not as extensive as the corresponding posterior borders of the outer palps are united to the body wall.

Food from the gills passed between the palps is conducted by the cilia covering their opposing surfaces to the corners of the mouth, of which the grooves formed by the union of the dorsal borders of the outer and inner palps are continuations.

GILLS.

As in most lamellibranchs the gills (figs. 11, 12 and 19), are four in number, there being two on each side of the body. Each of these gills appears as a thin and delicate striated membrane that runs from near the mouth, around the ventral side of the adductor muscle to and a little beyond the anal opening. The gills are very similar in appearance, pointed anteriorly and posteriorly and marked by distinct striations that radiate from their lines of attachment near the adductor muscle, toward their free borders. With proper illumination very fine striations may be seen crossing these at right angles.

Each gill consists of two thin membranes, called lamellæ (figs. 17, 18 and 19), that lie very close together and are attached to each other at intervals corresponding to the radial striations of the gill. Each pair of gills is suspended by a muscular membrane (figs. 19 and 20, sm.), most of the muscles of which are inserted on the corresponding shell valve near the border of the adductor muscle (fig. 7, sms.). The membrane however has the appearance of being suspended from the adductor muscle as connective tissue fibers extend along the surface of the muscle and bend it toward the visceral mass. Most of the muscles of the membrane run from the region of the adductor muscle directly toward the borders of the gills attached to it, but two distinct bands of muscles are present (fig. 18 lm.), that occupy positions along the sides of the blood space which runs along the dorsal borders of the gills and receives blood from the gills. When the gills are elevated these muscles contract and shorten the gills, at the same time throwing them into a series of plaits. Each of the gills that are attached to this membrane is attached by one lamella only. The outer gill is attached by its inner lamella and the inner gill by its outer lamella. The remaining lamellæ are free along their borders which are usually somewhat reflected.

The gills of lamellibranchs are usually attached so the dorsal borders of the outer lamellæ of the outer gills are attached to the mantle and the dorsal borders of the inner lamellæ of the inner gills are attached to the visceral mass, or behind the visceral mass, to each other. In this way the gills divide the space between the lobes of the mantle into a ventral space, the branchial chamber, into which the gills hang, and a dorsal space, the cloacal chamber, above the gills. This dorsal space is divided throughout the greater portion of its extent by the visceral mass and by the membranes that support the gills on each side, which in the scallop are muscular.

Although the gills on each side do not form the attachments described, the free edges of the gills are pushed out and make contacts that correspond with the attachments in other forms that have been described. It is important that such contacts should be made as the water that passes through the gills for purposes of respiration and feeding, in a manner to be described later, must be constantly renewed from the outside to be effective for either purpose, and if the outsides of the gills and the spaces between their lamellæ did not communicate with separate cavities, a current could not be formed. It is also important for a scallop, which swims by throwing powerful currents of water from the mantle chamber to have no permanent division between the branchial and the cloacal chambers as the pressure of the water in the cloacal chamber caused by the rapid closing of the shell would be certain to injure the gills. At such times the gills are kept from injury by the contraction of the muscles of the interlamellar junctions, so the lamellæ of each gill are drawn together and by the contraction of the suspensory membranes of the gills which draw them away from the margins of the shell and keep them from being crushed. No doubt the arrangement of the gills in this form is to be explained by its exceptional habits.

As before stated the two lamellæ of a gill are attached to each other at intervals corresponding to the striations that run the width of the gill. These lines of attachment (fig. 17, ilj.), the interlamellar junctions, form complete partitions so the space between the lamellæ is divided into a series of tubes, the water tubes, that are closed, except for minute openings in the sides, (io.) the inhalent ostia, and where they open into the cloacal chamber. Each tube extends from the free border of the gill (figs. 18 and 20), where it is closed by the joined lamellæ, to its opening in the cloacal chamber, and is bounded by the lamellæ and by the interlamellar junctions. Of these water tubes there are several hundred in the length of each gill.

Each lamella is composed of a series of delicate filaments, (fig. 17, gf.)the gill filaments, that run the width of the gill parallel to the more prominent striations. These filaments are of two kinds, large ones concerned in the formation of the inter-lamellar junctions, and small ones. They are all connected at intervals by cross bars, (ifj.) the inter-filamentar junctions, that run at right angles to them.

The crossing bars (the filaments and the inter-filamentar junctions), leave spaces, the inhalent ostia (fig. 17, io.) between them, that are the openings that have been referred to as leading into the water tubes. The inhalent ostia are much larger and more regular in the scallop than in most other lamellibranchs, as the lines of fusion that form the inter-filamentar junctions are not nearly as extensive as in most other forms.

Usually the filaments of one lamella are continuous with those of the other at the free margin of the gill, so it is quite possible to trace a filament from the suspensory membrane down one lamella around the margin of the gill and up to the free border of the other lamella. Whether filaments are always continuous in this manner or not has not been determined, but in the sections that have been examined the same number of filaments are constantly present on the two sides of any given water-tube.

The filaments are very similar in size and appearance, except those that are concerned in the formation of the inter-lamellar junctions. These are many times as large as the others and differ decidedly in shape as well as structure. Those placed next to these modified filaments are somewhat larger than the remainder but they do not otherwise differ in appearance or structure. The number of filaments concerned in the formation of water tubes is not entirely constant. Nineteen of the small filaments, between the large modified filaments, is a very common number but as few as seventeen and as many as twenty-two have been noticed. No attempt has been made to determine the relative number of filaments for each water tube in different parts of the gill but the variations mentioned occur within a space of ten or a dozen tubes.

Each of the smaller filaments is composed of a layer of surface epithetium that incloses some connective tissue and a large blood space. The connective tissue is so arranged that quite universally a strand of tissue extends across the blood space (fig. 21, fs.) from one side of the filament to the other, so in cross sections of the filament the blood space appears divided into two nearly equal portions. This Kellogg (14) has quite naturally taken for a functional division that allows the blood to pass down one side of the filament and back the other. That this is not actually its function is indicated by injections of the vascular system that I have made, and by the connections of the blood spaces of the filaments to the afferent and efferent vessels of the gill. There is every indication that the blood moves in the same direction on each side of the partition, if it is a complete partition. The only reason that I can suggest to explain its constant presence is that each acts as a brace to keep the filament from swelling into a cylinder with the pressure of the blood, and so partially close and interfere with the flow of water through the inhalent ostia. That there is great need for braces of this character in filaments shaped like these, where they are not supported along their sides by extensive inter-filamentar junctions as is commonly the case, is evident, but I have not examined other forms in which the filaments are similar, to find if similar braces exist.

The epithelial cells on the outsides of the filaments bear numerous rather short cilia (fig. 21, fc.) that have to do with moving currents over the surface of the gill. Between the filaments, but near their outer borders, the epithilial cells are modified in shape so they collectively give rise to a strong band of cilia (oc.) on each side of each filament. In transverse sections of filaments each of these bands appears as a bunch. These cilia are concerned in forcing water through the ostia and thus in creating the currents of water that furnish the food and oxygen for the animal.

The large modified filaments are roughly triangular in cross section and like the smaller filaments each has a surface layer of epithelium. The epithelium on the outer surface of the filament is thickly covered with cilia that correspond to the surface cilia of the other filaments but there are no bands of cilia along the sides. Inside the layer of epithelium is a pair of chitinous rods (fig. 21, cr.) that run nearly to the free margin of the gill. These rods are elastic and quite stiff and serve to keep the gill in shape. Similar rods are present in each filament in many forms but there seems to be no sign of them in the scallop in any but these enlarged filaments. Considerable connective tissue and well developed bands of muscle (mf.) are present, that together cut up the large blood space (bv'. into a number of small ones which are, however, connected with each other at frequent intervals, so they may be regarded collectively as one blood space.

With corn starch injecting mass these spaces will frequently inject for half the width of the gill. With gelatine injecting mass it is quite possible to inject the vessels of the smaller filaments as well and get the connection through the interfilamentar junctions. In these injections it frequently happens that a filament will be injected for only a portion of its length and in such cases the whole cavity of the filament is filled as far as the injection extends. This indicates that the apparent partition is not functional as a division between vessels.

The muscles of the large filaments are for the most part continuous with the muscular suspensory membranes. Fibers extend through the inter-lamellar junctions to the free lamella and serve to draw the lamellæ together. Other fibers extend through the inter-filamentar junctions and serve to draw the filaments together and so shorten the gill. A nerve (fig. 21, n.) is frequently present near the inner border (the border away from the outer surface of the gill) of the filament. How universally this is true has not been determined but I have frequently been unable to discover such nerves. Again each of a series of filaments may have its nerve. Branches from these nerves have been traced into the inter-filamentar junctions and presumably give out branches in turn to the filaments. They probably also control the muscles of the larger filaments, inter-lamellar junctions and inter-filamentar junctions. The inter-filamentar muscles are especially active in gills hat have been cut from the animal, and keep the gills in almost constant movement, folding the lamellæ and allowing them to straighten, as they contract and relax in different portions. The large filaments of one lamella are united to the large filaments of the other lamella by rather thin membranes, the inter-lamellar junctions (figs. 17 and 18, ilj.) that are thickened along their free borders, where a large blood vessel is present. They are likewise more extensive along this border so the lamellæ may be separated quite a distance along the upper border of the gill. The shape of the membranes is such as to allow greater separation than would be the case if the attachment extended straight across from one lamella to the other. The bend that is made, allows great freedom of movement to the free edge of the lamella, which may thus be separated from the attached border of the other lamella of the gill for a space of half an inch or more.

The inter-filamentar junctions (fig. 18, ifj.) are much heavier along the upper margins of the lamellæ than toward the free edge of the gill. These junctions are very muscular, and are much heavier near the large filaments than they are toward the middle of the water tube (fig. 17, ifj.). They join the filaments to each other and extend into the cavity of the water tubes as rather prominent ridges. Each inter-filamentar junction contains a rather large blood vessel that is connected with the vessels of the large and the small filaments, and thus serves to distribute blood either from or to the large vessels of the large filaments, which are connected in their turn to the vessels that supply blood to or take blood from the gills.

As the free edges of the gills are approached the inter-filamentar junctions become less and less prominent until, near the margin, the filaments near the middle of the water tubes are connected only by bunches of cilia like those in the mussel, Mytilus, and some other forms. That the junctions of this region should be less prominent is what might be expected, for the margins of the gills, after the gills have become sufficiently developed to show adult structure, are the growing and consequently the youngest portions. That the filaments should at first be connected by cilia only, may be looked upon as an indication of past history. The scallops presumably have had ancestors in which the gill filaments were united by cilia only.

Inasmuch as the gills are respiratory orgens, the arrangement of the blood spaces in them is of more than ordinary interest.

Two blood vessels are present in each of the suspensory membranes of the gills, near the borders of the gills that it supports. These vessels follow along the borders of the gills from near their anterior to their posterior ends. One, the dorsal, that is the one farthest away from the gills, supplies both of the gills with blood, the other, the ventral, which is very near the borders of the gills, receives the blood that is returned from both of the gills. The blood enters each gill by branches from the supplying vessel (figs. 17 and 18, ba'.) that run along the upper borders of the inter-lamellar junctions to the edge of the free lamella. Here they enter the large modified filaments of this lamella (fig. 17, ba".) and are continued down to the margin of the gill, giving off vessels to each of the inter-filamentar junctions except those near the margin of the gill, which consist of cilia only and are accordingly not vascular.

Through the inter-filamentar junctions the blood is supplied to the small filaments, so the blood vessels become a net work that corresponds to the structure of the gill itself. The blood makes its way around the margin of the gill, through somewhat broken passages to the other lamella. This takes place all along the margin in both large and small filaments. The vessels in the other lamella are similar to those already described, the blood being collected on this side into the vessels of the large filaments (fig. 17, bv'.), and finally poured into the vessel at the bases of the gills, which conducts the blood back to the heart (fig. 18, bv.).

It is quite possible to make out all of the connections described, in sections of the gills but the arrangement of vessels has been further demonstrated by injections of the gills with starch and with gelatine injecting masses. This can readily be accomplished through the supplying and receiving vessels of the gill with a hypodermic syringe. The animals are large and the vessels are fairly distinct so with a little practice it is quite easy to make successful injections. With a starch mass the vessels may readily be injected different colors as the mass is too coarse to pass out into the smaller vessels and complete the circuit. By this method it was easy to determine that the blood passing to the gill all passed along the borders of the inter-lamellar junctions to the free lamella and that all of the blood entering the vessel that carries the blood away from the gill comes from the attached lamella.

The general relation of the blood spaces of the gills to the rest of the circulatory system will be discussed under the head of the circulatory system.

The movement of water for respiration and feeding is dependent entirely upon the bands of cilia on the sides of the filaments. These, acting like so many small paddles, force the water through the inhalent ostia into the water tubes, thus driving the water along the water tubes into the space above the gills that corresponds to a cloacal chamber, and so out of the shell along the margin posterior to the adductor muscle and dorsal to the gills. The current of water which enters to take the place of that driven out is taken in anywhere along the ventral and anterior borders of the animal. By changing the position of the margins of the mantle so access is given at one place and denied at another, it is possible for the animal to vary the places where water is admitted and ejected. Whether this serves any definite purpose or is more by way of accident caused by performing other functions of the body, is not known, but powdered carmine allowed to settle in the water past the margins of the shell of an extended individual will show that such variations in the currents do occur.

This current of water not only supplies the means of respiration, allowing the blood that is passing through the gills to become charged with oxygen and to rid itself of carbon dioxide, but it serves to supply the animals with food.

The food for the most part consists of microscopic plants which are strained out of the water that passes through the inhalent ostia. These are passed along the surfaces of the gills by the cilia that cover the surfaces of the filaments, to their free margins and along the margins to the anterior ends of the gills. Here they are passed between the labial palps which inclose the anterior ends of the gills, and so on into the mouth.

Attention has not been given to the action of the feeding cilia in this form, but Kellogg (15) and Stenta (31) have found that the action is apparently under control in many forms, so food that is passed over the surface of the gills may be carried to the palps or may be passed onto definite tracts of cilia on the mantle that carry it away and finally eject it from the mantle chamber. It would thus seem that while the cilia on a gill are active, food is being strained out but that the animal may or may not eat the food gathered.

The ability to accept or to reject solid material that is brought to the gills in the current of water that is formed by the cilia on the gills is indicated by examining the stomach contents, as well as by the observations made by Kellogg and Stenta. The study of the food that is in the stomach shows that there has actually been selection of materials and that the ability to reject is not simply to allow the animal to continue respiration without feeding, for there are many forms of diatoms that are abundant in the water in which the animal lives that are not present in its stomach. The observations of Grave (8) on the food of the oyster indicate how great this selection may be and no one who has given any attention to the stomach contents of lamellibranchs will doubt that food selection is common among members of the group. No observations have been made on the speed with which food is gathered by scallops but as the method of feeding is so similar for most lamellibranchs the observations made by

Grave (8) on the oyster are of great interest. By a series of careful experiments he determined that oysters that had been kept out of water and in filtered water until most of the food had been digested or passed through the alimentary canal, collected on an average, upon being returned to the bottom from which they were taken, " 385 diatoms during the first hour, 550 during the second, 1,406 during the third and 4,301 during the fourth. This increasing rate of feeding is probably due to the gradual recovery on the part of the oysters from the shock of their unusual treatment in the laboratory. The rate at which feeding took place during the fourth hour is probably nearer the rate at which it occurs with oysters living undisturbed on the beds."

From these and other observations Grave draws conclusions regarding the length of time that an oyster must feed and the amount of food that water must contain, in order that oysters shall get proper food supply, that are open to criticism. He says, " The work on the food resources of Newport river show the average number of diatoms per liter (or about a quart) available to oysters on the natural beds, during the summers of 1900, 1901 and 1902 to be 23,432, and that the oysters of salable size examined during this time contained, on an average, 11,453 diatoms. If the usual rate of feeding under natural conditions is near the figure obtained from the above experiment, 4,301 diatoms per hour, then three hours is ample feeding time for an oyster; and taking 23,432 as the average amount of food contained in a liter of water over the natural oyster ground, it follows that in collecting its daily meal (11,453 diatoms) an oyster must filter altogether about 500 cc., or 16 oz. of water, and that about 167 cc., or 5⅓ oz., are filtered per hour." The error is in taking 11,453 diatoms, the average number to be found in an oyster's stomach at one time, as the average daily meal. This does not take into account the rate of digestion and accordingly the number that actually pass into the alimentary canal in a day is an unknown quantity. The observations indicate, however, that the number of diatoms used by an oyster is enormous and that the part taken by lamellibranchs in converting this great wealth of food material into a form that is available for the higher animals is very considerable. (See Brooks, 3.)

MUSCULAR SYSTEM.

The muscles of each of the organs are best described in connection with the structure of the organ concerned. As the muscle that functions in closing the shell is the only one that would not naturally receive attention in describing the organs, it will be necessary here to describe in detail only the adductor muscle.

There is but one adductor muscle in the adult scallop and this corresponds to the posterior muscle of those forms that possess two muscles. In the very young scallop the anterior adductor muscle is present (fig. 35, aam.) and for a time is the only functional one, but the posterior muscle soon makes its appearance. At what stage of development the anterior adductor muscle is lost has not been determined but a scallop a centimetre (half an inch) in diameter shows no indication of such a muscle.

In the adult scallop the adductor muscle has a greater area of attachment on the left, upper, valve than on the right, and the scar on the shell is comparatively smooth and indistinctly bounded. Usually there are some markings indicating the division of the muscle into bundles but they are not nearly as prominent as on the other valve.

The muscle is quite definitely divided into two portions. An anterior large rounded portion (fig. 10, pa.) and a posterior somewhat crescent shaped portion (pa'.) that is applied on its concave side to the anterior portion. The left end of the posterior portion is a somewhat narrower and longer crescent than the right end and is applied much more closely to the anterior portion of the muscle than at the right end (figs. 9 and 16). Where the muscle is attached to the right shell valve the separation of the anterior and posterior portions is marked by a deep cleft on the ventral side of the muscle. This cleft extends along the ventral side of the muscle for nearly half the length of the muscle where it becomes a very distinct line that may readily be followed to the other end of the muscle. The two portions of the muscle differ in color, the posterior portion being darker, and their physiology is quite different. The large anterior portion may be entirely severed and the posterior will close the shell with nearly as great rapidity as was the case before the muscle was injured, but if the posterior portion is severed and the anterior portion is left intact, the animal will not close its shell. If the shell valves are pressed together the muscle will not hold them, but they separate immediately when they are released. The meaning of this is not clear. I feel sure that it is not due to severing any nerve as the muscle has been carefully scraped from the shell with the same results. That there is some explanation that investigation will reveal seems likely. My own work has for the most part been carried on at some distance from the seashore, and the opportunity to investigate the action of the muscle has not yet presented itself.

Other prominent muscles of the body beside the usual interlacing muscles of the body wall are the radial and circular muscles of the margins of the mantle (fig. 16, rpm. and cpm.) the muscles of the suspensory membranes of the gills (fig. 20, sm.) and the retractor muscle of the foot (fig. 10, fm.) which is here confined to the left side. All of these are described in connection with the organs with which they are associated.

EXCRETORY ORGANS.

These organs lie just anterior to the adductor muscle, against which they are flattened, between the visceral mass and the suspensory membranes of the gills (figs. 12 and 20, e.). Each organ forms an elongated sac like body that runs from the extreme latteral prolongations of the pericardium ventrally, around the adductor muscle, and opens into the mantle chamber, above the gills and about one-third of the diameter of the adductor muscle from its ventral margin. The openings of the kidneys into the mantle chamber are large, slit like, and guarded by somewhat thickened lips. Not uncommonly the excretory organs of lamellibranchs consist of long coiled tubes, each organ being a single tube which may be nearly or quite cylindrical and of nearly even diameter, or the tube may be greatly sacculated or have certain enlargements. Such long coiled tubes strongly suggest nephridia, and they may be looked upon as modifications of this structure. Not uncommonly the organ is divided into a glandular and a non-glandular portion as in the fresh-water muscle, but it is usually coiled to the extent of possessing at least one loop.

In the scallop, however, the organ is of a calibre that suggests a sac more than a tube, that curves only to follow the curvature of the muscle and opens at one end by a rather broad opening into the pericardial cavity and at the other, by the slit like opening already described, into the mantle chamber. The pericardial opening of the right organ is a little more dorsal and a little nearer the mantle than the other. This seems to be caused by the shape of the adductor muscle which spreads out near its attachment to the left valve so the left excretory organ is forced in toward the median line of the body.

In structure the excretory organs are practically racemose glands. The pockets that are frequently found in the walls of the nephridia of other forms are here greatly extended and branched. The thick walls of the organs allow this without causing a roughened exterior. There is no division of the organ into glandular and non-glandular portions but it is glandular throughout.

The excretory organs are joined by the genital ducts near their inner, pericardial ends. The relationship of the two is further described in connection with the genital organs.

GENITAL ORGANS.

These organs occupy the greater part of the portion that has been called the visceral mass (fig. 12, vm.).

In this species of scallop the sexes are separate and may easily be distinguished by the color of the sexual products which give the color to the parts of the body containing them. In the female the color is bright salmon pink to dull pink, apparently differing with the number of eggs and possibly also with the maturity of the eggs. In the male the color is white or with a tinge of yellow. Pecten irradians is hermaphroditic, with the male portions of the organ dorsal, that is, near the foot, and the female portion in the remaining large, ventral and posterior portions of the visceral mass. The male portion is here white, the female brownish yellow or orange. Both kinds of sexual products are matured at the same time and there is considerable reason to believe that individual fertilization may be and possibly frequently is accomplished.

In the giant scallop the distribution of the gential organs is the same in both sexes. The organs occupy nearly the whole of that portion of the body that lies beneath the foot that is not occupied by the alimentary canal, and extend up dorsal to the foot so as to form a thin layer over the surface of a portion of the liver. When the organs are gorged with their products the portions of the body that contain them are plump and comparatively large. When spawning has been completed they are shriveled and small. In the adult there is no apparent separation into a pair of organs farther than by the possession of a pair of ducts. These are not very conspicuous and enter the kidneys of the respective sides near their dorsal ends. From this point out, the sexual products traverse the lumen of the kidney, so they are finally expelled into the water through the external opening of the kidney.

The products are expelled from the openings of the kidneys in streams. The animal occasionally flaps its valves together during the process so the products are thrown out of the shell and dispersed in the water. For the most part the animal lies with the valves separated and is rather indifferent to outside stimulations. At such times it is sometimes possible to pick a specimen up out of the water without causing it to close its shell. Soon after removal from the water, however, the animal recovers and responds as usual. Replaced in the water it may or may not immediately begin to spawn again.

The relation of the genital ducts and kidneys of lamellibranchs has long been considered as important for its possible bearing on the relation of the kidneys to nephridia and the pericardium to a cœlom. In the adult of this form the sexual ducts open into the kidneys near their pericardial ends. Nothing is known about their developmental relation. The openings are much farther from the external openings of the kidneys than I have found to be the case in Yoldia lamatula (5) or Nucula delphinodonta (7) but not so far as in the case of Solenoma where, as Stempell has found (30) for one species (Solemya togata) and I have verified for another one (Solenomya velum) the ducts open very near the pericardial ends of the kidneys. In view of what we know about these and other species studied and reported by Pelseneer, (22) Stempell (29) and others, where it would seem that we have all gradations from separate openings, near the outer end of the kidneys, openings near the pericardial end of the kidneys, and double openings, so the genital ducts may be connected with the kidneys by branchs and be continued to the outside as well, most of which arrangements are present among members of the Protobranchia, it is still very doubtful whether any significance can be attached to the relationship of the genital ducts and kidneys in different forms.

CIRCULATORY SYSTEM.

The animal is large enough to allow one to successfully inject the chief vessels with starch or gelatin injecting masses, and then by dissection and microscopic preparations to trace the distribution of the vessels of the different organs and to determine quite definitely the course taken by the blood in its circulation.

The heart is a typical, symmetrical lamellibranch heart with two auricles and one ventricle (fig. 11, 13 and 20) the latter perforated by the intestine which enters it near one end and leaves it near the other end. Dorsally the ventricle is prolonged somewhat, posterior to the intestine, where the morphologically anterior aorta is given off, and ventrally to a less extent it is prolonged anterior to the intestine, where the much smaller morphologically posterior aorta is given off. The walls of the ventricle are of about even thickness throughout their extent, and are quite smooth outside and inside. The auricles join the ventricle on each side near its middle, are somewhat triangular in shape, with the most acute angle receiving blood from the gills and mantle, at a point dorsal to the adductor muscle, and directly ventral to, but some distance from, the cartilage. The opening of each auricle into the ventricle is near the middle of the side of the auricle that lies next to the ventricle and farthest away from the opening where the auricle receives its blood. The muscles around the openings of the auricles into the ventricle, and to a less extent around the openings through which the auricles receive blood, are well developed and must act as spinctors that tend to keep the blood from being regurgitated. The walls of the auricles, unlike those of the ventricles, are roughened by pits that open into the cavities of the auricles. These seem to be formed by the arrangement of bands of muscle fibers along the borders of the pits. The arrangement gives the outside of the auricle a pebbly appearance that is very striking. Both auricles and venticle are composed of interlacing muscle fibers, and are capable of great extension. In preserved specimens, the heart is usually contracted and is not very conspicuous. In such contracted hearts the cavities of both auricles and ventricle are practically obliterated.

The heart lies in a somewhat triangular, spacious, pericardial cavity that is dorsal to the posterior half of the adductor muscle, and ventral to the posterior portion of the liver. Posteriorly, it is covered only by a somewhat thick, muscular membrane which separates it from the mantle chamber.

As already mentioned, two blood vessels leave the ventricle (figs. 11 and 13), one from each end. Although they are not so placed in reference to the ways the terms have been used in describing this form, the two ends correspond to the anterior and posterior ends of the ventricle in most forms of lamellibranchs. The posterior aorta is much the smaller of the two, leaves the heart ventral to the intestine (actually anterior to it) and divides immediately after leaving the heart, into two vessels, one of which, the smaller, follows along the intestine supplying it and surrounding portions with blood. The other vessel turns almost at right angles upon leaving the aorta and enters the adductor muscle, where it divides into a system of vessels that supply the muscle with blood.

The anterior aorta is much larger than the posterior aorta, and supplies all of the remainder of the body. It leaves the ventricle dorsal to (actually posterior to) the intestine and very soon gives rise to a vessel which passes into and supplies the wall that separates the pericardial cavity from the mantle chamber. From the pericardium the anterior aorta follows along the postero-dorsal border of the liver to the base of the ear. Here it gives rise to a branch (fig. 13, ppa.) which passes posteriorly to the extreme upper margin of the mantle that lines the ear, giving off along its course a number of branches which supply this portion of the mantle. Here it divides into two vessels, a right and a left, each of which bends abruptly ventrally (fig. 9, ppa.) and follows along the margin of the respective mantle lobe about opposite the line of attachment of the infolded ridge of the mantle, alongside but external to the pallial nerve. Very fine branches are given off from these vessels all along their courses, which further divide to form systems of capillary spaces that are finest and most numerous near the margins. Some of these capillary spaces are large enough to be injected with starch mass, and I have a preparation of the mantle lobe from which only the infolded ridge has been removed that was dehydrated, cleared, and mounted in balsam, in which the whole system of vessels can be traced. A gelatin mass not only fills the spaces mentioned, but passes out between the cells so that in sections it may be seen to be diffused throughout the tissue. This seems to hold good for all other parts of the body with the exception of the gills, in which organs the mass is more completely, but not entirely, confined to the blood spaces. The indication therefore is, that the blood spaces are not confined vessels, and that the blood functions as both blood and lymph. The posterior pallial vessel may be traced far anteriorily, gradually diminishing in size along its course. Here it finally joins the anterior pallial vessel. The anterior pallial artery (fig. 13, apa.) leaves the anterior aorta very near the cartilage and runs directly to the anterior border of the hinge region of the mantle, giving off vessels to this portion of the mantle on the way. Here it branches into right and left vessels, each of which bend abruptly ventrally (fig. 9, apa.) and pursues a course along the anterior border of the mantle similar to that taken by the posterior pallial artery at the other extremity of the animal.

Along the anterior border of the mantle, near the dorsal line, the vessel is rather small and slightly broken in its course. It may be possible that this represents the border line between the posterior and the anterior pallial arteries. There are other reasons for believing that a large share of the animal is morphologically equivalent to the posterior portions of other forms, and that the anterior portion is greatly reduced. This has received attention in another place.

Several vessels leave the anterior aorta to supply the liver and stomach. Most prominent among these is a vessel which leaves the aorta between the points of origin of the anterior and posterior pallial arteries. This bends out toward the left side of the liver, where, in injected specimens, it is very conspicuous, passes ventrally and sends branches to the major part of the liver and to the stomach.

A short distance in front of the cartilage the anterior aorta bends ventrally, passes through the liver and gives off a few small branches to it, sends a vessel to the palps in passing, and passes on to supply the foot and the visceral mass. The vessel that supplies the foot (fig. 13, fa.) leaves the aorta a short distance ventral to the mouth, passes along the body wall until the foot is reached and extends into the foot along its dorsal border. Just before entering the foot this, the pedal artery, gives rise to a small vessel that passes posteriorly along the single retractor muscle of the foot supplying it with blood. From the point of origin of the pedal artery the aorta extends into the visceral mass following along the enlarged portion of the intestine that leads away from the stomach, and supplying this and other portions of the intestine and the reproductive organs with small and with large branches. The enlarged portion of the intestine that comes from the stomach is especially well supplied (compare figs. 12 and 13), there being numerous small branches that are given out directly from the aorta, and large branches that follow along on the different sides of this portion of the intestine and likewise supply it with branches. A short distance ventral to the foot a large branch leaves the aorta and passes postero-ventrally to divide again and form small branches that supply the remaining loops of the intestine and the postero-ventral portions of the reproductive organs.

This completes what might be called the systemic arterial system. Beginning with the heart the system ends in the capillary spaces of the various organs. This system is most easily injected through the vessel in the suspensory membrane of the gills that is farthest from the adductor muscle, (fig. 11, bv.) with a hypodermic syringe, injecting toward the heart. If a starch mass that will not pass through the capillary spaces is used, all of the vessels thus far described will be injected, as will also the veins that return blood from the gills, as this vessel is the one that returns blood from the gills to the heart. If a gelatin mass is used all of the systems may be injected, but as the injecting mass may pass out of the spaces, between the cells of the various organs, such injection does not aid in tracing the course of blood flow.

The systemic veins (fig. 14) that collect the blood that is supplied by the systemic arteries from the various organs of the body, may be injected from several different vessels. They may be injected by pushing the needle beneath the mmbrane that covers the posterior surface of the adductor muscle. A large blood space occupies this position, into which the needle is inserted and the mass injected fills the systemic veins. Another point from which these veins may be injected is from one of the superficial vessels of the visceral mass. These vessels are very conspicuous, and may be very easily picked up with the needle. Still another vessel is the vein that returns blood from the liver, which may be seen on the left side of the animal anterior to, but near the large artery that supplies the liver. Injecting any one of these vessels will to a greater or less extent inject the others, but there does not seem to be an entirely free communication between them. They all carry blood to the kidneys, and seem to empty into a common sinus on either side, that lies alongside the kidney in the walls of the visceral mass. The sinuses of the two sides are conneected beneath the adductor muscle, but it frequently happens that a complete injection of the system is not obtained from an injection from any one of the veins mentioned. Just where the obstruction lies in such cases has not been determined. It has been noticed that obstructions are more likely to be encountered in injecting from the veins of the visceral mass than in injecting any of the others.

Inasmuch as blood spaces are cut in removing the muscle from the shell it has been found desirable in injecting this system of vessels to wedge the valves open and to inject from the posterior surface of the adductor muscle. In injecting after the animal is removed a considerable quantity of the injecting mass is sure to escape at the ends of the muscle.

The position of the veins may be seen in figure 14. A large vein comes from the liver, another from the foot, and the veins in the muscle unite to form a more or less definite sinus along the dorsal border of the muscle, and two smaller ones on the anterior and ventral side of the muscle. These sinuses unite near the anterior end of the kidneys. A series of vessels from the visceral mass unite along the borders of the kidneys and finally connect with these sinuses. Most of the blood from all of these organs is distributed to the kidneys through systems of capillary spaces. The branching of these vessels is not conspicuous on the surface of the kidneys, but is better seen by cutting the kidneys open. That not all of the blood necessarily traverses the capillary spaces of the kidneys is indicated by the fact that injections of the systemic veins frequently fill the vein that carries blood away from the kidneys as well as those leading to it. This is much more frequently the case when injecting from the posterior surface of the adductor muscle than when injecting from other places, and seems to be dependent upon a direct connection between the vessel in question and the sinuses on the anterior and ventral surface of the adductor muscle near the dorsal ends of the kidneys.

Of the blood that leaves the heart, only that which goes to the mantle remains to be accounted for. This is collected and returned directly to the heart (fig. 9, pv.).

All of the blood that leaves the kidneys is conducted to the gills. The blood from each kidney is collected into a sinus that runs along the border of the kidney that is applied to the adductor muscle. This sinus, which also seems to receive blood from the sinuses on the anterior and ventral surface of the adductor muscle, bends abruptly ventrally over the anterior end of the kidney and is continued on the lower border of the suspensory membrane of the gill (fig. 11, ba.) to the posterior end of the gill, supplying the gill with branches throughout its length.

The blood vessels of the gills have been described in connection with the structure of the gills, but for the sake of completeness the course of the blood through the gills will be traced in this connection.

Blood vessels leave the vessel that carries blood from the kidney, opposite each of the inter-lamellar junctions of each of the gills supported by the suspensory membrane. Each of these branches is continued along the free border of the membrane that forms the inter-lamellar junction (figs. 17 and 18, ba'.) until it reaches the free edge of the lamella, the edge that is not attached to the suspensory membrane. That is, if the branch supplies an outer gill, it leaves the suspensory membrane along the free border of an inter-lamellar junction and crosses over to the free border of the outer lamella of this gill. Here the vessel is continued down the enlarged, modified filament that is concerned in the formation of the inter-lamellar junction (fig. 17, ba″.) giving out side branches through each of the inter-filamenter junctions (as long as these are composed of tissue that can carry blood vessels) and so supplies the various filaments of the lamella. The blood thus distributed finds its way around the margin of the gill through small blood spaces and is continued up the other lamella of the gill, the blood of the small filaments being gradually collected through the vessels of the inter-filamenter junctions into the vessels of the large filaments, (fig. 17, bv′.) and by these poured into a vessel that lies just beneath the vessel that supplies the gill and runs parallel with it (figs. 11 and 18, bv.). This vessel receives all of the blood from both of the gills of the side, and carries it directly to the corresponding auricle of the heart. Just before the vessel empties into the heart it receives a rather large vessel from the corresponding lobe of the mantle which returns the blood that was sent to the mantle, back of the heart.

To sum up the course of the circulation of the blood briefly, it will be seen that of the blood that leaves the heart only that which is sent to the mantle is returned to the heart after traversing a single get of capillary spaces; that a small portion of the blood sent to the adductor muscle (that which is collected by the sinuses on the antro-ventral portion of the muscle) may be returned after traversing two sets of capillaries—those of the adductor muscle and those of the gills; and that the greater portion is returned only after traversing three sets of capillaries—those of the general system, those of the kidneys, and those of the gills.

The reasons for this arrangement of the circulatory system are at least in part not hard to explain. The blood which passes to the mantle loses some of its nourishing materials, but as the mantle lobes are thin and are bathed over such a large portion of their surfaces by a current of water, in which there is an abundance of dissolved oxygen, respiration, no doubt, takes place direct, and the blood has no need to pass through the gills to get a supply. Again the work of the mantle is not of such an active nature as to load the blood with nitrogenous wastes. It seems likely that the amount of nitrogenous waste in the blood that has traversed the mantle is so small that it would diminish the proportion of nitrogenous waste in the blood, if this blood were added to the blood that passes through the kidneys.

The blood that goes to the general system must in its progress lose a considerable portion of its oxygen, and (in all portions except around the alimentary canal, where there is, of course, a decided gain) food materials, and gain from the waste of the tissues a considerable amount of nitrogenous and carbonaceous wastes. It is then essential that such blood should go to the excretory and respiratory organs to get rid of these waste products and to gain oxygen. Inasmuch as the heart provides for but a single circulation it is, of course, necessary that the capillaries of these organs be traversed before the blood is returned to the heart. Why it is arranged so part of the blood may dodge the kidneys and be carried directly to the gills is not nearly so evident. Possibly the periodically great activity of the adductor muscle causes the blood to move through it so rapidly that the small kidneys cannot take care of it and properly perform their function, and the other channel is provided to carry the surplus away to the comparatively extensive gills where the increased flow can be taken care of with greater ease. It is, of course, essential that the amount of orygen in the blood at such times shall not be reduced. It is at any rate evident that there is a possibility that part of the blood that is returned from the muscle, liver, etc., may not pass through the kidneys, for when starch injecting mass is injected through a vessel that carries blood from one of the kidneys to the gills not only are the kidney and the gill injected, but part of the mass usually finds its way into the adductor muscle, liver, and other organs of the body.

The rate of the heart beat is slow, and as in other lamellibranchs is, no doubt, dependent upon the temperature of the animal as well as on other factors. The auricles and ventricle become very greatly distended during diastole, and contract so that their cavities are almost entirely obliterated in systole.

The three pairs of ganglia that are usually found in lamellibranchs are present in this form, but they differ greatly in size and they are not all placed in the usual positions.

The cerebral ganglia (fig. 15, cg.) are placed some distance ventral to the mouth, just beneath the outer covering of the body. They, like the other ganglia, are yellowish in color, and may frequently be faintly seen through the covering of the body. Each cerebral ganglion is somewhat elliptical in outline with the long axis directed dorso-ventrally and has a rather distinct swelling on the ventral (actually anterior) and outer side (the side away from the median plane of the body) (fig. 24, cg). The anterior end of each cerebral ganglion presents a forked appearance, due to the origin of two large nerve cords. The inner and ventral one of these two cords (figs. 23 and 24, cc.) is the commissure that joins the two cerebral ganglia. As the ganglia lie some distance ventral to the œsophagus, this commissure forms a long loop that passes dorsally around the œsophagus just posterior to the mouth. The outer and posterior of the two large cords that leave the anterior end of each ganglion is the anteror pallial nerve (figs. 15, 23 and 24, apn). This runs parallel with the commissure as far as the œsophagus and is then continued along the side of the liver and in the mantle, to the margin of the mantle in the region of the anterior ear of the shell, where it joins by several branches the circum-pallial nerve (cpn.) that follows along the margin of the mantle near the bases of the tentacles and eyes. The circum-pallial nerve will receive attention later.

Between the points of origin of the cerebral commissure and the pallial nerve, a small nerve (figs. 23 and 24, pn.) leaves the ganglion to be continued dorsally, and to supply the labial palp.

From the inner, ventral surface of each cerebral ganglion, a little in front of the middle, the cerebro-pedal connective leaves to join the pedal ganglion of the same side. The cerebro-pedal connective is smaller near the cerebral than the pedal ganglion (fig. 24, cpc.) and bears a ganglionic swelling on its outer side very near the pedal ganglion.

In the acute angle formed by the surface of the cerebral ganglion and the cerebro-pedal connective, a small nerve (otn.), the otocystic nerve, leaves the ganglion to be continued around the dorsal surface of the cerebro-pedal connective to the otocyst of the same side. This nerve will receive attention later.

Posteriorly the cerebral-ganglia taper rather gradually into the cerebral-visceral connectives which run along the sides of the visceral mass very near the adductor muscle until the visceral ganglia are reached.

The pedal ganglia lie very near each other (fig. 24, pg.), so the commissure that connects them is short and broad and presents ordinary ganglionic structure. They are separated from the cerebral ganglia only by a short interval, and lie anterior and slightly ventral to them, some distance dorsal to the base of the foot. They lie so near the surface that their color may frequently be distinguished through the body wall beneath the mouth. Two large nerves (fn.) leave each pedal ganglion to be continued into the foot where they supply the muscles of the foot and probably the byssal gland. The swellings on the cerebro-pedal connectives near the pedal ganglia have already been described. The otocystic nerves which usually leave the cerebropedal connectives near the pedal ganglia, in this form originate directly from the cerebral ganglia near the point where the connectives leave the ganglia.

The visceral ganglia (figs. 15, 23, and 25, vg.) are by far the largest and most complicated of the ganglia, and from them nerves are sent to most parts of the body. They are situated on the antro-ventral surface of the adductor muscle, nearly opposite the external opening of the kidneys. They are imbedded in a mass of connective tissue and are fused to each other so the commissure that connects them is nearly as broad as the ganglia themselves and shows ganglionic structure. The chief indication of the presence of a pair of ganglia is the arrangement of the nerves that leave them, and of the celebro-visceral connectives that join them. The ganglia are divided into very definite regions, each of which is connected with definite bundles of nerve fibers and, no doubt, has a particular function to perform. I have not had time to make a detailed study of the structure and nerve tracts of the ganglia, but I am satisfied that there is much more complexity than is ordinarily attributed to the ganglia of lamellibranchs. The dorsal surfaces of the ganglia are quite smooth, but when seen from the ventral surface (fig. 25) the regions that are indicated in the figure are always visible. On each cerebro-visceral connective, just before it joins the ganglion proper, there is a ganglionic swelling (x.) that supplies one of two roots of a nerve (figs. 15, 23, and 25, bn.) that leaves in an antro-dorsal direction along the border of the excretory organ, to bend ventrally and posteriorly in the suspensory membrane of the gills, and supply the gills of the corresponding side. Between the points where the cerebro-visceral connectives join the visceral ganglia, on the ventral side, there are four rather distinct swellings, with three less distinct swellings posterior to them. Extending laterally from the outer side of each ganglion is a somewhat flattened ridge (fig. 25. y.) from which all of the pallial nerves from this ganglion originate. These nerves (figs. 15 and 23, ppn.) pass laterally, posteriorly and anteriorly along the surface of the adductor muscle, to meet the mantle lobe and to be continued to the margins, where they unite with the circum-pallial nerve. It will be noticed that they unite with the circum-pallial nerve at intervals throughout the greater length of these nerves. As the pallial nerves that leave the visceral ganglia are in most forms distributed to the posterior portion of the mantle only, the distribution in this form may be looked upon as evidence that all of this portion of the mantle belongs morphologically to the posterior portion of the animal.

Other nerves leave the dorsal surface of the visceral ganglia near their posterior ends, and enter the adductor muscle directly. The nerves that supply the posterior division of the muscle are continued along the ventral surface of the anterior portion of the adductor muscle until this posterior portion is reached. Small nerves also leave the ventral side of the ganglia and penetrate the visceral mass.

All of the ganglia are well supplied with nerve cells, there being very many large polar cells present, but the number of the cells is far greater and their arrangement more complicated inthe visceral than in any of the other ganglia.

Nerve cells are also to be found in the circum-pallial nerves and in the branchial nerves. So abundant are the nerve cells in the circum-pallial nerves that they assume the structure of ganglia. The nerves by which they are connected with the visceral and cerebral ganglia contain no ganglionic cells. From the structural standpoint we would accordingly be justified in considering the circum-pallial nerves as separate ganglia, and the nerves connecting them with the visceral and cerebral ganglia as connectives.

The circum-pallial nerves of the two lobes of the mantle are connected with each other anteriorly and posteriorly near the hinge line (fig. 23, cpn). They are not of constant diameter but suddenly increase or diminish in size so that they have a rather irregular appearance. They lie just inside, that is, toward the median plane of the body, of the large pallial arteries that supply the mantle margin (fig. 26, cpn.) about opposite the line oi attachment of the infolded ridge. From them nerves are sent to the eyes and tentacles, to the infolded ridges and to the pallial muscles. Very likely the pallial muscles are partially supplied from the pallial nerves that come from the visceral ganglia, but of this I am not sure.

It seems probable that the ganglionic structure of these nerves has been developed to meet the needs of the very complex margins of the mantle. The development of such structure in the immediate region of the sense organs, is an indication of the ease with which such centers may be established when need arises. The branchial nerves are supplied with ganglionic cells throughout their length. These are present not only along the borders of the gills, but from the points where the nerves originate to their extremities. The almost constant activity of the gills no doubt renders such an arrangement desirable. No other nerves or connectives in the body seem to be supplied with ganglion cells.

The whole nervous system is modfied to meet the special needs of the animal. The cerebral and pedal ganglia are small, corresponding with the slight development of the anterior parts of the body and of the foot. The visceral ganglia are highly developed, corresponding to the excessive development of the parts that are supplied by these ganglia. Accessory centers have also been developed in the margins of the mantle and in the gills.

It seems that students of Mollusca quite commonly hold that the lamellibranch ganglia have been derived from a gastropod-like type, a type that possess at least one pair of ganglia, the pleural, that are not commonly found in lamellibranchs. This view seems to be based largely upon the acceptance of a hypothetical type for a primitive mollusk that seems to me to be a much better ancestor for the gastropods than for the other classes of the Mollusca. The discussion of this hypothetical form may be left for another place, but the discussion of the nervous system properly belongs here. About all of the actual evidence that we have of the presence of pleural ganglia in lamellibranchs is that in Nucula (22) and some other forms the anterior ganglionic mass is so shaped that it is possible to consider it as two ganglionic masses, and further that the connective that runs from this mass to the pedal ganglion is connected with this mass by two roots. The interpretation (22) that has been put on this is that the two apparent divisions of the ganglion represent respectively the cerebral and pleural ganglion, and that the roots of the connective represent the cerebro-pedal and pleuro-pedal connectives that have become fused before reaching the pedal ganglion. My own view, discussed in another paper (7) is that the apparent division into two ganglionic masses is superficial, and due to the swellings accompanying the origins of nerves, and that one of the cerebral ends of the connective may be the central end of the otocystic nerve which is fused for the greater part of its length with the connective, but, unlike most forms, is free near the ganglion. This view seemed to me most reasonable as Stempell (30) has found that in Soleyma togata, a supposed near relative of Nucula, the otocystic nerve arises directly from the cerebral ganglion and is separate from the connective throughout its length. So far as I know, the instance given by Stempell is the only one that has heretofore been reported where the otocystic nerves originate from the cerebral ganglia, and are free from the cerebro-pedal connectives throughout their length. Pecten tenuicostatus has the same arrangement. In this form the position of the ganglia, connectives and otocysts is such that it is a very simple matter for the otocystic nerves to make direct connection with the cerebral ganglia, but they do not join the ganglia at their nearest point. Instead they are continued around the connectives to join the ganglia in contact with, and posterior to them.

To me it seems probable that the separation into the two groups that have developed into the classes Lamellibranchiata and Gastropoda took place at an early date in the history of the Mollusca, probably before a complicated head apparatus was developed, and while the nervous system was of a very simple nature. If this was the case, we have no reason to search for pleural ganglia in lamellibranchs, for it is very probable that they never had them. In fact were ganglia ever present in this region in lamellibranchs, it would be more reasonable to view them as new formations for special purposes than as direct descendants from, and accordingly homologous with, the pleural ganglia of gastropods. The gastropod and lamellibranch are so different in structure and habits that we may reasonably expect important differences in their nervous systems. Gastropods and Cephalopods possess accessory ganglia that have evidently been developed to perform special functions. That such centers may be comparatively easily developed is indicated by the fact that the circum-pallial nerves of the scallop are essentially such centers. Is it not then more likely that pleural ganglia have been developed in the groups that need them than that lamellibranchs, which, so far as we know have never been more complicated than they are to-day, should have formerly possessed these ganglia and have since quite uniformly lost them?

SENSE ORGANS.

Eyes.—

The number and position of the eyes has been discussed in connection with the structure of the mantle, on the lobes of which they are borne. They have been so frequently and well described by other investigators that it does not seem necessary to give a detailed description here. Each eye (fig. 26) is club-shaped, pigmented near its outer end, and its position and general appearance indicate that it is probably a modified tentacle. The extreme end is occupied by the cornea, (co.) which consists of a single layer of transparent epithelial cells that are continuous with the layer of somewhat thicker cells that forms the remainder of the covering of the tentacle. Near the free extremity these cells are completely filled with a dark-brown or nearly black pigment, which gives the color already referred to, so that in sections of large eyes, where the pigmentation is deepest, the nuclei of the cells are not easily found. The pigmentation becomes less dense toward the base of the tentacle and gradually disappears. Muscle fibers that extend back into the eye stalk are attached to the edges of the cornea so in preserved specimens it is not uncommon to find the cornea pulled back so the pigmented portion extends around it as a ridge. These muscles may be of use in changing the focus of the eye. So far as I know, there is no other provision for focussing.

The lens (le.) is cellular in structure, and except for a thin layer of muscle and connective tissue fibers that cover its outer surface and are continuous with the muscle fibers at the edge of the cornea, it is in contact with the inner surface of the cornea. There is no space between them so the cornea, muscles and lens form a single optical lens. The inner surface of the lens is applied to the retina, (r.) but as part of the nerve (on.) that supplies the retina enters the eye from one side, the nerve is continued between the retina and the lens. The edges of the lens are bounded by a blood space.

In sections the lens varies greatly in shape. It may be nearly circular, indicating that the lens is nearly globular, or either its anterior or its posterior face may be greatly flattened. The shape shown in figure 26 is not uncommon, but sections in which the posterior face is drawn out and is very convex are not at all rare. It is a question whether these shapes indicate a possible focal range, or whether they are to a considerable extent distortions due to preservation.

The flattening of the outer face of the lens may be accomplished by the muscles that are attached to the margin of the cornea, and that are continued over the surface of the lens between it and the cornea. It is possible that injecting the blood space with blood and contracting muscles in the eye stalk which surround this blood space, may lengthen the lens—that is, make it more convex. The mechanism is not very complete, but it is hardly to be expected that focal changes take place with great rapidity.

The retina is rather thick, and is slightly concave toward the lens, with which it is always in contact. The exceedingly convex lens is no doubt sufficient to bring the light to a focus on the retina, although the retina is in contact with the surface of the lens. Judging from section it seems likely that the refractive indices of the cornea, lens, and retina are practically the same. If this is the case, the only refraction that takes place is when the light enters the cornea. In this case the relative convexity of the outer surface of the cornea determines the focal distance, and the shape of the inner portion of the eye is immaterial as long as the lens and retina are kept in contact. With such an arrangement the more convex the cornea the shorter the lens must be in order to place the retina at the focal distance, and vice versa.

The nerve that enters the eye on the side next to the shell, just in front of the surface of the retina that is applied to the lens, supplies the retina. The layer that resembles rods is placed on the side turned away from the lens, and it is to these that the nerve fibers are apparently distributed. A pigment layer, often of considerable thickness, lies next to the rods. Another nerve, a branch of the one already described, reaches the eye near its optical axis, and spreads out beneath this pigment layer. I have not traced its distribution.

Looking directly into it, the eye universally appears blue. The color is probably due to the breaking up of the light reflected from it by the small elements of which it is composed as there seems to be no blue pigment.

The development of the eye has not been carefully followed. It is noticeable that the small, presumably young eyes, have proportionately much thicker corneas than the large eyes have.

It is a difficult matter to determine by experiment how well a scallop sees. If an animal is placed in a position that is illuminated from one side, and allowed to remain undisturbed for some time, and then a sudden shadow is made to fall over it, it is almost sure to suddenly close its shell. If this be tried several times at short intervals the animal usually soon fails to respond. It is also to be noticed that Pecten irradians when approached in shallow water will either start to swim or close its valves. It is, of course, not at all certain that the stimulation that leads to this action is received through the eyes. The response is much more noticeable than with most other shallow water forms, but the scallop is naturally more active, and is well supplied with tactile tentacles as well as with eyes.

Quick motions outside of an aquarium made so the illumination is not materially affected, and so the aquarium is not jarred, frequently seem to cause response, but the results are so frequently negative that apparent responses may be accidental. Experiments to test the power of vision have not been devised.

Tentacles.—

The number and arrangement of the tentacles has been discussed in treating the mantle. Although the size, shape, and position of the tentacles differ considerably, they are all essentially of the same structure. As they are included in the color pattern of the margins of the mantle, some are pigmented and others are not. The tentacles are quite smooth when they are extended, and short, wrinkled, and conical when retracted. Each tentacle is covered by a layer of epithelium and bears near its free extremity several conical projections, "pinselzellen," each of which bears a cluster of sense cilia at its tip. These projections are always more numerous near the extremities of the tentacles than elsewhere, but they are scattered pretty well over their surfaces and may occur on the mantle also. Each tentacle (fig. 22) is supplied with a large nerve (n.) derived from the circum-pallial nerve, that runs the whole length of the tentacle near its middle line. Nerve cells are present in this nerve throughout its length. A connective tissue framework divides the interior into a number of spaces. Muscle fibers (mf.) that run lengthwise of the tentacle lie alongside the framework and surround the blood spaces (bs.). The nerve lies very near the center of the framework and occupies one side of a large blood space. The structure is very much the same as that of the special sense tentacle of Yoldia (5). The chief difference is, that in this tentacle there are a number of blood spaces, while in Yoldia there is only one.

The blood spaces serve to lengthen the tentacle, by having blood forced into them, and the muscle fibers shorten it.

Otocysts.—

The otocysts (figs. 15 and 24, ot.) are placed very near, and almost dorsal to the pedal ganglia, and accordingly not far from the cerebral ganglia, but a little ventral, anterior and nearer the median plane of the body than these ganglia. The otocysts are imbedded in a mass of connective tissue that surrounds the pedal ganglia, and may with comparative ease be dissected out with the pedal and the cerebral ganglia, and studied in total mounts.

Each otocyst consists of a nearly spherical pouch formed of epithelial cells that is connected with the exterior by a small canal (fig. 24, otc.) that opens almost opposite the cerebral ganglion of the corresponding side. Similar canals are present either as complete canals or as rudiments in different species of the Protobranchia, but so far as I know, have never before been described for any species outside of this group. As otocysts uniformly originate as invaginations from the surface epithelium of the animal possessing them, it is reasonable to suppose that these canals are simply persistent from the embryological condition, but this has not yet been proved. The otocysts are ciliated (whether the cilia are vibratile or not has not been observed) and usually contain a considerable mass of fine granular material that may be scattered, or collected into a very definte ball. It is not at all uncommon to find one otocyst nearly filled with this material, while the other is nearly empty. On the other hand, both may be nearly filled, or both may be nearly empty. The origin of this material is doubtful. In appearance it resembles fine fragments of debris such as is found on the bottoms where the scallops live, and there is sometimes some variation in the color of these particles. All of the particles seem to be sufficiently small to have been introduced through the otocystic canals, but I have not thus far found any of the shells of diatoms although the mud on which the animals live is full of them and many of them are as small as the particles that are found in the otocysts. The irregular, broken appearance of the particles and the fact that frequently there are many more particles in one otocyst than in the other rather points to their being foreign particles than to their being products of secretion.

The otocysts are usually considered to be static organs. So far as I know, there are no experiments that bear on the function of these organs in lamellibranchs, and the supposition that they are organs for determining position in space is based upon experiments on supposedly similar organs in other forms. The scallop normally lies on the right shell valve, but I am not sure that it makes any particular effort to turn over when it is placed on the other valve. When it swims and settles to the bottom, it settles uniformly on the right valve. Whether this is due to the shape of the shell or to some determining factor outside of the nervous system of the scallop or not, is not known.

EMBRYOLOGY.

From observations made early in the summer, it seemed probable that the giant scallop spawned rather late in the season; accordingly as soon as other duties permitted, August 20, 1901, quarters were procured at Bass Harbor, Mt. Desert Island, Maine, and work begun. Examination of specimens showed that for the most part they had not spawned, and that spermatoza removed from the testis and placed in sea water were active. Many trials were made while at Bass Harbor to artificially fertilize the eggs by cutting them out and mixing them with sea water containing sperm which had likewise been procured by cutting. Very few of the eggs showed any signs of development, and most of them that started did not develop normally. Eggs thus removed from a lamellibranch are irregular in shape, due no doubt to their crowded condition in the ovaries. For some reason that is not understood, the eggs of many species of lamellibranchs seldom round up, are incapable of fertilization, and soon go to pieces when they are cut out of the ovary. Such is the case with this form. Eggs removed even during the height of the breeding season did not develop well.

It was found that scallops that were full of eggs and sperm when placed in a floating car on August 23rd, had, when examined the next day, thrown most of their sexual products. Specimens had also been placed in large vessels of water at the same time, but these had not spawned and did not spawn although kept another day. The animals die rapidly in such vessels of water, seldom living more than three days, and frequently not more than one. A careful watch indicated that specimens put in the car did not spawn during the middle part of the day, so night observations were made. Fresh specimens were placed in the car and in a dory that had been carefully cleaned and partly filled with water, and left floating so that the temperature would remain something like that of the sea water outside. At intervals of a half hour up to midnight, the scallops in the car were examined by lantern light and a little of the water in the dory was examined microscopically, to see if eggs or sperm could be discovered. As they were apparently not spawning, they were left until just before sunrise, when observations were again begun. About 8 A. M. sperm were discovered in the water of the dory. Soon after several specimens began to throw sperm in such quantities that the water in their vicinity was turbid. Upon going to the car it was found that the water in the car and for some distance outside was so full of eggs and sperm that they could be dipped up in such numbers that the bottoms of white agate ware dish pans filled with the water became pink with the eggs that settled. The water was decanted and the eggs supplied with fresh sea water. Some of the eggs were transferred to glass dishes that were covered by loose glass plates that prevented undue evaporation, and excluded dirt that was rather in evidence in the shed on the steamboat wharf that served as a laboratory. Water was changed in all of the vessels at intervals during the time that the embryos remained alive.

The scallops that were put in the dory were removed as soon as eggs were abundant, and after allowing a few minutes for the eggs to settle, most of the water was dipped out and replaced by pure sea water. The results were not satisfactory, however, and as at 6 P. M. the embryos in the dory did not seem to be doing well, not much further attention was given them. All of them apparently died before those in the dishes were in bad condition. This is not strange, as a large quantity of sperm had to be left in the dory, and it was not possible to give the embryos as good care in the bottom of a comparatively foul dory as in the cleaner dishes.

The development is what may be considered normal for lamellibranchs. There is no part of the early larval history that is different from what might be expected for such a form, as it differs very little from Teredo (9 and 27), Dressinia (19), Ostrea (4), Mya (18), Cardium, and a host of others that have been described, or are familiar to every worker on lamellibranch embryology.

It will accordingly be necessary to describe the formation of the embryos only very briefly. As the age of the eggs could not be accurately determined it is not possible to give the exact time that elapsed before the polar bodies made their appearance, but probably the first polar body was given off in from half to three-quarters of an hour after the egg was laid. The first external sign of activity after fertilization is the formation of a prominent yolk-lobe, which nearly disappears after the first polar body is formed, to become prominent again when the second polar body is formed (fig. 27) and to disappear again after this is separated from the egg. It again becomes prominent when the egg cleaves into two cells, (fig. 29) and is slightly visible during the second cleavage. The polar bodies are given off from the side of the egg that is opposite the yolk-lobe, and although the egg is not inclosed in a membrane as is the case in many forms, the polar bodies adhere until the cells are provided with cilia and the embryo begins to swim. The adherence is apparently due to protoplasmic strands such as have been described by Andrews (1 and 2).

The first plane of cleavage passes through the point where the polar bodies were formed, and just to one side of the yolk-lobe (fig. 29). This divides the egg into two unequal portions, the larger of which contains the whole of the yolk-lobe. The next cleavage plane also passes through the point where the polar bodies were formed and nearly at right angles to the first cleavage plane (fig. 30). This also passes a little to one side of the yolk-lobe so at least a large portion of the yolk remains in one cell which is larger than the others.

The division into eight cells is accomplished by cleavage planes at right angles to the planes already described (fig. 31). In this way each of the four cells are divided unequally, those nearest the polar bodies being smaller than those on the opposite side. Continued division of the cells results in the formation of a mass of cells (fig. 32) some of which are confined to the surface, while others are large and extend into the interior, thus forming an almost typical epibolic gastrula. This stage of development is reached in from 12 to 14 hours, at which time many of the surface cells have acquired cilia and the embryos begin to roll around on the bottom of the dish.

An hour or two later the apical cilia make their appearance. They at first are not much longer than the others, and do not seem to be very numerous. Because of their motion and tendency to bunch together they are hard to count, but only four or five seem to be present at this early stage. They grow quite rapidly until they are nearly as long as the diameter of the embryo and increase in number until a considerable bunch is formed.

About this time the embryo begins to elongate slightly in the axis roughly corresponding to the direction of the apical tuft of cilia and the embryo begins to swim freely in the water. The motion is not very rapid, and is at first rolling, but as the apical cilia elongate the embryo begins to swim in definite lines, always with the apical cilia pointing forward. In swimming the embryo varies its direction almost constantly, and continually rotates on its longitudinal axis. The direction of the rotation may be changed from time to time.

Sections at this stage (fig. 33) show two pouches formed by the invagination of the surface layer of cells. On what is to become the dorsal portion of the animal, nearly opposite the apical cilia, is the larger of these two pouches (sg.). It is composed of large cells that are continuous with the surface cells. This is the shell gland. It soon spreads out and grows down on the sides to form the lobes of the mantle and to secrete the shell. The other invagination (ar.) is somewhat smaller than the one just described, is composed of smaller cells, and is situated on the ventral side. Like the other, this is continuous with the surface layer of cells. It has been formed apparently partially by the pushing in of surface cells, and partially by the division and separation of cells on the inside of the embryo. This is the first appearance of the alimentary canal, and probably represents a combined archenteron and stomodæum. The inner ends of the shell gland and archenteron lie very close to each other and may for a time be in contact. With the spreading out of the shell gland, which is accomplished in about 18 or 20 hours after the egg is fertilized, the embryo elongates decidedly (fig. 34) and becomes somewhat pointed behind; that is, the end directed away from the apical cilia becomes the pointed end. The embryo enlarges, due to the formation of a space beneath the shell gland, which has now become the mantle, and the surface cilia become restricted to the anterior end. The archenteron begins to grow rapidly, enlarges to form the stomach, (s.) and grows posteriorly to form the intestine (i.). The anterior adductor muscle (aam.) makes its appearance dorsal to the apical plate (ap.) and posterior to the dorsal margin of the portion that bears surface cilia, which later develops into the velum. The space between the developing alimentary canal and the body wall is quite extensive, practically surrounding the alimentary canal except where it joins the body wall at each end and where the anterior end of the stomach is in contact with the apical plate. The adductor muscle is in contact with the body wall on its anterior surface, but is otherwise surrounded by this space. A few greatly elongated spindle-shaped fibers resembling muscle fibers usually extend across the space. Almost universally one or two such fibers extend from the dorsal surface of the stomach dorsally and posteriorly to the body wall. Similar fibers have been noticed in the embryos of other lamellibranchs and are quite conspicuous in Nucula, (7) but their function is not known. The space is no doubt a schizocœle that is formed as the result of the arching up of the shell gland to form the mantle. This takes place much more rapidly than the internal organs grow, and the space is accordingly formed. Its ultimate fate has not been traced as the oldest of the embryos reared still have a remnant of it dorsal to the alimentary canal.

The stage that has been described is practically a trochophore. The cilia are in front of the mouth, but cover the whole area around the apical tuft instead of being arranged to form a band. Later, as the velum is formed, they are better developed along the margins of its lobes and thus form a band.

A stage similar to this is probably present in all forms of lamellibranchs that do not give protection to their embryos as is done by the Unionidæ, Sphærium, etc. Even here (32) something that corresponds to the stage may be recognized. At first sight the embryos of Yoldia (5) and Nucula (7) seem to differ considerably from the trochophore that has been described, but this is apparent rather than real. If the ciliated cells that cover these larvæ and form the tests, were pushed forward and the stomodæum shortened so the mouth would retain its position at the margin of the ciliated area, the two larvæ would be essentially alike. At a slightly earlier stage in Pecten a large part of the surface is covered with cilia, and this is changed only by the posterior development of the embryo, beginning with the flattening of the shell gland. Such a posterior development is normal in many trochophores as in the case of Dondersia (23), Dentalium (17), Chiton (10 and 16), and most lamellibranchs and gastropods, as well as in annelids, where the posterior development is so marked.

The shell gland spreads out laterally and forms the lobes of the mantle which secrete the shell valves (figs. 35 and 36). The ciliated area grows rapidly and forms the two lobes of the velum (vl.). The cerebral ganglon (cg.) are formed near the apical plate. The alimentary canal grows dorsally and is bent into the shape of a U. The stomach (s.) enlarges, the intestine (i.) acquires an anal opening, the greater part of the schizocœle becomes filled with mesoderm and the embryo assumes the form of a veliger. This change is accomplished inside of three or four hours, so active veligers are formed in about thirty hours after the eggs are laid. The shape of the embryonic shell is quite characteristic for the embryonic shells of lamellibranchs (12) and differs very greatly from the adult form. Risser reports that this is not the case with Pecten irradians (24) but the shells on very young embryos that I have reared are very similar. Until this stage is reached the embryos take little or no food. They now swim about actively through the water, frequently going to the surface. The cilia on the edges of the lobes of the velum are the means of locomotion. The apical cilia remain bunched and are moved rather gently in different directions but apparently function as sensory rather than locomotary cilia. Each individual occasionally retracts its velum between the valves of its shell, closes its shell, and slowly settles to the bottom. This is almost always the case whenever the animal is disturbed, as by jarring the dish in which the veliger is swimming, or when the animal runs into anything or is run into by another animal. In such cases the veliger may recover after falling a short distance, or it may fall to the bottom and remain quiet for some time. The response to disturbance, which is the usual response of lamellibranch veligers, has been taken into account by Mead and Barnes (18) who have devised a trap whereby quantities of the veligers of the soft-shelled clam, Mya arenaria, can be collected and reared without trouble to such a size that they may be used as seed in stocking clam ground.

The embryos of most lamellibranchs usually remain as veligers and swim about freely for a number of days, or even for some weeks. The embryos of Pecten were kept alive for only five days. Weather and an unsatisfactory place to work interfered with proper care and they were apparently weakened by starvation. This difficulty could probably easily be overcome, as in other cases, by putting them in vessels of sea water in which cultures of the diatoms that supply the greater part of their natural food have been started, but cultures could not be started at the time, and there have since been no opportunities to return to the scallop grounds during the breeding season. The young of Nucula proxima reared from eggs, have been kept alive for eleven months in a small jar of sea water in which a small quantity of mud from the bottom had been placed after straining it through silk bolting cloth to remove forms that might be enemies.

Many fishermen report having seen the young scallops attached to shells by means of threads during the early winter. In a few cases small Anomia were brought to me as young scallops, but most of the fishermen to whom these were shown did not accept them as young scallops. Their descriptions of young scallops were in some cases quite minute, and apparently accurate, and in all such cases the scallops were said to be attached by threads. Pecten irradians is known to attach itself by a byssus in the young (24) and even in the adult stage, and it is very probable that the young of the giant scallop attach themselves in the same way. If so, when the veligers settle permanently to the bottom, they must find something on which to attach themselves in order to keep from being destroyed. If this is true, the absence of suitable material for this purpose may be the reason that many of the old grounds, especially the shallow water grounds that have been much dredged, no longer support scallops. The present custom is to shuck the scallop before leaving the grounds, but the shells are usually badly attacked by boring sponges, and go to pieces quickly, so it is possible that they may not be of service when the breedng season arrives. I have had no opportunity to examine the run-out grounds, nor to make a careful study of existing beds, so the above are simply surmises that may not agree with facts.

SUMMARY.

Shell.—

The shell is adapted for swimming, in shape, in weight, in the position and strength of the muscle, and in the possession of a large cartilage, and a straight hinge line which will allow rapid movement without great strains or friction. (See pp. 7-11, and Figs. 1-7.)

Mantle.—

The mantle lobes are supplied with numerous sense tentacles and eyes which are probably of use in detecting enemies; with nerves that possess ganglion cells; with infolded ridges that regulate the opening of the mantle chamber when the shell is open and probably serve to direct the current of water thrown from the shell in swimming; and with strong pallial muscles which serve to withdraw the margins of the mantle when the shell is closed. (See pp. 12-16 and Figs. 9, 10, 16, 20 and 26.)

Foot.—

The foot is comparatively small, split at the end, and possesses a large byssal gland. It is probably not of much service in locomotion. The retractor muscle of the left side only is retained. (See pp. 16-19 and Figs. 8, 10, and 12.)

Alimentary Canal.—

The stomach lies near the hinge line surrounded by the liver. The portion of the intestine that leaves the stomach corresponds with it in structure. It seems probable that one loop of the intestine has been overlooked in previous dissections of scallops. (See pp. 19 and 20, and Fig. 12.)

Labial Palps.—

Unlike most forms, the palps are ruffled above and below the mouth. The reason for the arrangement is not known. (See pp. 20 and 21, and figs. 10 and 12.)

Gills.—

Each gill is attached by one lamella to a muscular membrane that serves to elevate the gills when the shell is closed. The other lamella is not attached. This arrangement makes it possible for the water to be thrown from the shell in swimming without injuring the gills. The inter-filamenter junctions are composed of cilia near the margins of the gills, and of tissue near the suspensory membranes. Their blood vascular supply is intricate. (See pp. 21-30, and figs. 11, 12, 17, 18, 19, 20, and 21.)

Muscular System.—

The anterior adductor muscle is lost at an early period of development. The posterior adductor muscle is distinctly separated into an anterior and a posterior portion. The anterior portion, which is much the larger of the two, may be cut without causing the shell valves to gap. If the posterior portion is cut without injuring the anterior portion, the valves immediately open.

Muscles for withdrawing the margins of the mantle and the gills are well developed. Only the left retractor muscle of the foot is present in the adult animal. (See pp. 31 and 32, and figs. 10, 16, 19, 20, and 26.)

Excretory Organs.—

These are essentially rather large sacs with glandular walls. They receive the genital ducts near their pericardial ends. (See pp. 32 and 33, and figs. 13 and 20.)

Genital Organs.

The genital organs are large, pink in the female, and white in the male. The genital ducts join the excretory organs near their pericardial ends. (See pp. 33-35.)

Circulatory System.—

The large size of the animal makes it possible to inject the vascular system successfully. Blood from the mantle is returned immediately to the heart. Most of the blood from other portions is returned to the kidneys, from which it is carried to the gills and then back to the heart. A portion may dodge the kidneys and go to the gills. Blood seems to act both as blood and lymph. (See pp. 35-42, and figs. 9, 11, 13, 14, 17, and 21.)

Nervous System.—

The cerebral and pedal ganglia are small and somewhat removed from their usual positions. The visceral ganglia are very large and complicated in structure. The circum-pallial nerves and the branchial nerves have ganglion cells throughout their length. The otocystic nerves originate directly from the cerebral ganglia. (See pp. 43-48, and figs. 15, 23, 24, and 25.)

Sense Organs.—

The eyes are numerous and optically arranged for the formation of images. The sense tentacles are exceedingly numerous and of ordinary structure. The otocysts have canals that open at the surface of the body and the otocystic nerves join the cerebral ganglia direct. The otoliths are composed of granular material that may have been introduced from the outside. (See pp. 48-53, and figs. 10, 20, 22, 24, and 26.)

Embryology.—

The development is normal and rather rapid. (See pp. 53-60, and figs. 27-36.)

LITERATURE.

1. **Andrews.** Some Activities of Polar Bodies. Johns Hopkins Univ. Circ., Vol. XVII., No. 132, 1897.
2. **Andrews.** Activities of the Polar Bodies of Cerebratulus. Arch. f. Entwicklungsmechanik. Bd. IV., 1898.
3. **Brooks.** The Origin of the Oldest Fossils and the Discovery of the Bottom of the Ocean. Smithsonian Report for 1894 (also Salpa.
4. **Brooks.** The Development of the American Oyster (Ostrea virginiana). Stud. Biol. Lab. Johns Hopkins Univ., Vol. 1, 1880.
5. **Drew.** Yoldia limatula. Memoirs from the Biol. Lab. of the Johns Hopkins Univ. Vol. 4, No. 3, 1889.
6. **Drew.** Locomotion in Solenomya and its Relatives. Anat. Anz. Bd. XVII., No. 15, 1900.
7. **Drew.** The Life-History of Nucula delphinodonta. Quart. Jour. of Micro. Sci. Vol. 44, Part 3, New Series, 1901.
8. **Grave.** Investigations for the Promotion of the Oyster Industry of North Carolina. U. S. Fish Com. Report for 1903.
9. **Hatschek.** Ueber Entwickelungsgeschichte von Teredo. Arb. Zool. Inst. Wien. Bd. 3, 1880.
10. **Heath.** The Development of Ischnochiton. Zool. Jahrb., Abth. f. Anat. u. Ontog. Bd. 12, 1899.
11. **Hyde.** The Histology of the Eye of Pecten. Mark Anniversary Volume, Harvard, 1903.
12. **Jackson.** Phylogony of the Pelecypoda. Memoirs Boston Soc. Nat. Hist. Vol. IV., No. 8, 1890.
13. **Jameson.** On the Origin of Pearls. Proc. Zool. Soc. London, 1902.
14. **Kellogg.** A Contribution to our Knowledge of the Morphology of Lamellibranchiate Mollusks. Bul. U. S. Fish Com. Vol. X., 1890.
15. **Kellogg.** The Ciliary Mechanism in the Branchial Chamber of the Pelecypoda. Science (2), Vol. 11.
16. **Kowalevsky.** Embryogénie du Chiton Polii (Philippi) avec quelques Remarques sur le Développement des Autres Chitons. Ann. Mus. Hist. Nat. Marseille. T. 1, No. 5, 1883.

17. Lacaze-Duthiers. Historie de l'Organisation et du Développement du Dentale. Ann. des Sci. Nat. Ser. 4, VII., 1857.

18. Mead and Barnes. Observations on the Soft-clam. (Fifth paper). Rhode Island, 34th Ann. Report of the Com. of Inland Fisheries, 1904.

19. Meisenheimer. Entwicklungsgeschichte von Dreissensia polymorpha. Zeit. f. Wiss. Zool. Bd. LXIX., 1900.

20. Patten. Eyes of Molluscs and Arthropods. Mitth. Zool. Stat. Neapel. Bd. 6, 1886.

21. Patten. The Embryology of Patella. Arb. Zool. Inst. Univ. Wien. Bd. VI., 1886.

22. Pelseneer. Contribution á l'Etude des Lamellibranchs. Arch. de Biol. XI., 1891.

23. Pruvot. Sur le Développement d'un Solénogastre. Compt. rend. Acad. Sci. Paris. CXI., 1890.

24. Risser. Habits and Life-History of the Scallop (Pecten irradians). Rhode Island, 31st Ann. Report of the Com. of Inland Fisheries, 1901.

25. Rice. Die Systematische Verwertbarkeit der Kiemen bei den Lamellibranchiaten. Jen. Zeit. f. Naturwiss. Bd. XXXI., 1897.

26. Schreiner. Die Augen bei Pecten und Lima. Bergens Mus. Aarbog, 1896.

27. Sigerfoos. The Pholidæ. Notes on the Early Stages of Development. Johns Hopkins Univ. Circ. Vol. 14, 1895.

28. Smith. The Giant Scallop Fishery of Maine. Bul. U. S. Fish. Com., Vol. IX., 1889.

29. Stempell. Beiträge zur Kenntniss der Nuculiden. Zool. Jahrb. Sup. 4. Fauna Chilensis, Heft 2, 1898.

30. Stempell. Zur Anatomie von Solemya togata. Zool. Jahrb. Bd. XIII., 1899.

31. Stenta. Zur Kenntniss der Strömungen im Mantelraume der Lamellibranchiaten. Arb. Zool. Inst. Univ. Wien. Bd. XIV., 1902.

32. Zeigler. Die Entwickelung von Cyclas cornea. Zeit. f. Wiss. Zool. Bd. 41, 1885.

REFERENCE LETTERS.

a.	Auricle.
aa.	Anterior aorta.
aam.	Anteroir adductor muscle.
ac.	Apical cilia.
ap.	Apical plate.
apa.	Anterior pallial artery.
apn.	Anterior pallial nerve.
aps.	Anterior pallial scar.
ar.	Archenteron.
ba.	Branchial artery.
ba′.	Branches of the branchial artery.
ba″.	Branches of the branchial artery in the modified filaments.
bg.	Byssal gland.
bn.	Branchial nerve.
bs.	Blood space.
bv.	Branchial vein.
bv′.	Branches of the branchial vein.
c.	Cartilage.
cc.	Cerebral commissure.
cg.	Cerebral gangloin.
cgl.	Cuticular gland.
co.	Cornea.
cp.	Cartilage pit.
cpc.	Cerebro-pedal connective.
cpm.	Circular pallial muscles.
cpm′.	Circular pallial muscles of the infolded ridge.
cpn.	Circum-pallial nerve.
cr.	Chitinous rods.
cvc.	Cerebro-visceral connective.
e.	Excretory organ.
f.	Foot.
fa.	Foot artery.
fc.	Feeding cilia.
fe.	Free edge of the unattached lamella.
fm.	Foot muscle.
fn.	Foot nerve.

fs.	Filament support, probably to keep the filament from swelling into a cylindrical shape with the pressure of the blood.
fv.	Foot vein.
g.	Gill.
gf.	Gill filament.
i.	Intestine.
ifj.	Inter-filamentar junction.
ig.	Inner gill.
ilj.	Inter-lamellar junction.
io.	Inhalent ostium.
ir.	Infolded ridge of the mantle.
l.	Liver.
le.	Lens.
lm.	Longitudinal muscles.
lp.	Labial palps.
lv.	Left valve of the shell.
m.	Mantle.
mf.	Muscle fibers.
n.	Nerve.
oc.	Ostium cilia.
oe.	Œsophagus.
og.	Outer gill.
on.	Optic nerve.
ot.	Otocyst.
otn.	Otocystic nerve.
p.	Pericardial cavity.
pa.	Posterior adductor muscle, anterior portion.
pa'.	Posterior adductor muscle, posterior portion.
paa.	Posterior adductor artery.
pas.	Posterior adductor muscle scar, anterior portion.
pas'.	Posterior adductor muscle scar, posterior portion
pav.	Posterior adductor muscle vein.
pg.	Pedal ganglion.
pl.	Pallial line.
pn.	Palp nerve.
ppa.	Posterior pallial artery.
ppn.	Posterior pallial nerve.
pps.	Posterior pallial scar.
pv.	Pallial vein.
r.	Retina.
rpm.	Radial pallial muscles.
rv.	Right valve of the shell.
s.	Stomach.
sg.	Shell gland.
sm.	Suspensory membranes of the gills.
sms.	Suspensory membrane scars.

st.	Sense tentacle.
v.	Ventricle.
va.	Visceral arteries.
vg.	Visceral ganglion.
vl.	Velum.
vm.	Visceral mass.
vv.	Visceral veins.
x.	Swelling on the visceral ganglion from which the anterior root of the branchial nerve originates.
y.	Swelling on the visceral ganglion from which the posterior pallial nerves originate.

PLATE 1.

Fig. 1.—A well preserved left shell valve showing the markings on the outer surface. Two-thirds natural size.

Fig. 2.—Outer surface of a left shell valve that shows distinct radial color markings. Two-thirds natural size.

PLATE 2.

Fig. 3.—Left shell valve badly mutilated by the attacks of boring sponges. The large barnacle near the margin of the valve shows that the rate of growth has not been very rapid for some time. Two-thirds natural size.

Fig. 4.—Outer surface of a right shell valve. The valve is flatter than its mate and has a conspicuous notch at the base of the anterior wing. The radiating ridges are worn so they are not as conspicuous as they are on the other valve. This valve is usually lighter in color than the left. The relatively dark color here is due to different printing. The round openings on the surface are due to recent attacks of the boring sponge. Two-thirds natural size.

PLATE 3.

Fig. 5.—Inside of a left shell valve. The markings on the inside of the left shell valve are never as conspicuous as they are on the inside of the right shell valve. Two-thirds natural size.

Fig. 6.—Inside of a right shell valve. The division of the adductor muscle into a large anterior and a small posterior portion is conspicuously shown by the scar on this valve. Two-thirds natural size.

PLATE 4.

Fig. 7.—Inside of the right shell valve of a specimen that has been rather badly attacked by boring sponges. The roughenings on the surface seem to cover the deep borings of the sponge. Two-thirds natural size.

FIG. 8.—Ventral view of the foot showing the split end and the opening of the byssal gland. Magnified three diameters.

PLATE 5.

FIG. 9.—Outer surface of the left lobe of the mantle showing the arrangement of blood vessels. Two-thirds natural size.

FIG. 10.—Animal as seen from the left side with the left shell valve and mantle lobe removed. The rounded bodies at the bases of the marginal row of tentacles are the eyes. Two-thirds natural size.

PLATE 6.

FIG. 11.—Animal as seen from the left side with the left shell valve and mantle lobe removed and with a portion of the pericardial wall cut away. A few of the blood vessels are shown. Two-thirds natural size.

FIG. 12.—Animal as seen from the left side with the left shell valve and mantle lobe removed, with the alimentary canal shown. Two-thirds natural size.

PLATE 7.

FIG. 13.—Animal as seen from the left side with the left shell valve and mantle lobe removed. Drawn to show the arterial system of blood vessels. Two-thirds natural size.

FIG. 14.—Animal as seen from the left side with the left shell valve and mantle lobe removed. Drawn to show the systemic veins. Two-thirds natural size.

PLATE 8.

FIG. 15.—Animal as seen from the left side with the left shell valve and mantle lobe removed. Drawn to show the nervous system. Two-thirds natural size.

FIG. 16.—Inner surface of the right lobe of the mantle showing the arrangement of the pallial muscles. Two-thirds natural size.

PLATE 9.

FIG. 17.—A portion of a gill showing the arrangement of parts. The figure indicates the inter-lamellar junctions cut at different levels. The further lamella is the one that was attached to the suspensory membrane and the vessel (ba′) was directly connected with the vessel that supplied the gill with blood (ba, Fig. 11). This vessel follows along the edge of the inter-lamellar junction to the free edge of the unattached lamella, (the one on the side nearest the observer in the figure) where it bends back and passes down the modified

filament as the vessel ba″. Branches are given off from this vessel through the inter-filamentar junctions to supply the filaments. The vessel bv′ is the vessel into which the blood that has traversed the gill is collected. It in turn communicates with the vein of the gill (bv., Fig. 11). Magnified about seventy diameters.

PLATE 10.

FIG. 18.—Vertical section (from the suspensory membrane to the free edge) of a gill. Taken next to an inter-lamellar junction. Magnified about fifteen diameters.

FIG. 19.—Section of an animal taken through the plane that connects the cartilage and the visceral ganglia. Two-thirds natural size.

FIG. 20.—Section of an animal taken through the plane that connects the heart and the outer ends of the excretory organs. Two-thirds natural size.

PLATE 11.

FIG. 21.—Transverse section of a modified filament (with [illegible] portion of an inter-lamellar junction) [illegible] filaments. The section is taken near [illegible] brane. Magnified about six hundred [illegible]

FIG. 22.—Transverse section of a sense tentacle [illegible] ng specimen. Magnified about one hundred sixty-five diameters.

PLATE 12.

FIG. 23.—Nervous system as seen from in front and a little to one side. Natural size. (Diagramatic.)

PLATE 13.

FIG. 24.—Cerebral and pedal ganglia with their nervous connections, as seen from the antero-ventral position. These ganglia and the otocysts lie in a mass of connective tissue and may be dissected out and mounted for study without injury. Magnified about fifteen diameters.

FIG. 25.—Visceral ganglia seen from the ventral side. These may easily be exposed for study by stripping the thin muscular covering from their ventral surfaces. They are hard to separate from the adductor muscle but they may be mounted with a thin piece of the muscle and studied in position. Magnified about fifteen diameters.

PLATE 14.

FIG. 26.—A section of the margin of the mantle taken through an eye. The section is taken rather near the hinge line on the posterior border, in a plane nearly corresponding with the line pa., Fig. 11. Most of the circular muscles leave the infolded ridge ventral to this point, and there are no tentacles on the ridge at this level. Magnified about fifty diameters.

PLATE 15.

FIG. 27.—An egg at the time of the formation of the second polar body showing the yolk lobe. Magnified about seven hundred diameters.

FIG. 28.—Two-celled stage after the yolk lobe has disappeared. Magnified about seven hundred diameters.

FIG. 29.—Two-celled stage soon after cleavage showing the yolk lobe. Magnified about seven hundred diameters.

ur-celled stage. Magnified about seven hundred diameters.

—Eight-celled [illegible]. Magnified about seven hundred diameters.

PLATE 16.

FIG. 32.—Late [illegible]ge stage. Magnified about seven hundred diameters.

FIG. [illegible]—A sagittal section of a slightly later stage than that shown in the preceding figure. Magnified about seven hundred diameters.

FIG. 34.—A somewhat later stage seen as a transparent object from the left side. Magnified about seven hundred diameters.

PLATE 17.

FIG. 35.—Veliger larva seen as a transparent object from the left side, with the velum extended. This stage is reached in about thirty hours after the egg is laid. The one figured is slightly older than this. Magnified about seven hundred diameters.

FIG. 36.—Veliger larva seen as a transparent object from the anterior end. Magnified about seven hundred diameters.

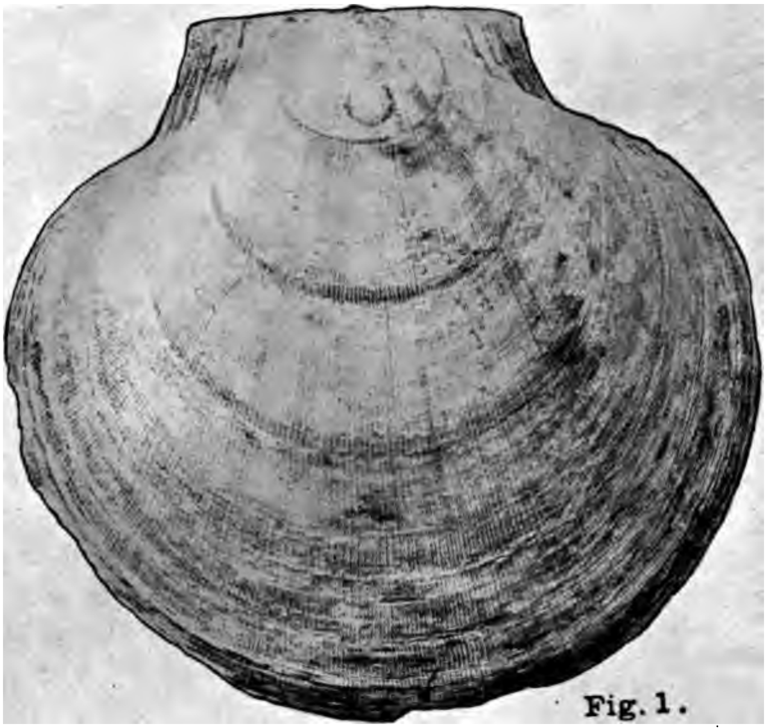


Fig. 1.

Fig. 2.

PLATE I.

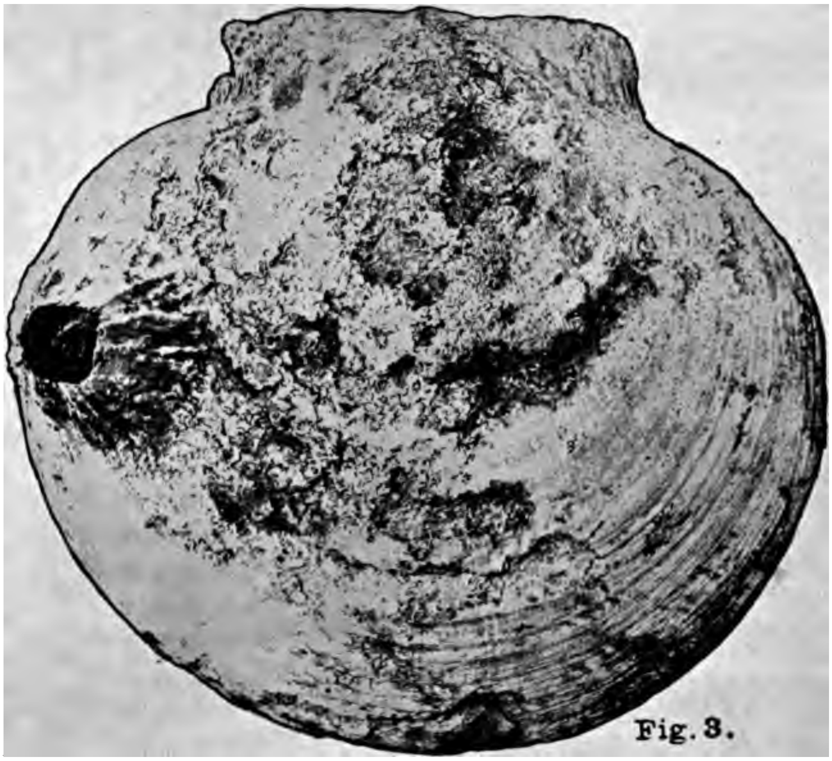


Fig. 3.

Fig. 4.

PLATE 2.

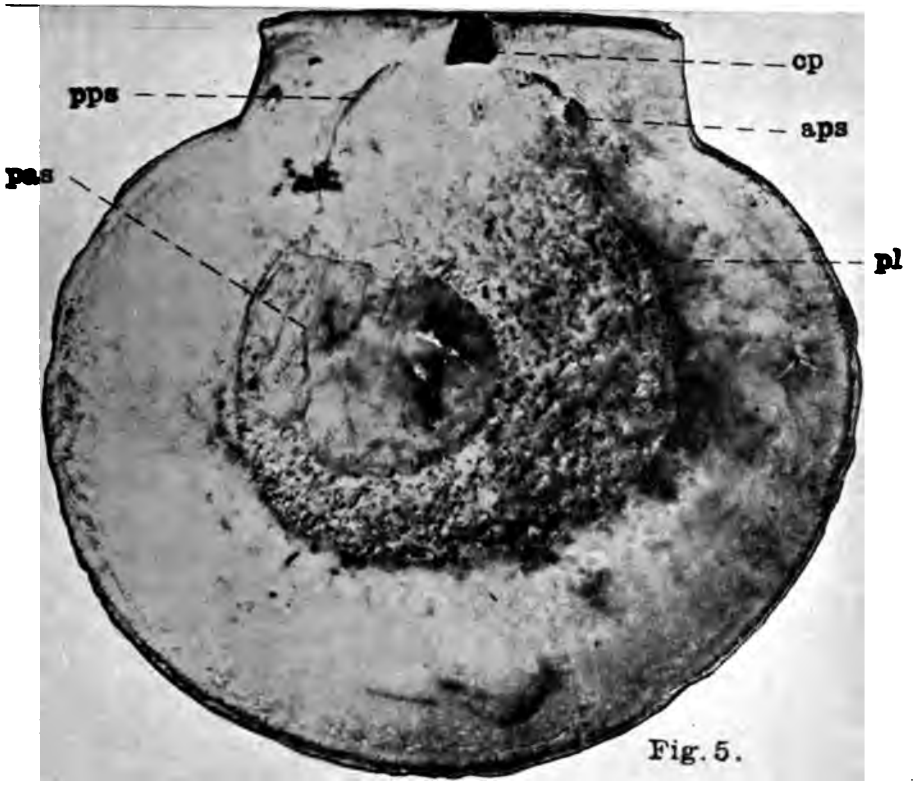


Fig. 5.

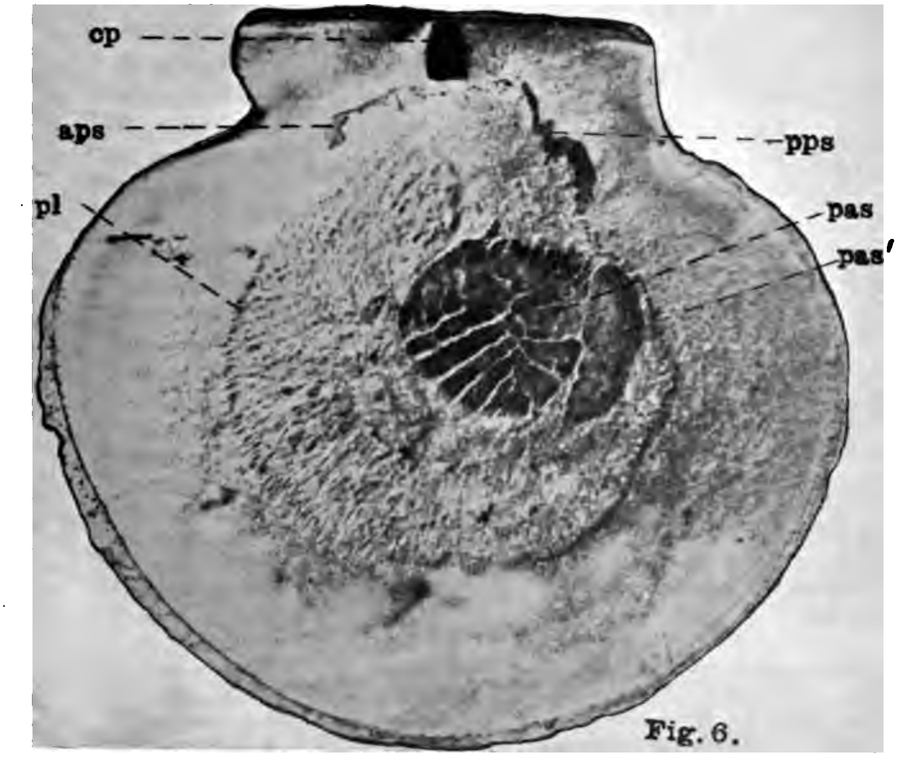


Fig. 6.

PLATE 3.

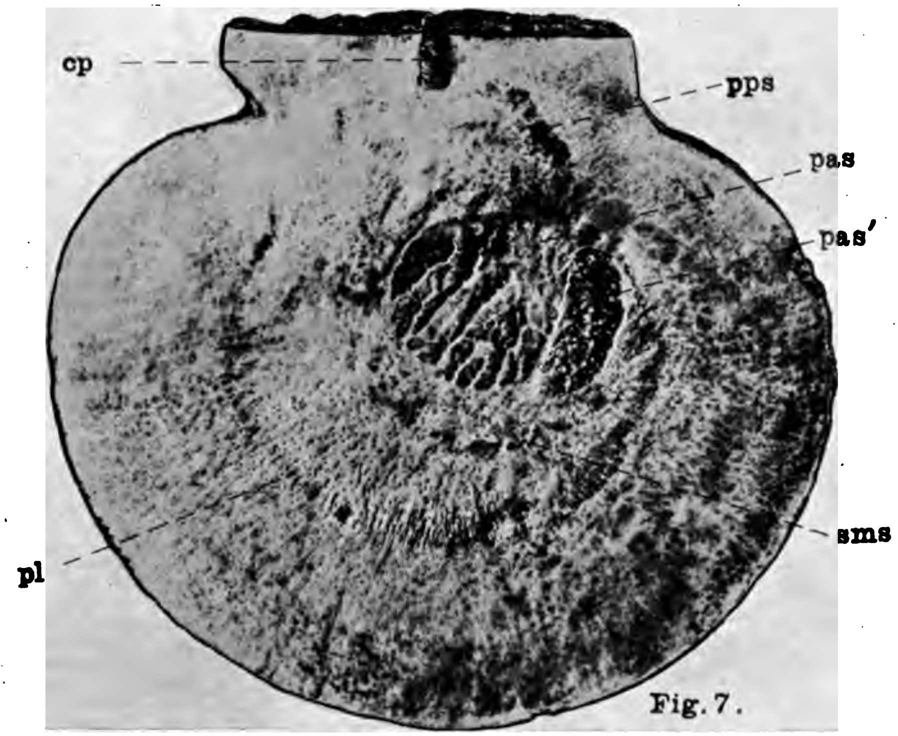


Fig. 7.

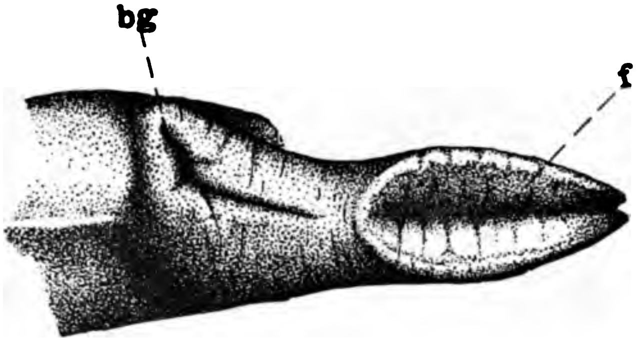


Fig. 8.

PLATE 4.

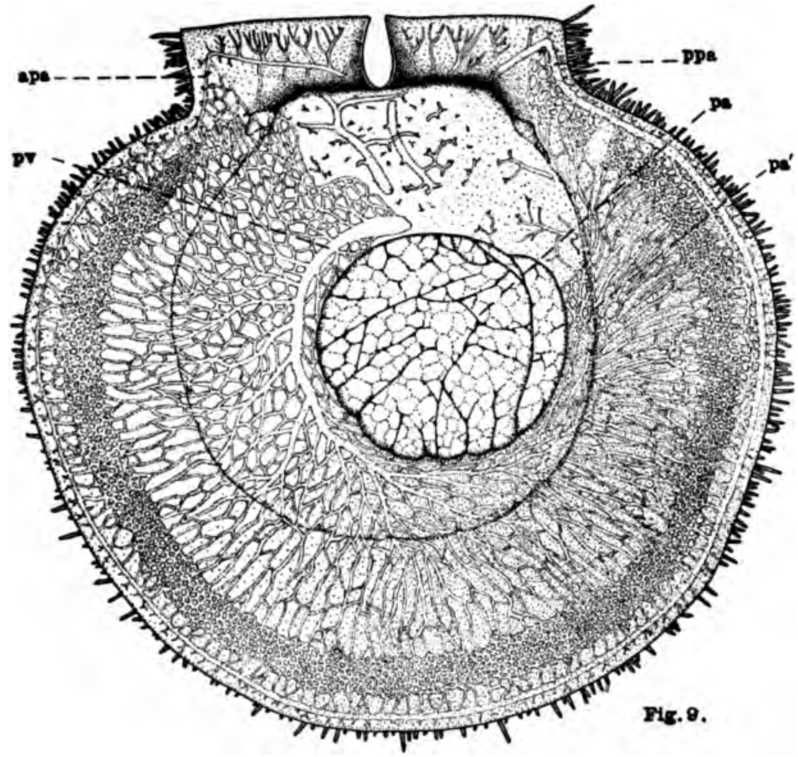


Fig. 9.

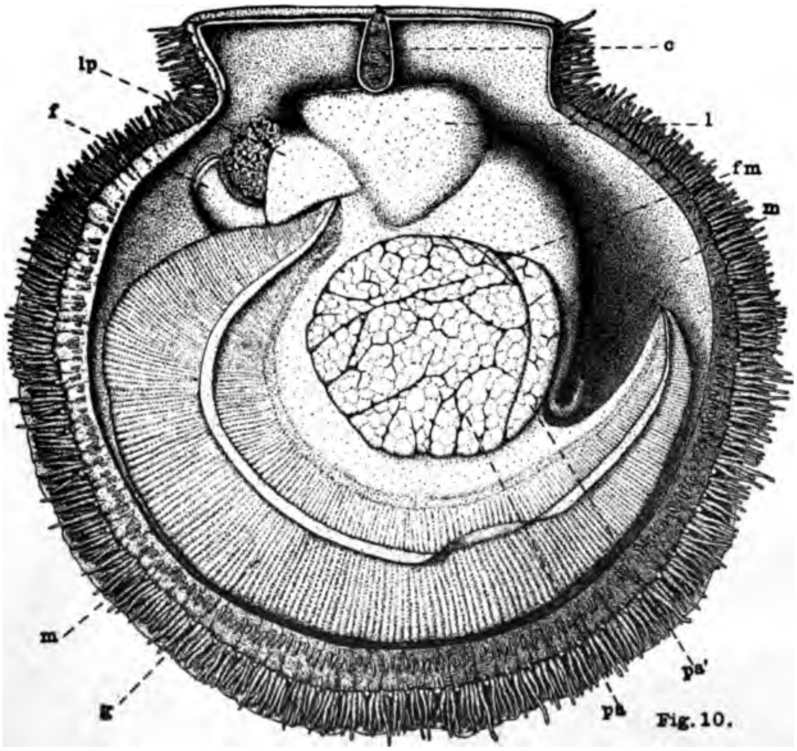


Fig. 10.

Drew del.

PLATE 5.

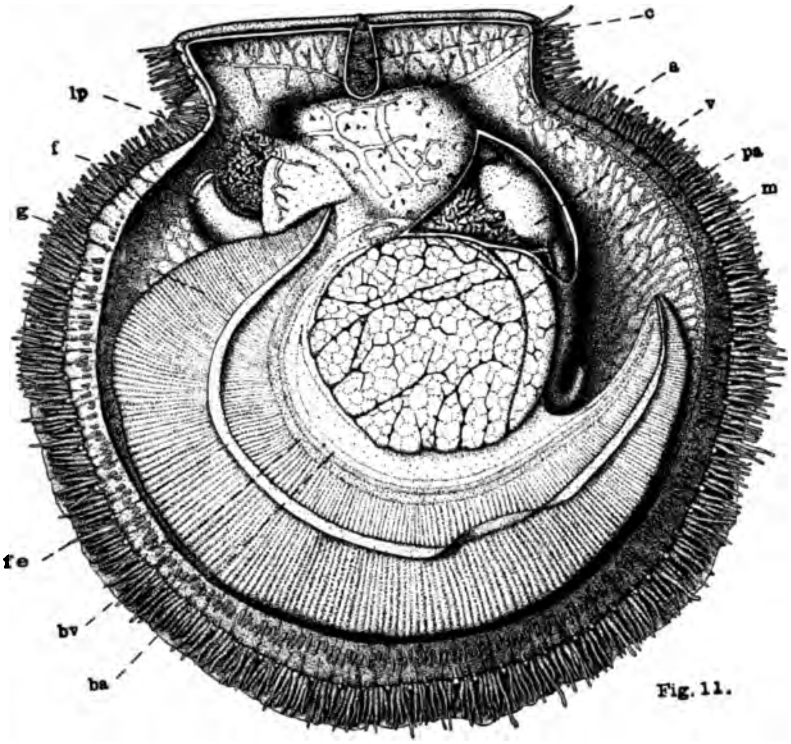


Fig. 11.

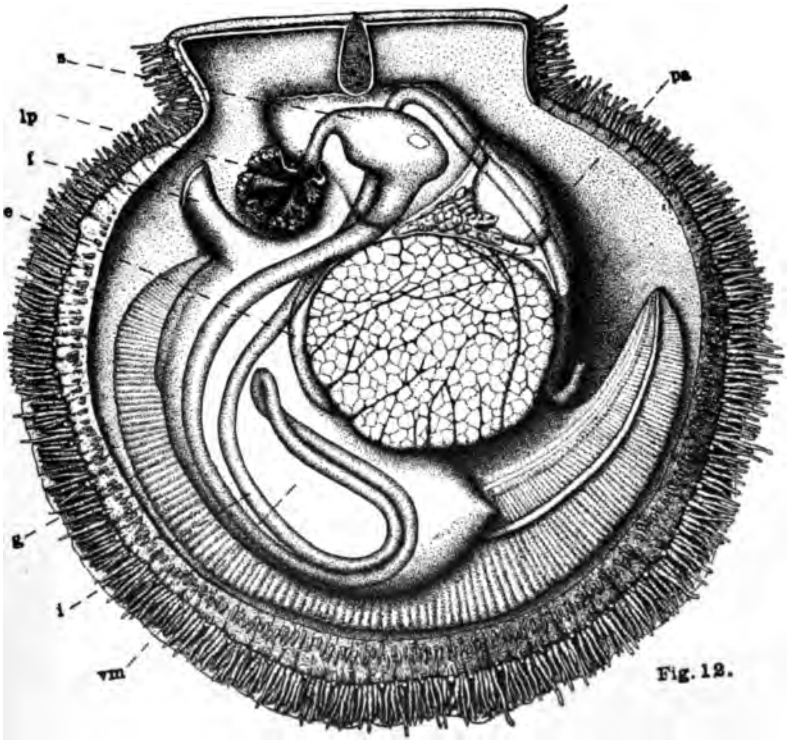


Fig. 12.

Drew del.

PLATE 6.

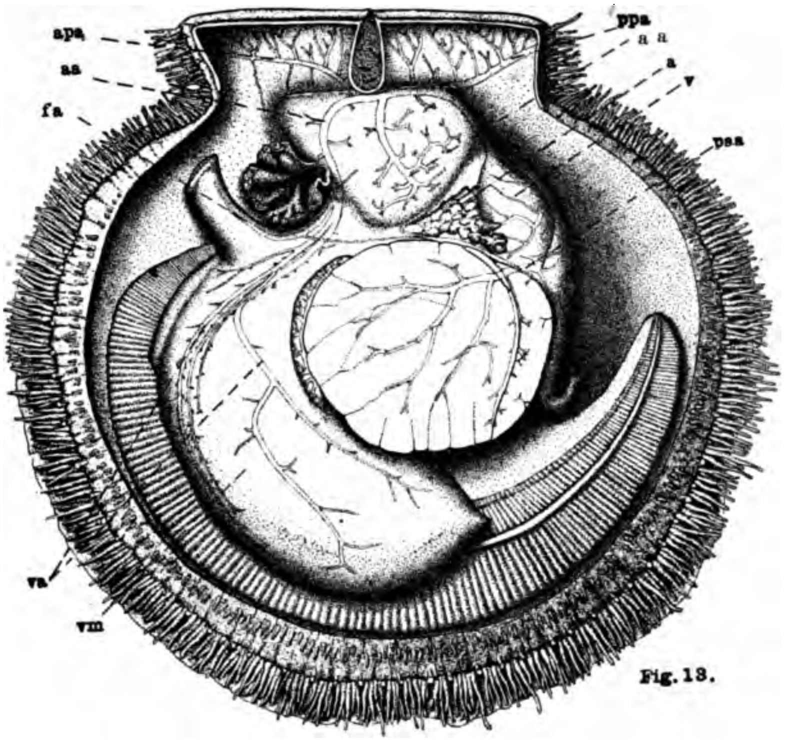


Fig. 13.

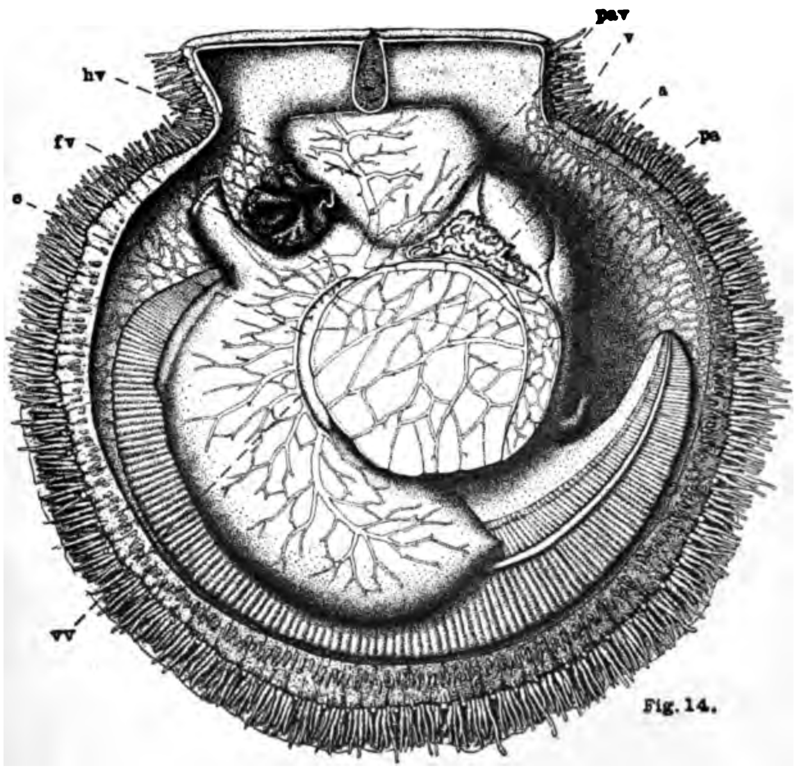


Fig. 14.

Drew del.

PLATE 7.

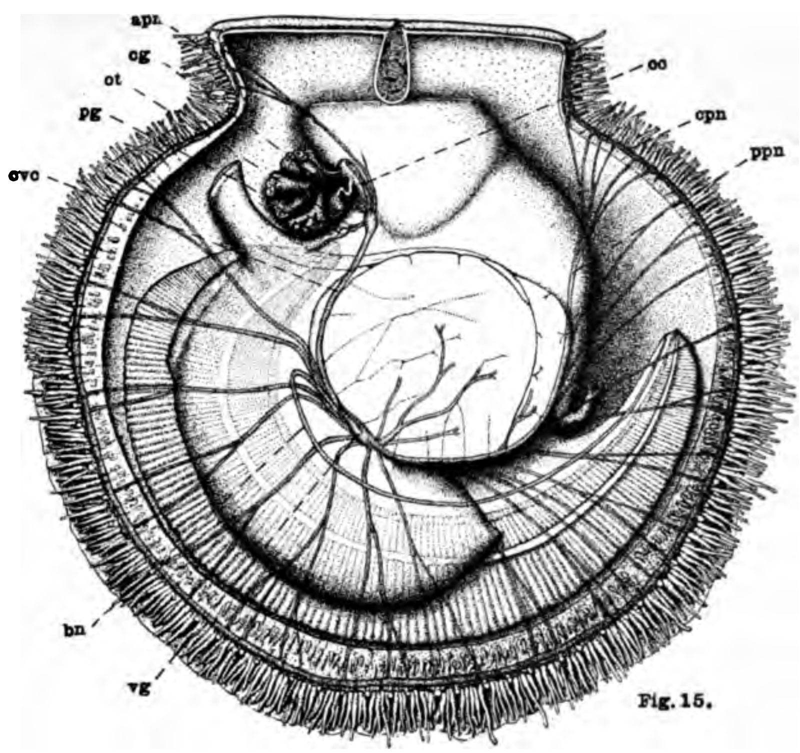


Fig. 15.

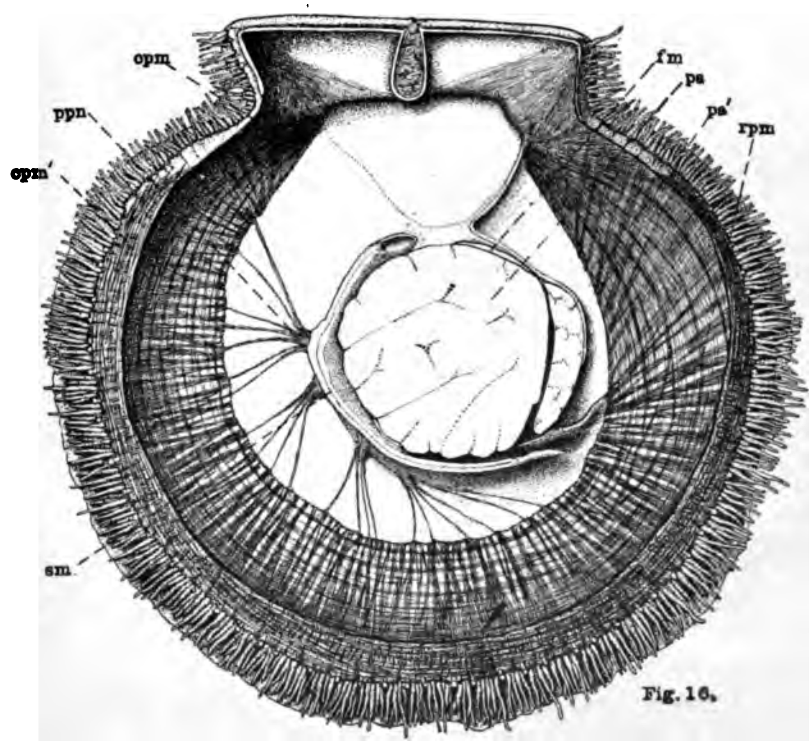


Fig. 16.

Drew del.

PLATE 8.

Drew del.

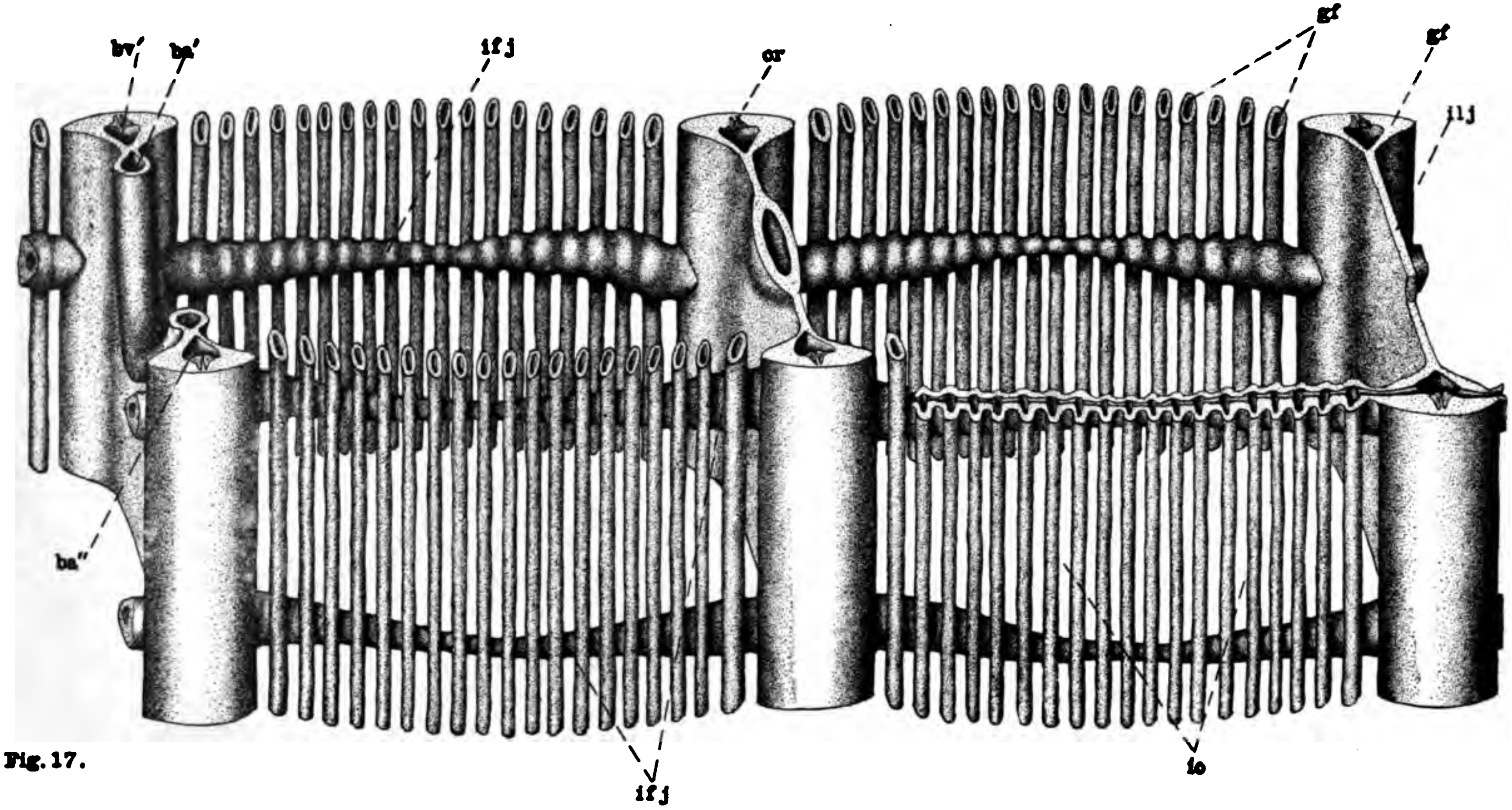
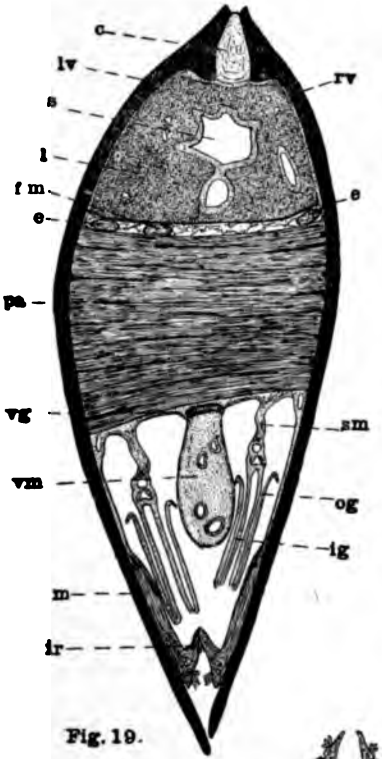


Fig. 17.

PLATE 9.



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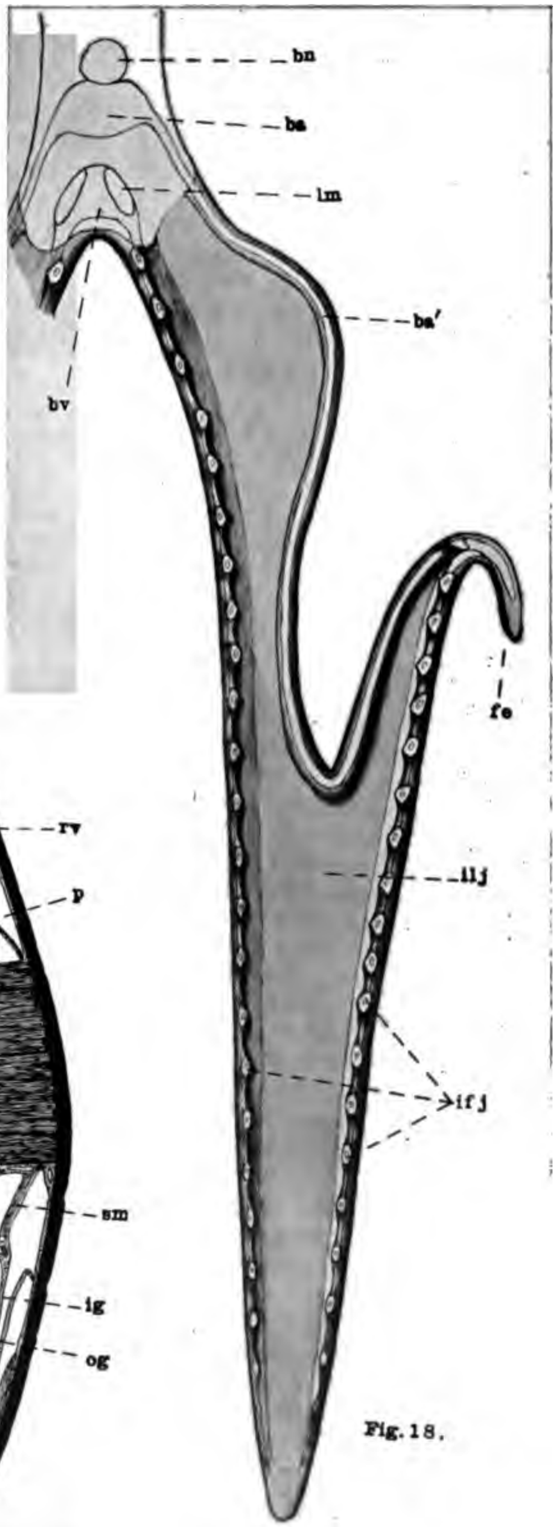

Fig. 18.

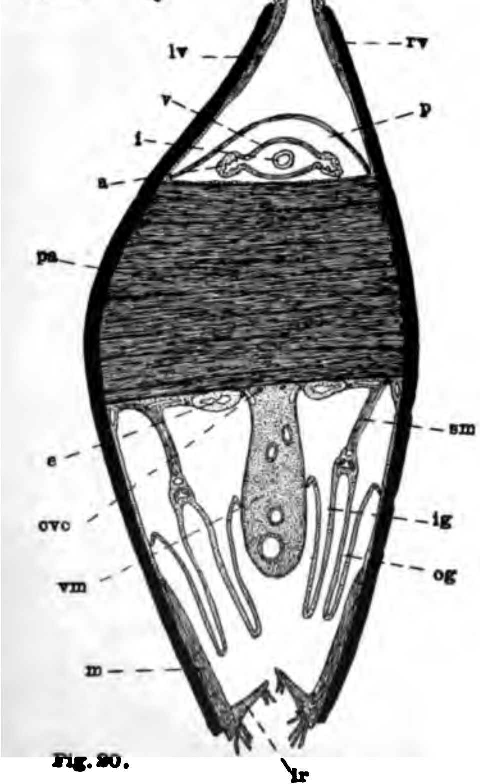

Fig. 20.

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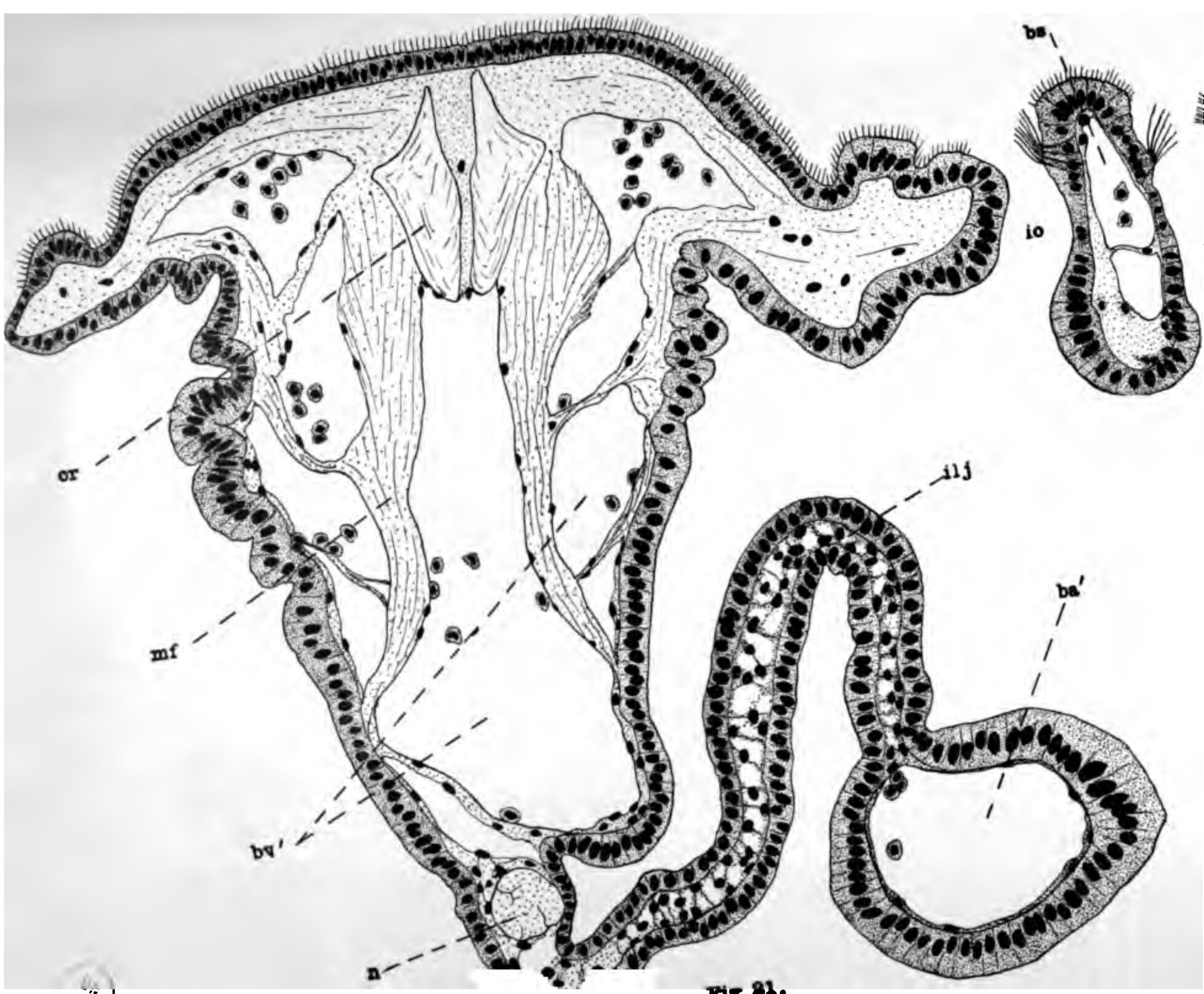
PLATE 10.



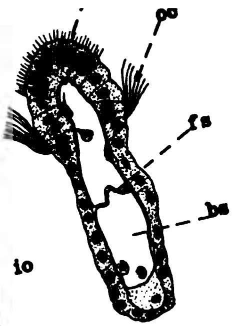
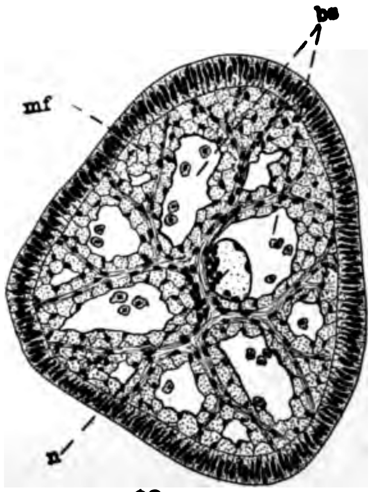


Fig. 21.



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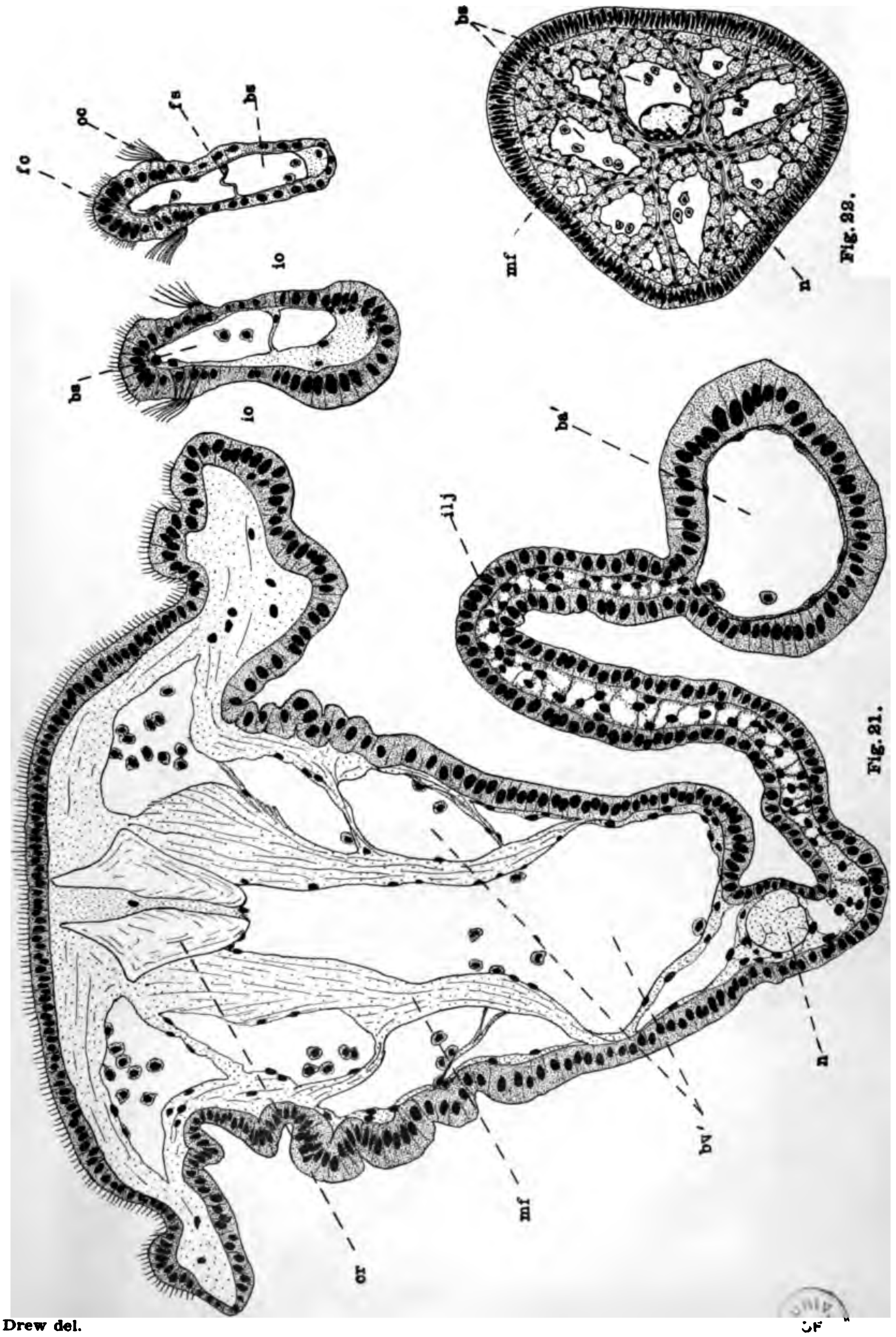

Fig. 22.

Fig. 21.

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PLATE II.

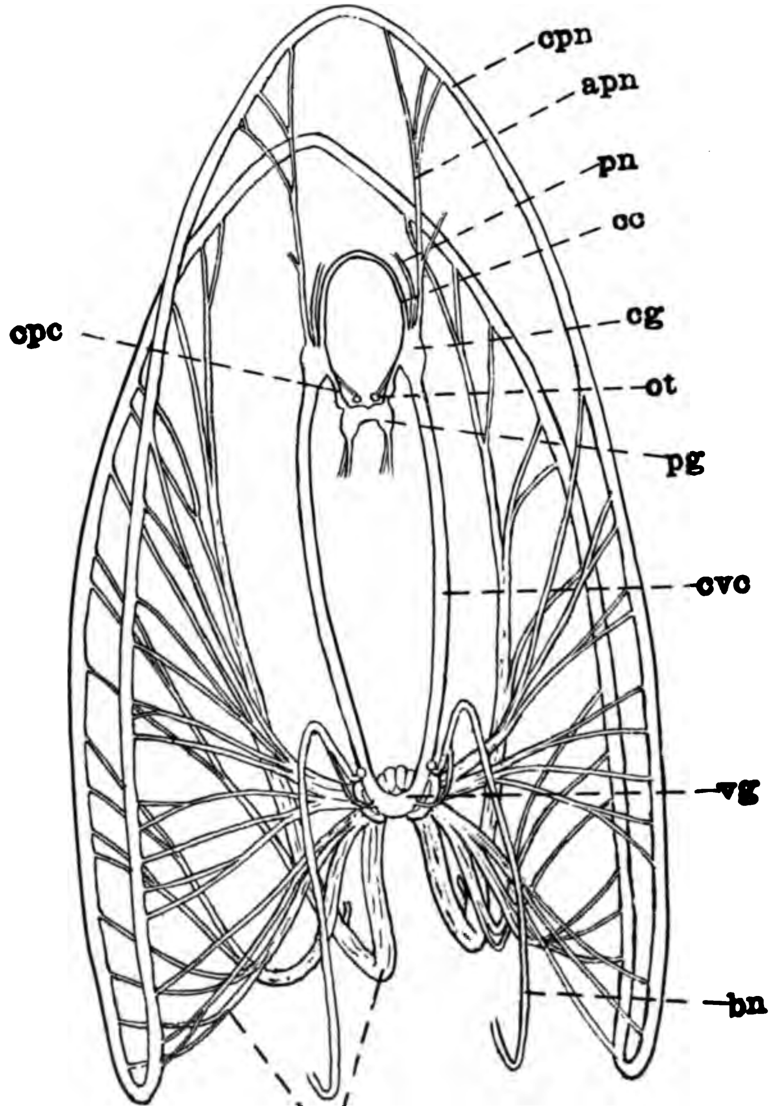

Fig. 23.

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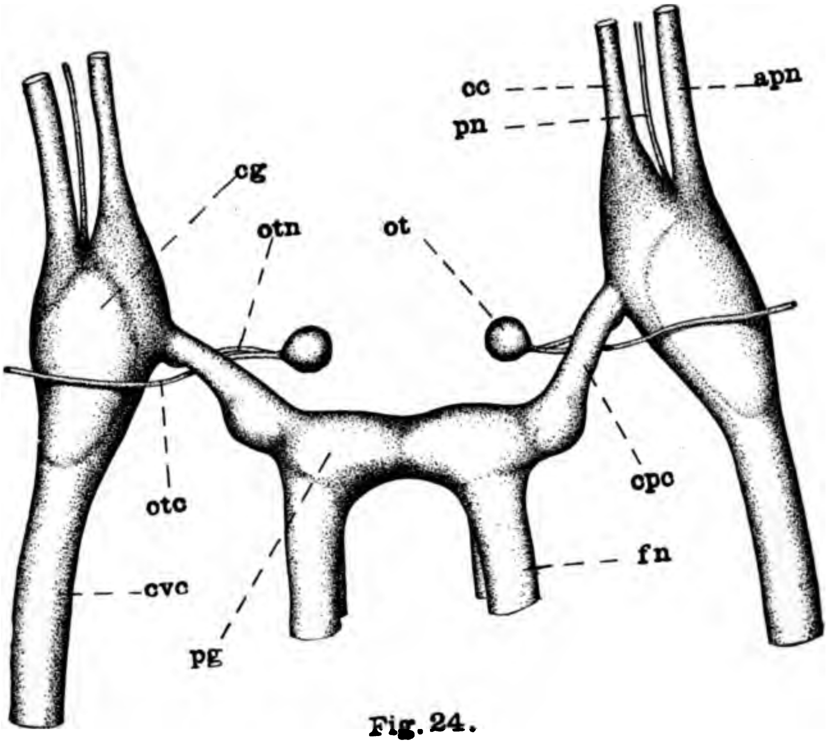
PLATE 12.



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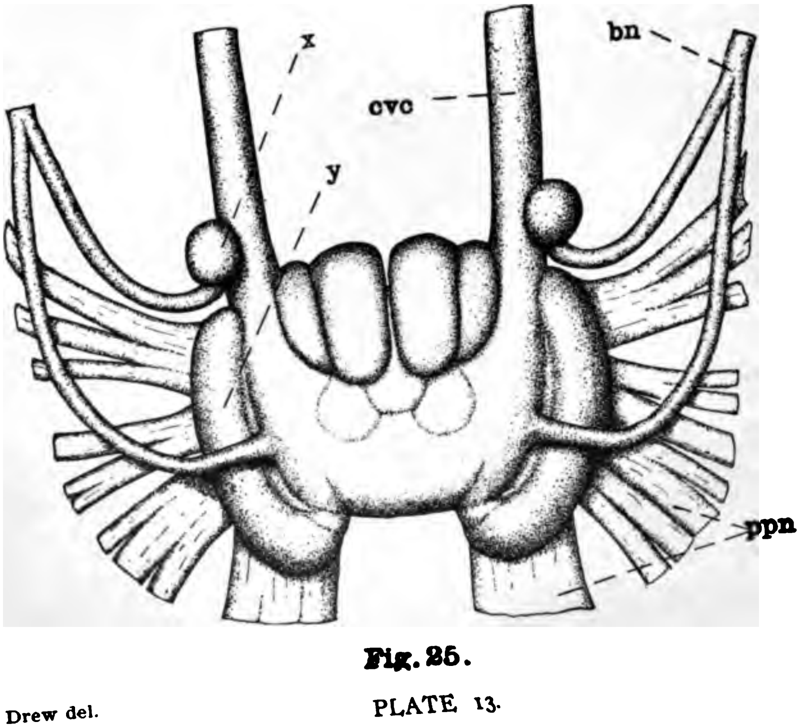

Fig. 25.

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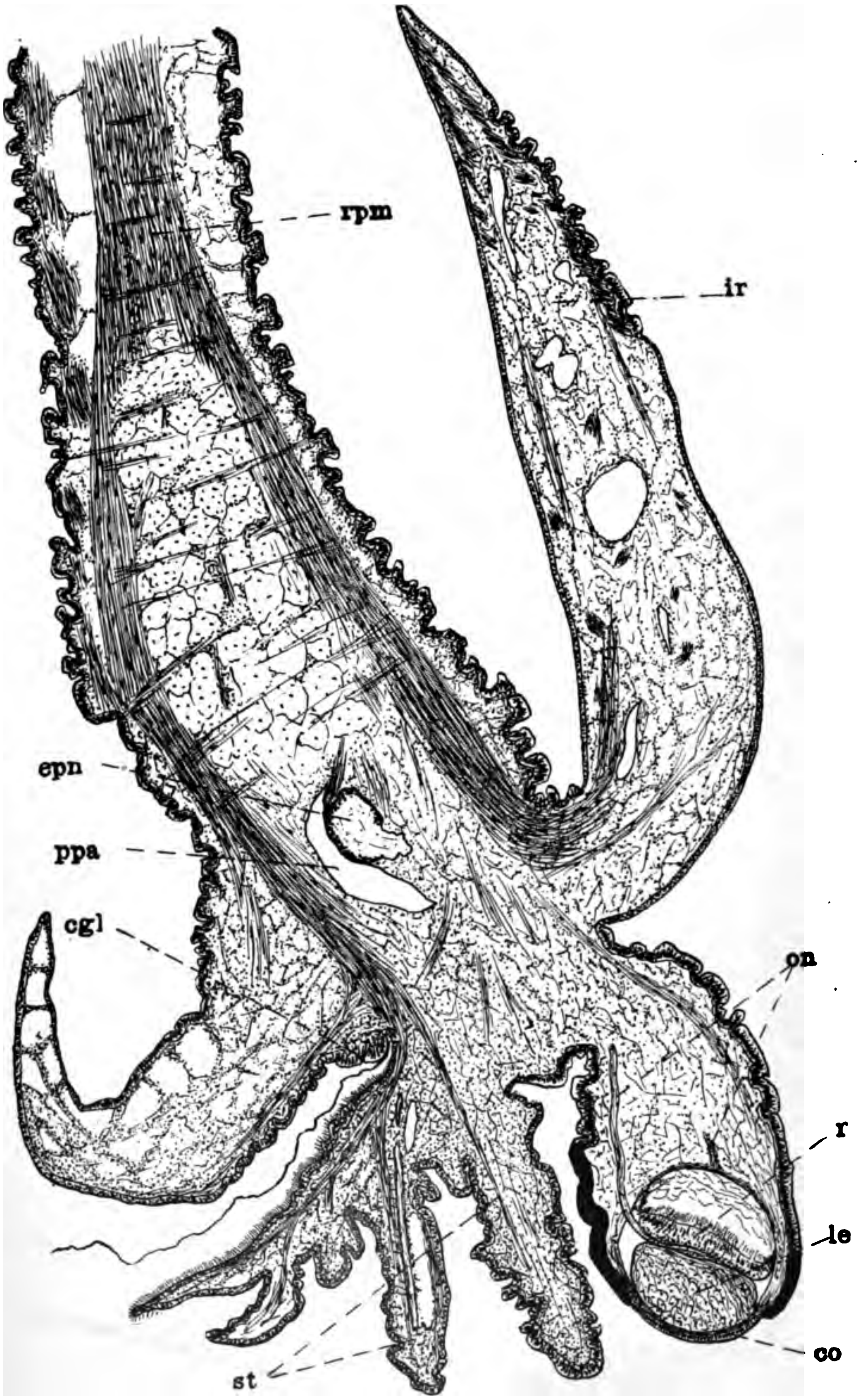

Fig. 26.

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PLATE 14.

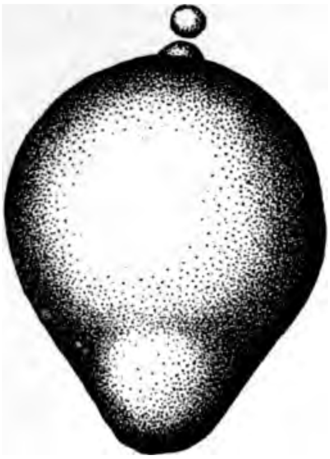


Fig. 27.

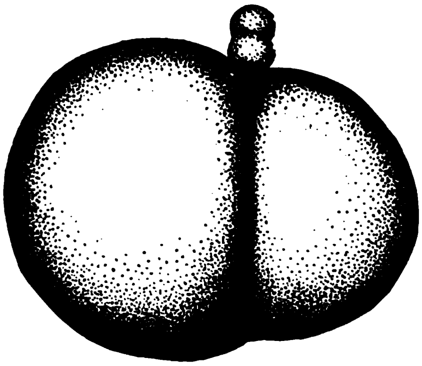
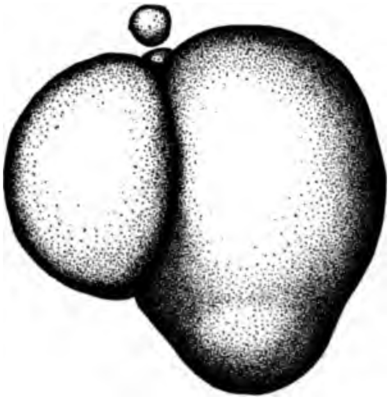


Fig. 28.



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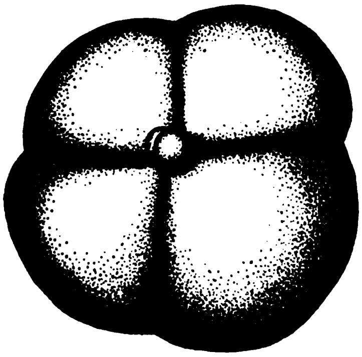

Fig. 30.

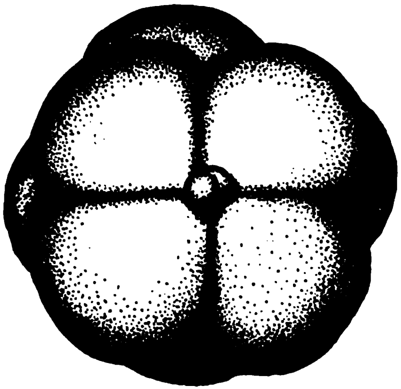

Fig. 31.

Drew del.

PLATE 15.

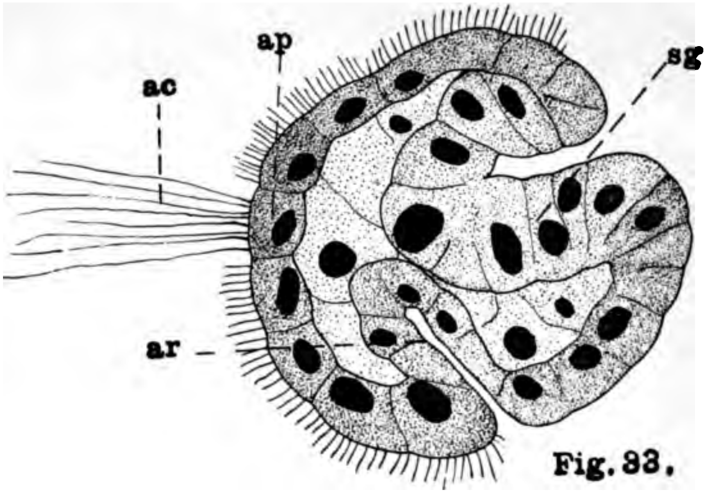

Fig. 33.

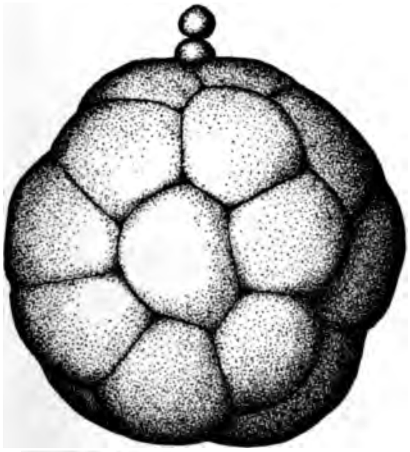

Fig. 32.

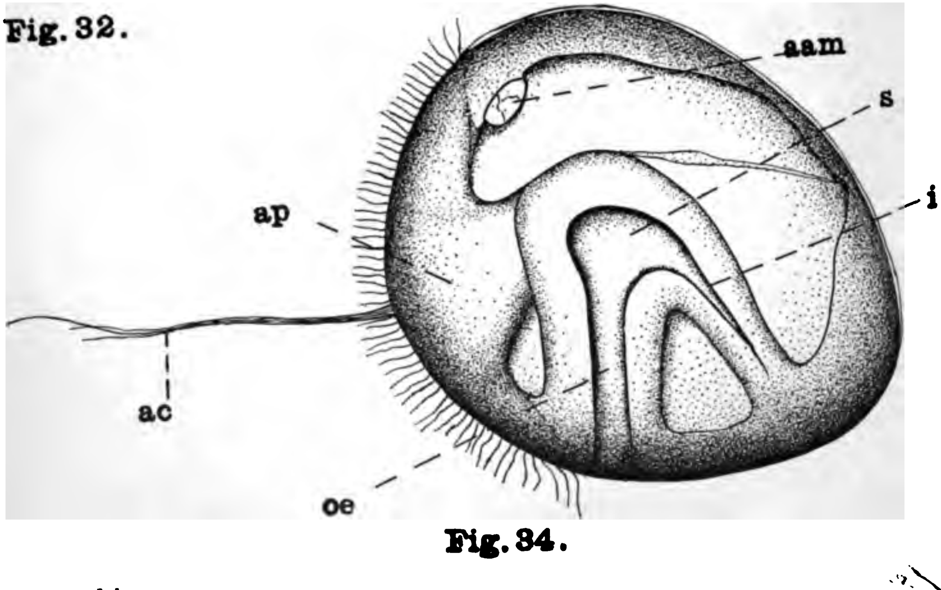

Fig. 34.

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PLATE 16.

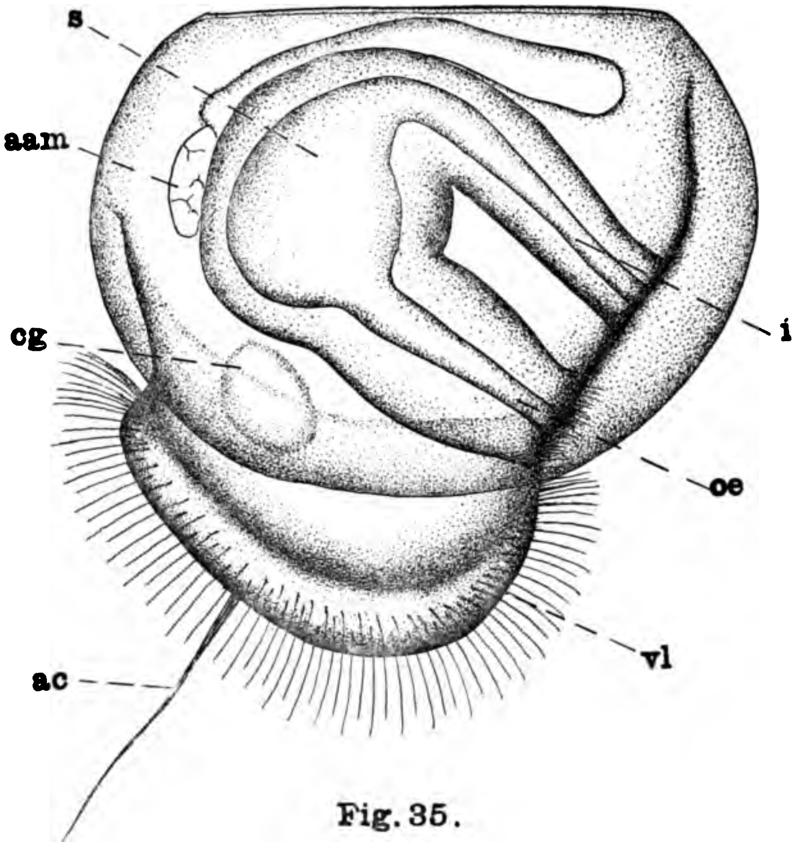

Fig. 35.

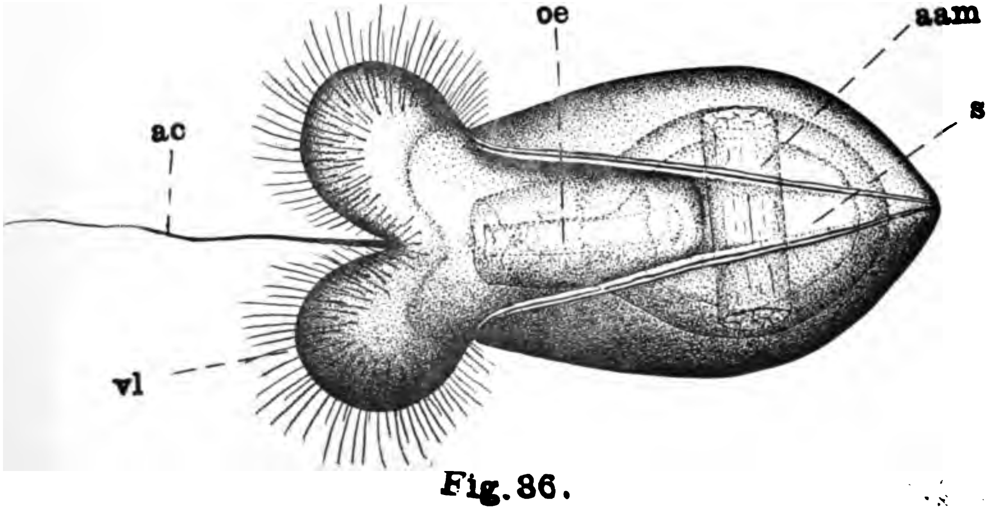

Fig. 36.

Drew del.

PLATE 17.

The University of Maine Studies

No. 7

Meteorological Conditions

AT

Orono, Maine

BY

JAMES STACY STEVENS
Professor of Physics

ORONO, MAINE
February, 1907

The University of Maine
Studies

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INTRODUCTION.

The present number of the UNIVERSITY OF MAINE STUDIES is a compilation from various sources. From January 1, 1869, to January 1, 1893, a series of meteorological records was kept at Orono, Maine, by Dr. M. C. Fernald, ex-president and sometime professor of physics at the University of Maine. Since that time the records have been continued by Drs. W. H. Jordan and C. D. Woods, former and present directors of the Maine Agricultural Experiment Station. These results have been averaged and tabulated by the author and are discussed in this paper.

A series of observations on precipitation has been carried on by Prof. H. S. Boardman, of the department of civil engineering, from 1900 to 1906 inclusive, and the results of these observations are printed here.

The work bearing upon the evaporation of snow and ice, and of liquids, was performed in the department of physics by Mr. F. C. Mitchell and Miss M. C. Rice. The matter used here is reprinted from the *Monthly Weather Review*.

Acknowledgment should be made to Prof. L. H. Merrill of the Experiment Station, and to Mr. S. L. Boardman of the Bangor *Commercial* for data supplied to the author; and to various students of the University for clerical work.

BAROMETRY.

The instrument used in the earlier period of these observations was made by J. S. F. Huddleston of Boston, Mass. It was twice compared with a standard instrument, and the error was regarded as small enough to be negligible, but was considered when making the observation. In later years the barometer used was one manufactured by James Green of New York City. It had an error of 0.003, and this error was always considered in recording. Recent standardization shows this barometer to have a negligible error. The times of observation was 7 a. m., 2 p. m., and 9 p. m. The altitude above sea level, as determined by means of the spirit level, was 134 feet from January, 1869, to June 11, 1879, and 129 feet from that time to January, 1893; during the remainder of the period to the present time it was 148 feet. The dates of the missing records were as follows: 1869, June and December; 1893, two-thirds of January; 1895, January and December; 1896, January, February, and June. From October, 1899, to 1903, inclusive, observations were made at 2 p. m. only. The latitude of the place of observation was 44° 54′ 2″ N., and the longitude 68° 40′ 11″ W.

The means published herewith have been reduced to the standard instrumental temperature. The latitude is 44° 54′ north and altitude small; therefore the gravity corrections may be neglected as being probably zero. The observations have been reduced to sea level by the formulæ and tables given in the Weather Bureau Instructions to Voluntary Observers. In order to take annual and other means I have thought it best to give in italics the best values I could obtain by interpolation between the months contiguous to those for which the data were fragmentary or missing. The means depend in part, therefore, upon graphic interpolations, using the monthly charts of the *Monthly Weather Review* for that purpose. The year 1896 was rejected in taking the average.

The figures are the hundredths of an inch and range from 29.54 to 30.12. The figures in italics in Table 1 imply that a number of observations were missing.

TABLE I.—*Monthly and annual barometric pressure at Orono, Me., reduced to sea level and standard gravity.*

	January.				February.				March.				April.			
	7 a.	2 p.	9 p.	Mn	7 a.	2 p.	9 p.	Mn	7 a.	2 p.	9 p.	Mn	7 a.	2 p.	9 p.	Mn
1869	79	74	77	77	73	69	70	71	85	81	82	83	68	64	67	66
1870	93	90	91	91	72	68	68	69	76	74	77	76	87	84	84	85
1871	00	01	98	99	79	76	75	77	82	75	79	79	73	70	67	70
1872	73	69	72	71	74	69	70	71	72	68	68	70	75	72	73	73
1873	88	86	90	88	72	68	68	69	68	67	68	68	70	70	72	72
1874	02	98	97	99	95	91	93	93	69	63	63	65	80	74	75	76
1875	98	92	90	94	80	78	77	78	92	87	91	91	77	72	74	75
1876	87	83	88	86	86	81	85	83	82	77	79	79	78	73	79	76
1877	88	85	89	88	80	76	78	78	84	79	83	82	86	83	84	84
1878	84	83	87	85	80	77	78	79	75	74	75	75	74	72	74	73
1879	75	71	72	73	80	78	83	80	99	93	91	94	70	66	70	69
1880	03	93	03	00	90	85	88	89	91	82	89	88	83	75	79	79
1881	95	91	92	93	02	93	98	98	59	57	59	58	65	59	64	63
1882	91	87	96	91	94	91	98	93	92	87	91	90	88	83	84	85
1883	06	01	02	03	05	00	05	03	77	73	73	75	89	84	88	87
1884	98	94	93	95	00	92	94	96	89	85	86	86	70	69	71	70
1885	91	87	80	86	80	77	77	78	86	83	85	85	89	85	85	87
1886	93	92	95	93	86	83	83	84	77	74	74	75	05	01	02	03
1887	88	90	87	88	06	01	02	03	76	71	74	74	88	82	83	84
1888	93	87	89	90	93	89	94	92	85	80	86	84	95	91	95	94
1889	87	84	85	85	91	86	93	90	75	71	72	73	87	83	85	85
1890	05	98	98	00	95	92	97	95	84	79	82	82	90	90	91	92
1891	90	86	89	88	92	89	92	90	02	98	00	00	82	77	80	80
1892	90	85	88	88	02	98	03	01	75	71	75	73	84	78	82	82
1893	95	90	92	92	93	87	89	89	91	86	89	89	95	91	93	93
1894	00	98	98	98	98	92	97	96	92	87	89	89	91	89	89	90
1895	90	86	87	88	73	62	54	63	78	76	74	76	90	86	89	88
1896	..	..	..	..	..	..	..	..	04	98	97	00	04	03	06	04
1897	89	82	89	86	95	87	90	91	89	82	86	86	89	84	88	87
1898	79	75	80	78	91	91	90	91	04	93	01	99	77	71	74	74
1899	87	86	87	87	75	75	77	76	81	74	77	77	87	80	84	84
Mean	91	87	89	89	88	83	86	86	83	78	81	81	83	80	80	81

TABLE I.—*Continued.*

	May.				June.				July.				August.			
	7 a.	2 p.	9 p.	Mn	7 a.	2 p.	9 p.	Mn	7 a.	2 p.	9 p.	Mn	7 a.	2 p.	9 p.	Mn
1869	65	61	63	63	70	66	70	69	75	72	74	74	84	81	81	82
1870	81	77	79	79	84	80	80	81	78	74	75	76	88	79	80	81
1871	69	76	71	72	74	69	71	71	78	74	77	77	81	77	78	79
1872	75	74	74	75	79	77	76	77	79	72	72	74	85	80	81	82
1873	83	80	79	80	80	75	76	77	32	79	80	80	90	87	87	88
1874	73	70	69	71	71	68	67	69	82	80	79	80	85	80	82	83
1875	79	75	75	77	82	78	82	81	78	76	76	77	91	88	89	89
1876	84	80	84	82	84	81	84	83	79	76	78	78	89	85	87	87
1877	77	74	76	75	78	79	79	79	79	76	76	77	82	79	80	80
1878	78	74	77	76	80	77	78	78	83	88	83	84	76	74	75	75
1879	82	87	94	88	79	76	78	77	81	78	79	79	80	76	78	77
1880	87	84	87	86	84	80	82	82	80	78	79	79	91	87	89	89
1881	98	94	95	96	78	74	76	76	79	75	77	77	87	83	85	85
1882	92	86	88	89	73	68	70	70	86	82	84	84	91	86	88	89
1883	90	84	86	87	88	85	85	86	82	79	80	81	89	85	87	87
1884	82	79	81	81	98	92	91	94	71	68	66	68	94	92	93	93
1885	93	88	90	90	83	79	79	81	85	81	83	83	88	86	85	86
1886	82	78	79	80	87	83	85	85	85	81	81	83	86	84	84	85
1887	97	93	92	94	95	92	91	93	87	84	85	85	88	85	86	86
1888	91	87	89	89	78	74	77	76	83	78	80	80	79	77	80	79
1889	83	79	82	81	88	83	85	85	85	83	83	84	93	90	91	92
1890	87	83	84	85	84	81	83	82	89	85	86	87	87	84	86	85
1891	89	85	88	87	82	79	80	80	88	86	67	87	90	86	88	88
1892	86	82	85	84	86	82	82	84	88	86	86	86	91	88	89	89
1893	78	74	75	76	92	90	90	91	76	77	74	75	83	80	79	81
1894	88	81	86	85	82	78	78	79	85	80	82	82	88	84	86	86
1895	85	85	87	86	95	93	89	92	85	89	84	86	84	91	88	88
1896	98	99	96	98	..	..	..	..	96	93	94	94	00	97	94	97
1897	84	78	80	81	77	70	82	77	84	82	53	83	79	76	77	77
1898	83	77	79	80	80	76	79	78	88	83	85	85	81	77	79	79
1899	86	81	83	83	81	77	80	79	77	73	76	75	85	81	84	83
Mean............	89	88	89	89	81	79	79	80	82	79	80	80	86	83	84	84

TABLE I.—*Concluded.*

	September.				October.				November.				December.			
	7 a.	2 p.	9 p.	Mn	7 a.	2 p.	9 p.	Mn	7 a.	2 p.	9 p.	Mn	7 a.	2 p.	9 p.	Mn
1869	00	96	98	98	76	73	77	75	76	72	74	74	75	70	68	68
1870	95	92	93	93	88	82	83	84	71	68	72	70	67	64	65	65
1871	91	87	88	89	86	87	84	86	73	73	73	73	79	78	80	79
1872	85	82	82	83	89	87	87	88	81	77	78	79	82	81	84	82
1873	89	86	85	86	92	82	86	86	65	70	71	69	90	89	89	89
1874	94	88	92	92	87	84	84	85	95	90	90	92	91	85	91	89
1875	83	77	79	79	80	79	80	80	82	82	81	81	79	75	76	77
1876	84	82	83	83	78	71	73	76	83	79	81	81	69	70	72	70
1877	90	85	88	88	93	88	88	89	96	93	94	94	95	92	94	94
1878	02	99	01	01	87	84	84	85	74	72	74	73	80	77	80	79
1879	99	95	96	96	92	88	91	90	94	90	93	92	02	00	04	03
1880	86	85	87	86	93	89	91	91	01	00	01	01	80	78	79	79
881	00	96	98	98	95	95	96	95	98	94	95	96	00	96	97	98
1882	97	94	96	96	01	94	95	97	98	95	95	96	89	85	89	88
1883	95	91	93	93	06	03	05	05	94	93	95	94	97	91	92	93
1884	95	90	93	93	97	92	95	95	88	87	89	88	01	98	97	99
1885	89	87	89	88	96	92	93	93	82	80	81	81	78	78	80	79
1886	03	94	98	98	08	03	05	05	82	82	82	82	97	94	98	96
1887	96	93	97	95	88	83	85	85	88	79	88	85	94	91	94	93
1888	98	94	95	96	76	73	77	75	98	95	96	96	77	74	77	76
1889	95	91	92	93	92	89	92	91	92	88	91	90	97	93	97	96
1890	01	99	99	00	78	74	76	76	85	83	86	85	85	84	89	86
1891	02	98	98	99	93	88	91	91	02	99	03	02	94	90	94	93
1892	01	97	00	00	77	73	76	75	92	89	91	91	82	75	80	79
1893	87	88	90	88	01	92	96	96	02	97	90	96	93	89	97	92
1894	00	06	93	99	92	82	89	88	96	81	84	87	90	03	02	98
1895	92	87	84	87	80	81	87	83	00	00	00	00	95	98	99	97
1896	03	99	00	00	93	94	96	94	12	10	11	11	03	05	06	05
1897	93	86	90	90	99	93	93	95	86	82	84	84	87	85	84	85
1898	85	81	82	83	93	89	93	92	84	78	81	81	77	75	79	77
1899	89	86	87	87	06	04	05	05	83	80	81	81	86	84	86	86
Mean..............	94	90	91	92	87	83	85	85	88	85	87	87	87	85	87	86

TABLE 2.—*Monthly and annual barometric pressure at 2 p. m. at Orono, Me.*

		Feb.	Mar.	Apr.	May.	June	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1900..........	75	77	71	72	74	72	73	92	85	98	82	81
1901..........	75	50	71	.....	......	......	......	......	85	87	72	83
1902..........	82	58	76	71	77	65	79	74	92	82	84	84
1903..........	68	73	04	70	95	85	67	86	90	85	78	74

The maximum barometric pressure reduced to 32° F. was 30.833 inches; the minimum, 28.423 inches;; and the mean, 29.842 inches. The correction for gravity is inappreciable.

THERMOMETRY.

Temperature observations began to be made by Dr. M. C. Fernald, January 1, 1869. From this date to January 1, 1893, observations were made three times a day, at 7 a. m., 2 p. m., and 9 p. m. In Table 3 the mean of these observations is found by assigning to the 9 p. m. observations a double weight. Beginning with 1893 the maximum and minimum temperature for each 24 hours were recorded. Table 4 shows the maximum and minimum for each month. The thermometer used from 1869 to 1893 was a Huddleston, since that time a Green. The location was changed in June, 1879, and about January, 1893.

TABLE 3.—*Monthly mean temperatures at Orono, Me., based on tridaily observations.*

Year.	January.				February.				March.			
	7 a. m.	2 p. m.	9 p. m.	Mean.	7 a. m.	2 p. m.	9 p. m.	Mean.	7 a. m.	2 p. m.	9 p. m.	Mean.
1869	16.6	23.1	18.8	18.4	16.5	27.3	21.6	21.8	18.5	30.6	23.9	24.2
1870	19.2	27.2	21.9	22.6	14.1	26.3	18.0	19.1	22.0	34.2	27.9	28.0
1871	12.6	18.2	16.0	15.7	15.2	25.8	21.2	21.0	30.5	39.6	34.3	34.7
1872	13.8	20.2	15.9	16.5	9.1	26.1	18.7	18.2	12.6	25.8	19.5	19.4
1873	9.7	20.1	15.1	15.0	8.5	22.8	17.4	16.5	21.5	32.6	27.6	27.4
1874	15.3	23.6	19.0	19.2	11.5	23.5	17.5	17.5	22.1	33.2	27.4	27.5
1875	1.1	14.6	9.0	8.4	8.1	18.9	13.5	13.5	18.2	30.4	24.9	24.6
1876	14.5	23.6	18.0	18.5	14.3	24.4	18.2	18.8	22.3	33.2	28.5	28.1
1877	2.8	16.3	9.1	9.3	19.8	31.8	26.1	25.9	24.2	34.1	27.7	28.4
1878	13.1	22.6	16.9	17.4	14.4	30.2	23.1	22.7	27.8	37.3	33.3	32.9
1879	8.1	19.8	13.3	15.6	8.1	23.1	16.8	16.2	21.9	33.4	28.1	27.9
1880	13.5	28.7	21.6	21.4	17.2	28.6	22.8	22.9	20.6	31.6	26.3	26.2
1881	8.7	20.0	12.7	12.2	16.8	28.4	22.9	22.8	30.9	36.2	34.1	33.8
1882	10.7	22.6	16.3	16.5	14.8	28.8	21.9	22.0	23.3	34.3	29.6	29.2
1883	4.1	17.4	11.7	11.2	11.3	23.7	17.2	17.4	15.7	27.7	21.5	21.6
1884	5.2	19.0	14.4	13.3	18.0	27.5	22.2	22.5	20.2	33.2	27.4	27.1
1885	11.1	21.2	15.6	15.9	3.0	21.4	15.3	13.8	11.3	26.6	19.3	19.1
1886	13.9	22.6	18.1	18.2	11.9	23.7	19.5	18.7	20.4	33.1	27.8	27.3
1887	9.5	18.4	14.4	14.2	12.3	22.8	17.1	17.4	20.7	32.3	25.3	25.9
1888	4.7	14.7	8.4	9.1	12.7	25.0	19.5	19.2	22.6	32.6	28.2	27.9
1889	20.6	28.6	24.9	24.8	9.5	19.0	16.1	15.2	27.7	39.5	33.0	33.3
1890	11.9	21.7	18.3	17.6	18.7	28.0	22.1	22.7	22.9	34.9	29.0	28.9
1891	15.8	25.6	20.9	20.8	19.4	27.7	22.7	23.1	23.9	34.9	28.3	28.9
1892	18.0	26.4	22.2	22.2	15.4	30.1	22.5	22.6	20.1	33.3	27.7	27.2
Mean	11.4	21.5	16.4	16.5	13.2	25.6	19.7	19.5	21.3	33.1	27.5	27.9

Year.	April.				May.				June.			
1869	35.3	45.1	32.2	39.2	45.1	59.2	48.8	50.5	.....	.....	.....	.....
1870	37.5	51.9	41.9	43.3	46.9	60.6	48.8	52.0	61.5	74.5	62.0	65.0
1871	36.1	46.8	40.1	40.8	44.9	58.4	48.2	49.9	57.7	70.2	58.6	61.3
1872	34.7	47.4	38.6	39.8	48.7	57.9	49.8	51.6	59.9	71.6	61.3	63.5
1873	35.4	45.4	37.8	39.1	47.9	61.1	48.7	51.6	55.5	69.2	57.5	59.9
1874	29.0	38.8	32.1	33.0	46.8	59.7	49.1	51.2	65.4	66.7	58.4	59.7
1875	31.7	43.2	34.8	36.1	47.2	59.6	49.5	51.8	56.8	68.9	57.8	60.3
1876	34.5	45.6	37.8	38.8	46.0	58.0	47.8	49.9	60.8	73.6	61.8	64.5
1877	37.4	51.3	41.8	43.1	47.7	61.6	50.5	52.6	60.3	72.0	60.2	63.2
1878	40.4	51.4	42.8	44.4	50.4	61.2	52.4	54.1	57.9	70.7	58.6	61.5
1879	33.5	45.2	37.0	38.2	50.8	65.4	52.7	55.0	57.1	66.0	57.1	59.3
1880	36.1	47.7	38.5	40.2	51.7	55.4	53.9	56.2	60.6	71.0	60.5	63.2
1881	33.3	46.7	39.2	39.6	47.7	59.9	51.5	52.7	54.4	68.1	55.4	58.3
1882	32.2	41.8	35.6	36.3	44.9	57.2	47.7	49.4	59.2	70.1	60.1	62.4
1883	34.5	45.9	37.6	38.9	47.0	59.6	50.5	51.9	62.6	72.3	61.3	64.4
1884	38.7	48.6	41.5	42.6	47.4	57.4	47.7	50.0	60.6	74.5	61.8	64.7
1885	35.8	48.9	39.1	40.7	47.7	61.5	49.3	51.9	58.9	69.6	59.3	61.8
1886	38.3	52.5	41.5	43.5	49.5	62.3	50.9	53.4	59.7	70.0	57.9	61.4
1887	32.3	44.4	36.7	37.5	47.7	64.6	53.0	54.6	59.9	70.9	59.7	62.6
1888	33.1	44.3	36.3	37.5	46.9	59.0	48.8	50.9	60.8	70.2	60.0	62.8
1889	40.2	53.4	43.3	45.1	52.7	66.8	53.0	56.4	62.9	72.5	62.1	64.9
1890	35.3	47.9	38.8	40.2	49.3	59.4	50.6	52.5	57.8	66.6	57.2	59.7
1891	37.7	47.9	40.1	41.4	47.1	60.6	50.2	52.0	57.6	69.1	58.0	60.8
1892	37.8	52.9	41.0	43.2	48.0	58.4	49.9	51.6	58.3	71.7	61.0	63.0
Mean	35.4	47.3	38.8	40.1	47.9	60.2	50.0	52.3	59.0	70.9	59.4	62.1

TABLE 3—*Concluded.*

Year.	July.				August.				September.			
	7 a. m.	2 p. m.	9 p. m.	Mean.	7 a. m.	2 p. m.	9 p. m.	Mean.	7 a. m.	2 p. m.	9 p. m.	Mean.
69	62.0	74.6	63.9	66.1	57.2	70.9	59.8	61.9	54.9	67.7	56.8	59.1
70	64.8	77.7	65.3	68.2	61.1	77.6	63.3	67.6	51.3	66.8	56.0	57.5
1871	62.4	75.4	64.0	66.5	58.9	74.7	63.4	65.4	48.0	63.0	52.6	54.1
1872	64.2	76.9	65.8	68.2	62.7	75.4	64.8	66.9	54.7	64.7	56.7	58.2
1873	64.8	76.8	64.3	67.4	58.4	72.4	60.2	65.8	50.1	63.8	52.9	54.9
1874	62.5	73.5	64.4	66.2	57.7	71.2	60.7	62.6	58.1	66.0	55.9	57.7
1875	52.7	74.6	63.2	65.9	62.3	76.9	65.4	67.5	48.7	61.5	52.3	53.7
1876	66.9	75.6	65.7	68.3	61.5	76.8	64.5	66.8	49.4	63.1	52.8	54.5
1877	64.0	75.6	65.2	67.5	62.7	75.0	65.0	66.9	52.5	70.1	57.6	59.5
1878	65.9	75.8	65.8	68.3	61.5	73.6	62.7	65.1	56.3	67.5	57.3	59.4
1879	63.9	75.4	63.5	66.6	59.3	73.1	62.3	64.3	52.2	63.7	54.8	56.4
1880	65.3	77.6	66.8	69.1	64.0	74.0	63.2	65.4	55.3	68.5	59.1	60.5
1881	63.3	73.6	64.5	65.8	64.1	76.1	65.9	68.0	55.8	68.1	59.1	60.5
1882	67.1	76.4	65.5	68.6	62.2	78.2	65.0	67.9	53.8	63.8	55.1	57.0
1883	61.3	71.8	63.6	65.1	60.2	75.0	61.6	64.6	49.7	69.3	54.8	57.2
1884	61.8	72.4	62.2	64.7	62.9	74.2	64.2	66.4	53.4	67.6	57.0	58.8
1885	65.1	75.2	64.9	67.5	58.9	71.8	61.1	63.2	49.5	63.8	52.5	54.6
1886	64.9	75.7	63.9	67.1	58.2	75.0	62.9	64.8	51.1	64.5	54.5	56.2
1887	69.0	78 3	68.2	70.9	59.9	71.0	60.9	63.2	49.5	64.5	55.1	56.1
1888	62.2	75.0	62.6	65.6	60.1	70.9	61.5	63.5	50.2	62.1	52.3	54.2
1889	63.9	74.8	63.8	66.6	61.2	73.1	62.2	64.7	55.3	67.3	59.3	60.3
1890	64.2	74.5	63.1	66.2	61.3	73.3	62.4	64.9	53.9	65.1	56.9	58.2
1891	62.7	75.0	61.0	64.9	62.2	73.7	64.8	66.1	55.4	69.0	58.9	60.6
1892	63.5	77.6	65.5	68.0	61.3	73.0	64.5	65.8	52.7	67.5	57.0	58.5
Mean	63.6	75.4	64.4	67.0	60.7	74.0	62.9	65.4	53.1	65.8	55.8	57.0

Year.	October.				November.				December.			
1869	41.4	52.8	43.4	45.3	28.1	37.0	32.2	32.4	.....	.....	.....	.....
1870	42.4	54.4	49.0	48.7	33.8	41.4	34.9	36.3	22.0	26.4	23.4	24.3
1871	43.3	54.2	46.4	47.6	25.9	33.6	27.7	26.7	15.1	21.2	15.9	16.5
1872	40.8	52.6	43.7	45.2	30.8	37.9	32.7	33.5	9.7	18.3	12.5	14.3
1873	41.5	54.9	45.7	47.0	22.1	29.6	23.9	25.0	14.7	25.3	20.3	20.2
1874	42.1	55.8	45.9	47.4	28.5	38.1	31.7	32.5	13.5	23.1	18.3	18.3
1875	39.9	48.8	42.2	43.3	23.0	31.6	26.9	27.1	13.6	23.5	18.6	18.6
1876	38.3	49.2	41.7	42.8	32.2	40.3	34.9	35.6	7.3	20.1	13.0	13.3
1877	38.2	49.3	43.4	43.6	34.0	42.7	36.9	37.8	21.4	31.7	26.0	26 3
1878	44.5	56.5	48.3	49.4	31.5	38.9	33.0	34.1	21.8	27.8	26.0	25.4
1879	46.2	57.5	48.4	50.1	30.6	38.2	33.4	33.9	16.2	24.9	18.9	19.7
1880	42.5	54.9	45.7	47.2	26.6	37.6	30.5	31.4	14.0	26.2	20.6	20.4
1881	43.3	52.6	43.9	45.9	31.7	40.2	35.8	35.9	28.1	34.8	30.1	30.8
1882	42.5	57.9	45.1	47.7	30.4	39.7	32.2	33.6	14.1	25.8	19.5	19.7
1883	38.5	50.7	41.3	43.0	31.1	40.9	34.0	35.0	16.7	27.2	20.0	21.0
1884	39.0	51.9	44.2	44.8	29.3	38.7	33.3	33.7	20.5	28.8	23.0	23.8
1885	42.5	53.7	45.3	46.7	32.1	41.6	35.9	36.1	19.1	28.2	23.1	24.4
1886	39.1	54.9	44.0	45.5	34.1	42.2	36.9	37.5	14.0	22.6	18.0	18.2
1887	38.0	49.2	42.9	43.3	31.1	39.2	33.2	34.2	20.9	28.3	22.3	23.5
1888	39.3	46.5	41.4	42.2	32.0	41.1	33.5	35.0	25.5	31.7	27.4	28.0
1889	39.0	51.4	41.4	43.3	33.7	44.7	37.7	38.5	24.3	31.4	27.0	27.4
1890	40.0	53.2	44.3	45.4	31.7	40.2	32.5	34.7	7.6	16.8	11.3	11.8
1891	40.0	53.0	44.2	45.4	32.1	42.6	39.2	38.3	27.1	37.1	32.0	32.2
1892	40.2	53.1	44.0	45.3	35.3	41.1	35.8	36.8	16.8	26.9	21.0	21.4
Mean	40.9	52.9	44.3	45.7	30.4	39.1	33.2	34.5	20.1	26.5	21.2	21.7

TABLE 3a—*Monthly Temperature from 1893 to 1904.*

	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.	Mean.
1893 ..	12.5	17.2	27.0	37.8	53.7	64.0	66.7	65.8	53.0	49.4	34.6	13.8	41.3
1894 ..	12.4	16.0	32.5	41.9	52.3	62.1	67.2	61.1	59.2	46.4	29.8	21.4	41.9
1895 ..	......	17.0	26.1	41.2	58.1	66.8	65.1	66.4	57.8	42.5	36.9	......	......
1896 ..	......	24.1	24.3	42.7	53.3	62.4	66.0	64.9	55.5	44.7	34.6	19.5	......
1897 ..	16.6	20.0	27.3	42.3	53.0	57.0	68.2	68.8	55.2	47.2	33.2	23.2	42.2
1898 ..	13.4	24.6	33.4	39.8	53.8	61.1	68.6	67.5	56.3	46.8	35.8	20.7	43.6
1899 ..	15.2	16.2	26.0	44.2	52.4	62.0	68.3	66.4	50.6	50.0	34.0	28.0	43.3
1900 ..	17.8	20.5	26.6	44.1	49.4	63.4	68.1	66.3	59.2	51.4	36.4	18.5	43.5
1901 ..	15.2	14.0	27.5	44.6	53.7	63.6	68.4	66.4	59.4	47.2	28.6	23.2	42.7
1902 ..	17.2	21.6	36.8	43.4	50.7	56.8	64.2	63.0	59.0	47.2	37.2	17.0	42.8
1903 ..	16.2	19.8	37.5	43.0	54.4	59.8	62.1	60.6	60.2	47.1	33.8	20.0	42.9
1904 ..	10.2	12.2	29.0	41.0	58.2	60.8	68.8	64.2	56.6	46.1	30.4	11.8	40.7
Av.	15.8	18.9	27.9	40.7	52.6	61.9	66.9	65.0	57.0	46.1	34.0	20.8	42.3

NOTE.—These averages refer to the entire period from 1889-1904 inclusive.

In Table 4, 1893-1904, the data for mean maximum and mean minimum do not appear for the years 1893-1896; the mean monthly temperature for these years is the mean of the tridaily readings, or ¼ (7+2+9+9). The monthly means for each hour have not been preserved. For 1897-1904 the mean monthly temperature is the mean of the mean maximum and the mean minimum. Records at 2 P. M. only were taken in this period.

TABLE 4.—*Monthly and absolute extremes and monthly mean temperatures.*

Year.	January.					February.				
	Absolute max.	Absolute min.	Mean max.	Mean min.	Mean monthly.	Absolute max.	Absolute min.	Mean max.	Mean min.	Mean monthly.
1893	51.2	—20.3	......	......	12.5	48.	—14.4	......	......	17.2
1894	45.6	—32.0	......	......	17.9	42.5	—29.5	......	......	12.9
1895	......	......	......	......	......	41.	—10.1	......	......	17.5
1896	......	......	......	......	......	43.	—30.	......	......	24.1
1897	52.	—18.	28.0	5.0	17.4	43.	—16.	31.6	8.1	20.2
1898	40.	—30.	24.6	2.2	13.2	47.	—25.	33.9	15.4	24.3
1899	49.	-29.	26.8	3.7	16.0	52.	—16.	25.1	7.4	16.5
1900	46.	—19.	31.2	4.5	17.8	50.	-21.	31.6	9.4	20.5
1901	42.	—20.	23.7	6.8	15.0	40.	—18.	24.9	3.1	14.2
1902	47.	—16.	26.8	7.7	17.3	52.	—15.	31.7	11.4	22.1
1903	41.	—23.	24.6	6.9	15.7	50.	—16.	28.8	10.8	19.2
1904	41.	—26.	21.8	—1.1	10.3	43.	—26.	23.7	0.8	12.3
Mean	45.5	—23.3	26.0	4.9	15.3	45.9	—19.8	28.9	8.3	18.4

Year.	March.					April.				
1893	47.4	0.6	......	......	27.1	59.2	13.0	......	......	37.8
1894	63.3	8.2	......	......	32.0	77.4	12.3	......	......	42.0
1895	47.0	— 3.5	......	......	26.9	69.0	12.0	......	......	42.9
1896	43.0	— 7.0	......	......	24.3	......	18.0	......	......	42.7
1897	48.	—11.	36.1	18.5	28.4	74.	14.	52.4	32.2	41.8
1898	60.	5.	45.3	21.5	32.2	65.	9.	48.6	30.6	38.8
1899	51.	— 3	34.3	17.6	26.5	84.	18.	56.7	31.8	43.3
1900	52.	—10.	39.1	14.0	26.6	78.	21.	56.2	32.0	44.1
1901	49.	—13.	36.7	18.3	27.7	76.	25.	53.5	35.6	44.7
1902	62.	2.	45.2	28.5	36.9	75.	27.	53.7	33.1	43.4
1903	64.	0.	47.4	27.7	37.5	76.	18.	55.7	30.9	43.0
1904	51.	— 7.	39.5	18.4	29.0	62.	16.	52.4	29.6	41.0
Mean	53.1	— 2.4	40.9	20.6	27.8	72.3	16.9	53.6	32.0	42.1

Year.	May.					June.				
1893	82.4	31.0	......	......	53.7	84.0	39.1	......	......	64.0
1894	84.9	30.0	......	......	52.4	88.0	37.0	......	......	60.9
1895	89.0	31.0	......	......	55.1	91.0	37.0	......	......	64.8
1896	......	21.0	......	......	53.3	......	......	......	......	......
1897	76.	29.	62.9	43.0	52.1	83.	39.	67.5	46.4	57.0
1898	76.	28.	64.7	43.0	53.1	87.	36.	71.1	51.1	61.5
1899	80.	26.	64.6	40.1	52.3	87.	37.	73.9	50.0	62.1
1900	83.	26.	63.0	39.5	49.5	86.	38.	77.4	49.4	63.4
1901	85.	32.	64.5	42.9	53.9	91.	38.	74.9	52.2	63.8
1902	83.	28.	61.2	40.2	50.6	84.	34.	67.4	46.2	56.8
1903	83.	26.	69.4	39.5	54.4	81.	32.	73.3	47.4	60.4
1904	82.	29.	71.6	44.7	58.1	87.	38.	73.7	48.0	60.8
Mean	82.2	28.1	65.1	41.8	53.2	86.3	36.8	72.4	48.8	61.4

TABLE 4.—*Concluded.*

Year.	July.					August.				
	Absolute max.	Absolute min.	Mean max.	Mean min.	Mean monthly.	Absolute max.	Absolute min.	Mean max.	Mean min.	Mean monthly.
1893	89.5	46.1	......	......	66.7	95.0	46.7	......	......	65.8
1894	93.8	44.5	......	......	66.9	86.8	35.9	.....	......	61.6
1895	89.0	43.0	......	......	64.5	86.0	41.0	......	......	64.1
1896	86.0	55.0	......	.....	66.0	92.0	39.	75.0	54.0	64.7
1897	93.	43.	79.0	57.0	66.6	85.	41.	74.0	53.0	64.2
1898	99.	39.	79.5	57.6	68.3	85.	41.	78.3	56.7	67.3
1899	91.	41.	77.0	59.6	68.4	93.	40.	78.1	54.8	66.5
1900	89.	47.	79.8	56.4	68.1	......	....	......	......	66.3
1901	100.	40.	80.2	56.6	68.6	86.	43.	76.9	55.9	66.7
1902	87.	43.	75.3	53.C	64.7	85.	39.	74.4	51.8	63.1
1903	88.	54.	77.9	46.2	62.1	81.	38.	73.6	47.7	60.5
1904	87.	46.	80.4	57.2	68.8	88.	40.	76.6	51.8	64.6
Mean	91.9	43.5	78.4	55.5	66.6	87.3	40.4	75.9	53.2	64.6

Year.	September.					October.				
1893	71.8	30.7	......	......	52.3	72.0	25.5	......	......	47.9
1894	89.6	27.0	......	......	61.3	66.0	27.0	......	......	46.1
1895	92.5	26.5	......	......	56.6	73.9	13.0	......	......	42.9
1896	87.	28.	65.0	46.0	53.8	68.	23.	53.0	37.0	44.7
1897	90.	28.	68.0	42.0	56.2	79.	19.	60.0	34.0	46.9
1898	85.	29.	70.7	45.9	58.6	86.	19.	57.6	36.0	47.2
1899	88.	23.	67.9	45.3	56.6	76.	22.	62.2	37.7	50.0
1900	93.	27.	72.2	46.2	59.2	76.	19.	60.9	41.8	51.4
1901	89.	28.	71.1	47.7	59.5	71.	20.	58.0	36.4	47.6
1902	82.	30.	69.4	48.7	59.5	75.	17.	56.7	37.8	47.3
1903	89.	29.	74.0	46.5	60.2	71.	22.	57.8	36.4	47.1
1904	80.	26.	67.5	43.6	55 5	69.	20.	55.1	36.3	46.1
Mean	86.4	27.7	69.5	46.0	58.3	73.5	20.5	57.9	33.7	47.1

Year.	November.					December.				
1893	57.4	9.3	......	......	33.7	40.2	—22.0	......	......	14.3
1894	59.0	— 5.9	......	......	34.5	45.5	— 7.0	......	......	22.4
1895	71.0	10.0	......	......	36.9	......	....	......	......	......
1896	68.	— 4.	32.8	25.9	34.6	45.	— 9.	29.0	10.0	20.0
1897	59.	3.	41.0	25.0	33.8	51.	—11.	30.4	15.9	23.3
1898	55.	10.	42.7	28.7	36.3	43.	—13.	29.6	11.8	21.4
1899	58.	8.	43.4	24.6	34.0	57.	— 9.	37.4	18.7	28.0
1900	72.	9.	42.6	28.6	35.6	45.	—16.	23.0	81.1	15.6
1901	58.	— 8.	37.3	20.0	28.6	55.	—17.	31.9	14.5	23.3
1902	58.	18.	46.0	28.3	37.2	53.	—28.	25.9	8.7	17.1
1903	70.	2.	43.7	23.9	33.8	50.	—10.	30.0	10.0	20.0
1904	50.	0.	39.7	21.1	30.5	39.	—27.	22.5	1.1	11.9
Mean	61.3	5.0	41.0	25.1	34.1	47.6	—14.7	28.8	11.0	19.7

Table 5 gives, in the second column, the average temperature for each month for the period of 24 years (1869 to 1892, inclusive), and in the third column the average temperature for 35 years (1869 to 1904 inclusive), also the highest and lowest mean temperature during the whole period (1869 to 1904):

TABLE 5.—*Mean and extreme monthly temperatures.*

Month.	Average for 24 years.	Average for 35 years.	Highest temperature.		Lowest temperature.	
			Degrees.	Year.	Degrees.	Year.
January	16.11	16.0	57.8	1880	—35.6	1878
February	19.33	19.2	52.0	1899	—30.0	1886
March	27.37	28.1	68.3	1894	—22.0	1869
April	40.56	40.0	84.0	1899	1.0	1874
May	52.17	52.4	90.0	1880	21.0	1886
June	62.18	61.9	98.5	1878	32.0	1903
July	67.16	67.1	100.0	1901	34.0	1903
August	65.09	64.9	96.7	1876	35.0	1873
September	57.12	57.3	93.0	1900	23.0	1899
October	45.61	46.1	86.0	1898	18.0	1895
November	35.22	34.2	72.0	1900	—16.2	1875
December	21.57	21.3	60.6	1888	—36.3	1880

VAPOR TENSION AND RELATIVE HUMIDITY.

In Tables 6 and 7 are given the vapor tension and the relative humidity at 7 a. m., 2 p. m., and 9 p. m., for 1869-1875, inclusive. From 1869-1875 the relative humidity was recorded at 7 a. m., 2 p. m., and 9 p. m., and the mean taken.

The hygrometer used throughout was of the Huddleston type and was made in Boston, Mass.

TABLE 6.—*Mean vapor pressure.*

Year.	January.			February.			March.			April.		
	7 a. m.	2 p. m.	9 p. m.	7 a. m.	2 p. m.	9 p. m.	7 a. m.	2 p. m.	9 p. m.	7 a. m.	2 p. m.	9 p. m.
1869	.081	.099	.096	.078	.104	.100	.083	.112	.101	.172	.188	.177
1870	.101	.111	.112	.084	.104	.090	100	.107	.106	.190	.218	.209
1871	.074	.087	.090	.083	.096	.097	.150	.166	.161	.177	.190	.194
1872	.084	.092	.084	.066	.091	.088	.076	.092	.089	.152	.165	.169
1873	.079	.093	.087	.067	.082	.087	.106	.121	.127	.160	.164	.167
1874	.100	.123	.114	.078	.089	.090	.101	.117	.118	.126	.138	.134
1875	.044	.063	.062	.070	.089	.086	.091	.103	.108	.131	.141	.143

Year.	May.			June.			July.			August.		
1869	.262	.285	.289	......	......	......	.474	.520	.491	.397	.405	.417
1870	.256	.267	.268	.467	.506	.465	.496	.497	.505	.470	.480	.459
1871	.239	.243	.238	.390	.411	.386	.487	.474	.485	.465	.476	.471
1872	.273	.288	.280	.445	.467	.463	.511	.522	.519	.517	.528	.545
1873	.242	.243	.250	.350	.343	.374	.505	.498	.487	.413	.418	.429
1874	.246	.262	.257	.374	.396	.402	.498	.528	.518	.436	.438	.466
1875	.249	.266	.257	.385	.445	.386	.500	.481	.488	.528	.572	.562

Year.	September.			October.			November.			December.		
1869	.405	.424	.417	.265	.280	.263	.144	.170	.171	......	......	.....
1870	.345	.372	.373	.265	.275	.274	.172	.179	.167	.112	.116	.114
1871	.313	.334	.332	.262	.282	.271	.125	.136	.134	.084	.095	.092
1872	.385	.408	.415	.249	.259	.254	.158	.163	.169	.071	.085	.076
1873	.325	.358	.354	.247	.273	.271	.108	.109	.109	.086	.105	.105
1874	.384	.428	.398	.243	.260	.259	.153	.162	.159	.084	.104	.091
1875	.325	.375	.346	.239	.232	.226	.120	.133	.135	.086	.096	.096

TABLE 7.—*Relative humidity.*

Year.	January.			February.			March.			April.		
	7 a. m.	2 p. m.	9 p. m.	7 a. m.	2 p. m.	9 p. m.	7 a. m.	2 p. m.	9 p. m.	7 a. m.	2 p. m.	9 p. m.
1869..........	83	72	80	76	68	77	72	60	68	80	64	76
1870..........	87	70	84	88	70	81	77	53	66	84	58	78
1871..........	85	71	85	82	59	75	84	65	78	81	60	77
1872..........	90	68	87	90	61	77	87	63	78	75	50	72
1873..........	86	75	88	87	61	81	86	63	80	78	53	74
1874..........	89	79	89	87	64	80	75	56	71	74	57	71
1875..........	83	69	86	84	70	83	78	55	74	74	50	66

Year.	May.			June.			July.			August.		
1869..........	83	56	81	.....	.....	.....	84	60	83	83	54	80
1870..........	78	51	75	85	59	83	81	53	80	85	53	77
1871..........	74	48	67	82	57	78	88	55	81	88	54	80
1872..........	79	61	78	85	61	84	84	57	80	89	61	88
1873..........	69	45	72	77	50	77	80	54	80	83	53	80
1874..........	73	48	71	83	61	79	88	65	86	89	57	86
1875..........	75	53	68	79	59	79	86	56	84	92	62	89

Year.	September.			October			November.			December.		
1869..........	91	62	88	92	67	87	89	78	88	.....	.....	.....
1870..........	72	56	82	91	62	84	85	66	80	86	71	83
1871..........	89	47	81	87	60	81	86	66	82	87	75	89
1872..........	89	67	88	92	63	86	90	69	89	81	72	82
1873..........	85	60	84	89	61	83	83	64	79	87	68	86
1874..........	93	67	88	87	57	81	89	68	84	84	74	84
1875..........	89	61	85	88	65	81	88	70	85	88	67	85

PRECIPITATION.

In Table 8 are tabulated the precipitation records at Orono, Me., from 1869 to 1904, inclusive. They include the total precipitation, the total snowfall, the number of days with 0.01 inch or more precipitation, and the maximum in 24 hours, with the date on which maximum occurred.

Table 9 gives the days during the period in which the precipitation was 2.50 inches or over.

The rain gauge was a Huddleston pattern during the first half of the observations, but one furnished by the U. S. Weather Bureau during the last half. They were well located in an exposed place, about 100 feet from the nearest building.

The scarcity of heavy rainfalls between 1896 and 1904 is noticeable.

TABLE 8.—*Precipitation.*

Year.	January.					February.				
	Total inches.	Total snowfall, in inches.	Days with .01 inch or more.	Maximum in 24 hours.	Date of maximum.	Total inches.	Total snowfall, in inches.	Days with .01 inch or more	Maximum in 24 hours.	Date of maximum.
1869	2.54	10.75	14	0.80	5	4.26	32.25	11	1.38	7
1870	5.62	26.0	14	1.29	2	4.30	15.0	12	1.89	19
1871	2.60	13.5	13	1.50	17	2.53	14.0	7	.87	18
1872	2.18	16.0	8	0.76	17	1.70	13.5	7	.98	4
1873	4.09	22.0	18	0.63	5	2.96	28.0	8	1.15	22
1874	4.57	25.0	16	1.45	8	5.50	40.0	13	2.85	4
1875	2.00	19.7	11	0.47	22	3.80	8.5	11	.85	25
1876	3.92	23.0	17	1.35	20	8.39	25.5	14	4.45	15
1877	3.29	28.5	14	0.80	16	1.20	10.5	7	.60	13
1878	5.08	15.0	15	1.80	11	2.41	14.0	7	1.40	25
1879	3.28	31.5	12	1.24	3	3.56	16.0	13	1.88	12
1880	2.83	13.0	14	0.94	22	2.83	16.5	15	.74	24
1881	2.08	16.5	8	0.83	10	3.35	13.5	13	1.15	12
1882	4.19	30.0	19	0.80	22	3.96	30.0	12	1.20	5
1883	2.44	15.0	13	0.60	31	2.34	13.0	13	.64	5
1884	4.44	17.5	9	2.04	9	6.85	26.5	20	1.27	23
1885	4.73	31.0	11	1.40	28	4.45	22.0	8	2.20	10
1886	6.64	37.0	17	3.40	31	5.42	32.0	12	2.60	28
1887	7.56	33.5	17	1.98	24	5.89	33.5	11	1.41	24
1888	4.97	37.5	12	1.60	27	6.11	20.5	12	2.26	20
1889	5.37	15.5	11	1.35	8	5.20	28.3	14	2.12	7
1890	3.33	19.5	17	1.25	16	4.57	13.0	14	1.45	8
1891	7.66	32.5	17	1.67	12	2.95	14.0	16	.56	3
1892	4.80	18.5	13	1.57	13	1.96	17.5	12	.85	12
1893	0.85	......	......	......	......	5.75	......	......	......	......
1894	3.01	......	2	2.0	30	1.73	15.0	2	.80	15
1895	......	......	......	......	......	0.83	......	......	......	......
1896	......	......	......	......	......	2.26	......	......	......	......
1897	3.08	23.3	7	1.0	28	2.38	9.5	5	1.38	7
1898	6.32	42.5	9	1.32	7	8.05	39.0	9	2.91	22
1899	2.75	10.0	5	1.25	6	2.27	13.5	7	.80	45
1900	8.14	26.3	10	1.98	12	6.75	28.0	10	1.94	13
1901	4.33	25.5	12	1.20	12	1.95	19.5	5	1.0	5
1902	3.65	13.0	10	1.73	22	1.80	18.0	8	......	......
1903	3.62	15.2	9	0.87	21	3.92	21.5	8	.74	12
1904	3.63	34.0	8	1.0	9	2.57	18.0	11	.62	22

TABLE 8.—*Continued.*

Year.	March.					April.				
	Total inches.	Total snowfall in inches.	Days with .01 inch or more.	Maximum in 24 hours.	Date of maximum.	Total inches.	Total snowfall, in inches.	Days with .01 inch or more.	Maximum in 24 hours.	Date of maximum.
1869	3.36	10.42	9	.953	23	2.39	1.75	11	1.98	1
1870	2.11	10.50	12	.813	29	3.55	2.0	12	1.37	21
1871	4.11	8.0	13	2.01	22	4.01	1.0	15	.92	29
1872	5.23	38.0	14	1.80	10	1.93	3.0	11	1.10	10
1873	4.70	31.0	14	.80	30	2.59	5.0	11	.785	19
1874	3.40	14.0	10	1.45	4	3.76	30.0	16	1.15	30
1875	4.45	33.6	16	1.58	25	3.85	4.5	10	2.44	5
1876	8.20	18.0	14	3.25	21	1.65	9.0	13	.64	6
1877	5.67	11.0	17	2.50	29	3.18	.5	12	1.10	6
1878	2.73	8.0	13	.72	18	3.46	0.0	20	1.05	7
1879	3.40	18.5	14	.86	31	3.51	0.0	16	1.04	30
1880	2.86	18.0	10	1.24	24	4.15	2.0	13	1.98	30
1881	3.64	5.5	11	1.53	12	1.28	6.0	7	.92	15
1882	5.20	15.0	19	2.85	2	2.05	9.0	14	.75	20
1883	1.89	7.5	7	72	28	3.80	2.5	12	1.27	20
1884	4.37	22.5	16	1.35	27	3.38	0.5	18	1.52	16
1885	2.78	15.0	10	1.08	2	2.34	3.5	13	.83	5
1886	2.87	22.0	10	1.22	22	1.80	1.0	7	1.42	7
1887	5.88	26.5	15	2.90	29	5.08	14.0	10	3.26	30
1888	6.48	26.0	20	1.62	29	1.58	16.0	14	.50	21
1889	4.62	4.0	12	2.90	9	1.93	4.0	8	.92	27
1890	5.81	3.6	15	1.25	3	2.02	6.0	9	.81	5
1891	5.20	12.0	10	1.60	10	3.26	11.0	13	1.25	3
1892	2.52	17.0	7	1.00	3	1.12	0.5	7	.42	10
1893	1.45	....	7	.82	12	2.18	....	13	.65	15
1894	1.23	2.5	10	.89	25	1.18	3 5	7	.35	9
1895	2.39	1.6	......	1.18	14	3.81	....	11	1 42	9
1896	6.95	....	......	....	......	......	....	......	....	......
1897	3.96	6.5	12	.72	10	3.03	0.0	10	.84	9
1898	2.23	13.0	7	.70	31	4.95	9.0	12	2.19	19
1899	4.76	28.0	11	.90	16	0.66	.5	2	.55	8
1900	5.47	16.5	5	2.20	16	2.01	0.0	7	.62	19
1901	5.46	11.8	11	1.80	21	5.12	0.0	9	1.86	28
1902	8.89	14.	19	1.86	17	2.94	0.0	13	.84	10
1903	6.22	2.	11	1.26	8	1.71	0.5	5	.62	8
1904	3.18	17.	9	.74	8	2.31	3.5	10	.64	10

TABLE 8.—*Continued.*

Year.	May.					June.				
	Total inches.	Total snowfall, in inches.	Days with .01 inch or more.	Maximum in 24 hours.	Date of maximum.	Total inches.	Total snowfall, in inches.	Days with .01 inch or more.	Maximum in 24 hours.	Date of maximum.
1869	2.95	0.0	14	1.20	4	......	......	......	......	......
1870	1.96	0.0	11	.49	11	2.07	0.0	6	1.75	9
1871	3.48	1.5	12	2.12	5	2.58	0.0	12	.69	13
1872	3.92	0.0	15	.94	5	4.47	0.0	16	1.07	2
1873	1.96	0.0	11	1.32	12	1.32	0.0	12	.56	4
1874	4.74	0.0	8	2.60	31	4.93	0.0	14	1.60	18
1875	3.31	0.0	11	1.15	25	4.85	0.0	8	2.20	19
1876	3.73	0.0	14	1.15	29	2 56	0.0	11	1.42	5
1877	1.94	0.0	13	1.05	3	1.98	0.0	9	.74	8
1878	2.14	0.0	10	1.25	23	5.42	0.0	10	2.50	24
1879	1.80	0.0	13	.58	14	4.73	0.0	15	1.75	4
1880	2.17	0.0	12	1.30	31	.73	0.0	8	.28	8
1881	4.85	0.0	15	2.75	17	3.38	0.0	11	.94	29
1882	4.52	0.0	12	2.65	29	4.44	0.0	13	1.85	6
1883	5.10	0.0	17	2.98	24	3.66	0.0	10	1.04	21
1884	5.42	0.0	15	1.23	29	1.37	0.0	6	.80	24
1885	3.38	8.	8	1.15	2	4.60	0.0	10	2.60	30
1886	4.67	0.0	10	1.45	8	2.74	0.0	9	1.35	27
1887	1.25	0.0	8	.64	30	3.36	0.0	11	1.22	24
1888	2.81	0.0	10	1.44	14	3.65	0.0	10	1.26	23
1889	1.86	0.0	10	.78	10	4.93	0.0	16	.88	2
1890	10.52	0.0	19	2.35	6	3.84	0.0	15	.97	14
1891	2.81	0.0	12	1.55	17	3.20.	0.0	10	1.34	28
1892	1.94	0.0	11	1.13	23	5.96	0.0	17	2.10	20
1893	2.55	0.0	12	.67	17	2.69	0.0	12	.58	6
1894	3.94	0.0	7	1.40	19	2.90	0.0	9	.59	1
1895	2.13	0.0	5	.96	12	1.35	0.0	7	.45	27
1896	......	......	......	......	......	......	......	......	......	......
1897	4.49	0.0	11	1.42	13	3.71	0.0	13	.94	4
1898	1.02	0.0	4	.61	30	5.28	0.0	10	2.10	......
1899	4.12	0.0	9	1.27	20	4.10	0.0	13	1.17	14
1900	8.24	0.0	13	2.25	3	3.83	0.0	7	1.04	2
1901	2 07	Trace.	13	1.17	28	1.79	0.0	9	.50	23
1902	2.77	0.0	10	.74	26	6.03	0.0	16	1.25	26
1903	.73	0.0	3	.46	5	2.09	0.0	6	.77	13
1904	4.26	0.0	11	.96	11	2.17	0.0	8	.58	5

TABLE 8.—*Continued.*

Year.	July.					August.				
	Total inches.	Total snowfall, in inches.	Days with .01 inch or more.	Maximum in 24 hours.	Date of maximum.	Total inches.	Total snowfall, in inches.	Days with .01 inch or more.	Maximum in 24 hours.	Date of maximum.
1869	1.62	0	12	.53	16	1.91	0	8	.84	28
1870	1.78	0	12	.44	29	3.21	0	6	2.42	4
1871	2.13	0	16	.50	31	3.85	0	8	1.66	27
1872	2.68	0	16	.37	19	6.23	0	15	1.37	17
1873	3.26	0	12	.67	27	1.81	0	6	1.13	3
1874	2.10	0	9	.95	3	5.39	0	9	4.20	9
1875	2.11	0	12	.33	7	2.32	0	11	.16	4
1876	5.80	0	17	2.50	24	.91	0	4	.46	25
1877	1.64	0	10	.80	26	5.28	0	15	2.30	10
1878	4.77	0	8	1.30	22	3.00	0	12	1.40	18
1879	5.79	0	12	2.45	23	5.66	0	10	4.80	19
1880	3.32	0	12	.60	24	1.54	0	8	1.00	4
1881	2.72	0	18	1.04	27	5.89	0	12	2.95	8
1882	3.10	0	11	.65	2	1.64	0	6	.85	15
1883	6.90	0	15	2.95	14	.53	0	5	.40	23
1884	2.38	0	15	.65	6	3.17	0	11	1.00	22
1885	4.70	0	14	1.52	31	7.36	0	11	2.85	6
1886	1.05	0	8	.48	16	2.27	0	11	1.12	17
1887	7.11	0	11	4.38	25	4.60	0	10	1.92	11
1888	2.47	0	11	.80	11	4.59	0	19	1.34	14
1889	3.23	0	10	1.12	20	1.65	0	12	.35	9
1890	3.84	0	11	1.23	8	4.55	0	17	1.28	20
1891	3.56	0	11	1.27	24	4.67	0	10	2.04	27
1892	1.99	0	9	1.40	4	6.42	0	12	2.80	12
1893	3.23	0	9	.88	3	3.90	....	....	......	......
1894	2.41	0	6	1.16	24	2.01	0	6	1.28	3
1895	2.85	0	......	.29	7	2.14	0	3	1.24	24
1896	2.58	0	......	1.67	5	4.26	0	......	.90	23
1897	2.02	0	9	.65	22	5.09	0	6	1.79	25
1898	2.44	0	5	.85	21	31.4	0	7	1.10	5
1899	4.49	0	10	2.00	21	......	....	......	......	......
1900	2.53	0	9	1.34	25	1.58	0	9	.48	14
1901	2.75	0	11	1.15	30	3.76	0	8	2.06	25
1902	1.81	0	8	.40	8	4.96	0	10	2.45	11
1903	6.49	0	15	2.25	23	2.22	0	17	1.03	20
1904	2.43	0	10	.75	5	4.46	0	10	1.66	10

TABLE 8.—*Continued.*

Year.	September.					October.				
	Total inches.	Total snowfall, in inches.	Days with .01 inch or more.	Maximum in 24 hours.	Date of maximum.	Total inches.	Total snowfall, in inches.	Days with .01 inch or more.	Maximum in 24 hours.	Date of maximum.
1869	3.67	0	9	1.37	27	9.57	9	15	2.13	5
1870	2.23	0	6	1.12	4	5.53	1.5	12	1.82	20
1871	1.10	0	9	.38	27	7.50	0	12	4.43	13
1872	3.55	0	13	.92	24	6.01	0	13	1.25	3
1873	4.74	0	9	1.36	19	6.56	0	10	2.70	21
1874	4.37	0	10	2.90	20	1.14	0	7	.50	2
1875	5.10	0	10	1.95	17	4.75	0	15	1.31	31
1876	4.28	0	12	2.00	21	3.91	4	12	1.65	24
1877	1.11	0	5	.50	18	4.78	7	14	1.80	5
1878	2.00	0	9	.55	12	4.73	0	15	2.20	24
1879	4.93	0	10	2.25	8	3.49	0	10	2.30	29
1880	3.84	0	10	2.63	16	4.15	0	11	2.45	23
1881	2.35	0	9	1.00	11	3.57	0	14	1.98	18
1882	6.44	0	12	3.65	24	1.09	0	7	.53	18
1883	2.23	0	11	1.08	26	4.97	0	9	1.65	26
1884	2.19	0	13	.60	20	2.70	0	13	1.55	23
1885	2.52	0	5	1.56	23	5.12	0	12	1.56	3
1886	4.11	0	9	1.54	28	1.42	0	9	1.08	31
1887	.95	0	11	.54	25	3.00	0.25	9	1.15	21
1888	6.97	0	13	1.83	26	7.51	5	18	3.18	8
1889	2.21	0	5	1.28	19	4.04	0	11	1.89	30
1890	4.67	0	11	2.40	18	3.36	0	11	1.45	18
1891	3.68	0	8	2.37	7	2.85	0	11	1.70	8
1892	3.91	0	5	3.00	14	1.79	0	10	.65	27
1893	5.02	0	10	3.00	16	4.32	......	......	......	......
1894	3.40	0	5	1.70	20	1.53	......	10	1.62	14
1895	1.05	0	3	.52	12	1.51	0.12	5	1.50	14
1896	8.00	0	9	4.34	6	3.75	0	15	.77	15
1897	2.65	0	7	.92	9	1.01	0	3	.88	12
1898	2.29	0	5	.94	5	6.19	0	7	1.71	5
1899	3.20	0	5	1.08	20	2.92	0	7	1.10	9
1900	2.94	0	7	1.22	21	5.70	T.	8	2.05	10
1901	4.22	0	8	1.39	11	4.12	T.	8	2.70	14
1902	1.94	0	8	.71	13	5.04	0	13	1.17	6
1903	1.21	0	4	.55	27	3.44	1.0	8	1.17	17
1904	6.47	0	13	2.37	14	3.10	T.	10	1.06	21

TABLE 8.—*Concluded.*

Year.	November.					December.				
	Total inches.	Total snowfall, in inches.	Days with .01 inch or more.	Maximum in 24 hours.	Date of maximum.	Total inches.	Total snowfall, in inches.	Days with .01 inch or more.	Maximum in 24 hours.	Date of maximum.
1869	3.36	.75	6	1.55	7	...	......	....	....	......
1870	5.61	5.50	15	1.38	4	3.04	18.25	18	.70	13
1871	3.58	15.0	13	2.10	8	4.16	27.50	16	1.20	23
1872	7.06	10.0	14	2.40	6	3.62	31.50	18	.50	22
1873	5.05	24.0	10	1.44	8	1.74	14.0	12	.46	13
1874	3.06	10.0	9	.95	23	1.98	13.0	9	.60	14
1875	3.87	14.2	10	1.45	11	1.51	18.0	13	.48	17
1876	4.35	0.5	10	2.50	8	4.67	43.0	12	1 40	18
1877	7.95	3.0	12	2.60	27	2.15	6.0	7	1.40	6
1878	4.91	8.5	15	1.75	23	7.92	14.0	12	3.55	10
1879	2.98	10.0	12	1.62	29	3.60	19.5	17	1.10	7
1880	3.52	7.0	13	1.58	7	1.90	12.5	14	.65	16
1881	2.81	5.0	11	1.40	4	6.83	8.0	15	1.98	23
1882	1.78	5	6	.70	13	2.85	21.0	14	.62	6
1883	3.75	3	11	1.22	27	2.99	12.0	16	1.22	28
1884	3.90	7	13	1.28	6	4.74	16.0	11	2.20	22
1885	5.37	0.5	14	2.68	9	5.64	28.0	15	2.24	20
1886	3.67	6	16	4.58	7	6.85	38.5	12	1.74	24
1887	3.48	1	13	1.80	16	4.72	6.5	14	2.12	12
1888	5.73	10	12	1.84	10	4.96	19.6	11	.40	18
1889	4.50	6	11	1.41	3	3.40	6.5	11	.78	19
1890	2.67	4.5	8	1.05	18	4.10	28.5	15	10	27
1891	2.88	2	8	1.36	27	4.76	10.5	9	.78	30
1892	4.47	4	13	1.22	19	2.26	6.5	7	.96	3
1893	1.43	......	4	.53	22	4.21	.....	10	.80	5
1894	1.24	0.5	4	.37	10	1.75	......	4	.90	27
1895	3.61	......	....	1.25	8	....	......		...	......
1896	4.28	5.5	11	1.41	5	1.30	......	6	.58	8
1897	5.04	6	8	1.10	3	3.58	12.8	10	.22	5
1898	6.84	6	8	2.50	10	1.07	7.0	4	.37	5
1899	2.01	7.5	6	.86	15	3.09	6.5	9	.75	4
1900	4.59	7.8	1	1.89	26	2.02	11.8	6	.80	5
1901	2.54	19.8	9	1.50	12	7.94	21.5	12	1.89	15
1902	1.76	3	7	.81	12	4.74	24.3	11	1.13	16
1903	2.79	15.5	9	....	7	3.14	9.3	9	.96	13
1904	1.62	5.8	7	.83	14	2.00	19.2	7	10	28

TABLE 8a.—*Average Precipitation, 1869-1904.*

January	4.10	**July**	3.22
February	3.78	**August**	3.50
March	4.27	**September**	3.51
April	2.79	**October**	4.11
May	3.41	**November**	3.99
June	3.43	**December**	3.68

Average annual precipitation, 43.79.

TABLE 9.—*Days with 2.5 inches of precipitation.*

Year.	Day	Amount.	Year.	Day.	Amount.	Year.	Day.	Amount.
		Inches.			Inches.			Inches.
1871....	Oct. 12	4.43	1880...	Sept. 16	2.68	1887...	Apr. 30	3.96
1873....	Oct. 21	2.70	1881...	May 17	2.75	1887...	July 25	4.38
1874....	Feb. 4	2.85	1881...	Aug. 8	2.96	1888...	Oct. 8	3.18
1874....	May 31	2.60	1882...	Mar. 2	2.85	1889...	Mar. 9	2.90
1874....	Aug. 9	4.20	1882...	May 29	2.65	1892...	Aug. 12	2.80
1874....	Sept. 20	2.90	1882...	Sept. 24	3.63	1892...	Sept. 14	3.00
1876....	Feb. 15	4.45	1883...	May 24	2.98	1893...	Sept. 16	3.00
1876....	Mar. 21	3.25	1883...	July 14	2.96	*		
1876....	July 24	2.50	1885...	June 30	2.60	1896...	Mar. 4	4.60
1876....	Nov. 8	2.50	1885...	Aug. 6	2.85	1896...	Sept. 6	4.34
1877....	Mar. 29	2.50	1885...	Nov. 9	2.68	1898...	Feb. 22	2.91
1877....	Nov. 27	2.60	1886...	Jan. 31	3.40	1898...	Nov. 10	2.56
1878....	June 24	2.50	1886...	Feb. 28	2.60	1901...	Oct. 14	2.70
1878....	Dec. 10	3.53	1886...	Nov. 7	4.58			
1879...	Aug. 19	4.80	1887...	Mar. 29	2.90			

* Complete precipitation records were not kept during this period.

TABLE 10.—*Opening, closing of navigation, Penobscot River, Bangor, Me.*

Year.	Open.	Closed.	Year.	Open.	Closed.	Year.	Open.	Closed.
1816....	....	Nov. 28	1847...	April 23	Dec. 21	1878...	April 2	Dec. 19
1817....	....	Nov. 23	1848...	April 12	Dec. 21	1879...	April 24	Dec. 19
1818....	May 1	Dec. 10	1849...	April 1	Dec. 7	1880...	April 6	Nov. 26
1819....	April 19	Dec. 5	1850...	April 12	Dec. 8	1881...	Mar. 20	Dec. 11
1820....	April 18	Nov. 28	1851...	April 8	Dec. 30	1882...	April 10	Dec. 9
1821....	April 15	Dec. 1	1852...	April 21	Dec. 15	1883...	April 12	Dec. 16
1822....	April 10	Dec. 5	1853...	April 5	Dec. 8	1884...	April 6	Dec. 19
1823....	April 19	Dec. 9	1854...	April 27	Dec. 5	1885...	April 18	Dec. 17
1824...	April 1	Dec. 12	1855...	April 15	Dec. 1	1886...	April 16	Dec. 5
1825....	April 11	Dec. 14	1856...	April 16	Dec. 1	1887...	April 23	Dec. 22
1826....	April 5	Dec. 16	1857...	April 6	Dec 10	1888. .	April 15	Dec. 13
1827....	April 2	Dec. 6	1858...	April 11	Dec. 12	1889...	Mar. 31	Dec. 14
1828....	April 1	Dec. 18	1859...	Mar. 30	Dec. 9	1890...	April 6	Dec. 6
1829....	April 14	Dec. 16	1860...	April 16	Dec. 7	1891...	Mar. 26	Dec. 16
1830....	April 9	Dec. 8	1861...	April 11	Dec. 20	1892...	April 2	Dec. 19
1831....	April 9	Dec. 3	1862...	April 18	Dec. 3	1893...	April 14	Dec. 13
1832....	April 19	Dec. 4	1863...	April 19	Dec. 2	1894...	Mar. 22	Dec. 23
1833....	April 9	Dec. 1	1864...	April 8	Dec. 12	1895...	April 5	Dec. 11
8834....	April 8	Dec. 9	1865...	Mar. 31	Dec. 8	1896...	April 12	Dec. 16
1835....	April 17	Nov. 27	1866...	April 1	Dec. 13	1897...	April 7	Dec. 22
1836....	April 12	Nov. 27	1867...	April 18	Dec. 4	1898...	Mar. 26	Dec. 14
1837....	April 15	Nov. 27	1868...	April 18	Dec. 10	1899...	April 10	Dec. 27
1838....	April 21	Dec. 24	1869...	April 11	Dec. 9	1900...	April 3	Dec. 12
1839....	April 17	Dec. 1	1870...	April 8	Dec. 21	1901...	April 2	Dec. 20
1840....	April 1	Dec. 1	1871...	Mar. 13	Nov. 17	1902...	Mar. 21	Dec. 8
1841....	April 17	Dec. 19	1872...	April 19	Dec. 10	1903...	Mar. 12	Dec. 13
1842....	Mar. 21	Nov. 19	1873...	April 19	Dec. 2	1904...	April 3	Dec. 6
1843....	April 21	Nov. 30	1874...	April 16	Dec. 11	1905...	Mar. 31	Dec. 12
1844...	April 12	Nov. 27	1875...	April 16	Nov. 29	1906...	April .6	Dec. 6
1845....	April 21	Dec. 7	1876...	April 12	Dec. 10	1907...	April 11	.....
1846....	Mar. 29	Dec. 15	1877...	Mar. 29	Dec. 30			

TABLE 11.—*Dates of some severe frosts at Orono, Me.*

Year.	Date.	Year.	Date.	Year.	Date.
1869	Oct. 6	1881	June 6, 7	1892	Sept. 8
1870	Sept. 12	1881	Sept. 21	1893	Sept. 11
1871	Sept. 11	1882	Sept. 13	1894	Sept. 8
1872	Oct. 5	1883	Aug. 29	1895	....
1873	Aug. 28	1884	Sept. 13	1896	Sept. 5
1874	Oct. 4	1885	Sept. 12	1897	Sept. 27
1875	Sept. 11	1886	Sept. 14	1898	....
1876	June 8	1887	Sept. 11	1899	....
1876	Aug. 22	1888	Sept. 6	1900	....
1877	Sept. 7	1889	Oct. 8	1901	....
1878	Sept. 23	1890	July 19	1902	....
1879	June 9	1890	Sept. 22	1903	Sept. 30
1879	Sept. 26	1891	Oct. 9	1904	Sept. 22
1880	Sept. 24				

TABLE 12.—*Thunderstorms at Orono, Me.*

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1869							2					
1870				2		2	1	2				
1871				1	1	2	3		1			
1872						2	2	2	3			
1873				1		1						
1874			1		1	2	2					
1875					2	1	2		1			
1876					1		1	1				
1877					1		2	4	1			
1878					3	2	5	1	1			
1879					4	2	3	1				
1880					4		5	1	1			
1881					1	2	3	4	1			
1882					2	3	6	2	2		1	
1883					1	2	2	2		1		
1884					2	3	3	1	1	1		
1885				2	2	2	3	1		3		
1886					2	3	3	1	2		2	
1887					1	2	5	3	2			
1888					1	3	2	3				
1889					1	4	4	3		1		
1890						2	2	2	1	1		
1891					2	3	1	4	2			
1892						2		5				
1893						2			1			
1894								1				
1895												
1896									1			
1897									1			
1898												1
1899							9					
1900				1	1							
1901	1		1				2	1				
1902				3	2		2	3				
1903									2	2		
1904				1	3	3	2		5			

TABLE 13.—*Solar halos at Orono, Me.*

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1869												
1870												
1871												
1872												
1873												
1874				1								
1875												
1876				1		1			1			
1877				1								
1878							1					
1879						1						
1880				1	1							
1881												
1882												
1883												
1884			1		1					1		
1885			1									
1886								1				1
1887	1			1								
1888			1		1							
1889		1										
1890		1		3	1			1				
1891		3			2							
1892				2	2							
1893			1	2							2	
1894		1		2								
Sum	1	6	4	14	8	9	1	2	1	1	2	1

TABLE 14.—*Lunar halos at Orono, Me.*

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1869				1								
1870			1									
1871												
1872		1			1							
1873												
1874	1			1								
1875				1					1			
1876			2									
1877	1		1									
1878		2								1		
1879	1								1	1		
1880			2	1				1				
1881	2	2		1						1		
1882		1										
1883						1						
1884	2				1				1	2		
1885			1	2								1
1886		1		1		1					1	1
1887		1	1	1						1	1	2
1888			1	1						1		1
1889	1	3	2		1							3
1890	4	1	2					1		2		
1891		1		1	1	2				1	1	1
1892	2	2	2		1							1
1893	1	7		3					1			
1894			2									
1895												
Sum	15	22	17	14	5	4	0	2	4	10	3	10

TABLE 15.—*Auroras at Orono, Me.*

Years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1869	......	......	4	5	2	......	......	......	3	4	1	......
1870	3	3	4	1	1	1	......	1	2	1	2	2
1871	......	5	3	2	2	2	2	1	5	2	8	2
1872	1	2	2	......	2	......	1	4	......	3	3	2
1873	2	......	1	3	1	3	2	......	1	2	......	......
1874	2	1	......	2	......	......	1	......	2	5	......	1
1875	......	1	......	2	......	......	......	......	1	......	......	......
1876	......	......	......	1	......	......	......	......	1	......	......	......
1877	1	......	......	1	......	......	......	......	......	......	......	......
1878	......	1	......	......	......	......	......	......	1	......	......	2
1879	......	......	......	1	......	......	......	......	1	1	......	......
1880	......	......	3	2	......	......	......	4	......	1	3	......
1881	1	......	......	2	......	......	......	......	1	......	......	1
1882	......	2	2	1	......	......	......	1	......	4	3	3
1883	......	5	3	1	......	......	1	......	1	1	......	......
1884	......	......	3	4	......	......	......	......	......	1	1	......
1885	......	......	......	......	1	......	......	3	1	1	1	3
1886	......	......	2	2	......	1	......	2	3	3	1	......
1887	......	2	......	1	3	......	......	2	1	1	2	......
1888	1	1	1	......	3	1	......	1	13	3	......	1
1889	......	......	......	1	......	1	1	......	......	1	4	2
1890	3	2	......	......	......	......	3	2	3	2	5	......
1891	1	1	3	1	3	1	......	......	4	2	3	1
1892	1	8	6	6	1	......	4	1	3	5	1	3
1893	......	......	......	1	......	......	......	......	2	......	5	......
1894	......	5	2	......	5	2	3	1	......	......	......	......
1895	......	......	......	3	1	......	......	......	......	2	......	......
1896	......	......	......	......	......	......	......	......	......	1	......	......
1897	......	1	5	3	......	......	......	......	......	......	......	......
1898	......	......	1	......	......	......	......	......	......	......	......	......
1899	......	......	......	......	......	......	......	......	......	......	......	......
1900	......	......	......	......	......	......	......	......	......	......	......	......
1901	......	......	......	......	......	......	......	......	......	......	......	......
1902	......	......	......	......	......	......	......	......	......	......	1	......
Sum	16	40	45	46	22	12	18	23	37	48	44	23

In Table 10 are given the dates of the opening and closing of navigation on the Penobscot River at Bangor each year from 1816 to 1905. Table 11 contains the dates of the severe frosts at Orono. Table 12 shows the number of thunderstorms each month from 1869 to 1904. Tables 13 and 14 give the solar and lunar halos, and in Table 15 are shown the number of auroras observed during each month. The following notes regarding various phenomena, while by no means complete, serve to indicate the character of the climate of Orono:

Ice.—The latest date on which ice was formed each year from 1869 to 1875 was, 1869, April 11; 1870, April 8; 1871, March 13; 1872, April 20; 1873, April 20; 1874, April 16; 1875, April 16.

Snow.—Five inches of snow fell on May 3, 1885.

Gales.—Gales or high winds are recorded on the following dates: 1875, October 31; 1880, February 1, March 30, April 29; 1883, November 12; 1884, November 23; 1886, November 6, 18.

Destructive winds are recorded on the following dates: 1870, July 14; 1873, July 26; 1882, August 15; 1890, July 8; 1892, June 14.

Parhelia are noted as follows: 1887, January 31; 1889, February 22; 1890, January 18, February 10, March 25, 31, April 29; 1891, February 2, 3, 5, 27, May 21, 22; 1892, February 7.

Meteors were seen: 1875, March 24; 1887, September 15; 1888, January 4, December 28; 1889, November 17; 1890, August 11, 12; 1891, January 8.

The zodiacal light was observed in the evening on the following dates: 1877, March 21; 1878, January 29, 30; 1879, January 10, 14, 23; 1880, January 11; 1882, March 7, 8; 1883, January 29, February 7, 8, 26, March 8; 1886, February 22, 23; 1887, February 14, 21; 1888, February 2, 3, 29, December 23; 1889, December 16; 1890, January 17, 18, 21, 29, February 9, 10, 11, 13, 15, 16, March 9; 1891, January 8, 10, February 2, 10, 27, March 6, 7. Observations were made practically every evening but of course certain of the phenomena may have been missed.

Earthquakes occurred: 1870, October 20; 1871, October 19; 1872, January 9; 1881, June 21.

Precipitation.—During the period in question the total annual rainfall averaged 36.00 inches and the snowfall 94.43 inches, making the average annual precipitation 45.44 inches, or 3.79 inches per month.

Cloudiness and wind.—The mean percentage of cloudiness for the twenty-four years was 52. The direction and force of the wind, recorded in accordance with the instructions of the United States Weather Bureau, resulted as follows: Northwest and west, 40 per cent; southwest and south, 28 per cent; northeast and north, 20 per cent; southeast and south, 12 per cent.

Barometric pressure.—The maximum barometric pressure reduced to 32° F. was 30.833 inches; the minimum, 28.423 inches; and the mean, 29.842 inches. The correction for gravity is inappreciable.

Humidity.—The mean pressure of vapor for fifteen years (1869-1884) was 0.257 inch of mercury.

The relative humidity ranged from a maximum of 100 per cent to a minimum of 10 per cent, with a mean for the 24-year period of 77 per cent.

Thunderstorms.—The number of thunderstorms observed during the period was as follows:

Year.	No.	Year.	No.
1870	7	1882	12
1871	5	1883	12
1872	10	1884	10
1873	4	1885	13
1874	4	1886	13
1875	6	1887	11
1876	4	1888	12
1877	7	1889	11
1878	9	1890	10
1879	12	1891	13
1880	9	1892	8
1881	13		

When these numbers are plotted there seem to exist periods of maxima and minima of thunderstorms.

Summary of temperature observations.

Mean of warmest day, August 7, 1876	85.3
Mean of coldest day, January 8, 1878	—17.2
Absolute highest temperature, August 31, 1876,	96.7
Absolute lowest temperature, December 31, 1890	—36.3
Mean of maximum temperatures	51.26
Mean of minimum temperatures	33.68
Mean of the mean maximum and minimum temperatures	42.47
Mean of three daily readings for the same period	42.48

The agreement between the last two numbers in the above list is remarkable. So far as these observations go, the average of the maxima and minima is essentially the same as the average of three daily readings when carried through a sufficiently prolonged period. Taking the records for each separate month of the twenty-four years, it is found that about once a year the mean from the maximum and minimum differs from that of three daily readings by as much as one degree.

A striking result is obtained if we take the mean of the mean daily temperature for each month of the period under consideration, and then in turn take the mean of the months which differ by six. This is shown, as follows:

Mean temperature for twenty-four years.

Month.	Mean.	Month.	Mean.	Mean of both.
	°		°	°
January	16.09	July	67.40	41.75
February	19.21	August	65.54	42.38
March	27.31	September	57.51	42.41
April	40.19	October	45.81	43.00
May	52.51	November	34.12	43.32
June	62.41	December	25.57	41.99
Average	36.29	Average	48.66	42.48

Comparing these results with the mean temperature for the whole period (42.48°), we observe that in no case does the mean of the pairs of months considered differ by as much as one degree therefrom. It is hoped that other observers who have recorded the data for long periods will apply this test.

The mean temperature for each month shows that the maximum occurred in July, 67.40°, and the minimum in January, 16.09°. This latter is contrary to the prevailing opinion regarding Maine temperature, as February is generally regarded as the coldest month. When the monthly means are plotted, the curve has the general characteristics of curves of this class plotted by other observers. See, for example, Loomis's Treatise on Meteorology, p. 31, where is plotted a like curve for New Haven, covering a period of eighty-six years. The similarity of the two curves is striking.

DAILY PRECIPITATION AND THE ACCUMULATION OF PRECIPITATION.

The following tables and curves show the amount of rainfall at Orono, Me., for each day from January 1, 1900, to January 1, 1907, and the total for each year from January 1 to the given time.

The accompanying curves show the mean monthly accumulation of rainfall for the years 1900, 1901, and 1905. The first of these years was characterized by an excess of precipitation, the second by a normal amount, and the third by an unusual scarcity.

The monthly mean accumulation curve was obtained by averaging the results obtained from the Experiment Station extending over a period of 35 years.

TABLE 16—1900.

Days.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	.80		1.54									
2			1.00			1.04		.04				
3				.58	2.25							
4		.50			.70							.13
5		1.43			.17							.80
6		.15	.61							.18		
7							.04					
8	.13					.17	.14				.06	
9		.13			.55						.47	.03
10				.03				.42		2.05	.21	
11									.64	1.49		
12	1.98						.20			.74	.03	
13		1.94		.12				.19				.15
14				.11	.46	1.03	.07	.02			.10	
15		.10			.49					.76		
16	.50		2.20				.16		.49			
17					.50		.54	.48	.04	.23		
18		1.00		.41	.62		.03	.17				
19			.12	.62	.76			.10			.37	
20	1.32				1.52						.04	
21	.30				.10		.01	.06	1.22		.20	
22		.25			.05				.13			
23		.05		.14				.06	.01			
24								.04		.20		.71
25	.90	1.20				.07	1.34				.60	
26	.27										1.89	
27					.07	.71					.62	
28												.20
29	1.44					.76			.41			
30						.05				.05		
31	.50											
Total......	8.14	6.75	5.47	2.01	8 24	3.83	2.53	1.58	2.94	5.70	4.59	2.02
Total from Jan. 1.....	8.14	14.89	20.36	22.37	30.61	34.44	36.97	38.55	41.49	47.19	51.78	53.80

TABLE 17—1901.

Days.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1	.05	......	.05	.05	......	.01	......	......	.01	......	.18	......
2	.03	......	......	......	.11	......	.49	......	......	......	......	......
3	......	......	......	......	......	.23	......	.34	......	.61	......	......
4	......	......	.20	......	......	......	......	.01	......	......	......	1.20
5	......	1.00	.40	.80	.08	......	.05	......	......	......	......	......
6	......	.30	......	......	......	......	.10	......	......	.06	......	......
7	.10	......	......	......	......	......	.04	.84	......	......	......	......
8	......	......	......	1.07	......	.39	.01	.03	......	......	......	......
9	......	......	.15	.25	......	.09	.07	.08	......	......	.02	......
10	......	......	......	......	......	......	......	......	......	......	......	1.06
11	.05	......	.82	......	.16	......	......	......	......	......	......	......
12	1.20	......	.03	.12	.09	.04	......	......	1.30	......	......	......
13	......	......	......	......	.05	......	......	......	.22	......	......	.10
14	......	......	......	......	......	.05	......	......	......	......	1.00	......
15	.02	.65	......	......	......	......	......	......	......	2.70	......	1.07
16	.78	......	......	......	......	......	......	.40	.88	......	......	......
17	......	......	......	......	......	......	......	......	.38	.60	......	.13
18	.15	......	......	......	......	......	.50	......	......	......	......	......
19	......	......	......	......	.02	.50	......	......	.03	.04	.03	......
20	.80	......	......	......	......	......	......	......	.35	......	......	......
21	......	......	1.80	......	......	.43	......	......	......	.07	......	......
22	......	......	......	......	......	......	.04	......	......	.06	......	......
23	......	......	......	1.66	.02	......	......	......	......	......	......	......
24	.50	......	......	.15	.10	.05	.09	......	......	.01	.06	1.39
25	......	......	......	......	......	......	......	2.06	......	......	......	......
26	......	......	......	......	......	......	......	......	......	......	.75	......
27	.45	......	1.21	......	......	......	......	......	......	.01	......	.40
28	......	......	.59	......	1.17	......	.21	......	......	......	......	......
29	......	......	.15	.90	.23	......	......	......	1.05	.06	......	.41
30	......	......	......	.12	.02	......	1.15	......	......	......	......	1.18
31	.02	......	.06	......	.02	......	......	......	......	......	.50	......
Total	**4.33**	**1.95**	**5.46**	**5.12**	**2.07**	**1.79**	**2.75**	**3.76**	**4.22**	**4.22**	**2.54**	**6.94**
Total from Jan. 1	**4.33**	**6.28**	**11.74**	**16.86**	**18.93**	**20.72**	**23.47**	**27.23**	**31.45**	**35.67**	**38.21**	**45.15**

TABLE 18—1902.

Days.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1			.78	.02	.26	.34	.30		.05	.05		
2			.50	.06			.20	.01				
3	.20	.50				.30						.20
4						.13			.15			
5	.02											
6								.33		1.17		.60
7			.70		.20		.05	.18	.12	.14		.20
8	.10					1 30	.40	.32			.08	
9		.50			.09							
10			.40	.84		.16	.34		.60			15
11				.39				2.45				.05
12	.70			.26		44					.81	
13		.20		.20		.26			.71	.05		
14											.12	
15	.15						.31	.23				
16						.47	.04					1.13
17	.03		1.56			.02	.17					
18		.60										.05
19	.05		1.60						.06	.35	.15	
20			1.03	.12						.30		
21			.72	.19								.03
22	1.73		.15	.10		1.48		.18			.03	1.09
23				.08	.08			1.09	.05			
24			.04		.45	.03						
25								.12		.06		
26	.05			.47	.74	1.05		.05			.30	
27	.62			.02	.05					.21		.90
28			.04		.50				.20	2.67	.27	
29			.81		.06							.17
30			.56	.17	.31	.05						.20
31			.20	.02	.03					.04		
Total....	3.65	1.80	8.89	2.94	2.77	6.03	1.81	4.96	1.94	5.04	1.76	4.77
Total from January 1.	3.65	5.45	14.34	17.28	20.05	26.08	27.89	32.85	34.79	39.83	41.59	46.36

TABLE 19—1903.

Days.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1												
2							.36			.05		
3	.54	.40										
4	.05	.41		.50							.30	.20
5		.60	.32		.46				.34	.63		
6	.40						.16					
7				.43			.73	.03			1.20	
8	.60		1.26	.62			.03					
9		.60				.34	.44	.26				
10							.11	.32				.62
11	.40		2.11			.51	.12					
12		.74								.90	.15	
13						.77						.96
14						.35						
15							.08			.04		
16		.08		.10			.05					
17	.07	.60	.16					.40	.30	1.17	.61	
18						.01			.02			
19					.25		.42					
20								1.03				
21	.87		.71		.02		.57					.66
22											.12	
23			.98				.08			.37		
24			.04								.18	.18
25				.06		.11	2.25	.03		.18		
26												
27			.10						.55	.10		.03
28	.07	.46									.03	
29							.52				.20	.50
30	.62					.03	.57					
31			.54					.15				
Total	3.62	3.89	6.22	1.71	.73	2.12	6.49	2.22	1.21	3.44	2.79	3.15
Total from January 1.	3.62	7.51	13.73	15.44	16.17	18.29	24.78	27.00	28.21	31.65	34.44	37.59

TABLE 20—1904.

Days.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1		.45	.10	.25			.02	.04		.02		
2							.18	.26	.17			
3	.50	.30	.48			.02	.50		.13		.05	
4									.60			
5						.58	.75		.06			.07
6						.43		.18				
7				.20		.02				.17	.02	.03
8		.20	.74			.01		.03	.03	.03		
9	1.00											
10				.64			.13					
11		.05					.11	1.66		.22		
12				.17	2.37							
13	.19						.31		2.37	.94		
14								.07		.10	.83	
15		.20	.20					.03				
16	.40			.25	.69						.03	
17								.65				
18			.30						.09	.02		.20
19		.20			.10							.10
20	.05		.12	.15	1.01				.31			
21					.01			1.47		1.06	.31	
22		.62			.03	.26		.07				
23	.49	.05	.69									.40
24	.10				.03		.07		.91	.06	.17	
25		.20	.05	.32		.46	.02					
26					.01	.13				.48		
27	.90				.01							
28		.30										1.10
29			.50				.34		1.24		.21	
30				.33		.26			.56			
31												.10
Total	3.63	2.57	3.18	2.31	4.26	2.17	2.43	4.46	6.47	3.10	1.62	2.00
Total from January 1.	3.63	6.20	9.38	11.69	15.95	18.12	20.55	25.01	31.48	34.58	36.20	38.20

TABLE 21—1905.

Days.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1								.44	.03		.84	
2	.08						1.24	.03				
3						.50						.85
4	.80				.47				.64		.71	.41
5									.39			
6		.40		1.36	.02	.57					.75	
7	1.85		.10		.09			.50			.05	.09
8			.05			.02		.12			.22	
9			.07		.61							
10	.05	.30		.02								1.20
11				.01								
12	.35									.23		
13		.50			.03	.69			.98	.01	.06	.30
14												
15				.06			.03					
16				.04	.68			.60	.15		.41	
17	.05	.35			.80						.10	
18					.19				.69			
19	.30		.23		.17		.02		.05	.31		
20					.06			.27	.03	.23		
21				.73								.11
22	.50					.81		.17				.22
23												.04
24									.07			
25		.25					.07					
26	.30	.40	.36		.02		.10					
27			.02			.51					.15	
28						.03			.12			
29											.79	.29
30					33				.04			
31							.73					
Total...	4.28	2.20	.83	2.22	3.47	3.13	2.19	2.13	3.19	.78	4.08	3.51
Total from January 1.	4.28	6.48	7.31	9.53	13.00	16.13	18.32	20.45	23.64	24.42	28.50	32.01

TABLE 22—1906.

Days.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
1					.15	.10					.09	.05
2						.24					.63	
3			.30		.33	.02			.66			.10
4	.47		1.42									
5		.05			.20		.51					
6				.19	.08	.88		.02		.93		.45
7												.07
8									.03		.07	
9		.88				.05	.08		.07			
10			.76		.89	.27			.01	2.02	.08	
11				.90	.01		.50	1.24		19	.19	.60
12	.41						.01	.01			.36	
13					.09						.13	
14								.01	.04		.03	
15		.80	.50		15						.15	.20
16	1.41			.95	14						.48	.15
17			.02		.08		.10					
18	.20								11			
19												
20	.10		.60	.04			.10			.21		.05
21		.09					.24					.59
22			.15	.02		.39					.11	.01
23							.20		.03	.10		.20
24	.50			1.29		.87		.85				
25				.07	.48					.91		
26		.45		.01	.04							.90
27				.03	1.18	.01	.02	.06	.41		.34	
28			.28		.85					.48		
29					.82	.03	.71				.05	
30				.15					.15	.01		
31			.31							.05		
Total	3.09	2.27	4.34	3.65	5.44	2.86	2.47	1.69	1.51	4.90	3.52	3.37
Total from January 1.	3.09	5.36	9.70	13.35	18.79	21.65	24.12	25.81	27.32	32.22	35.74	39.11

THE EVAPORATION OF LIQUIDS.

The principal object of these experiments was to compare the relative rates of evaporation of certain liquids under different conditions of temperature, surface, wind velocity, etc. Two Babington's atmidometers (A and B) were employed.

The scale divisions on each instrument were carefully calibrated, and the following constants determined:

A, 15.4 grams per division; B, 25.3 grams per division.

That is to say, it required these masses to be placed in the upper pan to depress each stem through one scale division. It is obvious therefore that the total evaporation in the pan of A which would cause a rise of one division, would be equivalent to 15.4 grams.

The pans used had slightly different diameters, so that the surface areas exposed were as follows: A, 7.1 sq cm., B, 6.2 sq. cm.

The observations were made by filling the pans with the liquid to be tested, then focusing the cross wire of a telescope on a certain division on the scale, and noting the rise due to evaporation in given intervals. That the evaporation rates were fairly constant is shown by the figures in Table 1 which give an idea of the nature and results of the experiments with ether and alcohol. The time interval was five minutes, and there are recorded the corresponding scale readings, the rise due to evaporation and the equivalent in grams for each liquid. Both these sets of observations were made simultaneously. When the surface of B is reduced to the same dimensions as that of A it is seen that ether evaporates nearly ten times as rapidly as alcohol.

In Table 24 the conclusions of a series of observations similar to those in Table 23 are given. The temperature, pressure, and relative humidity were kept fairly constant. Expressing these results relatively, water being taken as unity, we have the following: Water, 1.0; alcohol, 3.2; carbon bisulphide, 8.8; ether, 28.8; chloroform, 40.0.

In Table 25 a comparison is made of the relation of evaporation to the extent of surface. If we multiply the evaporation of A by the surface of B it should equal the evaporation of B multiplied by the surface of A. Our result gives 0.248 and 0.247, respectively, which shows that within the limits of the accuracy of the experiment evaporation is proportional to the extent of the surface.

TABLE 23.—*Ether and alcohol.*

Periods.	Ether, A.			Alcohol, B.		
	Readings.	Differences.	Grams.	Readings.	Differences.	Grams.
h.m.						
1.51	2.8			6.6		
56	9.2	6.4	0.41	7.5	0.9	0.03
2.01	15.3	6.1	0.39	8.5	1.0	0.03
06	20.9	5.6	0.36	9.4	0.9	0.03
11	26.9	6.0	0.38	10.4	1.0	0.03
16	32.7	5.8	0.37	11.6	1.2	0.04
21	37.8	5.1	0.32	12.5	0.9	0.03
26	42.9	5.1	0.32	13.6	1.1	0.04
31	48.4	5.5	0.36	14.8	1.2	0.04
36	54.8	5.4	0.35	15.7	0.9	0.03
41	60.5	5.7	0.37	16.7	1.0	0.03

Mean, A, 0.36. Mean, B, 0.033. B reduced to surface area of A = 0.038.
Temperature, 23.0° C. Pressure, 758.9 mm. Relative humidity, 42 per cent.

TABLE 24.—*Conclusions from experiments with various liquids.*

Liquids.	Periods.	Evaporation ratios.	Temperature.	Pressure.	Relative humidity.
	Minutes.		°C.	Mm.	%
Water and alcohol	10	0.024 :0.08	24.7	748.5	41
Chloroform and carbon bisulphide	1	0.10 :0.022	23.3	758.8	50

TABLE 25.—*Comparison of surface areas. Chloroform.*

Periods.	Readings.	Differences.	Grams, A.	Readings.	Differences.	Grams, B.
h. m.						
9.58	3.0			1.0		
59	4.5	1.5	0.05	1.5	0.5	0.032
10.00	5.5	1.0	0.03	2.0	0.5	0.032
01	6.8	1.3	0.05	2.4	0.4	0.026
02	7.8	1.0	0.03	3.1	0.7	0.045
03	8.9	1.1	0.04	3.8	0.7	0.045
04	9.9	1.0	0.03	4.4	0.6	0.039
05	11.0	1.1	0.04	4.9	0.5	0.032
06	12.0	1.0	0.03	5.4	0.5	0.032
07	13.3	1.3	0.05	5.8	0.4	0.026
08	14.8	1.5	0.05	6.4	0.6	0.039

Mean, A, 0.040. Mean, B, 0.0348. Ratio of surfaces, 7.1: 6.2.
Temperature, 16.6°, C. Pressure, 763.9. Relative humidity, 45 per cent.

Table 26 indicates that the *relative* evaporation of liquids is approximately constant, and is independent of the velocity of the wind over the exposed surface. In the above work the temperature was different under the two conditions by an average of about 12° C. It was determined that in the case of ether a difference of 1° C. corresponded to a difference of about 0.001 gram per minute.

TABLE 26.—*Rate of evaporation with and without wind.*

Liquids.	Evaporation per minute (no wind).	Velocity of wind, feet per minute.	Corresponding evaporation.
Alcohol	0.007	186	0.03
Chloroform	0.04	200	0.16
Ether	0.072	220	0.28

THE EVAPORATION OF SNOW AND ICE.

The object of the series of experiments on the evaporation of clear ice and snow is to determine to what degree the evaporation is affected by (a) temperature, (b) amount of atmospheric pressure, (c) velocity of wind, and (d) area of exposed surface.

It has been assumed that the laws for the evaporation of solids like ice follow those for liquids. Dalton states that: "Evaporation is that process by which liquids and *solids* assume the gaseous state at their free surfaces. The *rate* of evaporation depends upon temperature of the liquid or *solid,* the extent of the exposed surface, and the facility with which the gaseous particles can escape from the neighborhood of the surface either by diffusion through the air or by the motion of the air itself." This is equivalent to saying that evaporation of liquids and solids depends upon temperature, amount of exposed surface, atmospheric pressure, humidity, and wind.

The evaporation of a liquid may be seen at any time and that of a solid such as ice is often seen in the winter and spring when snow disappears with the temperature continually below 0° C. Also some chemical substances such as camphor and iodine evaporate without first passing into the liquid state.

Two different methods were used in this experiment, which continued throughout the first three weeks of the month of March, 1906, whenever the temperature remained below 0° C. During the first two weeks of the month the conditions were quite favorable. Attempts were made previous to March; but the weather was so mild for a greater part of the winter months —Dec., Jan., and Feb.—that nothing was accomplished from which any conclusions could be drawn.

FIRST METHOD.

A piece of clear ice, in a cubical form, measuring 5 cm. on a side, was weighed in a small wire holder so arranged that the ice was exposed to the air freely on all sides. After each weighing the ice with holder was taken from the balances and suspended in the free atmosphere. The temperature was carefully taken, estimating to tenths of a degree, and the barometric pressure estimating to hundredths of an inch. These readings on weight, temperature, and pressure were taken and recorded every hour during the day from 9 a. m. to 4 p. m. for seven successive days. This experiment was performed in the attic of the Camden High School building.

A maximum and minimum thermometer hung near the piece of ice and from this the temperatures were taken for each night excepting the first—February 28.

The average evaporation per hour was found each night excepting March 2. It was found that this hourly evaporation during the nights was considerably less than during the days.

TABLE 27.—*Data obtained by weighing method.*

Average loss per hr. .15 g. Loss in volume = 10.93 cm.³

Date 1906.	Hour.	Temperature C.	Pressure in in.	Weight of ice.	Loss in weight per hour.	Remarks.
Feb. 28..	9	−8.0	29.5	115.360		
	10	−8.	29.5	115.224	.136	
	11	−8.1	29.5	115.089	.135	
	12	−8.0	29.52	114.954	.135	
	1	−7.8	29.51	114.816	.138	Cloudy.
	2	−7.3	29.5	114.676	.140	Hourly evap. .139 g.
	3	−7.1	29.5	114.533	.143	
	4	−6.9	29.49	114.386	.147	
Mar. 1..	9	−7.3	29.7	112.511	.125	Min. temp. −11° C.
	10	−7.1	29.7	112.362	.149	
	11	−6.9	29.71	112.206	.156	Partly cloudy.
	12	−6.6	29.705	112.048	.158	
	1	−6.	29.71	111.888	.160	Hourly evap. .145.
	2	−5.2	29.7	111.723	.165	
	3	−4.9	29.72	111.559	.164	
	4	−5.1	29.72	111.395	.164	
Mar. 2..	9	−8.1	30.05	109.430	.130	Min. temp. −10° C.
	10	−8.	30.09	109.292	.138	
	11	−7.6	30.1	109.150	.142	Fair.
	12	−7.1	30.	109.003	.147	
	1	−6.5	30.02	108.838	.165	Error due to hasty reading.
	2	−6.2	30.	108.695	.143	
	3	−5.7	29.95	108.535	.158	
	4	−5.5	29.93	108.375	.163	
	5	−6.	29.93	108.203	.169	Hourly evap. .154.
Mar. 3..	8	−5.	29.2		.138	Min. temp. −6.5° C.
	9	−3.7	29.		.170	
	11	−1.	29.		.178	Dim. of ice at time of last reading 4.85 cm. Volume therefore 114.07 cm.³
	12	−0.	No read-	ing taken		

Surface area 150 cm.² Volume 125 cm.³

On March 3rd at 12 o'clock the temperature became 0° C. and as the ice began to melt no further readings were taken.

The dimensions of the cubical piece of ice used decreased in the 74 hours from 5 cm. to 4.85 cm. or the volume from 125 cm.³ to 114.07 cm.³, while the weight decreased from 115.36 g. to 103.807 g. or a loss of 11.353 g. in 74 hours making an average hourly decrease by evaporation of 0.153 g.—approximately.

From these data it may be seen that the amount of evaporation increases as the temperature increases when the pressure remains constant, and as the experiment was performed indoors there was no wind or air currents. The glass sliding door of the balance was kept open while all weighings were being made to avoid the effect of heat on the experiment. During each of these days the pressure was quite constant. Feb. 28th it held about 29.5, March 1st approximately 29.7, while on March 2nd it was 30, and during the time that the temperature was below 0° C. for the 3rd the pressure was 29.9 so we may consider each of these days as having a fairly constant barometric pressure, and consequently determine the effect of temperature change during each day.

During the first day the temperature increased from -8° C. to -6°.9 C. while the amount of evaporation increased from 0.136 g. to 0.147 g. per hour. The second day the temperature increased from -7°.3C to -5°.1C., the evaporation per hour from 0.149 g. to 0.164 g. The third day the temperature increased from -8°.1C. to -6°C., the evaporation from 0.138 g. to 0.169 g. per hour.

It may be seen also that the amount of evaporation increases as the atmospheric pressure increases. This is due, without doubt, to the fact that the humidity of the air is less with a larger pressure than with a low pressure, and it seems that the evaporation is less on cloudy days than on partly cloudy, and less when partly cloudy than when fair. At 2 p. m. the first day is noticed a temperature of -7°.3 C., at the end of the hour, 7°.1 C., while the amount of evaporation for the hour is 0.143 g. On the second day at 9 and 10 a. m. we find the same temperature but an amount of evaporation of 0.149 g. or an increase of 0.006 g. per hour. On the first day from 9 to 10 a. m. we find an evaporation of 0.136 g., while on the third day for the same hour we have 0.138 g. evaporation. As all other conditions apparently remain the same the conclusion is that the evaporation increases with atmospheric pressure, or with a decrease of humidity.

The minimum temperature for each night was recorded by the maximum and minimum thermometer. It was found that the amount of evaporation per hour during the night is considerably less than during the day—the average for the three nights being 0.131 g. per hour while the average for an hour in the day is 0.153 g.

Next a piece of ice in the cubical form, as nearly as could be cut and shaved, with a side of 3.54 cm. or 44.356 cm.^3 in volume was used and the following data obtained, the method of procedure being the same as in the previous case. It will be noticed that the amount of exposed surface in this case is approximately one-half as much as in the previous part of the work.

TABLE 28.—*Data obtained by weighing method.*

Surface area 75.18 cm^3. Volume 44.36 cm^3. Weight 40.81 g.

Date 1906.	Hour.	Temperature C.	Pressure in in.	Weight of ice.	Loss in weight per hour.	Remarks.
Mar. 4...	9	—10.5	30.30	40.810		
	10	—10.1	30.30	40.746	.064	
	11	— 9.6	30.32	40.671	.065	
	12	— 8.5	30.31	40.606	.065	
	1	— 8.	30.30	40.539	.067	Fair.
	2	— 7.3	30.28	40.473	.066	
	3	— 5.1	30.29	40.406	.067	
	4	— 5.2	30.30	40.341	.065	
	5	— 5.4	30.30	40.273	.068	
Mar. 5...	9	— 8.9	30.28	39.313	....	Min. temp.—12.
	10	— 8.2	30.26	39.251	.062	
	11	— 7.3	30.25	39.186	.065	
	12	— 6.1	30.25	39.116	.070	
	1	— 5.	30.25	39.054	.062	
	2	— 4.9	30.26	38.994	.060	Fair.
	3	— 5.2	30.27	38.931	.063	
	4	— 6.	30.27	38.863	.068	
	5	— 7.8	30.27	38.799	064	
Mar. 6...	9	— 6.	30.10	37.823	....	Min. temp.—10.5.
	10	— 5.4	30.11	37.757	.066	
	11	— 4.3	30.08	37.690	.067	Cloudy in A. M. fair in P. M. with heavy wind.
	12	— 3.6	30.08	37.620	.070	
	1	— 3.4	30.07	37.555	.065	
	2	— 2.2	30.09	37.487	.068	
	3	— 2.	30.09	37.418	.069	
	4	— 1.5	30.09	37.346	.072	
	5	— 1.5	30.08	37.241	.075	

Average per hour .0637.

The data were obtained by the same method, same apparatus, and in the same place as the data in Table 23.

The average evaporation was 0.0637 g. per hour. The area of the exposed surface was approximately one-half of that in the first part being 75.18 cm.^3 while in the first it was 125 cm.^3 The amount of evaporation is approximately one-half, thus proving that the amount of evaporation is proportional to the area of the exposed surface.

The second table shows, as the first did, that the amount of evaporation increases as the temperature increases.

SECOND METHOD.

In this method the ice was placed in a wire cage suspended from a coiled spring. By use of an index and scale the rise of the ice due to evaporation could be accurately measured. A box 3 x 1 x ½ was placed outside the laboratory window, and in this box was placed the barometer, thermometer, and wire suspended from the top. The velocity of the wind was estimated according to directions given in Ward's Laboratory Exercises in Meteorology.

By this method it was possible to make all readings through the window and thereby allow no heat to reach the snow or ice from the laboratory. The window was on the north side of the building where the sun did not strike the box during the day. As only the side of the box facing the window was taken out it was not possible for the wind to strike the apparatus with much force; but a free circulation of air was obtained.

TABLE 29.—*Data obtained by wire method.*

Date. 1906.	Hour.	Temperature C.	Pressure.	Height of ice.	Loss in weight per hour.	Remarks.
Mar. 12..	12	—8.	30.00	30.5		Nimbus clouds.
	1	—3.	30.00	30.67	.17 cm.	
	2	—3.	30.00	30.84	.17	Snow P. M.
	3	—4.1	30.00	31.00	.16	Average evap. per hr. .158 cm.
	4	—5.	30.05	31.15	.15	
	5	—6.	30.05	31.29	.14	Wind W. Vel. 1.
Mar. 13..	8	—6.3	30.30	35.44		New piece of ice.
	9	—6.	30.29	35.61	.170	
	10	—5.4	30.30	35.80	.190	No clouds.
	11	—4.8	30.31	36.00	.200	Wind W. Vel 4.
	12	—3.6	30.31	36.227	.227	
	1	—2.4	30.31	36.465	.238	
	2	—1.5	30.32	36.700	.245	Average evap. per hr., .22.
	3	—1.	30.33	36.950	.240	
	4	—0.5	30.30	37.200	.250	
Mar. 14..	9	—3.	29.89	34.786	.142	Same piece of ice.
	10	—2.	29.93	34.618	.168	
	11	—2.	29.93	34.447	.171	No clouds.
	12	—1.5	29.90	34.269	.178	Wind N. W. Vel. 2.
	1	—1.0	29.99	34.089	.180	
	2	—1.5	29.99	33.911	.178	Average evap. per hr., .16.
	3	—3.	29.99	33.839	.172	
	4	—3.2	30.00	33.669	.170	
	5	—4.	30.00	33.508	.166	

From these data it is seen that the amount of evaporation increases as the temperature increases. On March 12th the temperature decreased from -3° C. to -6° C. and the amount of hourly evaporation decreased from 0.17 cm. to 0.14 cm. On the 13th the temperature increased from -6°.3 C. to -0°.5 C. and the evaporation increased from 0.17 cm. to 0.25 cm. On the 14th the temperature at 9 a. m. was -3° C. and increased to -1° C. at 1 p. m. then decreased to -4° at 5 p. m. while the hourly evaporation increased from 0.168 cm. to 0.180 cm. then decreased to 0.166 cm.

The table also shows that the hourly evaporation increases as the velocity of the wind increases. On the 12th with a velocity of one unit and at 1 p. m. with temperature -3° C. and pressure 30 in the hourly evaporation was 0.17 cm.,On the 14th at 3 p. m. with same temperature and approximately same pressure, but velocity of wind two units, the hourly evaporation was 0.172 cm. On the 13th with conditions about the same at 1 p. m., but wind velocity of four units, the hourly evaporation was 0.238 cm. The large evaporation for the 12th was due in part without doubt to the increased pressure, showing that the amount of evaporation depends upon the clear condition of the atmosphere, such as usually accompanies a great pressure.

On the 17th of March an experiment was commenced in the same way with snow in place of ice and was carried on in a similar manner.

TABLE 30.—*Data for evaporation of snow.*

Date 1906.	Hour.	Temperature C.	Pressure.	Height of snow.	Loss in weight per hr.	Remarks.
Mar. 17..	9	−2.	29.82	42.90		Wind W.
	10	−3.	29.83	42.39	.510	Vel. 2.
	11	−2.2	29.84	41.885	.505	
	12	−0.8	29.84	41.363	.522	
	1	−1.	29.85	40.840	.523	No clouds.
	2	−1.3	29.85	40.320	.520	Average loss per hr. .512.
	3	−1.9	29.85	39.810	.510	
	4	−2.6	29.86	39.300	.510	
Mar. 18..	9	−14.	30 05	45.300		New lot of snow.
	10	−12.5	30.05	44.880	.420	
	11	−11.5	30.06	44.444	.436	Wind N. W.
	12	−10.3	30.05	43.999	.445	Vel. 4.
	1	−10.	30.04	43.449	.450	Cloudy.
	2	− 9.1	30.04	42.991	.458	Average loss per hr. .451.
	3	− 8.	30.03	42.531	.460	
	4	− 7.	30.02	42.046	.485	
Mar. 19..	9	−10.	30.01	33.761	.435	Wind N. W.
	10	− 8.	30.02	33.541	.510	Vel. 5.
	11	− 8.6	30.03	32.735	.516	
	12	− 7.5	30.03	32.215	.520	
	1	− 6.9	30.02	32.685	.530	No clouds.
	2	− 6.3	30.03	32.149	.536	Average loss per hour .507.
	3	− 5.8	30.04	31.608	.541	
	4	− 5.	30.06	31.058	.550	

The temperature for the three days during which this part of the experiment was continued remained at all times below 0° C. There was quite a high wind during a greater part of the time and the effect of wind upon the evaporation may easily be seen. The amount of evaporation increased considerably with an increase of wind velocity.

The snow was put into the wire receiver very lightly so as not to diminish the size of the pores or space between the crystals.

The wind caused the index to vibrate up and down so that it was necessary to make the readings by the method of vibrations. This is why the distance is carried out to the third decimal place.

The iron wire made a very delicate means of detecting the loss in weight. The length of the wire was about three feet so that a very small decrease in weight made a large difference in the height of the index.