

Handle with

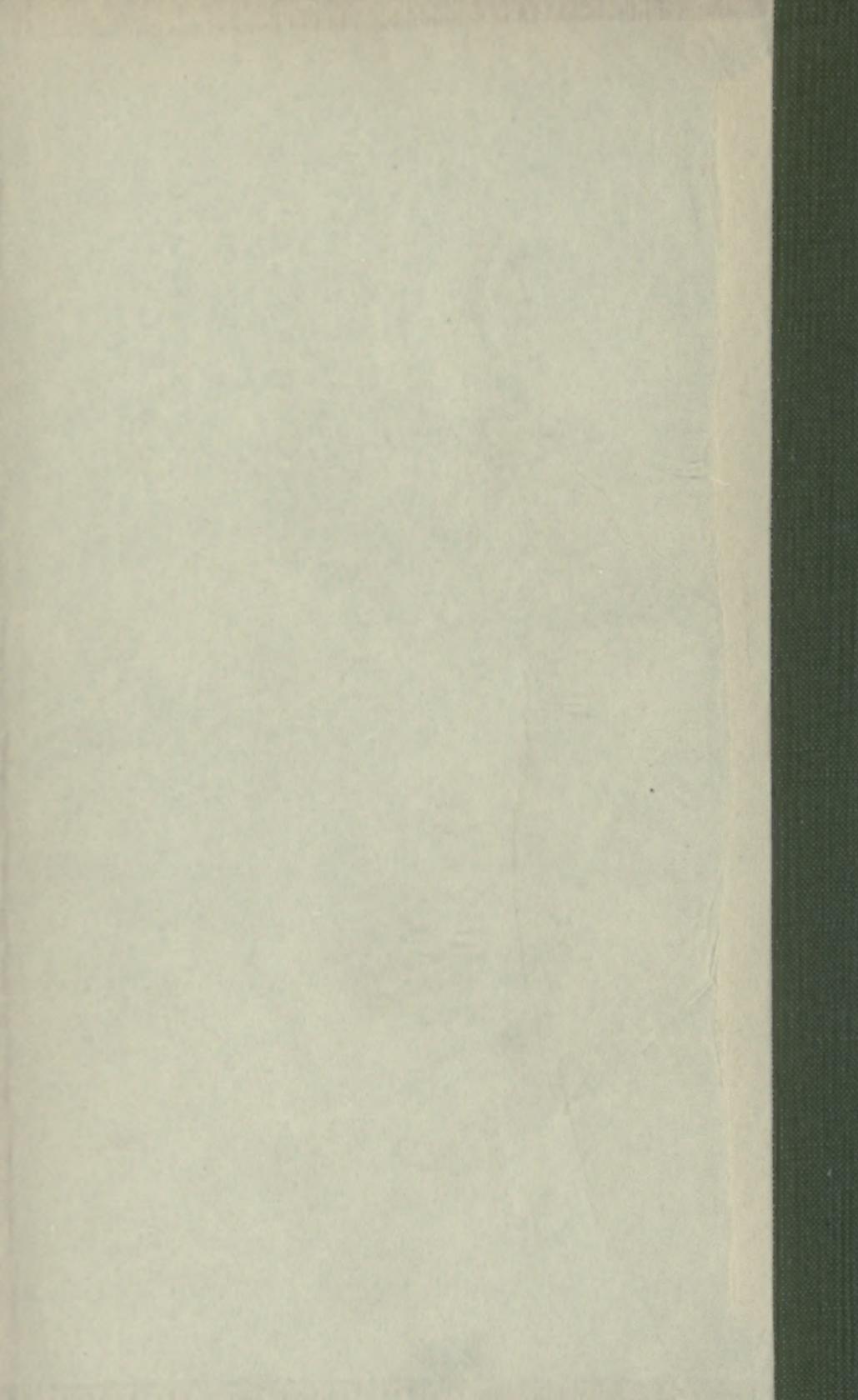
EXTREME CARE

This volume is damaged or brittle
and **CANNOT** be repaired!

- photocopy *only if necessary*
- return to staff
- *do not* put in bookdrop

Gerstein Science Information Centre

UNIV. OF
TORONTO
LIBRARY



72101
A

TRANSACTIONS

OF THE

American Microscopical Society

ORGANIZED 1878

INCORPORATED 1891

EDITED BY THE SECRETARIES

Twenty-Fifth Annual Meeting

HELD IN

PITTSBURG, PENNSYLVANIA, JUNE 27 AND 28, 1902.

VOLUME XXIV

Printed by
THE NEW ERA PRINTING COMPANY,
LANCASTER, Pa.

1903

346920
16.2.38





American Microscopical Society

QH
201
A3
v.24-25
cop.2

101-30
24330

OFFICERS FOR 1902-1903

<i>President:</i> E. A. BIRGE.....	Madison, Wis.
<i>Vice-Presidents:</i> WILLIAM H. SEAMAN.....	Washington, D. C.
A. M. HOLMES.....	Denver, Col.
<i>Secretary:</i> HENRY B. WARD.....	Lincoln, Neb.
<i>Assistant Secretary:</i> R. H. WOLCOTT.....	Lincoln, Neb.
<i>Treasurer:</i> J. C. SMITH.....	New Orleans, La.
<i>Custodian:</i> MAGNUS PFLAUM.....	Pittsburg, Pa.

ELECTIVE MEMBERS OF THE EXECUTIVE COMMITTEE

L. B. ELLIOTT.....	Rochester, N. Y.
M. J. ELROD.....	Missoula, Mont.
F. S. HOLLIS.....	New Haven, Conn.

EX-OFFICIO MEMBERS OF EXECUTIVE COMMITTEE

Past Presidents still retaining membership in the Society

R. H. WARD, M.D., F.R.M.S., of Troy, N. Y., at Indianapolis, Ind., 1878, and at Buffalo, N. Y., 1879.	
H. L. SMITH, LL.D., of Geneva, N. Y., at Detroit, Mich., 1880, and at Cleveland, O., 1885.	
J. D. HYATT, of New York City,	at Columbus, O., 1881.
ALBERT McCALLA, Ph.D., of Fairfield, Ia.,	at Chicago, Ill., 1883.
T. J. BURRILL, Ph.D., of Champaign, Ill.,	at Chautauqua, N. Y., 1886.
GEO. E. FELL, M.D., F.R.M.S., of Buffalo, N. Y.,	at Detroit, Mich., 1890.
FRANK L. JAMES, Ph.D., M.D., of St. Louis, Mo.,	at Washington, D. C., 1891.
MARSHALL D. EWELL, M.D., of Chicago, Ill.,	at Rochester, N. Y., 1892.
SIMON HENRY GAGE, B.S., of Ithaca, N. Y.,	at Ithaca, N. Y., 1895.
A. CLIFFORD MERCER, M.D., F.R.M.S., of Syracuse, N. Y.,	at Pittsburg, Pa., 1896.
W. C. KRAUSS, M.D., of Buffalo, N. Y.,	at Columbus, O., 1899.
A. M. BLEILE, M.D., of Columbus, O.,	at New York City, 1900.
C. H. EIGENMANN, Ph.D., of Bloomington Ind.,	at Denver, Col., 1901.
CHARLES E. BESSEY, LL.D., of Lincoln, Neb.,	at Pittsburg, Pa., 1902.

The Society does not hold itself responsible for the opinions expressed by members in its published Proceedings unless endorsed by a special vote.

TABLE OF CONTENTS

FOR VOLUME XXIV

The Annual Address of the President, Evolution in Microscopic Plants, by Charles E. Bessey	5
Two Growths of <i>Chlamydomonas</i> in Connecticut, by Frederick S. Hollis,	13
A Method of Concentrating Plankton without Net or Filter, by B. L. Seawell	17
Prevention of the Pedetic or Brownian Movement in Milk or other Liquids with Minute Objects in Suspension, by Simon Henry Gage..	21
Stereoscopic Photomicrography with High Powers, by F. E. Ives, with Plate I.....	23
The Structure and Classification of the Phycomycetes, with a Revision of the Families and a Rearrangement of the North American Genera, by Charles E. Bessey, with Plate II.....	27
The Early Morphogenesis and Histogenesis of the Liver in <i>Sus scrofa</i> <i>domesticus</i> , including Notes on the Morphogenesis of the Ventral Pancreas, by D. C. Hilton, with Plates III to VI.....	55
Cultural Studies of a Nematode associated with Plant Decay, by Haven Metcalf, with Plate VII.....	89
Data for the Determination of Human Entozoa, by Henry B. Ward, with Plates VIII-XI.....	103
The North American Species of <i>Limnesia</i> , by Robert H. Wolcott, with Plates XII and XIII.....	139
Necrology, C. M. Vorce, with Plate.....	163
Minutes of the Annual Meeting.....	171
Minutes of the Mid-Winter Meeting.....	176
Treasurer's Report	178
Custodian's Report, Spencer-Tolles Fund.....	179
Constitution	181
By-laws	182
List of Members.....	185
List of Subscribers.....	192
Biennial Index for Volumes XXIII, XXIV.....	193
Advertisements	I

TRANSACTIONS

OF

The American Microscopical Society

TWENTY-FIFTH ANNUAL MEETING, HELD AT PITTSBURG, PENNSYLVANIA, JUNE 27 AND 28, 1902

THE ANNUAL ADDRESS OF THE PRESIDENT

EVOLUTION IN MICROSCOPIC PLANTS¹

By CHARLES EDWIN BESSEY

Although there are many students of the lower forms of plants and although many microscopists give much time to the examination of the simpler algae and fungi, they are too generally studied as *mere forms*, little or no attention being given to their relationship to one another, or to questions as to their origin and development. We have heated discussions as to little details of structure,—as in the case of the markings on the diatom wall,—while we have nothing in regard to the meaning and origin of these markings and other details. Perhaps this is a result of the excessive appreciation of facts which modern laboratory science has given us. We have come to such a pass that often the only things we appreciate in an investigation are the structural facts brought out, while we overlook as unworthy of our serious attention the deeper meaning and significance which are equally obvious. How rarely do we find that a student of the bacteria, the fresh-water algae, the fungi, the lichens, the liverworts, mosses, or ferns, sees in the varied and beautiful forms the thread of evolution which binds them all together. And yet it is true that these lower forms of plants show the method of evolution more clearly than do the higher plants. These simple

¹ Condensed from the notes of an oral address.

organisms are more plastic, they respond more readily to their environment, than do the higher forms, which have become more stabilized. Here I might speak of experimental results, but these must be passed by now for want of time. In this address I can only glance at some of the more marked indications of evolution, as brought out in their natural classification.

Away down at the beginning of the vegetable kingdom are the minute single-celled protophytes or water-slimes (*Chroococcus*, *Gloeocapsa*, etc.) in which each plant consists of a bit of faintly colored protoplasm surrounded by a thin wall. There is no definite nucleus here, and the only indications of nuclear matter are a few granules scattered in the protoplasm. We can scarcely conceive of simpler living things. Near them and a little higher are the blue-green water-slimes (of the families *Oscillatoriaceae*, *Nostocaceae*, *Scytonemaceae* and *Rivulariaceae*) in which the cells cohere in elongated filaments. In the lowest of these the cells are quite undifferentiated, all the cells of a filament being apparently exactly alike, but in the subsequent families some differences appear. Thus in the nostocs there are here and there larger cells (heterocysts) among the otherwise similar cells. In the rivularias the differentiation is carried a step further, the cells gradually diminishing in diameter from one end to the other. In all these plants the individual cells are yet very simple. The walls are a little more defined in the higher forms, and the nuclear matter, while still consisting of separate granules, is a little more condensed.

In the lower green-slimes (*Protococcaceae*) we find at once evidence of marked improvement. The most significant advance is in the development of a distinct nucleus. Instead of a collection of granules lying in the protoplasm we have here a rounded body sharply set off from the surrounding cytoplasm. Here, also, the coloring matter of the cell is no longer diffused throughout its protoplasm, but it is restricted to one or more protoplasmic masses (chromatophores) which lie in the colorless cytoplasm.

But the greatest advance is made in the methods of reproduction. While in the protophytes new plants are formed only by the fission of the cells, in these green-slimes we find for the first time that cells may divide into several motile zoospores. These may swim about for a time, and then come to rest, when they form walls, and are quite like the cells from which they sprang. This motility is clearly

a device for the distribution of the plants, and in fact each zoospore is to be regarded as a young plant which is able to move away from the plants in whose midst it originated, and thereby to live in a less crowded environment. Some of these zoospores, however, do not settle down in the manner described, but two meeting, fuse into one cell, which is consequently larger and stronger, and more capable of enduring adverse conditions than either of the cells which enter into its composition. In this simple fusion of zoospores we have the beginning of that series of mechanisms which gradually increases in complexity up to such wonderful structures as the flowers of the lilies, orchids, roses, and thistles. What a distance from this primitive sexual mechanism to that of the higher plants; and yet between these widely separated extremes there is such an easy gradation that it is not difficult for us to trace the path by which the most complex flower was evolved from this simple beginning.

The brook-silks and water-flannels (*Confervoideae*) show again how from the single-celled condition plants pass easily to the filamentous structure. We have here a repetition of the evolution of the filamentous plant body from the single cell which we have already noticed in the protophytes. Here, however, the filaments are composed of cells which are considerably differentiated. While in the lower brook-silks the cells as a rule are both vegetative and reproductive, in the higher forms there is a pretty sharp distinction between the cells having these two functions, and with this development we observe the setting aside of some cells whose function is neither vegetative nor reproductive, but merely mechanical, as in the "holdfast cells" of many species.

In many *Confervoideae* the sexual mechanism closely resembles that of the green-slimes, consisting of two equal, free-swimming zoospores, which fuse into a single cell which ultimately develops into a new plant. In other species the two fusing zoospores (now called gametes) are differentiated into two sizes, both still ciliated and motile, while in still others the larger gamete is non-ciliated and motionless, and the smaller is ciliated and very active. In fact the activity of the smaller gamete (now called the male gamete) appears to be increased directly as the female gamete becomes less active, and when the latter ceases activity altogether the former becomes extremely active. This change in the activity of the gametes involves the permanent inclusion of the female gamete in the cell in

which it originates, thus affording it some protection before and after its union with the male gamete. Here is the beginning of a series of protective devices which show a gradually increasing complexity, and so admirably illustrate the principle of increasing parental care as a factor in evolution. Compare, for a moment, the zygote of *Protococcus* or *Conserva*, with no parental protection whatever, with that of *Oedogonium*, in which the wall of the parent cell affords some protection, and then contrast these with the amount of protection afforded by the parent flowering plant, in the thistle, for example, where coat upon coat of thick-walled cells surround the zygote and later the embryo plant.

In the brook-silks we have further illustrations of the modification of the plant body through the influence of a particular environment, whereby from these the group of the pond-scums (*Conjugatae*) has arisen. Through living in quiet waters some brook-silks became sluggish in habit. They no longer produce zoospores, since simple fragmentation of the filaments answers every purpose of zoospores, and to this sluggishness we may also ascribe the peculiarities of the conjugative sexual act of the pond-scums. From the filaments of the pond-scums it is a short step to the desmids, most of whose filaments break up still more easily than do those of the pond-scums. This easy fragmentation of the filament results in the unicellular condition of most desmids. By a similar easy fragmentation of the filament the diatoms have been evolved from the pond-scums, and here the deposition of silica in the cell wall makes necessary some peculiar structural changes, of much complexity, but of minor morphological importance. Desmids and diatoms are pond-scums in which the filaments suffer easy solution.

In like manner we may find the origin of the green-felts and their allies (*Siphoneae*) from the water-flannels (*Cladophoraceae*), by a continuation of the modification which has taken place in passing from the brook-silks (*Confervaceae*) to the water-flannels. While in the brook-silks the filaments are composed of cells separated by partitions, in the water-flannels the cell-like segments of the filaments are coenocytes in which there are no partitions between the component cells. In the green-felts this lack of partitions is carried one step further, and as a consequence the filaments are tubular, with partitions at long intervals only. In this way, we may assume, there arose the group of plants constituting the order *Siphoneae*, all of

whose members are characterized by tubular, and little-septated, filaments. Even in those species in which the filaments are compacted into somewhat massive plants, this tubular character prevails.

It is instructive to glance at the chlorophyll-less members of the class of the green-algae (Chlorophyceae) which we have been considering. The more important of these are in the families of the water-moulds (Saprolegniaceae), downy-mildews (Peronosporaceae), and black-moulds (Mucoraceae). The first of these show comparatively little modification in the structure of the plant body from that of a green-felt, like *Vaucheria*. The differences are those which are related directly to the parasitic or saprophytic habits of the water-moulds. Thus, of course, there has been a disappearance of the chlorophyll, and a reduction in the size of the plant body, both of which modifications are such as we should expect under the circumstances. With these we find, also, the production of numberless, minute zoospores, which may be contrasted with the single, large zoospore of *Vaucheria*; yet here again, this is quite what we should look for in plants which through parasitism or saprophytism have become dependent upon a particular host or substratum. The great number of zoospores is directly correlated with the dependent habit of the plants.

The downy-mildews, which are mainly aerial (that is, non-aquatic), and parasitic in the tissues of higher plants, show first of all those modifications which are due to change of habitat. The aquatic adaptations are here replaced by aerial adaptations, as seen in the firmer walls, the substitution, temporarily or permanently, of conidia for zoospores, and the entire suppression of antherozoids. When these structural changes are thus accounted for, there remain few others. In fact the downy-mildews, although parasitic, have retained so many of the characteristics of the green-felts that their relationship is most evident. We may regard the downy-mildews as green-felts which have become parasitic on higher plants, and which for this reason have become modified as here indicated.

The black-moulds (Mucoraceae) have often been regarded as related more closely to the pond-scums (Conjugatae), but I am convinced that they are not so related, but on the contrary that their origin is to be sought in the green-felts, with which they are evidently related in the structure of the plant body at least. As the black-moulds are mostly saprophytic, and aerial, their reproductive

apparatus is correspondingly modified. Thus there is a complete suppression of zoospores, which is effected by the simple device of the walling in of every little cell (zoospore) resulting from the division of the terminal segment (sporangium) of one of the branches. The zoosporangium has easily been modified into a sporangium containing walled spores. The spores are the homologues of the zoospores, and doubtless were derived from them. In the sexual apparatus the greatest modifications have taken place. The gametangia, instead of being quite unlike in size and shape, as they are in the green-felts, water-moulds, and downy-mildews, have suffered such degenerative modification that they are little unlike. This is, perhaps, to be correlated with their saprophytic habit, and there is little doubt that these sexual organs are on the way to extinction. The infrequency of their occurrence in the ordinary species shows that they are obsolescent, to say the least.

In passing, I may say that the group of the brown seaweeds (Phaeophyceae), although related to the green-algae, constitute a side line ending abruptly with the rockweeds and the kelps, and that no higher forms have sprung from them. No higher forms can be traced back to the brown-algae. Their evolutionary line ends with their own higher members.

Coming back to the line of the green-algae, we find at the highest point the interesting plants which constitute the genus *Oedogonium*. Here we have the highest development yet reached, especially in the reproductive apparatus; yet this is easily seen to be based directly upon the structure characteristic of other green algae. From *Protococcus*, with its free-swimming isogametes, to *Conferva*, *Sphaeroplea*, and *Oedogonium* there is an easy gradation by which from the first very simple sexual act there has evolved the much higher act as seen in the last genus. In *Oedogonium* the gametes are quite unequal in size, and the minute antherozoid is highly motile, while the large egg is entirely wanting in motility, and remains within the wall of the egg-cell. After fertilization the egg becomes a thick-walled zygote, protected somewhat by the surrounding wall of the egg-cell. There is to be observed here some care of its offspring by the parent plant, inasmuch as the egg is at no time without protection of the wall of the egg-cell.

This parental care is notably increased in the closely related plants of the genus *Coleochaete*, in which, after a fertilization in all essen-

tials like that in *Oedogonium*, the parent plant covers the egg-cell, and with it the egg, with a layer of protective cells, thus constituting a primitive kind of fruit. Essentially the same structures occur in the red seaweeds, in which the parental care of the results of fertilization is often considerably more marked. Fertilization is no longer confined to the egg alone, but its stimulation extends to cells and tissues which are not at all sexual in nature, but accessory, rather, and belonging not to the new structure but to the structure of the parent plant.

Passing to the liverworts and mosses we note that the protective tissue, which in the cases cited grows around the egg-cell only after fertilization, now is developed by the parent plant long before fertilization. Yet this notable modification was anticipated in the stoneworts (*Characeae*), the highest of the green-algae, where the egg as it develops becomes surrounded by a protective envelope in every essential like that which surrounds the fertilized egg of *Coleochaete*.

From the liverworts to the lower ferns is but a short step, as is shown in the essential identity of the sexual organs. The egg-cell is surrounded before fertilization by a layer of protective tissue exactly as in the liverworts, and so evident is the identity of structure that egg and protective tissue have long been given the same technical name,—the "archegone." In the higher fernworts its sole modification is that it is sunken for nearly its whole length into the tissues of the parent, thus affording still greater protection to the egg before and after fertilization.

Had I the time I might speak of the gradual evolution of the plant body from the liverworts to the ferns, and flowering plants, in which step by step simpler structures are modified into those with greater and greater complexity. I can only say in passing that from one end of the series to the other there is a close continuity, and that the complex structures of the thistle and sunflower are easily derivable from the simple plant body characteristic of the lower liverworts.

The vegetable kingdom is a unit as to origin, and its multitudes of forms are connected by an unbroken series of evolutions of structure into structure. To the discerning mind there are no exceptions, no forms which are not related to others earlier than they. This evolution has not been confined to a single line, but has given rise

to a multitude of branches and branchlets of the genealogical tree which represents the vegetable kingdom. Yet from the lowest there is a continuous series to each ultimate form, whatever its position, just as there is from the lowest to the highest. Evolution has been in many directions, and while the general trend has been upward, it has often been outward, and even downward, resulting in divergence, or even degeneration.

TWO GROWTHS OF CHLAMYDOMONAS IN CONNECTICUT

By FREDERICK S. HOLLIS

Growths of *Chlamydomonas* in water-supplies, although comparatively infrequent, have in several instances been studied and the presence of an unpleasant odor in the water proven to be associated with the growths.¹ The object of the present paper is mainly to record the presence of two recent growths in Connecticut in water of rather different character.

The first growth was observed in Walker's Pond at Burnside on September 11, 1900, when a sample received contained *Chlamydomonas* to the extent of 14,476 individuals or 5,790 standard units per c.c., while all other forms present amounted to only 886 standard units per c.c. On October 4, 1,354 individuals or 542 standard units were still present, while of other forms there were 293 standard units per c.c. The water was very turbid and had the marked, unpleasant odor due to *Chlamydomonas*.

Walker's Pond receives the water of the Hockanum River about two miles above its junction with the Connecticut. Hockanum River has its source in the overflow of Shenipsit Lake, the water-supply of Rockville, a source which at times supports considerable growths, as, for example, one of about 1,000 standard units per c.c. of *Synura* during the present winter. During its course of sixteen or eighteen miles the river receives considerable contamination, both of manufacturing waste and sewage. Filter beds have recently been put in operation for the removal of the South Manchester sewage, but were not in practical operation for any considerable time during the period when samples were taken. Averages of chemical analyses for 1900 and two previous years, together with the individual monthly analyses during 1900, when the growth was observed,² are as follows:

¹ "Chlamydomonas in Spot Pond." F. S. Hollis and H. N. Parker. *Jour. N. E. W. W. Assn.*, Vol. XIV, No. 1. "Chlamydomonas and its Effect on Water Supplies." G. C. Whipple. *Trans. Am. Mic. Soc.*, Vol. XXI.

² Rept. Conn. St. Bd. of Health, 1900, p. 334.

CHEMICAL ANALYSIS, WALKER'S POND, BURNSIDE
PARTS PER MILLION

Date	Turbidity	Sediment	Odor	Residue on Evaporation						Nitrogen						
				Total at 100° C.		Non-vol. Mineral		Volatile Organic		Chlorine	Of Free Am.	Total Organic		Of Nitrates	Of Nitrites	
				Unfilt.	Filt.	Unfilt.	Filt.	Unfilt.	Filt.			Unfilt.	Filt.			
1895.				-4	87.3	98.6	71.0	79.1	16.3	19.5	6.03	.172	.607	.802	.025	.10
1896.				-4	79.3	81.4	60.5	60.3	18.8	21.1	5.61	.194	.589	1.156	.023	.14
1900.				-4	73.7	80.7	56.6	61.1	17.1	19.6	4.65	.183	.628	7.22	.025	.16
May 28, '00.	Slight.	Small (brown).	Mouldy.	-4	65.5	67.5	52.5	52.5	13.0	15.0	2.70	.180	.900	.950	.016	.15
June 12.	Very slight.	Scanty (brown).	None.	-4	66.0	70.0	51.0	54.0	15.0	16.0	3.70	.198	.620	7.40	.016	.20
July 6.	Clear.	Small (brown).	Swampy.	-4	69.0	70.5	53.0	53.5	16.0	17.0	5.30	.180	1.100	1.200	.024	.05
Aug. 15.	Distinct.	Moderate (red).	{ Mouldy and unpleasant.	-5	61.0		45.0		16.5				.320	.380	.036	.24
Sept. 11.	Very marked (green). Marked (organisms).	Small. Moderate, floccu- lent, organisms.	{ Marked unpleasant. Chlamydomonas. Mouldy and oily. Chlamydomonas.	-3	84.5	93.5	63.0	67.5	21.5	26.0	5.30	.052	.220	.360	.016	.12
Oct. 4.				-4	95.5	102.0	75.0	78.0	20.5	24.0	5.80	.192	.610	.700	.040	.19

CHEMICAL ANALYSIS OF WATER FROM CRYSTAL LAKE RESERVOIR, WINSTED
PARTS PER MILLION

Date	Turbidity	Sediment	Odor	Color	Residue on Evaporation				Nitrogen of				Alkalinity				
					Total at 110° C.		Non-vol. Mineral		Volatile Organic		Chlorine	Free Am.		Album. Am.	Nitrates	Oxygen Consumed	Hardness
					Unfilt.	Filt.	Unfilt.	Filt.	Unfilt.	Filt.							
May 29, '02	Distinct green from organ- isms.		Distinctly unpleas- ant. Chlamy- domonas.	Unfilt. .38 Filt. .36	41.0	19.0	22.0	1.36	.004	.186	.09	.67	8.0	7.0			

The second occurrence was in the water-supply of Winsted. It was present in the tap water during the last six months of 1901, reaching a maximum of 232 individuals per c.c. in the middle of November; and the water during this growth had, in addition to the usual mouldy or vegetable odor, an unpleasant odor due to the *Chlamydomonas*, which was most marked when the numbers were greatest, in November. The growth during 1901 did not, I believe, cause complaint on the part of the consumers, but on May 29, 1902, samples were sent from the Crystal Lake Reservoir and from a tap supplied with water from this source, to ascertain the cause of a disagreeable odor that had been marked for three or four weeks. The odor of the water was the sharp, unpleasant, and slightly oily, odor, similar to an odor of putrefaction, which is characteristic of large numbers of *Chlamydomonas*. The microscopical examination showed that the organisms were in a well-advanced stage of growth, but perfectly fresh. *Chlamydomonas* was present to the extent of 970 individual or 242 standard units per c.c., sufficient to give a considerable turbidity and a greenish tinge to the water. Other forms amounted to 492 standard units per c.c.

Crystal Lake Reservoir is a natural lake situated 250 feet above Winsted, the elevation of which was increased 10 feet about 1895, and the new level maintained by conducting the water of two brooks into it through a tunnel, about a half mile long, cut through the rock of the hills. It has an area of 137 acres and available capacity of 390,000,000 gallons.

The *Chlamydomonas* present in Walker's Pond were about $17\frac{1}{2}$ μ long and 14 μ broad, corresponding to .4 of a standard unit. Those in Crystal Lake Reservoir were somewhat smaller, being 14.3 μ long and 11 μ broad, corresponding to .25 of a standard unit. Each growth contained some individuals much smaller than this average, but the great majority were uniform in size. Among those in Walker's Pond were a few of the flask-shaped forms described by Mr. Whipple in the Brooklyn supply. Those of each growth had a cleft or divided chromatophore inclosed in a lorica; but the portions of the chromatophore were smaller and more widely separated in the Winsted growth. The contractile vacuole, oil globules, and starch grains were well marked in those from each locality. The red eye-spots were far more abundant in the Winsted specimens.

The flagella of the forms from Winsted were studied with care, especially with high illumination. While swimming, the form appeared to have one flagellum, or possibly two, projecting forward about twice the length of the body. These were slightly curved toward the extremity and had but little motion. Several were seen in which there appeared to be two of these flagella starting from the lorica but which were brought closely together about a quarter of their length forward and appeared beyond this point as one. On coming to rest, these flagella remained stationary and two other flagella were brought forward, which, during motion, were curved backwards and were in such rapid motion as generally to escape detection. The forms generally rose in the cell during the examination and rested against the under side of the cover-glass. On touching the cover-glass lightly, the forms at rest with the swimming flagella projecting forward along with those not used in swimming, quickly curved the swimming flagella back more closely along the lorica than in the position while swimming. The straighter flagella, not used in swimming, are not drawn back unless the cover-glass is tapped harder and, even then, never as completely as the apparently more flexible swimming flagella.

Associated with each growth were moderate numbers of other infusoria, considerable numbers of diatoms, and some rotifers. In the case of the larger rotifers, it was evident that they had been preying upon the *Chlamydomonas*.

In filtering the foregoing samples use was made of a column of sand of the usual depth which passed through a 60-mesh sieve but was retained by a 120-mesh. The filtrate was found by the use of a centrifuge to contain *Chlamydomonas* in numbers which, by comparison with an unfiltered sample, were estimated to amount to nearly twenty per cent of the total number. The numbers given are corrected on this basis.

A METHOD OF CONCENTRATING PLANKTON WITHOUT NET OR FILTER

BY B. L. SEAWELL

Quantitative plankton studies have always been but approximate at best, because of the many sources of error met with in concentrating the organisms into a small volume of water by means of net or filter. And great difficulties have constantly beset planktologists in their endeavors to determine the quantitative value of these errors.

The Sedgwick-Rafter method seeks to eliminate the errors of the net-filter by filtering measured samples of water (taken by dipping or pumping) through a layer of sand, upon which the organisms are detained, to be afterward removed by washing the sand with a small measured portion of filtered or distilled water. While this method eliminates many sources of error, it does not avoid several others, such as the adhering of organisms to the sides of the funnel containing the sand, the passing of organisms between the sand grains, and the adhering of organisms to the sand grains in the processes of washing and decanting from the sand. Many who have used the net-filter method are well aware of the host of errors and difficulties that arise, such as the loss of the smaller planktons passing through the meshes of the net, the clogging of the net, with its concomitant change of coefficient, and the elaborate and uncertain methods of determining the coefficient of the net.

In the early stages of my study of the plankton of Pertle Springs Lakes, I sought to obviate some of these errors and difficulties by devising a filter for filtering samples taken by dipping or by the plankton pump, without its usual filter. The filter succeeded in removing all planktons from the water, even those as small as bacteria, but there was a slight loss in recovering them from the filter in the small volume of water representing the final concentration; and the time and labor incident to the manipulation of the air-pump attachment to my filter became a serious objection. To eliminate the errors and difficulties of the net-filter method, I devised a plan

which, so far as I have yet detected, is open to but two objections, both of which are of minor importance and can be overcome. This plan is the following: The samples are collected by dipping, or by the use of a plankton pump, without the filter. A measured quantity, say 500 c. c., is placed in a conical flask (Erlenmeyer's) of say 750 c. c. capacity (so as not to make it too deep), 5 c. c. of 40 per cent formaldehyde added, and the two well mixed at once. All plankton will soon die, and all or most of them will gradually settle to the bottom—*none* adhering to the sides. At the end of a sufficient period, say one week, the clear water is carefully siphoned off till about 150 c. c. remain. This partially concentrated sample, after mixing well, is poured into a conical flask of 150 c. c. capacity, and allowed to settle for another week. The siphoning is again done, carefully avoiding the drawing off of any of the plankton, and the well-mixed, concentrated sample transferred to a conical flask of 75 c. c. capacity. This flask has a base so small in diameter that all but about 20 c. c. can be safely siphoned away, and this final residue, containing practically all the plankton of the original sample, may be filed for later study in two 10 c. c. vials. After another week of settling, during which the vials should be slightly jarred a few times, to prevent adherence of organisms to the sides, a small portion of the clear fluid may be poured off, and about half a cubic centimeter of glycerine added, to serve as a preservative, as the formaldehyde may slowly evaporate. An occasional addition of a few drops of formaldehyde might more certainly insure the preservation of the organisms, which are usually by this method in good condition for microscopic examination.

The chief source of error to be overcome in this method arises when there chances to be present some organisms, such as *Aphanizomenon*, whose specific gravity is not greater than that of water, and they thus fail to be drawn to the bottom by gravitation. Such organisms, however, can be secured by filtering the siphonate, and washing the filter with a small quantity of filtered or distilled water. Again, alcohol might be added till the specific gravity of the floating organisms is relatively great enough to cause them to sink. Of course the filtering will lose some organisms, and the alcohol would bleach them, but neither difficulty is very serious. It might be objected that this method will not secure sufficient quantities for accurate volumetric determinations, but this can be overcome by

using larger flasks for the first concentration, and by using slenderer graduated tubes for volumetric measurements. I am at present testing the details of a plan for overcoming this apparent objection.

I think it not essential for future plankton studies that they be made through the painful elaboration of methods of determining the coefficient of a costly filter-net, and the chilly process of filtering vast columns of cubic meters of water when the temperature above the ice ranges from 10° to -10° Fahrenheit.

PREVENTION OF THE PEDETTIC OR BROWNIAN MOVEMENT IN MILK OR OTHER LIQUIDS WITH MINUTE OBJECTS IN SUSPENSION

By SIMON HENRY GAGE

For the purpose of photography or for measurement and counting it is very objectionable to have minute particles in constant motion. For several years efforts have been made to obviate this pedetic or Brownian movement, especially during the photographing of the globules of milk. None of the inhibitors of the movement described in the text-books proved at all satisfactory, but finally complete success was attained by mixing the milk with a dilute solution of gelatin. Various mixtures were tried, and all gave fairly good results, but the following proved entirely satisfactory:

Clear gelatin, like that used in bacteriology or for food..... 10 grams.
Distilled water 90 c.c.
Filter through filter paper.

If the gelatin is acid it may be neutralized with carbonate of soda. Neutralization is usually, however, unnecessary. This ten per cent gelatin solution is then mixed with the milk by placing a drop of the solution on a slide and adding to it a drop of the milk to be examined. With a scalpel the two are thoroughly mixed, and a cover added and pressed down to avoid too thick a stratum. The slide is then placed on a cake of ice or other cold body for fifteen minutes or more to set the mixture. For other liquids with suspended particles the preparation for examination is exactly the same.

When the preparation is examined the pedetic movement will not be found even in the smallest particles. The gelatin solution is so bland that it does not seem to injure the milk globules in the least. The only objectionable feature is a slight tendency to agglutinate the globules; but no such tendency was observed in the experiments made with other liquids containing suspended particles.

STEREOSCOPIC PHOTOMICROGRAPHY WITH HIGH POWERS

By F. E. IVES

WITH ONE PLATE

The expert microscopist is able more or less perfectly to determine the form of objects with a monocular microscope by focusing successively upon different planes and thus deriving from a series of observations a concrete mental image of the object. The capacity for visualizing a concrete image out of a series of such observations, however, varies greatly with different individuals, depending as it does not only upon the amount of practice with the microscope, but also upon an inherent faculty which some people possess more than others. It may be doubted, however, whether even the most gifted in this respect can generate a concrete mental image of microscopic objects with anything like the certainty and effectiveness with which they are presented by the binocular microscope when using low powers. That binocular microscopes are not more used is no doubt due largely to the fact that only some special forms, difficult of perfect construction and correspondingly costly and troublesome, are adapted for critical work with the higher powers. But even if we admit that the trained microscopist can do very well without binocular vision, we must nevertheless recognize the fact that ordinary photomicrographs with high-power objectives are defective in that they represent as spread out upon a single plane details of structure which the use of the fine adjustment of the microscope readily show to belong to different planes. For instance, in a photograph of *Pleurosigma angulatum* showing white dots and "intercostal markings," the appearance in the photograph would lead one to suppose that it was a representation of a single structure in one plane, whereas in reality the white dots belong to one plane and the "intercostal markings" to another. The use of the fine adjustment shows that this appearance is due to focusing a plane between white dot and black dot, and I have long thought that it should be possible

to see this clearly in a binocular microscope adapted to critical work with high powers, and also to show it in a stereoscopic photomicrograph. The latter feat I have recently accomplished, and in the belief that further development and understanding of this method of working may prove of value, I venture to present the results and briefly describe the procedure adopted.

The three examples of stereoscopic photomicrography in high powers which I have to show and the only ones I have so far attempted, were made in a single evening, with the same objective and amplification;—Zeiss 3 mm. apochromatic objective, 18 compensating eye-piece, 13½ in. fixed-focus camera complete in itself, amplification 1,700, Welsbach light, Cramer isochromatic plates without color screen.

The objects are *Pleurosigma angulatum*, *Coscinodiscus asteromphalus*, and a *Triceratium*. Only a small portion of each frustule is shown. *Pleurosigma angulatum* was dry mounted, in cover-glass contact, and different parts appear in different focal planes owing to roundness of field of the objective; thus we have white hexagons on one part and white dots on another, with various effects between, where the stereoscope shows structure on two distinctly separate planes. *Coscinodiscus* shows a membrane with lace-like areolations, supported by a thick grid which is in most parts hexagonal. *Triceratium* shows a bossed membrane which appears to be punctured by groups of round holes in parallel rows, and supported by a hexagonal grid.

The first essential to the production of these results is that none of the diffraction pencils which define such minute detail shall be cut off at the back of the objective. The difference between the two elements of the stereogram must be due entirely to differences in the centering of the illuminating cone, and in order to avoid an exaggerated appearance of relief, the separation of the angles of illumination must not be greater than it would be in low power work with an objective of say .30 or .35 n. a., and the central rays should act in both photographs. The angular aperture of the illuminating cone for *Pleurosigma* and *Coscinodiscus* was only about .70 n. a., and was decentered, first to the right, for one photograph, and then to the left, for the other photograph, but altogether so little that half of the illumination was alike for both photographs. For the *Triceratium* I opened the condenser diaphragm until it only

just touched the edges of the full dry cone, and then decentered to cover about one quarter of the aperture, first on one side, and then on the other.

The fact that the diffraction image and the dioptric image occupy different planes when the microscope tube length is not correctly adjusted, makes it of vital importance for truthful representation to make such adjustments correctly, and no doubt considerable caution should be used in interpreting the results until further experiment has more positively determined the value and limitations of the method.

EXPLANATION OF PLATE

Plate I

APPARATUS FOR STEREOSCOPIC PHOTOMICROGRAPHY

The camera with which the photographs referred to in the text were made. It is a simple box camera having a lens the focus of which corresponds exactly to the length of the box, and is adjustably mounted on a base fitting against the base of the microscope, in such manner that it may be brought into use in a few seconds, without disturbing the microscope, and removed as a rigid whole by a single rectilinear movement of one hand.

The camera swings from centres concentric with the pivot of the microscope, making it quickly adjustable for inclination, and may be used without even refocusing provided that the microscopist's vision is emmetropic.

For stereoscopic work, two plates are exposed in quick succession, condenser diaphragm decentered to the right for one and to the left for the other, and are then developed together.

PLATE I



THE STRUCTURE AND CLASSIFICATION OF THE PHYCOMYCETES

WITH A REVISION OF THE FAMILIES AND A REARRANGEMENT OF
THE NORTH AMERICAN GENERA

By CHARLES E. BESSEY

WITH ONE PLATE

The phycomycetes include nine families of fungi (six, to ten, twelve, or even nineteen according to different authors) which have been brought together very largely on account of their evident relationship to the filamentous alga. These families, as here limited, are the Synchytriaceae, Chytridiaceae, Saprolegniaceae, Cladochytriaceae, Ancylistaceae, Peronosporaceae, Mucoraceae, Entomophthoraceae, and Monoblepharidaceae. They differ very much in the structure of the plant body, and it is difficult to see on what grounds they can be regarded as constituting a single group. Some are rounded cells, which live parasitically in the tissues of higher plants; others are globular coenocytes with parasitic rhizoids; others are branching, non-septate, coenocytic filaments; while still others are septated filaments consisting of ordinary uninucleated cells. Yet in the latest scheme of classification, which is found in the third edition of Engler's "Syllabus der Pflanzenfamilien" (1903) the phycomycetes are treated as a natural class of the true fungi (Eumycetes).

In some recent work on the lower plants it has been necessary for me to examine these and other related forms with some care, and as a result I have been able, as I think, to show that they do not constitute a single group, but that on the contrary they have arisen through the fungal modification of several algal types. Thus I regard the Synchytriaceae as having originated from or near the Protococcaceae in the order Protococcoideae by the adoption of the parasitic habit. In like manner the Chytridiaceae originated from or near the Botrydiaceae in the order Siphoneae, and the Saproleg-

niaceae from or near the Vaucheriaceae in the same order of algae. It seems probable that the Cladochytriaceae, Ancylistaceae, Peronosporaceae, Mucoraceae, and Entomophthoraceae are mere modifications of the Saprolegniaceae, due to increasing hysterozytism. The Monoblepharidaceae, on the other hand, probably came from quite a different algal phylum,—the Confervoideae,—and their morphological characters suggest a close affinity with the Oedogoniaceae.

The mutual relationships of these families, and their relationships to the algae are shown in a general way in the accompanying plate, where the orders are printed in vertical lines, and the families in horizontal, the fungi being distinguished by being underlined.

It will be seen that the phycomyces are distributed among three orders, *viz.*, Protococcoideae, Confervoideae, and Siphoneae, all of the class Chlorophyceae, of the branch Phycophyta. It follows that in any treatment of these fungi their affinities with their algal relatives, rather than their mutual relationships, must dominate their classification. It is no more possible to treat them as a single monophyletic group, without doing violence to Nature, than it is to treat the lichens as a single group, or the parasites among the flowering plants.

The branch Phycophyta includes two classes, Chlorophyceae and Phaeophyceae, the latter constituting a side line which ends abruptly with the higher brown seaweeds,—the Laminariaceae and the Fucaeeae. The class Chlorophyceae, on the contrary, has not only been fertile in variations within the class, but from it have been evolved the higher groups of plants. The order Protococcoideae must be regarded as representing the primitive type of the Phycophyta, and from this came the principal phylum now represented by the order Confervoideae. From the latter it is easy to derive the simpler Carpophyta as represented by the Coleochaeteae, and thence the steps are not difficult to trace to the other classes of the carpophytes (Rhodophyceae, Charophyceae, Ascomyceteae, and Basidiomyceteae), and the lower Bryophyta. The order Confervoideae is thus to be regarded as the principal phylum leading up to the higher groups of the vegetable kingdom. It has given rise, also, to two lateral phyla, represented by the orders Conjugatae and Siphoneae. The origin of the Conjugatae as a result of increasing sluggishness of Ulotrichaceae has been sufficiently discussed elsewhere.¹ By a

¹ "The Structure and Classification of the Conjugatae," in *Transactions of the American Microscopical Society*, Vol. XXIII, pp. 145-147.

decreasing septation of the filament, the Ulotrichaceae gave rise to the Cladophoraceae, and from the latter the passage is not difficult to the simpler Siphoneae, and thence to the more complex marine forms, and along another line which passes through or near the Vaucheriaceae to a group of half a dozen families of fungi. It is possible also that from the vicinity of the Ulotrichaceae a genetic line originated from which the Phaeophyceae were derived.

BRANCH II — PHYCOPHYTA

Phycophytea, Spore Tangles

Single cells, threads, or masses, the latter forming a branching plant with rhizoids; reproducing asexually (propagation) by fission, and sexually (generation) by the union of two protoplasts (gametes) to form a single spore (zygote) which is often a resting-spore. Plants from microscopic to large, sometimes a hundred metres or more in length, mostly aquatic, normally containing chlorophyll in chromatophores, but this often obscured by a yellowish or a brownish coloring matter (phycoxanthin and phycophaein), exceptionally without chlorophyll (as in the hysterochytes).

KEY TO THE CLASSES.

- A. Mostly one-celled or filamentous (rarely stratose or tabular) plants, mostly chlorophyll-green, or yellowish (colorless in hysterochytes), *Chlorophyceae.*
- B. Mostly massive or filamentous (very rarely one-celled) plants, brown or olive-green (no hysterochytes in this class), *Phaeophyceae.*

CLASS CHLOROPHYCEAE

Green Algae

Plant-body from microscopic single cells to large multinucleate, non-septate, branching coenocytes, or threads of cells, simple or branched, or rarely plates or tubes of cells; cells containing chlorophyll (excepting in hysterochytes) and thus bright green but this sometimes obscured by phycoxanthin and then yellowish or brownish; asexual reproduction (propagation) by fission of the whole plant or some of its parts, or by zoospores; sexual reproduction (generation) by the formation of a zygote (usually within the parent plant) as the result of the union of equal, undifferentiated gametes (isogametes), or of unequal male and female gametes

(heterogametes, *i. e.*, androgametes and gynogametes), which are motile zoospores (planogametes) or motionless protoplasts (aplanogametes), as follows: (I) isogamy, (1) both planogametes, (2) both aplanogametes; (II) heterogamy, (3) androgametes and gynogametes motile, (4) androgametes (now called antherozoids) motile, gynogametes (now called oospheres or eggs) motionless. Typically fresh-water plants ("fresh-water algae"), but with many marine species also. Their zoospores and antherozoids usually have two terminal cilia, sometimes four, or a crown, rarely they are ciliated throughout. The hysterothytes are parasitic or saprophytic, and colorless, and show more or less morphological degradation. (Species, 7,000 to 8,000.)

KEY TO THE ORDERS.

- A. Plants all unicellular; generation planogametic, *Protococcoideae*.
 B. Plants filamentous or stratose; generation from planogametic isogamy to gynogametic heterogamy, *Confervoideae*.
 C. Plants filamentous (or unicellular by solution); generation aplanogametic, *Conjugatae*.
 D. Plants tubular or spheroidal coenocytic; generation from planogametic isogamy to gynogametic heterogamy, *Siphonae*.

Order PROTOCOCOIDEAE

Green Slimes

Plants microscopic, unicellular, but sometimes aggregated into definite and regular colonies, green (except in the hysterothytes), with mostly parietal chromatophores, occasionally concealed in old plants by a red pigment; propagation by cell-division and zoospores, and the formation of agamic, thick-walled resting spores (chlamydospores); generation isogametic, or heterogametic, resulting in the formation of a single zygote. In many species the vegetative cells, or even the zoospores (after losing their cilia) divide repeatedly within a gelatinous mass, and then constitute the "Palmella stage," formerly supposed to be distinct genera, *e. g.*, *Palmella*, *Glococystis*, etc. Many cells of Protococcoideae contain one or more contractile vacuoles.

KEY TO THE FAMILIES.

- A. Vegetative cells not ciliated,
 I. Cells single, or in loose irregular colonies, or in gelatinous masses,

- a. Cells containing chlorophyll,
 - 1. Not forming zoospores, *Pleurococcaceae.*
 - 2. Forming zoospores, *Protococcaceae.*
- b. Cells without chlorophyll, *Synchytriaceae.*
- II. Cells aggregated into regular colonies, *Hydrodictyaceae.*
- B. Vegetative cells ciliated, *Volvocaceae.*

But one of the foregoing families, the Synchytriaceae, is composed of fungi, and accordingly the others will not be noticed further at this time.

Family SYNCHYTRIACEAE

Vegetative cells mostly spherical or ellipsoidal, not ciliated, without chlorophyll, growing solitary or merely approximated in the cells of aquatic or terrestrial plants, each eventually becoming a zoosporangium, or dividing into several to many zoosporangia; propagation by zoospores, and the formation of agamic resting spores; generation by the union of two equal, free-swimming, uniciliate gametes (known for but one genus).

KEY TO THE GENERA.

- A. Each vegetative cell becoming a single zoosporangium, or resting spore,
 - I. Zoospores with two cilia, 1. *Olpidiopsis.*
 - II. Zoospores with one cilium,
 - a. Zoosporangia free within the host cell (at least not grown fast to its wall),
 - 1. Resting spore formed by union of two planogametes, 2. *Reessia.*
 - 2. Resting spores agamic, 3. *Olpidium.*
 - b. Zoosporangial wall grown fast to that of the host cell, 4. *Pleolpidium.*
- B. Each vegetative cell dividing into several to many zoosporangia, or one to many resting spores,
 - I. Zoospores with two cilia,
 - a. Zoosporangia completely filling the host cell, 5. *Rozella.*
 - b. Zoosporangia only partly filling the host cell, 6. *Woronina.*
 - II. Zoospores with one cilium,
 - a. Zoosporangia formed directly from the vegetative cell, 7. *Synchytrium.*
 - b. Zoosporangia formed by the protoplasm after it has escaped from the vegetative cell, 8. *Pycnochytrium.*

1. *Olpidiopsis* Cornu. Zoosporangium smooth, globose, ellipsoid, or fusiform, emptying by a tube; zoospores ellipsoid, biciliate; rest-

ing spores globose or ellipsoid, thick-walled, and roughened or spinose.—Minute parasites in the cells of water moulds (Saprolegniaceae) and pond scums (Zygnemataceae). Resting spores 60 to 70 μ in diameter.

2. *Recessia* Fischer. Zoosporangium smooth, thin-walled, almost completely filling the host cell, emptying by a short or long tube; zoospores few, very large, uniciliate, rarely developing directly into new plants, usually acting as gametes and uniting to form a biciliate, free-swimming body, which penetrates a host cell and there forms a thick-walled zygote; the latter eventually dividing internally into smaller zoospores which, escaping by a tube, penetrate other host cells, and later form zoosporangia.—Minute parasites (two species) in the cells of *Lemna* and *Cladophora*. The cells for several days after entering their hosts show amoeboid movements.

3. *Olpidium* A. Braun. Zoosporangium smooth, globose, emptying by a tube; zoospores globose or oblong, with a single cilium; resting spores globose, thick-walled, smooth, arising by the formation of a thick wall about the vegetative cells.—Minute parasites in the cells of marine and fresh-water algae, fungi, flowering plants, pollen, spores, and rotifers. Zoosporangia 15 to 70 μ in diameter; resting spores 16 to 40 μ .

4. *Plecolpidium* Fischer. Vegetative cells at first small with a distinct wall, soon entirely filling, and its own wall growing fast to the wall of the host cell, then producing numerous uniciliate zoospores which escape through a short tube; resting spores occupying only a part of the host cell, thick-walled, finely spinose.—Minute parasites (few species) in various water fungi (Saprolegniaceae and Monoblepharidaceae).

5. *Rozella* Cornu. Vegetative cell occupying the whole width of the host cell from whose protoplasm it is indistinguishable; zoosporangia arising through the successive formation of cross septa, hence arranged in a single row, each emptying by a very short tube; zoospores reniform, laterally biciliate; resting spores formed by the division of the vegetative cell into several cells which then round up and secrete a thick, spinose wall.—Minute parasites (two species) in water moulds (Saprolegniaceae). Zoospores 6 to 8 by 4 μ ; resting spores 20 μ in diameter.

6. *Woronina* Cornu. Vegetative cell through the successive formation of cross septa by the host becoming a row of cells occupying

the whole width of the host filament; each one of these cells may divide into numerous spherical or flattened zoosporangia, which but partly fill the host cell; zoospores biciliate, escaping through a short tube; resting spores arising by the rounding up and division of the protoplasm of a cell and the formation of one or more spherical masses of resting spores, which on germination divide internally to form zoospores.—Minute parasites in water moulds (*Saprolegnia*) and green felt (*Vaucheria*), and rotifers. Zoosporangia 14 to 30 μ ; zoospores 2 to 4 μ by 4 to 5 μ ; resting spores 4 to 5 μ .

7. *Synchytrium* DeBary. Vegetative cell large, spherical, thin-walled, often yellow or orange-red, later dividing internally into many, smooth, closely packed, and angular zoosporangia; zoospores globose, uniciliate, escaping through short-necked openings; resting spores arising by the formation of a thick wall about a vegetative cell, sometimes several, by the division of the cell.—Microscopic parasites (many species) in the epidermal cells of higher plants, often producing colored galls. Zoosporangia 24 to 60 μ ; zoospores 2 to 3 μ ; resting spores 30 to 150 μ .

8. *Pycnochytrium* DeBary. Vegetative cell at maturity provided with a firm wall, its protoplasm escaping through a small opening, and secreting a new wall (within the same host cell), then dividing internally into numerous, spherical or angular zoosporangia; zoospores spherical to elongated, uniciliate, escaping through short, papillary openings; resting spore arising by the formation of a thick, brown wall about a vegetative cell, sometimes several, from the division of the cell.—Microscopic parasites (of several species) in the epidermal cells of higher plants, forming small galls. Zoosporangia 20 to 25 μ ; resting spores 40 to 280 μ in diameter.

Order CONFERVOIDEAE

The Confervas

Plants filamentous or stratosse, sometimes imperfectly septate, the segments being multinucleate, and therefore coenocytes, green, with definite ovoid or lamelliform chromatophores (except in hystero-phytes); propagation by the fracture of the filaments, or the formation of zoospores; generation by the union of two planogametes (isogametes or heterogametes), or of eggs (gynogametes) and antherozoids (androgametes).—Mostly fresh-water algae, floating on

ponds and in running waters. The principal families, but one of which is hysterozytic, are indicated below.

KEY TO THE FAMILIES.

- A. Plants stratosc, cells in one or two layers, *Ulvaceae.*
 B. Plants filamentous,
 I. Generation isogamic,
 a. Plants with true cells (uninucleate),
 1. Elongated filiform, mostly simple, *Confervaceae.*
 2. Minute, short filiform, branched, *Chroolepidiaceae.*
 b. Plants with coenocytic segments (multinucleate),
 1. Rhizoids lateral, small or wanting, *Cladophoraceae.*
 2. Rhizoids terminal, large, *Pithophoraceae.*
 II. Generation heterogamic,
 a. Both gametes biciliated, motile,
 1. Several eggs in each oogonium, *Sphaeropleaceae.*
 2. One egg in each oogonium, *Cylindrocapsaceae.*
 b. Only the antherozoids ciliated,
 1. Plants green (holophytes), *Oedogoniaceae.*
 2. Plants colorless (hysterozytes), *Monoblepharidaceae.*

Family MONOBLEPHARIDACEAE

Plants filamentous, tubular below, septate above, branching, colorless; propagation by unciliated swarmspores (zoospores); generation by the union of unciliated antherozoids with large eggs produced singly in terminal or intercalary oogonia; antherids usually near the oogones, subterminal.—Small saprophytic fungi found in water on decaying plants and animals. But one genus is known.

1. *Monoblepharis* Cornu. Vegetative filaments cylindrical, of uniform diameter, branched; swarmspores with one (posterior) cilium; oogone enlarged, spherical or clavate, terminal or intercalary; antheridia cylindrical, usually just beneath the oogones.—Two species, on dead plants and animals in water.

Order CONJUGATAE

Pond Scums

This order is characterized in the place referred to earlier in this paper. Although some of the phycomycetes (*Mucoraceae* and *Entomophthoraceae*) have been hitherto referred to this order, it is much more likely that they belong to the Siphoneae, and accordingly they are here so disposed.

Order SIPHONEAE

Plants saccate or tubular, often much branched, non-septate or partially septate, multinucleate and therefore coenocytic, the filaments sometimes aggregated into plants of definite form, green (except in hysterophytes) with discoid, parietal chromatophores; propagation by (1) the internal division of the protoplasm of a part (sporangium), or the whole of the plant into spores,—in water into zoospores,—in the air into walled spores; (2) the contraction of definite masses of protoplasm into agamic resting spores (aplano-spores or chlamydospores); generation by the union of (1) ciliated isogametes, (2) ciliated heterogametes, (3) antherozoids with non-ciliated gynogametes, (4) antherid nuclei (non-ciliated) with non-ciliated gynogametes, in all cases producing zygotes.—Fresh-water and marine algae, and many filamentous fungi (hysterophytes), including many families. Only the more important algae (from the standpoint of this paper) will be noticed.

KEY TO THE FAMILIES.

- A. Generation, where known, isogamic.
- I. Plants small to large, branched, septate, very rarely non-septate (holophytes), *Valoniaceae*.
 - II. Plants minute, clavate, pyriform, or spherical, terminating below in a simple or branched rhizoid, non-septate,
 - a. Plants green (holophytes), *Botrydiaceae*.
 - b. Plants colorless (hysterophytes), *Chytridiaceae*.
- B. Generation, where known, typically heterogamic.
- I. Plants consisting of long, branching, non-septate filaments (in some hysterophytes very much reduced),
 - a. Chlorophyll-bearing (holophytes), *Vaucheriaceae*.
 - b. Without chlorophyll (hysterophytes),
 1. Aquatic, parasitic and saprophytic on aquatic plants and animals,
 - a. Plants consisting of well-developed free filaments and endogenous rhizoids, *Saprolegniaceae*.
 - b. Plants consisting of endogenous filaments, no rhizoids,
 1. Filaments branched, *Cladochytriaceae*.
 2. Filaments simple, sometimes reduced to one or two cells, *Ancylistiaceae*.
 2. Not aquatic,
 - a. Parasitic in the tissues of higher plants (rarely aquatic, and parasitic or saprophytic), *Peronosporaceae*.

- b. Saprophytic on various substances or parasitic on other fungi (rarely aquatic), *Mucoraceae*.
 c. Parasitic in the bodies of insects (rarely in plants, still more rarely saprophytic), *Entomophthoraceae*.

Family CHYTRIDIACEAE

Plants minute, saccate, spherical to elongated, parasitic or saprophytic, colorless, with a simple or branching rhizoid below, the latter penetrating the host; propagation (1) by the division of the protoplasm of the plant body into spherical, uniciliate zoospores, which escape through special openings, or (2) by the transformation of the protoplasm into an agamic resting spore, or (3) by the formation of resting spores in the rhizoids; generation unknown (or of doubtful occurrence in *Polyphagus*).

KEY TO THE GENERA.

- A. Zoospores escaping through simple or tubular openings, rhizoids fine, usually branched,
 I. No rhizoidal enlargement below the plant body,
 a. Plant-body epiphytic, 1. *Rhizophidium*.
 b. Plant-body endophytic, 2. *Entophlyctis*.
 II. With rhizoidal enlargements below the plant-body spherical or elongated, endophytic or epiphytic,
 a. Parasitic, epiphytic, 3. *Phlyctochytrium*.
 b. Saprophytic, only the rhizoids imbedded in the nourishing stratum, 4. *Rhizidium*.
 B. Zoospores escaping through an opening provided with a removable cap; rhizoids mostly simple, 5. *Chytridium*.
 Anomalous Genus.—Plant with many rhizoids, the slender ramuli penetrating several hosts, 6. *Polyphagus*.

1. *Rhizophidium* Schenk. Plant epiphytic, mostly spherical (or somewhat elongated), its simple or branching rhizoid penetrating the host; zoospores formed in the unmodified plant body, posteriorly uniciliate, escaping singly by a simple or tubular opening; resting spores thick-walled, formed by the direct transformation of the protoplasm of the plant-body.—Species many, parasitic on fresh-water algae, water moulds, minute aquatic animals, pollen cells, etc. Plants 15 to 50 μ ; zoospores 2 to 3 μ .

2. *Entophlyctis* A. Fischer. Plant endophytic, spherical to pyriform, with the branching rhizoids arising basally, or at several points; zoospores posteriorly uniciliate, escaping through a tube of

varying length; resting spores thick-walled, formed by the direct transformation of the protoplasm of the plant-body.—Species several, in fresh-water algae. Plants 5 to 25 μ ; zoospores 3 to 5 μ .

3. *Phlyctochytrium* Schroeter. Plant epiphytic, spherical, ellipsoidal, or pyriform, the rhizoidal enlargements spherical, single or several, endophytic or epiphytic, with branched rhizoids; zoospores escaping singly through the usually terminal opening; resting spores thick-walled, formed by the direct transformation of the protoplasm of the plant-body.—Species several, on fresh-water algae and minute aquatic animals. Plant-body 10 to 30 μ by 30 to 35 μ ; zoospores 2 to 4 μ .

4. *Rhizidium* A. Braun. Plant saprophytic, spherical or ellipsoidal, with an elongated rhizoidal enlargement bearing branched rhizoids which are imbedded in the nourishing stratum; zoospores posteriorly uniciliate, escaping in a mass of slime; resting spores thick-walled and hairy, formed by the direct transformation of the protoplasm of the plant-body; in germination the protoplasm escapes through a terminal opening in a mass which remains attached to the empty wall and divides internally into zoospores.—The single species is saprophytic in the slime of fresh-water algae. Plant-body 40 to 80 μ by 25 to 40 μ ; zoospores 5 μ ; resting spores 15 to 30 μ .

5. *Chytridium* A. Braun. Plant epiphytic, spherical or ellipsoidal, with a short tubular rhizoid (which rarely may have fine lateral branches) penetrating the host cell; zoospores escaping by the falling away of a circular cap; resting spores formed within the rhizoid, soon becoming as large as the plant-body, thick-walled, in germination producing a tube which enlarges terminally and produces zoospores.—Species several, on green and red algae. Plant-body 15 to 60 μ by 15 to 30 μ ; zoospores 25 to 40 μ .

Here may be placed provisionally the genus *Polyphagus* which is unquestionably related to the foregoing genera, from which in fact it differs only in its peculiar generation, regarding which we may quite properly question whether it is not after all a case of cannibalism, followed by the formation of agamic resting spores in the rhizoids, as in *Chytridium*.

6. *Polyphagus* Nowakowski. Plant free, spherical or ellipsoidal, with numerous rhizoids arising at different points, much branched, the ultimate ramuli much attenuated and penetrating the separate hosts; zoospores ellipsoidal, uniciliate, formed by the escape of the

plant protoplasm into a cylindrical thin-walled sac, and its subsequent internal division; generation (?) by the contact of a rhizoid of one plant with the body of the other, the result being the transfer of the contents of the latter into a swelling in the former, and the formation of a thick-walled, oval or irregular resting spore (zygote?).—Species one, parasitic on *Euglena*, one plant often penetrating several hosts with its slender ramuli. Plant about 37μ ; resting spore 20 to 30μ .

Family SAPROLEGNACEAE

Water Moulds

Plants minute, aquatic, without chlorophyll, parasitic or saprophytic on animals and plants, consisting of mostly branching, non-septate (or sparingly septate) filaments, attached by branching rhizoids which penetrate their hosts; propagation (1) by the formation of numerous, mostly biciliate, zoospores in the ends of branches set off by cross-walls, or by the formation of aplanospores, (2) by the formation of single spherical conidia ("chlamydozoospores"); generation by the formation of one or more eggs in each more or less spherical oogone, which are fertilized by the transfusion of the protoplasm of the clavate antherid (usually originating near by) through slender fertilizing tubes which penetrate the oogone wall. (Occasionally the eggs develop without fertilization.)

There are two sub-families (considered to be families by some authors).

I. Filaments not constricted,

Saprolegniaeae.

II. Filaments constricted,

Leptomitaceae.

Sub-family SAPROLEGNIAEAE

Vegetative filaments of uniform diameter, not constricted; zoosporangia cylindrical to ovoid; oogones with one or more eggs.

KEY TO THE GENERA.

A. Zoospores biciliate,

I. In several rows in the zoosporangia,

a. Escaping from the zoosporangium by a single terminal opening,

1. Dispersing upon escaping from the zoosporangium,

a. Zoosporangia ovoid,

1. *Pythiopsis.*

b. Zoosporangia cylindrical,

2. *Saprolegnia.*

2. Encysting about the mouth of the zoosporangium, 3. *Achlya*.
 b. Escaping singly by individual openings, 4. *Dictyuchus*.
 II. In one row in the zoosporangia, 5. *Aphanomyces*.
 B. Zoospores multiciliate, 6. *Myrioblepharis*.

1. *Pythiopsis* DeBary. Vegetative filaments slender; zoosporangia terminal, ovoid, the later ones forming laterally below (not within) the older ones; zoospores originating in several rows in the zoosporangium, ovoid, terminally biciliate, germinating directly after coming to rest; oogones terminal, each containing one, rarely two or three eggs.—Species one, on dead animal and vegetable matter.

2. *Saprolegnia* Nees. Vegetative filaments stout, unbranched, or paniculately branched; zoosporangia terminal, cylindrical, the later growing through the empty older ones; zoospores originating in several rows in the zoosporangia, ovoid, terminally biciliate, encysting soon after dispersing, later escaping again as reniform, laterally biciliate zoospores which germinate upon coming to rest; oogones mostly terminal, rarely intercalary, each with one or more, commonly many, eggs.—Species many, on dead, rarely on living, animals.

3. *Achlya* Nees. Vegetative filaments stout, mostly branched; zoosporangia terminal, cylindrical or clavate, the later ones forming laterally below (not within) the older ones; zoospores originating in several rows in the zoosporangia, ovoid, terminally biciliate, encysting immediately, without dispersing, at the mouth of the zoosporangium, later escaping as reniform, biciliate zoospores which germinate upon coming to rest; oogones terminal, rarely intercalary, each with one or two, commonly many, eggs.—Species many, on decaying vegetable or animal matter, rarely on living animals.

4. *Dictyuchus* Leitgeb. Vegetative filaments of medium thickness, somewhat branched; zoosporangia terminal, cylindrical or clavate, the later ones forming laterally below the older ones; zoospores originating in several rows in the zoosporangium, and there encysting, becoming polyhedral by mutual pressure, later escaping through lateral openings (one for each zoospore), reniform, laterally biciliate, germinating upon coming to rest; oogones terminal or intercalary, each with one or many eggs.—Species three, on decaying animal or vegetable matter.

5. *Aphanomyces* DeBary. Vegetative filaments very slender, little branched; zoosporangia terminal, narrowly cylindrical; zoospores

formed in a single row in the zoosporangium, fusiform, encysting in a cluster about the mouth of the zoosporangium, later escaping as reniform, laterally biciliate zoospores, and germinating upon coming to rest; oogones terminal or intercalary, each with one egg.—Species few, on decaying animal matter, and living or dead plants.

6. *Myrioblepharis* Thaxter. Vegetative filaments slender, little branched; zoosporangia ovoid to spherical, terminal, the later formed within the older ones, the contents escaping as a single, multiciliate mass, which later divides into usually four oval or oblong multiciliate zoospores; generation unknown.—The place of this singular genus is problematical, and its position here is merely provisional. Its single species occurs on submerged sticks.

Sub-family LEPTOMITACEAE

Vegetative filaments divided by constrictions into segments, often much enlarged below; zoosporangia cylindrical, pyriform, or ellipsoid; resting conidia often present; oogones with but one egg.

KEY TO THE GENERA.

- A. Plant body of segments similar in size and form,
 - I. Zoospores biciliate,
 - a. Zoosporangia cylindrical, 7. *Leptomitus*.
 - b. Zoosporangia spherical or ovoid, 8. *Apodachlya*.
 - II. Zoospores uniciliate, 9. *Gonapodya*.
- B. Plant body composed of an enlarged basal segment, bearing smaller terminal branches,
 - I. Constrictions in all parts of the plant body,
 - a. Zoosporangia of one kind,
 - 1. Basal segment of plant body similar in form to the branches, 10. *Sapromyces*.
 - 2. Basal segment of plant body of much different form from the branches 11. *Rhipidium*.
 - b. Zoosporangia of two kinds, smooth-cylindrical, and ovoid-prickly, 12. *Araiospora*.
 - II. Constrictions only at the base of the zoosporangia and conidia, 13. *Blastocladia*.

7. *Leptomitus* Agardh. Vegetative filaments slender, somewhat stouter below, branched, the segments long-cylindrical; zoosporangia cylindrical, terminal, the later ones formed directly below the earlier; zoospores ovoid, terminally biciliate, dispersing immediately upon escaping; generation unknown.—One species, in water containing organic matter.

8. *Apodachlya* Pringsheim. Vegetative filaments slender, simple or sparingly branched, segments cylindrical; zoosporangia broadly oval or pyriform, terminal, or apparently lateral by the branching of the filament; zoospores encysting at the mouth of the zoosporangium, later escaping as reniform, laterally biciliate zoospores, which germinate upon coming to rest; generation unknown.—Two species, on decaying algae.

9. *Gonapodya* Fischer. Vegetative filaments moniliform, much branched, the segments short-ellipsoidal to cylindrical; zoosporangia long-oval, terminal, the later forming within the older, empty ones; zoospores oval or elliptical, very variable in size, uniciliate, dispersing immediately upon escaping; generation unknown.—Two species, on decaying plants in water.

10. *Sapromyces* Fritsch. Vegetative filaments with a slightly enlarged basal segment, umbellately branched above, the segments similar to but smaller than the basal segment; zoosporangia sub-cylindrical or nearly oval, terminal or lateral; zoospores discharged in a mass, at first surrounded by a thin membrane, soon escaping as reniform laterally biciliate zoospores; oogones terminal, or lateral in whorls, pyriform.—Two species, on decaying vegetable matter.

11. *Rhipidium* Cornu. Vegetative filaments with a very large basal segment, swollen above, often lobed or branched, bearing many slender branches; zoosporangia terminal or lateral on the slender branches, broadly oval; zoospores discharged in a mass, at first surrounded by a thin membrane, soon escaping as reniform, laterally biciliate zoospores; oogones terminal, spherical.—Species few, on decaying vegetable matter.

12. *Araiospora* Thaxter. Vegetative filaments with a much enlarged, cylindrical, basal segment, from whose summit arise smaller, umbellately divided branches of similar segments; zoosporangia terminal or lateral, in whorls of two kinds, (1) smooth, broadly cylindrical, or elliptical, (2) spinose, ovoid or pyriform; zoospores discharged in a mass, at first surrounded by a delicate membrane, soon escaping as reniform, laterally biciliate zoospores; oogones in whorls or umbels, spherical.—Two species, on decaying vegetable matter.

13. *Blastocladia* Reinsch. Vegetative filaments with an enlarged cylindrical basal portion (stem) which is much branched above, the branches rather stout, constrictions only immediately below the zoo-

sporangia; zoosporangia terminal or lateral, cylindrical to broadly oval; zoospores oval or elliptical, terminally biciliate, dispersing upon escaping from the zoosporangium; resting conidia terminal or sub-terminal, bluntly ovoid; generation unknown.—Two species, on decaying vegetable matter.

Family CLADOCHYTRIACEAE

Plant a reduced, slender, parasitic or saprophytic, much-branched, non-septate filament, developing terminal and intercalary enlargements, which become (1) zoosporangia, or (2) resting spores (probably agamic); zoospores spherical or ellipsoid, uniciliate, escaping through a tube or papillary orifice; antherids and oogones appear to be wanting.—Minute parasites in the parenchyma cells of aquatic higher plants, or the slimy secretions of green algae. (In this family, which is doubtless related to the Saprolegniaceae, the structural degeneration, due to their hysterozytic habits, appears to have affected the sexual reproductive organs more than the vegetative filaments. Compare also with Ancylistaceae.)

KEY TO THE GENERA.

A. Only zoospores known,

1. *Cladochytrium*.

B. Only resting spores known,

2. *Physoderma*.

1. *Cladochytrium* Nowakowski. Vegetative filaments widely dispersed in the host, intracellular, giving rise to terminal and intercalary spherical or ellipsoid zoosporangia; resting spores unknown.—Minute parasites (of few species) living in the cells of higher plants. Zoosporangia 18μ to larger; zoospores 2 to 5μ .

2. *Physoderma* Wallroth. Vegetative filaments intracellular, penetrating the walls from cell to cell, giving rise to terminal and intercalary spheroidal or ellipsoid, thick- and brittle-walled, brown resting spores; zoosporangia unknown.—Minute parasites (of few species) living in the cells of higher plants. Resting spores 25μ by 15μ to 30μ .

Family ANCYLISTACEAE

Plant a reduced, parasitic, colorless filament (sometimes a single cell, or even a naked mass of protoplasm), at first non-septate, later dividing into several cells which (1) become zoosporangia and divide into zoospores, which are mostly biciliate, or (2) develop long germinating tubes which penetrate new hosts, or (3) transform

into antherids or oogones; the single egg within the oogone is fertilized by means of a tube, resulting in the production of a thick-walled zygote. (In *Diplophysa* and *Rhizomyxa* the single cell composing the whole plant may form a single zoosporangium, or by division, an antherid and an oogone.)—Minute parasites living in the cells of various aquatic plants, and the root-hairs and epidermal cells of higher plants. (In this family, which is doubtless related to the Saprolegniaceae, the structural degeneration, due to their hysterozytic habits appears to have affected the vegetative filaments more than the sexual reproductive organs. Compare with Cladophytriaceae.)

KEY TO THE GENERA.

A. Zoospores present,

I. Plant body always with a cell wall, zoospores usually biciliate,

a. Producing several zoosporangia, or oogones,

1. Plant a branched filament,

1. *Lagenidium*.

2. Plant an unbranched filament,

2. *Mysocytium*.

b. Plant body producing but one zoosporangium or oogone,

3. *Diplophysa*.

II. Plant body without a cell wall until the formation of reproductive cells; zoospores uniciliate,

4. *Rhizomyxa*.

B. No zoospores known,

5. *Ancylistes*.

1. *Lagenidium* Schenk. Vegetative filament at first unbranched and tubular, later with spherical, clavate, or cylindrical branches, becoming septate, the whole plant eventually consisting of reproductive cells; zoosporangia usually broad-cylindrical, straight or curved, the contents escaping by a tube into a bladderly enlargement outside of the host and there dividing internally into reniform, laterally biciliate zoospores; antherids usually cylindrical, lateral or intercalary, penetrating the oogone wall by a fertilizing tube; oogones intercalary, swollen or spheroidal, containing an undifferentiated protoplasm, which becomes condensed after fertilization into a spherical, smooth-walled zygote.—Minute parasites (of few species) in the cells of fresh-water algae, and pine pollen cells. Filaments 3 to 7.5 μ ; zygotes 11 to 29 μ .

2. *Mysocytium* Schenk. Vegetative filaments unbranched, at first tubular, later constricted into a chain of two to many oval or ellipsoidal cells, the whole plant eventually consisting of reproductive cells; zoosporangia formed from the unmodified cells, their con-

tents escaping by a tube into a bladdery enlargement outside of the host and there dividing into reniform, laterally biciliate zoospores; antherids and oogones similar, the former penetrating the latter by a direct fertilizing tube; oogone containing undifferentiated protoplasm which becomes condensed, after fertilization, into a spherical, smooth-walled zygote.—Minute parasites (of few species) in the cells of fresh-water algae and aquatic worms. Filaments 20μ in diameter; zygotes 15 to 20μ .

3. *Diplophysa* Schroeter. Vegetative plant body consisting of but a single, spherical or ellipsoidal cell which may transform directly into a zoosporangium; zoospores ovate or spheroidal, uniciliate or biciliate, escaping singly by a tube; generation by the division of the vegetative cell into two cells, the smaller of which becomes the antherid, and eventually pierces the other—the oogone—with a fertilizing tube, the result being a thick-walled zygote.—Minute, and very much reduced parasites (of few species) in fresh-water algae and water moulds. Antherids 28 to 30μ ; zygotes 68 to 78μ .

4. *Rhizomyxa* Borzi. Vegetative plant body at first a plasmodium-like mass of protoplasm, later (1) dividing directly into ovate, uniciliate zoospores, or (2) forming thin-walled resting sporangia, which eventually give rise to similar zoospores, these escaping singly through a short tube; generation by the division of the plant body into two-walled cells, the smaller of which becomes the clavate antherid, and pierces the other—the oogone—with a fertilizing tube, the result being a smaller, thick-walled zygote.—Minute, and very much reduced parasites (one species) in the hairs and epidermal cells of roots of many higher plants. Zoospores 5 to 6μ ; oogones 25 to 40μ ; zygotes 15 to 20μ .

5. *Ancylistes* Pfitzer. Vegetative filaments unbranched, or with short protuberances, at first tubular, later dividing into numerous cells; propagation by means of long "infection tubes" sent out by the cells of the filaments, coming in contact with and penetrating other hosts; zoospores wanting; generation by the transformation of certain cells into antherids, and others (in larger filaments) into oogones, the former penetrating the latter by a fertilizing tube, resulting in the contraction of the undifferentiated oogone protoplasm into a spherical or ellipsoid, thick-walled zygote.—Minute parasites (one species) in desmids of the genus *Arthrodia* (*Closterium* of authors). Male filaments 6μ ; female, 10μ ; zygotes 15 to 24μ .

Family PERONOSPORACEAE

Downy Mildews

Plants minute, without chlorophyll, mostly endophytic, and typically parasitic (rarely aquatic, and parasitic or saprophytic on animals or plants), consisting of much-branched, non-septate filaments which penetrate their hosts, and from which they send out (into the air or water) slender, more or less branched conidiophores; rhizoids not present; propagation by the formation of conidia which may give rise to laterally biciliate, usually reniform, zoospores (1) immediately (then known as zoosporangia), or (2) after falling (then known as metasporengia), or they may germinate after falling, by sending out a slender tube which grows directly into a new filament; zoospores after a period of activity, becoming spherical, motionless cells and germinating by sending out a slender tube which forms a new filament; generation by the formation of a single spherical egg in each globular oogone, which is then fertilized by the transfusion of the protoplasm of the clavate antherid (usually originating near by) through the slender fertilizing tube, resulting in the formation of a thick-walled zygote; the latter germinates directly, or by the formation of zoospores.

KEY TO THE GENERA.

- A. Conidia giving rise to zoospores,
- I. Conidia formed in chains, or singly, not terminating the growth of the conidiophore,
 - a. Zoosporangia, as well as metasporengia, formed, the contents being extruded before the formation of zoospores, 1. *Pythium*.
 - b. Only metasporengia present, the contents escaping as zoospores,
 1. Conidia formed in chains, 2. *Albugo*.
 2. Conidia formed singly, becoming lateral by the continued growth of the conidiophore, 3. *Phytophthora*.
 - II. Conidia formed singly, terminating the growth of the conidiophore,
 - a. Conidiophores several times branched,
 1. Persistent; zygote free from the oogone wall. 4. *Plasmopara*.
 2. Fugacious; zygote attached throughout to the oogone wall,
 5. *Sclerospora*.
 - b. Conidiophores simple, terminally swollen, bearing conidia on short sterigmata, 6. *Basidiophora*.
- B. Conidia germinating by a slender tube,
- I. Germinating tube arising from a terminal papilla, 7. *Bremia*.
 - II. Germinating tube lateral, conidia not papillate, 8. *Peronospora*.

1. *Pythium* Pringsheim. Vegetative filaments slender (without haustoria) penetrating the cells of the host, saprophytic or parasitic on animals or plants in water, or parasitic within the tissues of land plants; conidia rounded or elliptical, forming singly or in chains on unmodified portions of the plant, of two kinds (1) zoosporangia, and (2) metasporengia, emitting their protoplasm in a mass through a short tube, and then by division forming many zoospores; oogones terminal or rarely intercalary, the smooth or rough-walled zygote free from the oogone wall, and germinating like the conidia, or by the growth of a tube into a new filament.—Species many.

2. *Albugo* J. F. Gray (*Cystopus* Leveille). Vegetative filaments growing parasitically in the intercellular spaces of their hosts, and sending short, terminally swollen haustoria into the adjacent cells; conidiophores clavate, grouped in large masses beneath the epidermis, which they rupture, bearing terminal chains of conidia, which germinate, after falling, by the internal formation of zoospores which escape through a terminal orifice; oogones mostly terminal, rarely intercalary, the rough-walled zygote free from the oogone wall, germinating by the internal formation of zoospores.—Species many, in dicotyledons.

3. *Phytophthora* DeBary. Vegetative filaments growing parasitically in the cells and intercellular spaces of their hosts, and sending their slender, sparingly branched conidiophores out into the air through the stomata, or directly through the epidermal cells; conidia ovate or ellipsoidal, at first solitary and terminal, becoming lateral by the continued growth of the conidiophore, germinating after falling, by the internal formation of zoospores, which escape through the terminal papillary orifice; oogones mostly terminal, the smooth zygote free from the oogone wall, and germinating by a tube terminated by a conidium.—Species few, in various dicotyledons, and the seedlings of conifers.

4. *Plasmopara* Schroeter. Vegetative filaments growing parasitically in the intercellular spaces of their hosts, bearing small haustoria, and sending into the air through the stomata numerous persistent branched conidiophores, which are monopodial, except for the ultimate branchlets; conidia spherical to ellipsoidal, single, terminating the growth of the branches, germinating by the internal formation of zoospores, or by the extrusion of the protoplasm, which becomes a walled cell, later growing by tubular prolongation into

a new filament; oogones usually terminal, the smooth zygote free from the oogone wall, and germinating by a tube terminated by a conidiophore.—Species many, in dicotyledons.

5. *Sclerospora* Schroeter. Vegetative filaments growing parasitically in the intercellular spaces of their hosts, bearing small haustoria, and sending into the air through the stomata the stout, fugacious conidiophores, which are monopodially branched, except for the ultimate branchlets; conidia ellipsoidal, single on basally-swollen ultimate branchlets, whose growth they terminate, germinating after falling, by the internal formation of zoospores; oogones terminal, entirely filled by the smooth, spherical zygote, whose walls are grown fast to the thick, irregular oogone wall; germination unknown.—Species two, in grasses and joint rushes.

6. *Basidiophora* Roze & Cornu. Vegetative filaments growing parasitically in the intercellular spaces of their hosts, bearing small haustoria, and sending into the air through the stomata the unbranched, capitately swollen conidiophores, which bear at their summits several short projections (sterigmata) each terminating in a single, spherical or ellipsoidal conidium; conidia germinating after falling by the internal formation of zoospores, which escape through the terminal capillary orifice; oogones terminal, the irregularly wrinkled zygote free from the oogone wall; germination unknown.—Species one, in Compositae.

7. *Bremia* Regel. Vegetative filaments growing parasitically in the intercellular spaces of their hosts, bearing short or clavate unbranched haustoria, and sending into the air through the stomata the repeatedly dichotomous conidiophores whose ultimate branchlets bear terminal, shallow cups, each with several short marginal sterigmata, bearing as many ellipsoidal conidia; conidia germinating by the protrusion of a slender tube through the terminal papilla; oogones terminal, thin-walled, completely filled by the smooth, thin-walled zygote; germination unknown.—Species one, in Compositae.

8. *Peronospora* Corda. Vegetative filaments growing parasitically in the intercellular spaces of their hosts, bearing large, branched (rarely small) haustoria, and sending into the air through the stomata the repeatedly dichotomous conidiophores whose ultimate branches are simple; conidia ellipsoidal, to ovate, without a terminal papilla, germinating laterally by a slender tube; oogones usually terminal, larger than the zygote, whose walls are irregularly thickened;

germination by means of a slender tube.—Species very many, mostly in dicotyledons.

Family MUCORACEAE

Black Moulds

Plants saprophytic or parasitic, consisting of much branched, non-septate vegetative filaments, which bear the more or less erect sporophores, the former more or less rhizoid-like and penetrating the substratum, the latter aerial (in one genus aquatic), cylindrical or swollen, simple or branched, and often bearing rhizoids below; propagation (1) by the internal division of the end cells of the aerial branches (sporophores) into internal spores, (a) in single enlarged end cells (sporangia) each producing few to many irregularly arranged spores (zoospores in one genus), and (b) in several or many narrow (or spherical) end cells, each producing one, or more often, few to many spores in a single row, these set free as a row of spores ("conidia") by the early dissolution or fracture of the sporangial wall (sometimes apparently formed by abstriction); (2) by the formation of thick-walled resting cells (chlamydo-spores) in the vegetative filaments; generation by the coming together of two usually lateral branches, mostly upon vegetative filaments, the formation of a septum near the end of each, the absorption of the wall between the united cells, and the fusion of their contents into a zygote, which eventually becomes thick-walled.

KEY TO THE GENERA.

- A. Plants aquatic, 1. *Zygochytium*.
 B. Plants not aquatic, living saprophytically or parasitically in the air,
 I. Sporophore or its branches with a single, terminal, enlarged, spheroidal, many-spored sporangium,
 a. Sporangium with a columella,
 1. Sporangium-wall little, if at all, thickened,
 a. Plant without stolons, sporophores single,
 1. Sporophore simple, at least not dichotomously branched.
 a. Aerial filaments smooth-walled,
 §. Glossy, dull, gray or brown, 2. *Mucor*.
 §§. Metallic green or olive, 3. *Phycomyces*.
 β. Aerial filaments thorny, 4. *Spinellus*.
 2. Sporophores dichotomously branched, 5. *Syzygites*.
 b. Plant with stolons bearing rhizoids and tufted sporophores at the nodes, 6. *Ascophora*.

- a. Sporangium-wall thickened above, thin below, 7. *Hydrogera*.
 b. Sporangium without a columella, 8. *Mortierella*.
 II. Sporophore with a single terminal, enlarged, many-spored sporangium,
 and few to many lateral, smaller, few-spored sporangia,
 9. *Thamnidium*.
 III. Sporophore much-branched, with many small, spherical, one-spored
 (conidia-like) sporangia on short lateral branches,
 10. *Chaetocladium*.
 IV. Sporophore much-branched, bearing terminal clusters of narrow, few-
 spored sporangia,
 a. All of the ramuli bearing sporangia, 11. *Piptocephalis*.
 b. Some of the ramuli circinate and sterile, 12. *Dispira*.
 V. Sporophore unbranched, bearing upon the terminally enlarged apex
 many narrow, radiating sporangia (resembling conidia chains),
 13. *Syncephalis*.

1. *Zygochytrium* Sorokin. Plants aquatic, saprophytic, the pale yellow filaments erect and irregularly branched, attached to the substratum by short, irregular rhizoids; sporangia solitary on the ends of the branches, without columella, opening by a circular lid; zoospores spherical, uniciliate; zygote spherical, thick-walled, red, formed by the union of lateral branches from the erect filaments.—One species, on dead flies, gnats, wasps, etc., in water.

2. *Mucor* Linne. Plants saprophytic, the vegetative filaments smooth-walled, abundant, and penetrating the substratum, rhizoid-like and tapering at the extremities, at first white, later dusky or blackish; sporophores erect, simple or monopodially or sympodially branched; sporangia many-spored, spherical or pyriform, thin-walled, mostly dark-colored, with a large columella; spores spherical or elliptical, mostly dark-colored, escaping by the irregular rupture of the sporangium wall; zygotes formed in the vegetative filaments (rarely found).—Species many, on organic matter.

3. *Phycomyces* Kunze. Plants saprophytic, the vegetative filaments smooth-walled, abundant, and penetrating the substratum, rhizoid-like and tapering at the extremities; sporophores erect, simple, metallic-green or olive; sporangia large, many-spored, spherical, thin-walled, brownish, with a large, pyriform columella; spores ellipsoid, yellowish, escaping by the dissolution of the sporangium wall; zygotes formed in the vegetative filaments, the adjacent cells with dichotomously branched, dark-brown outgrowths.—Two species on oily or decaying organic matter.

4. *Spinellus* Van Tieghem. Plants parasitic, composed of delicate filaments penetrating the host, and brown, thorny, irregularly-branched, aerial filaments which bear the sporangia and sexual cells; sporophores simple; sporangia large, spherical, with a globular columella; spores fusiform to spherical, escaping by the dissolution of the sporangium wall; zygote barrel-shaped, smooth, formed in the aerial filaments.—Species few, on agarics.

5. *Syzygites* Ehrenberg. Plants saprophytic, composed of delicate filaments penetrating the substratum, and dichotomously branched aerial filaments which bear the sporangia and sexual cells; sporophores dichotomously branched, eventually septated; sporangia spherical, with a hemispherical columella; spores round or ellipsoid, escaping by the early dissolution of the sporangium wall; zygotes spheroidal and smooth, formed on specially developed dichotomously branching aerial filaments.—One species on decaying agarics and other large fungi.

6. *Ascophora* Tode. Plants saprophytic, composed of delicate filaments penetrating the substratum, and dichotomously branched aerial filaments which send out stolons in all directions, these bearing rhizoids and sporophores at the nodes; sporophores non-septate, simple, tufted, swollen just below the nearly spherical sporangium; columella hemispherical, collapsing and becoming umbrella-shaped when old; spores spherical or somewhat angled, escaping by the early disappearance of the sporangium wall; zygotes spherical or nearly so, with a thick, warty, dark-brown wall, formed in the mass of vegetative filaments in or on the substratum.—Species few, on organic matter and decaying substances.

7. *Hydrogera* Wiggers (*Pilobolus* Tode). Plants saprophytic, composed of much-branched filaments with tapering, rhizoid-like ramuli, penetrating the substratum, without stolons, and producing erect, simple, terminally enlarged sporophores, which arise from swollen portions of the vegetative filaments; sporangium terminal, hemispherical, with its wall thickened, black, and cuticularized above, and thin and evanescent below; columella small, conical; spores spherical or ellipsoid; zygotes spherical or barrel-shaped, formed in the mass of vegetative filaments.—Species few, on excrement.

8. *Mortierella* Coemans. Plants saprophytic, composed of very slender and weak, branching filaments penetrating and running over

the substratum, spreading by many stolon-like anastomosing branches, more or less septate when old; sporophores erect, single or tufted, simple or branched, mostly colorless, sometimes with rhizoids below; sporangia terminal, spherical, thin-walled, without columella; spores mostly spherical or elliptical, colorless, variable in size, escaping by the early rupture of the sporangium wall; zygote formed in the mass of vegetative filaments, spherical, surrounded by the dense growth of filaments arising from the adjacent cells.—Species many, on excrement and other decaying matter.

9. *Thamnidium* Link. Plants saprophytic, composed of much-branched, colorless filaments penetrating the substratum, without stolons, and producing erect, branched sporophores; sporangia of two kinds, (1) larger, single, terminal, many-spored, with a columella, (2) smaller, clustered, lateral, few-spored, without a columella; spores alike, spherical or ellipsoid, escaping by the disappearance of the sporangium wall; zygotes spherical or barrel-shaped, thick-walled, dark brown or black, formed in the mass of vegetative filaments.—Species few, on excrement and other decaying matter.

10. *Chaetocladium* Fresenius. Plants parasitic or saprophytic, composed of slender, colorless, much-branched filaments, attached to their hosts by clusters of short, thick rhizoids (haustoria); sporophores rarely erect, mostly creeping, at length septate, repeatedly branched, each branch ending in a long-pointed sterile thread; conidia-like sporangia spherical, single (not in chains) approximated in botryoid clusters, on short lateral branches; zygotes formed on the vegetative filaments, spherical, naked.—Species few, on other Mucoraceae.

11. *Piptocephalis* DeBary. Plants parasitic, consisting of slender, branching filaments, producing here and there dense clusters of rhizoids which penetrate their hosts, sometimes producing stolons; sporophores erect, dichotomously branched, septate and brownish with age, the ultimate ramuli not terminally enlarged; "conidia" cylindrical or spherical, in radial chains clustered on the ends of the ramuli; zygotes formed on the vegetative filaments, spherical, naked.—Species few, on other Mucoraceae.

12. *Dispira* Van Tieghem. Plants parasitic, consisting of slender branching filaments attached to their hosts by large rhizoids; sporophores erect, septate, colorless, much branched, some of the ulti-

mate ramuli sterile and circinate, the others terminally swollen and papillate, bearing numerous short, 1-septate sterigmata, each developing terminal clusters of "conidia"-chains of two ovoid hyaline cells; zygote spherical, brownish, formed by the union of two contiguous cells in a filament (in the single known case the filament attaches itself to its host, cuts off a swollen cell next to the host, this soon emptying its contents into the adjacent cell, which then becomes a zygote).—Species few, parasitic on other Mucoraceae.

13. *Syncephalis* Van Tieghem and Le Monnier. Plants parasitic (rarely saprophytic), consisting of very slender, branching and anastomosing filaments, producing numerous clusters of rhizoids which penetrate their hosts; sporophores stout, erect, mostly unbranched, enlarged above, and bearing a cluster of forked rhizoids below; "conidia" cylindrical to fusiform, in many radiating chains clustered on the enlarged summit of the sporophore; zygote spherical, naked, formed on the vegetative filaments.—Species many, on other Mucoraceae (occasionally on excrement).

Family ENTOMOPHTHORACEAE

Insect Fungi

Plants parasitic in the bodies of insects (rarely endophytic or saprophytic), consisting of much-branched, tubular, mostly endozoic, filaments, eventually septate, and often separating into distinct segments, sometimes bearing rhizoids which attach the host to the substratum; propagation by the abstriction of single conidia from the ends of short, aerial filaments and by the asexual formation of resting spores in the vegetative filaments; generation (mostly within the host) by the union of two approximate or adjacent cells or segments, and the development of a thick-walled zygote.

KEY TO THE GENERA.

- | | |
|-------------------------------------|---------------------------|
| A. Parasites of insects, | 1. <i>Entomophthora</i> . |
| B. Parasites of plants, | |
| I. In the cells of fern prothallia, | 2. <i>Completozia</i> . |
| II. On higher fungi, | 3. <i>Conidiobolus</i> . |
| C. Saprophytes on excrement, | 4. <i>Basidiobolus</i> . |

1. *Entomophthora* Fresenius. Vegetative filaments growing mostly in the soft interior tissues of insects, in some cases growing

externally also, branched, commonly separated into segments, sometimes bearing rhizoids which attach the host to the substratum; conidiophores simple, or more or less branched, penetrating the body-wall of the host and forming upon each a single, terminal, spherical or fusiform conidium; resting spores formed asexually in the vegetative filaments, or by the union of the protoplasm of two cells.—Species many (including, also, those of *Empusa*, *Lamia*, and *Tarichium* of some authors), parasitic on flies, mosquitoes, aphids, locusts, caterpillars, and many other insects.

2. *Completozia* Lohde. Vegetative filaments growing in the cells of fern prothallia, at first tubular, later with many irregular branches; conidiophores simple, penetrating the cell wall, each forming a single ovoid conidium; asexual resting spores produced by the contraction of the protoplasm of a vegetative cell, and the formation of a thick wall.—One species, not yet reported for North America.

3. *Conidiobolus* Brefeld. Vegetative filaments growing parasitically on higher fungi (rarely saprophytic), well developed, much branched, more or less septate, and eventually separating into segments; conidiophores erect, simple, clavate, each bearing a single, ovoid conidium; zygotes thick-walled, spherical, formed by the union of two segments of the vegetative filaments.—Species two, not yet reported for North America.

4. *Basidiobolus* Eidam. Vegetative filaments growing saprophytically on excrement, well developed, much branched, at first continuous, later septate; conidiophores erect, clavate, each bearing a single terminal, ovoid conidium; zygotes thick-walled, spherical, formed by the union of two adjacent filaments.—Species two, on the excrement of frogs and lizards.

NOTES ON THE SEXUAL ORGANS OF SAPROLEGNIACEAE, PERONOSPORACEAE, MUCORACEAE, AND ENTOMOPHTHORACEAE

1. Typical antherids and oogones occur in the aquatic holophytic plants constituting the family Vaucheriaceae.

2. The antherids and oogones of the Saprolegniaceae are so modified on account of their parasitic habit, as to result in the suppression of the antherozoids, and the transfer of the contents of the antherid to the oogone directly. The same has occurred in the Peronospora-

ceae, here perhaps in part due to the fact that fertilization takes place in the air (not in the water).

3. The sexual organs of the Mucoraceae are of the type of the Saprolegniaceae, as modified in the non-aquatic Peronosporaceae, and like them they are lateral diverticula each of which cuts off an end cell (antherid and oogone).

4. The sexual organs of the Mucoraceae are in process of extinction; in the ontogeny of each plant they never fully develop, and are no more than mere rudiments (anlagen); phylogenetically they are not rudiments but vestiges.

5. These physically under-developed and but little differentiated sexual organs of the Mucoraceae conjugate prematurely, before the oogone is ready for fertilization, and the act is merely a fusion of the nearly undifferentiated gametes. At the instant of conjugation there is no oogone proper in which a zygote can form, but this premature conjugation stimulates the growth of the egg cavity (oogone, zygogone).

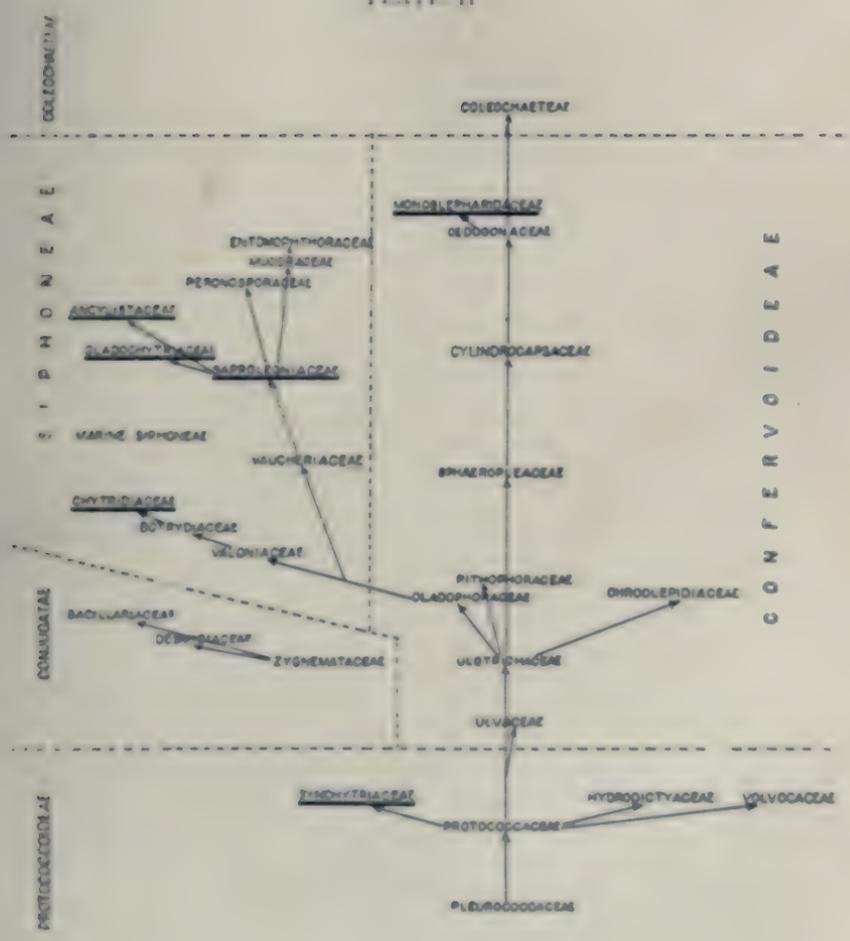
6. The sexual organs of the Entomophthoraceae are similar to those of Mucoraceae, and are likewise in process of extinction.

EXPLANATION OF PLATE II

CHART SHOWING THE RELATIONSHIP OF THE PHYCOMYCETES

The names of the orders are printed in vertical lines and the families in horizontal. Those of the fungi are underlined.

PLATE II



THE EARLY MORPHOGENESIS AND HISTOGENESIS OF THE LIVER IN *SUS SCROFA DOMESTICUS*

INCLUDING NOTES ON THE MORPHOGENESIS OF THE VENTRAL PANCREAS

Published under a grant from the Spencer-Tolles Fund

By DAVID C. HILTON

WITH FOUR PLATES

TABLE OF CONTENTS

	PAGE
I. Introduction	56
II. Morphogenesis	57
1. The simple protonic wall	57
A. Stage 1.....	57
B. Stage 2.....	59
C. Stage 3.....	62
D. Stage 4.....	64
2. Relation of morphologic variations to blood sinuses.....	66
3. General configuration of the external surface.....	67
A. Smooth wall.....	67
B. Papillated wall.....	67
C. Rod-like extensions.....	67
D. Network of rods.....	68
4. Comparisons of results with those of other authors.....	68
5. Notes on the ventral pancreas.....	72
III. Histogenesis	73
1. The simple, smooth wall of the proton.....	73
A. Basic structure.....	73
B. Development	74
2. Development of the glandular structure.....	75
A. Potential evaginations in the smooth wall.....	75
B. Papilla formation (Exuberant evaginations).....	77
C. Rod-formation	78
D. Relation of vascular spaces to protonic structure.....	79
3. Other authors on histogenesis.....	80
4. Fusion of rods. Collateral growth. Disorganization.....	81
5. Problems in trabeculation.....	82
6. The vaso formative cells of Van der Stricht.....	83
7. The gall-bladder wall.....	83

IV. List of embryos.....	84
V. Bibliography	84
VI. Explanation of plates.....	86

INTRODUCTION

The material used in this research was selected from a collection of five hundred embryos obtained at the packing houses in South Omaha, Nebraska. The embryos ranged in length from 4 to 25 mm. They were taken from the warm uteri, and, while their hearts were beating, placed in killing and fixing reagents. For this purpose different reagents were used, such as picro-nitric acid, chromo-nitric acid, Zenker's fluid, formol-acetic acid-alcohol mixture, and 10 per cent formaldehyde. The specimens were hardened in 75 per cent alcohol.

The approximate age and the degree of development of each embryo were determined by counting the protovertebrae and comparing the count and general appearance of the specimen with Keibel's tables and charts. Measurements furnish very inaccurate data, and are not to be relied on.

Sections of series P and K were cut 6μ thick, the others, 10μ . In all, twenty-five series of sections were studied. Those from which drawings are produced in this paper were stained as follows:

- Series X¹ (Dr. Peterson's)—borax carmine.
- Series D—Grenacher's alum carmine.
- Series G—Ehrlich's acid haematoxylin, picric acid.
- Series J—Ehrlich's acid haematoxylin.
- Series P—borax carmine, picric acid.
- Series K—Ehrlich's acid haematoxylin.
- Series S—Grenacher's alum carmine, picric acid.

All of the above series were killed and fixed in formol-acetic acid-alcohol solution. Eleven models of the hepatic proton were constructed at a magnification of $100\times$.

Aside from my own material, I have had access, through the kindness of Dr. Peterson, of Omaha, Nebraska, to his sections and models of Series X¹ which furnished the most primitive stage studied.

I would not close this introduction without expressing my sincere thanks and obligation to Dr. Henry B. Ward, for several years

my teacher, whose kindness and helpful suggestions have made this undertaking both pleasant and profitable.

MORPHOGENESIS

The simple wall of the proton

In so far as this research reveals the morphologic changes that the proton of the liver suffers, there are four distinct stages of form-condition under which it is convenient to discuss the subject.

In the first stage, the proton is a modified strip of the ventral epithelium of the foregut bordering the yolk-stalk; no part of the proton forming as yet an evagination of the enteric canal. In the second stage, a part of the proton forms a shallow evagination. In the third stage, a greater proportion of the proton is included in the now partially subdivided evagination which opens by a broad mouth into the foregut, but no part of the proton borders the yolk-stalk. In the fourth stage, the entire proton is an evagination with a complete posterior surface, and it opens by a more or less constricted neck into the lumen of the foregut.

Stage I (Fig. 11). At this period of growth, the ventral wall of the foregut where it lies dorsad to the heart extends approximately in an antero-posterior direction (*i*), but where it approaches the posterior end of the sinus venosus (*sv*) it arches ventrad, gradually assuming a dorso-ventral attitude posterior to the heart (*ht*) and postero-ventrad to the sinus venosus. Here the intestinal wall constitutes the lining of the anterior inner surface of the yolk-stalk where it opens into the intestine (*ys*). At about the level of the ventral aspect of the heart the wall of intestinal epithelium, having tapered to a very thin margin, becomes continuous with the delicate extra-embryonic lining of the yolk-stalk (*bys*). That portion of the ventral wall of the foregut described as lying behind the heart, and assuming an approximate dorso-ventral direction, is the earliest rudiment of the liver observed. Its greatest thickness is two to three times as great as that of the ordinary epithelial lining of the intestine, and the point at which the intestinal epithelium thickens abruptly, caudad to the sinus venosus, defines the dorsal border of the hepatic proton (*bd*).

Between the proton and the heart is an area filled with embryonic connective tissue rich in blood supply. This vascular area of tissue

is the septum transversum, and that part of it immediately contiguous to the proton is called the prehepatic (*ph*). The liver finally comes to be completely within it, and derives its interstitial tissue therefrom.

The sinus venosus is the largest blood space in the septum transversum and is dorsally situated within it (Figs. 11, 12, and 13, *sv*). Anteriorly it opens into the heart. Posteriorly it comes in close proximity to the dorsal portion of the anterior surface of the proton (Figs. 11, 12, and 13, *ds*). On each side of the median plane a short extension of the sinus projects posteriad. Each projection is formed by the union of two veins,—the vitelline and umbilical.

The umbilical veins extend in an antero-posterior direction, each lying in the lateral body wall (Fig. 14, *vu*). The veins of this pair have scarcely any extensions into the septum transversum.

The vitelline veins extend antero-posteriad in the extreme dorsal portion of the septum transversum. There is one at each lateral aspect of the intestine, and for a great part of their length above the liver proton, they are included in folds of the septum transversum which project dorsal into the pleuro-peritoneal cavity (Fig. 14, *vt*). Large sinus-like extensions from the ventral surface of this latter pair of veins dip into the septum transversum and ramify it with a vascular network (Figs. 14, 15, and 16, *vn*; also other figures). The higher the stage of development, the more the branches of this network increase in relative number and diameter. Close to the wall of the proton, the vascular spaces are large and more or less sinus-like. These sinuses decrease in size and increase in number toward the more peripheral region of the septum transversum, where they appear more like capillaries.

Minot (98) gives an account of a similar sinus-like structure of the vascular system in the mesonephros of the pig embryo. The vascular spaces in the septum transversum about the proton of the liver agree with the vessels described by Minot in respect to communication, size, irregular curvature, and the make-up of their walls which follow the surface of the liver rods rather than their own and independent curve as is characteristic of true capillaries. Minot states that there is little mesenchyme between the vessels and the tubuli of the mesonephros. About the proton of the liver and the vascular spaces surrounding it there is considerable mesenchyme,

but it is not so disposed as to form in any sense a supporting wall for these spaces, with the exception of the sinus venosus. These spaces are often much larger than the vitelline veins with which they communicate (Fig. 14, *sn*).

According to the foregoing description of the hepatic proton, it may be defined as that thickened portion of the ventral wall of the foregut lying upon the prehepaticus posterior to the heart, and extending in a dorso-ventral direction from a point posterior to the sinus venosus ventrad into the yolk-stalk where it ends, after tapering to a thin border. Its border, on the one hand, is attached in that it is an extension of the intestinal wall (Fig. 11, *bd*), and, on the other hand, is free where its thin edge ends in the extra-embryonic lining of the yolk-stalk (Fig. 11, *bys*). Of its two surfaces, the inner or lumen surface is in contact with the embryonic fluid within the lumen of the enteric canal and yolk-stalk; the outer surface bounds the prehepaticus posteriorly.

Stage 2 (Figs. 1, 1a, 1b). The principal difference between this stage and stage 1 may be grouped under changes in the thickness, the extent, and the form of the proton.

In thickness, the wall has doubled that found in stage 1. The variations in thickness are numerous and promiscuously distributed, with the exception that along the attached border—that continuous with intestinal epithelium—and along the free border, the wall averages thinner than elsewhere. The free border always tapers to a thin edge, and at this stage flares outwards, causing a depression on the external surface parallel with it.

The extent of the proton has been augmented greatly by addition to the original. This increase has occurred by virtue of two processes. The first is cell proliferation, most obviously indicated by the ventral prolongation of the intestinal wall on the lateral inner surfaces of the yolk-stalk (*ys*), immediately posterior to the original proton of stage 1. And the second is the differentiation of this intestinal increment into hepatic structure. The differentiation has gradually extended posteriad from the protonic inception. Therefore, posteriorly the hepatic tissue is least mature; whereas, anteriorly it is most mature. The ventral prolongation of the intestinal wall into the yolk-stalk is greater anteriorly, so that the yolk-stalk border of the proton and of the intestine lying posterior to it, slants postero-dorsad from its more anterior portion.

As to the form of the proton in this stage, a very noteworthy consideration is that to describe it in the terms of a shallow out-pocketing of the enteric canal is incomplete. Cut the proton by a plane transverse to a median sagittal section of it, in a line drawn from the most anterior point on its dorsal border where it is continuous with the intestine, to the most anterior point on the free border at the yolk-stalk. Such a plane is inclined dorso-ventrad and slightly posteriad (*ld*). This divides the proton into two portions. The part anterior to the plane describes a shallow basin-like evagination, which in this model is imperfect on account of the excessive anterior (sinus) depression (*ds*), although it is seen clearly in other models. The broad mouth of the evaginated portion coincides with the plane, opens posteriorly, and is inclined very slightly dorsad. That part of the proton posterior to the plane is not any part of an evagination. It consists in a posterior alar continuation of each lateral wall of the evagination (*ea*).

There are the dorsal and the posterior borders. The former extends approximately in an antero-posterior direction. It is U-shaped; the convexity of the U constituting the dorsal border of the anterior surface, and each limb of the U making up the dorsal border of the lateral surface of its own side. This border is attached in that throughout its entire length, the proton is continuous with the intestinal wall.

The latter border is divided into an upper, attached, and a lower, free, portion. Since the difference between the structure of the hepatic tissue and the ordinary intestinal epithelium fades out by degrees posteriorly, it is difficult to determine by a line exactly where the proton ceases and the intestine begins. But this line defining the attached part lies approximately dorso-ventrally on each side, from the intestine above to some point on the free border below. The model (Fig. 1) includes an area about as far posteriad as the location of this border (*bp*). The lower, free part consists in the thin edge of the proton at the yolk-stalk. It is U-shaped. The arch of the U constitutes the posterior boundary of the ventral surface of the proton. Each limb of the U extends postero-dorsad on its respective side, to that point where it meets the ventral end of the attached portion, being here continuous with the intestinal yolk-stalk border.

There are the internal and external surfaces which have been increased greatly in extent, and have become subdivided into a ventral, an anterior, and two lateral aspects. These surfaces possess a few characteristic features. The anterior surface presents a deep indentation (sinus depression) across its dorsal portion (*ds*). It is observable in most of the specimens, but not in all (Figs. 1 and 2). This indentation when present subdivides the anterior portion of the proton into two lobes, of which the one lying dorsad to the indentation is the smaller. The lateral surfaces vary considerably in contour. At their anterior and ventral margins they arch into the corresponding surfaces. Their two remaining margins are continuous directly with the intestine, except the free yolk-stalk portion of the posterior margin. The ventral surface, in most cases, is convex where it arches dorsad into the anterior and lateral surfaces, and concave antero-posteriorly where its free border flares downward slightly at the yolk-stalk.

According to most of the models, the diameter of the proton from the ventral border of the intestine above, to the ventral surface of the proton below, is much greater than its dimensions from side to side, although this relation is sometimes reversed (*dl*, *dvd*).

Three important concomitant changes have taken place with this increase in the number and the extent of borders and surfaces, and enter as factors in producing the difference in form and location between the proton of stage 1 and of stage 2. First, the down-growth of the wall of the enteric canal along the lateral as well as along the anterior inner surface of the yolk-stalk, and the subsequent differentiation of the same from anterior to posterior into hepatic tissue, has occurred. Second, the lateral aspects of the U-shaped free border have approximated each other and fused progressively from before backward. As a result of this fusion, the ventral surface of the proton has been brought into existence and constantly increased by posterior extension. Third, the posterior recession of the yolk-stalk on a plane with the newly developed ventral surface of the proton, and the growth of the prehepaticus beneath this surface have proceeded (compare Figs. 11, 12, and 13, *ph*). On account of these changes, the proton which in stage 1 could be said only to lie upon the prehepaticus, begins to lie partially within it.

The contours of the internal and external surfaces coincide in general, although there are promiscuous variations in the mural thickness, aside from the regular variations previously noted. There are certain small, sharply-defined projections on the external surface, which will be described under histogenesis.

A more matured condition of the proton in this stage differs slightly from the preceding proton in that the features of special interest in the foregoing specimen are more obvious in this one (Figs. 2, 2a, and 12). The most important new feature seen in this model is the anterior constriction. It is indicated by a constriction at the dorsal border of the anterior surface immediately beneath the intestine (*ca*). It is the beginning of the progressive separation of the proton from the intestine. By virtue of the constricting process and the extension of the ventral surface, the evaginated portion is deepened and enlarged. The enlargement has taken place partially at the expense of the lateral alar extensions, in so far as they have been incorporated into side walls of the evaginated increment. The more sacculated the proton becomes the deeper it is embedded in the septum transversum.

Stage 3 (Figs. 3, 3a, and 13). The ultimate extent to which the intestinal wall differentiates into hepatic tissue is nearly, if not wholly, determined at this stage. The remarkable recession of the yolk-stalk has been accompanied by an increase in the antero-posterior length of the ventral surface of the proton, by way of fusion, such as is described in the foregoing stage. Of great significance is the fact that the differentiation of the ordinary intestinal epithelium into hepatic structure, has not kept pace with the recessive migration of the yolk-stalk. Therefore, the free border of the proton is no longer existent. In its place is the line of union of the proton with the intestine lying posteriorly between the hepatic tissue and the yolk-stalk (*i*). Accordingly, the mouth of the evagination does not, as in the previous stage, open into the space where the lumina of the intestine and of the yolk-stalk conjoin, but into the lumen of the foregut proper.

On the ventral surface of the model, there are three depressions extending transversely across it. The most posterior one (*d₁^a*) indicates the locality where the foregut dips slightly into the yolk-stalk. The middle one (*cp*) indicates the region where the ventro-posterior limit of the proton passes into the ordinary epithelium of

the foregut. The most anterior one (dr^1) is an incipient constriction between that part of the proton which develops all or most all of the glandular structures—pars hepatica of Brachet (*P. hep.*)—and the portion which is the rudiment of the gall-bladder and ventral pancreas structures—pars cystica of Brachet (*P. cy.*).

Thus, the pars cystica is here outwardly indicated for the first time as that convexity of the ventral protonic surface lying between the anterior and middle ventral depressions. In the previous stages, the form-conditions of its presence are not only lacking, but the tissue rudiment of it is wholly unformed or only partially existent; since all or nearly all of the intestinal epithelium which can be recognized as part of the hepatic proton partakes of the characteristic structure of the pars hepatica. In view of the fact that the proton develops antero-posteriad and dorso-ventrad, and since the gall-bladder occupies the ventro-posterior part of the proton, it is clear that the pars hepatica is formed before the pars cystica. The wall of the pars cystica is somewhat thicker than that of the pars hepatica, and represents about one-third of the mural area (Figs. 3, 3a, and 13).

The mid-ventral depression (posterior constriction), is the counterpart of the anterior constriction already mentioned. The latter is more pronounced than in stage 2. The deepening of these separates the proton from the intestine more and more. They are connected by a more or less perfect longitudinal furrow on each side, running posteriad and finally ventrad. These furrows are the lateral aspects of the zone of constriction demarking the proton from the intestine.

Not only has the ventral wall of the proton extended posteriad, but that region of it posterior to the most anterior ventral depression, including as it does the ventral surface of the pars cystica, is now inclined slightly dorsad, antero-posteriorly. This dorsal inclination becomes greater and greater in subsequent development, until it is practically dorso-ventral in direction. Then this portion of the proton becomes part of the posterior wall (Figs. 4 and 4a, *P. cy.*).

After cutting the proton by a plane in the manner that those of stage 2 are cut, thus dividing it into evaginated and alar-extension portions, the following conditions are very noticeable. First, it is clear that the evaginated portion has deepened. This is due to

encroachment upon the lateral alar extensions as observed less conspicuously in the previous stage, to further extension of the ventral wall, and to increase in the anterior and posterior constrictions. Second, the mouth of the evagination is inclined more antero-posteriad, and opens more dorsad into the lumen of the foregut. Third, the alar extensions, instead of being almost posterior to the evaginated portion as in stage 1, are dorso-posteriad (*dl*). Since there is no free border, the line for the plane to pass through must be drawn to the most ventral point on the posterior border, instead of the most anterior point on the free border as in the previous stage.

The evagination has become trilobed by the anterior and the anterior ventral depressions. Since the former one is not constantly found in different specimens of this and older stages, the bilobing of the anterior wall is adventitious, but the bilobed condition of the ventral wall is a constant character of the development. In this stage the lobulation is not apparent on the lateral surfaces.

Stage 4 (Figs. 4 and 4a). By a process of lateral fusions and antero-posterior separations of the walls in the posterior constriction between the proton and intestine, this constriction has been deepened so greatly, that, on account of this deepening and possibly by the orientation of the posterior portion of the ventral wall into an approximate dorso-ventral direction, a posterior surface to the proton has been created.

The dorsal border of this new surface is on a level with the same border of the lateral and anterior walls. Consequently, no plane cutting the proton in accord with previously given directions will divide it into two parts. The alar extensions of previous stages have been incorporated completely into the evagination. Therefore, the proton is now an evagination from the ventral surface of the foregut into the septum transversum, and its cavity communicates dorsally by a slightly constricted neck, with the lumen of the foregut.

The variations in the contour of the proton and in its relative dimensions seem to become greater in these more advanced stages. In lateral aspect and in median sagittal section, there is considerable antithesis between the proton of embryo G under discussion and that of embryo D (Figs. 5 and 5a). The former is very deep and the depression between the pars hepatica and the pars cystica is slight.

In the latter this depression is very deep, and thereby makes the liver proton appear to be a quite double evagination. The proton of embryo G in cross-section is narrow, deep, regular, and U-shaped. Embryo P furnishes a proton which is extremely irregular on every side. A cross-section through the deepest portion of the pars hepatica of embryo D would reveal a shallow evagination with a lateral dimension exceeding the dorso-ventral measurement several times,—the reverse of the proportions found in embryo G.

The solution of the problem as to whether in embryo D there are really one or two diverticula may be approached from two standpoints.

Standpoint 1. Take dorso-ventral measurements in the median plane from the dorsal wall of the intestine, to the ventral surface of the intestine anterior to the proton (d^1), to the same surface posterior to the proton (d^2), and to the surface of the depression between the pars hepatica and pars cystica (d^3). The last measurement is no greater than the first or second, and no point elsewhere on the depression is below the level of the point measured to. And since the intestinal caliber anterior and posterior to the proton is about equal, the space between the two diverticula may be considered to be in the level of the ventral surface of the intestine. Therefore, there are two separate diverticula.

Standpoint 2. Cut the proton by a plane as directed for demonstrating the evaginated portion in other models. At no point does the depression rise quite high enough to meet the plane. Therefore, the plane may be considered to coincide with the mouth of a single, deeply bilobed evagination.

The view that there are two diverticula appears to me the most obvious and satisfactory. In assuming this attitude, the objection to it that has been pointed out may be answered by referring to the fact that the dorsal wall of the intestine above this depression suffers down-curving, at least as great as the distance which the depression lacks of meeting the plane.

This is the only model which has shown two distinctly separate diverticula, and is the only one in which the intestinal wall above dips downward. The contour of the intestine at this place may have been straight normally, although not the slightest evidence was discovered to indicate the curved condition to be abnormal. The external appearance of the embryo before embedding was perfect.

The belief that there are two separate diverticula does not in the least dispose one to the conclusion that they were so primarily. They probably were not, because a simple exaggeration of the anterior ventral depression could have been the factor which made two separate diverticula out of a single primary one, in the manner similar to that by which the bilobing of other protons has been effected.

The rudiment of the gall-bladder which in the previous stage is very shallow and basin-like, and opens dorsad within the primary evagination of the proton, is, in the present stage, a somewhat deeper evagination of the ventral part of the posterior wall, and opens anteriorad (*gb*).

In the posterior wall, between the gall-bladder and the intestine above, is a more or less conical, bilobed, solid outgrowth of tissue. This is the ventral pancreas (*pv*). It is a thickening of that portion of the pars cystica which goes to form the ductus choledochus.

Only one stage later than that just reviewed has been modelled (Fig. 6). In it the zone of constriction has closed in so as to leave a very small, narrow neck at the mouth of evagination (*n*). The evagination is somewhat flask-shaped and deeply divided into four lobes, aside from that portion composing the rudiment of the ventral pancreas. One of these lobes extending posteriorad and to the right is the gall-bladder. It is well rounded; its wall being thicker on an average than that of the pars hepatica. Its surface is smooth and sharply defined from the adjacent tissue of the prehepaticus. Of the other three, one is to the right (*rt*), one is to the left (*l*), inclining dorsad, and one proceeds ventrad (*v*). The left one is the smallest. They taper toward their distal end and, at their proximal extremity, spread out into the walls of the main cavity of the flask. Where the proton joins the intestine, the latter runs somewhat transversely from left to right (*itr*).

Relation of morphologic variations to blood sinuses

Idiosyncrasies in mural contour are accompanied by corresponding peculiarities in the disposition of adjacent sinuses.

In embryo D (Fig. 16) there is a large vessel lying immediately beneath the deep depression between the pars hepatica and pars cystica. On both sides of the deep, narrow, U-shaped wall of embryo G (Fig. 14) are observed very large sinus-like spaces.

The proton appears to have dipped ventrad in the narrow interval between the vessels.

In embryos X¹, J, and K (Figs. 11, 12, and 13), the sinus venosus at its posterior end lies close to the anterior wall of the proton, in such a way that it coincides with the anterior (sinus) depression (*ds*) which bilobes the anterior surface. This depression is seen in the models of embryos J and K. Thus, the bilobing of the anterior surface seems to be due to the close approximation of the sinus which by active pressure, or its own resistance, makes an indentation.

In the very irregular wall of embryo P (Fig. 15), the deep depressions are filled, more or less, with large sinuses. From these observations it appears that the irregularities of growth are the results of obstructions to expansion, offered here and there by these sinuses.

General configuration of the external surface

In stage 1 (Embryo X¹) and in stage 2 (Embryos S and J), the surface, although sinuous by virtue of indentations and convolutions, is smooth, and well defined from the adjacent tissue of the septum transversum. The few exceptions to this are some minute papillary excrescences. They protrude slightly from the general surface. In stage 1 they are less in number and in magnitude than in the later stages (Fig. 15, *p*).

The papillae develop earliest and are largest on the anterior median surface. Posteriorly over the lateral and ventral surface, they become smaller and fewer and finally disappear. In other words, the older the protonic wall, the more mature and numerous are the papillae. Consequently, the more advanced the stage of development, the more completely and extensively is the posterior and younger region of the proton involved in the extrusion of papillae.

In stage 3, where for the first time there is a definite *pars cystica*, it is necessary to state that this part of the proton always possesses a smooth, well-defined wall, excepting perhaps at its most anterior portion. The *pars hepatica*, however, especially anteriorly, is studded with numerous papillae, some of which have grown out into short rods. These rods are usually separated by vascular spaces. It often happens at this stage that several of them near the median anterior region of the proton, where they are more mature, are not separated but are closely approximated, forming a more or less com-

pact cell mass (Figs. 13 and 19, *rc*). This is the only structure apparently homologous to the "kompakte Leberanlage." It is minutely discussed under histogenesis.

In stage 4 (Embryos G and D), the papillae and rods have still further increased in number, magnitude, and range. Most of the simple short rods of stage 3 have elongated and branched. These branches, in most places, have united end to end, and form a network (Figs. 14 and 16). This configuration of the wall occupies at least the anterior half of the proton. It becomes less complex posteriorly and the rod disappears altogether at a limit indicated (Fig. 4, *rl*). Posterior to this limit the surface is smooth or slightly papillated. But within this smooth wall, as far posterior as the dotted line (*pl*), the cell arrangement peculiar to potential evaginations is discernible. Since all this structural variation which determines hepatic tissue, covers about four-fifths of the wall, that amount is gland-formative and represents wholly or almost entirely the pars hepatica portion of the proton. These potential structures are discussed under histogenesis.

In later stages, this net-work of rods becomes larger and more complex, and finally arranged into the characteristic glandular structure. In the case of embryo E, the rods arise from all parts of the proton excepting from the gall-bladder, the appended ventral pancreas, and the narrow neck leading to the intestine.

Comparison of results with those of other authors on mammalia

His (81) says that the "Leberanlage" first appears as a longitudinal strip on the ventral side of the foregut. Peterson (99) also demonstrated this in the pig. This research confirms it likewise.

"Kölliker (79) hatte bei dem Kaninchen zwei Lebersprossen beschrieben, deren erster am zehnten Tage auftritt, während der zweite erst am elften Tage der Schwangerschaft erscheint. Sie stehen zu einander in einem ungefähren rechten Winkel." [Quoted from Brachet (96).]

Kölliker's two "Lebergänge" are given as right and left. Stage 3 furnishes two "Lebersprossen" in the relation of right angle to each other, but one is anterior and projects forward, the other is posterior and projects downward. The anterior one is the pars hepatica. The posterior one is the pars cystica (Fig. 3a). The model of embryo K, which is taken as the type of stage 3, is evi-

dently trilobed instead of bilobed. However, since the anterior (sinus) depression, which divides the pars hepatica into two parts, is adventitious, and since the anterior ventral depression, which divides the proton into the pars hepatica and pars cystica, is a constant element in the morphology, the bilobed condition is the characteristic one.

"Felix (92) dagegen will die zwei Leberknospen, aus denen diese Drüse hervorgehen soll, bei menschlichen Embryonen gefunden haben. Indessen sind diese beiden Knospen weit davon entfernt, denen zu gleichen, welche Kölliker bei dem Kaninchen gesehen hat. Denn er giebt an, dass der eine kranial, der andere kaudal gelegen sei. Der letztere endlich ist ganz und gar rudimentär und kann in späteren Stadien kaum wieder erkannt werden." [Quoted from Brachet (96).]

This research does not bear out the results of Felix, because no atrophic "Leberknospe" is present. On the other hand, both the pars hepatica and pars cystica undergo progressive metamorphosis.

"His (81) hatte die zwei von Kölliker beschriebenen Divertikel weder beim Kaninchen, noch beim Menschen wiedergefunden. Stets sah er jedoch nur einen einzigen, der von der ventralen Wand des Darmrohres ausging und der zum grossen Teil mit dem Septum transversum zusammenhing; durch Zellwucherung seiner Wände entstand aus ihm eine dichte, kompakte Zellmasse: die kompakte Leberanlage.

"Die Gallenblase tritt später auf in Gestalt eines sekundären Divertikels des Leberausführungsganges." [Quoted from Brachet (96).]

The proton of stage 1 is more primitive than this, because no diverticulum appears in the former. Otherwise the proton of stage 1 answers in a general way to this description. The evaginated portion of the proton in stages 2 and 3, and the entire proton of stage 4, correspond more or less to His' description. Although the gall-bladder appears subsequent to the beginning of the hepatic portion of the proton, it is, nevertheless, evident in stage 3, wherein there is as yet no well-defined "Ausführungsgang." Moreover, in stage 4 and in the latest stage modelled, the gall-bladder is below the "Ausführungsgang." Concerning the "kompakte Leberanlage" of His, which is confirmed by Brachet and by Hammar, a discussion is found under histogenesis.

Hammar (97) after stating the proton in some other classes of vertebrata to be a fold of the ventral gut wall, turns to mammalia and describes it in the rabbit, in the following quotations:

"Auch bei den Säugetieren wird eine stufenähnliche, sich zwischen die Venenschenkel des Herzens hervorschiebende Leberfalte beim Darmverschlusse gebildet (Fig. 4)."

This statement indicates that the proton in the pig and rabbit does not differ materially in position and derivation.

"Während diese letztere sich zum trabeculären Leberparenchym herausbildet, wird die Leberfalte allmählich durch eine caudalwärts fortschreitende Abschnürung (Fig. 5) als ein selbständiger Gang vom Darmrohre abgetrennt."

In connection with this last quotation, it should be noted that he observes the anterior constriction, proceeding "caudalwärts," to be the only factor potent in the separation of the proton from the intestine. And, according to his model (Fig. 5), this seems to be true, since no posterior counterpart to it, such as the posterior constriction in the proton of the pig, is appreciable. The fact that the anterior constriction between the proton and intestine is slight in the pig, and that in the rabbit it extends posteriad as far as the posterior border of the ventral surface, makes a vast difference in the appearance of the two protons. In the rabbit the proton, as presented by Hammar's Fig. 4 and Fig. 5, is entirely a deep evagination projecting anteriorly. At its posterior aspect alone it opens into the foregut where that receives the yolk-stalk. The shallow proton of the pig embryo in those stages corresponding to the aforementioned figures of Hammar, presents both posterior and dorsal aspects open, and it is an evagination only in part.

If in stage 3 (Fig. 3) the anterior constriction was deepened antero-posteriorly, until it furnished a dorsal surface about equal in length to the ventral surface of the proton, it would give an evagination projecting anteriorly beneath the intestine and opening into it posteriorly. The dotted line (*ha*) indicates the imagined constriction. Such a condition is what Hammar gives for the rabbit in his Fig. 4 and Fig. 5.

"Unmittelbar caudalwärts von der compacten Leberanlage sprosst ein anfangs ganz kurzer Zapfen von der ventralen Wand dieses Ganges hervor (Fig. 6)."

Hammar's model illustrated by his Fig. 6, the gall-bladder rudiment of which he describes in the above quotation ("ein anfangs ganz kurzer Zapfen"), resembles very closely the model of the proton in embryo G, representing stage 4. The two models differ mainly in the shape of their gall-bladder rudiments. In the rabbit model under discussion, it is a long, narrow projection. Between Hammar's Fig. 5 and Fig. 6, a constriction at the posterior extremity of the ventral surface of the proton has evidently occurred, since in Fig. 6 the proton projects ventrad instead of anteriad and opens dorsad instead of caudad as in Fig. 5. In other words, the mouth of the evagination has been shifted and a posterior wall created, undoubtedly by the initiation and deepening of the posterior constriction. These phenomena transpired in the proton of the pig during stage 3, and resulted in the form-condition of stage 4. The metamorphosis in both instances is similar, and it is not unlikely that the factors producing it in both are the same.

Brachet (96):

"Auch bei dem Kaninchen wird die Leber durch eine breite longitudinale Ausbuchtung (renflement) der ventralen Darmwand angelegt, welche sich über diese vom Sinus venosus bis zum Nabel hinzieht. In den vorderen und mittleren Partien dieser Ausbuchtung, oder dieser Vorstülpung der ventralen Darmseite fängt das Epithel zu wachsen an, bildet einen epithelialen Zellhaufen, welcher in Verbindung mit dem Septum transversum tritt und zur 'kompakten Leberanlage' von His wird."

The above elucidation of the derivation and relation of the proton to the septum transversum answers to the condition found in the pig. As to the posterior boundary, it answers to the two early stages, but not to later ones, because in them the ordinary intestine intervenes between the proton and the "Nabel." As to shape, stage 1 in the pig proton is more primitive, since as yet there is no "Ausbuchtung" or "Vorstülpung." Concerning the "epithelialen Zellhaufen," a discussion is made under histogenesis, where the "kompakte Leberanlage" is taken up.

"An dem hintersten oder kaudalsten Teile der Wand jener Ausbuchtung (renflement) findet niemals eine derartige Zellwucherung statt. Er bleibt immer glatt und wohl von seiner Umgebung abgegrenzt. Durch Abschnürung und Eingenwachstum bildet sich später die Gallenblase daraus."

"In der That kann man also auch hier bei der primitiven Leberanlage eine 'Pars hepatica' und eine 'Pars cystica' unterscheiden. . ."

"Eine doppelte Abschnürung, die in kranio-kaudaler wie in kaudokranialer Richtung erfolgt, trennt sowohl die 'Pars hepatica' wie die 'Pars cystica' von der ventralen Wand des Darmrohres und lässt sie nur noch durch einen breiten Stiel damit verbunden der dann seinerseits später zum Ductus choledochus wird."

All points considered in the three paragraphs just quoted are true for the proton of the pig.

No author speaks of that portion of the proton which, in certain stages, extends beyond the evaginated portion, and which is designated in this paper as the lateral alar extension.

Notes on the origin of the ventral pancreas

The ventral pancreas is located on the posterior portion of the pars cystica. In case the gall-bladder portion of the pars cystica has been differentiated from the ductus-choledochus portion, the ventral pancreas appears on the latter, thus being situated between the gall-bladder and the intestine.

There are three form-conditions of the ventral pancreas illustrated in the plates. The most primitive is that in the model of embryo D (Fig. 5). Herein it is in the shape of two elongated solid outgrowths projecting caudad and slightly ventrad from the posterior lateral aspect of the pars cystica, considerably to the right of the median line (*pv*). One is several times smaller than the other and situated antero-ventrad to it. The latter is club-shaped and about three to four times longer than the smaller one.

The second morphologic feature of interest is observed in the model of embryo G (Fig. 4). Both embryo D and embryo G belong to stage 4 in the development of the hepatic proton, but embryo G is decidedly the more mature as respects the liver proton and probably also as regards the ventral pancreas. It subsists in a solid, single, and somewhat conical extrusion of cells placed in the median line, dorsal to the gall-bladder and ventral to the intestine. Although the ventral pancreas in this case is single, it is not simple, because a laterally bilobed condition is present. Moreover, these two lobes stand in the same relation that obtains between the two separate projections of embryo D; that is, the right lobe arises more

anteriorly and is slightly ventral to the left, which is closely limited to the posterior aspect of the proton.

The most mature form of the ventral pancreas, furnished by embryo E, the oldest one studied, is that of a long narrow solid outgrowth of cells which is not bilobed. At the distal end it is inclined slightly upward and apparently toward the right side of the transverse intestine above it.

If the various forms of the ventral pancreas in this small series represent successive changes in its growth, it has originated by two solid diverticula at first situated posteriorly on the right side of the pars cystica. These later have occupied the posterior surface in the median line by shifting posteriad, and have fused into one outgrowth by approximation. Furthermore, this fused pancreatic proton has increased in length posteriad and dorsad toward the right aspect of the intestine. Wlassow (95) discovered in the pig merely a single outbudding from which the ventral pancreas was derived.

HISTOGENESIS

The simple, smooth wall

In stages 1 and 2, as above defined, the external surface of the protonic wall is nearly smooth. This smooth wall includes a varying portion of the proton in all stages described in this paper. Its histological structure provides the basis for the more highly specialized formations that constitute the liver.

In stage 1, the intestinal epithelium is composed of a single layer of short columnar cells. Where the intestine becomes continuous with the hepatic proton, an immediate alteration in the cell-arrangement and in the thickness of the wall is evident.

Not only has the wall of the proton differentiated from the intestinal wall in (1) cell-arrangement, and in (2) thickness, but also in (3) plasma-staining properties. Where the protonic wall has been developing the glandular structure, Ehrlich's acid haematoxylin, picric-acid, and other plasma stains give a deeper coloration to the plasmatic portion of the liver cells than to any other tissue contiguous. Nuclear stains also take avidiously. When surrounding tissues are well stained, the liver is liable to be over-stained. Stages 1 and 2 do not exhibit this peculiarity in plasma-staining as much as those more advanced, nor does the posterior portion of the proton

indicate it so markedly as the anterior, because the more differentiated the tissue is, the deeper it stains. The pars cystica shows it little, if any.

Stage 1 (Fig. 7). The free yolk-stalk border of the proton is composed of a single layer of cuboidal or polyhedral cells (*cc*). Next to the margin of cuboidal cells is a region of short columnar or wedge-shaped cells (*csw*). Then, more distal from the free border where mural thickness increases, they are longer and more closely packed. Where the wall gains its average diameter, they are slender wedge-shaped cells, generally spanning from surface to surface (*chw*).

At intervals, polyhedral cells with spherical nuclei are found adjacent to the inner surface. They are often observed in process of mitosis. In fact, most of the karyokinesis in the proton is near this surface and in these cells (*cm*).

The nuclei of the marginal cuboidal cells are generally spherical; of the columnar and wedge-shaped cells the nuclei are generally oblong or ovate; and the longer the cells, the longer their nuclei are.

Since so many of the long cells, even in the thickest part of the wall, span its entire width, one can hardly demonstrate that more than a single cell-layer exists in the proton wall. But wherever the wall is composed of columnar or wedge-shaped cells, there are at least two regions corresponding to the mural surfaces and characterized by peculiar cell-structure and arrangement. The regions are (1) the inner, where the inner extremities of the long wedge-shaped cells and the polyhedral cells with spherical nuclei are found; and (2) the outer, made up of the outer, nucleated extremities of the long wedge-shaped cells. Of these regions, the former occupies about one-fourth the diameter of the protonic wall, and karyokinesis is more common in it than in the latter, which constitutes the remaining three-fourths of the diameter.

The nuclei of the long cells are in three more or less definite series or rows, where the wall is of ordinary thickness, and in two rows in the tapering portion of the wall composed of short, wedge-shaped cells. As regards the three rows of nuclei in the former region, those of the inner row are approximately ovate. Their narrower end points outward and is often located between the inner extremities of two nuclei of the middle row (Figs. 7, 8, and 17, *ni*).

The nuclei of the outer region are of similar shape. Their inner extremity is the narrower and lies between the outer ends of nuclei of the middle region (*no*). The nuclei of the middle region are oval or ovate, tapering at either or both ends. Thus the nuclei of the long cells are observed to dove-tail with each other. As regards the two rows of nuclei in the latter region of the wall, they are more rotund and dove-tail with one another near the middle of the mural diameter. Aside from this general tendency toward serial variations in form and arrangement, some spherical or oval nuclei are evident everywhere, especially in the inner and outer series.

Stage 2 (Figs. 8 and 17). The principal differences in the histology of stage 2 and of stage 1 are observed in (1) a much more rapid transition from the thin yolk-stalk border to the normal thickness, and in (2) the greater thickness of the wall, involving an increase in the length and number of cells and nuclei.

Stages 3 and 4. The histology of the wall in these subsequent stages varies only in minor details from that in stage 2. Of course, the tapering yolk-stalk border is absent. The mural thickness may or may not be greater. If it is considerable, there may be more than three rows of nuclei evident. The typical arrangement is less conspicuous because of the increasing multiplicity of secondary changes incident to the developing glandular structures.

Development of the glandular structure

Potential evagination. The incipency of gland development is very evident, even in stage 1. It is indicated by a peculiarity of arrangement among the nuclei of the long wedge-shaped cells. At the indicated place on the figure (Fig. 7, *ep*), six nuclei form a little arch, its base resting on the inner surface and its vault reaching to the outer surface of the wall. The cup-shaped cavity of the arch is filled with the cytoplasmic inner extremities of the cells possessing the nuclei which compose it. These cells and their nuclei are perpendicular to the surfaces. The cells themselves are not peculiar, excepting as regards the collective arrangement of their nuclei. Furthermore, this structure is entirely within the wall at its ordinary thickness. Nothing can be observed of it superficially. It is a potential evagination. Probably even a much earlier condition of this is found among the layer of short, columnar cells, in the taper-

ing yolk-stalk portion of the wall (Fig. 7, *op*). Here four or five spheroidal and oval nuclei form a very low arch.

It seems that the conditions for the development of the potential evagination are found in (1) the chaotic distribution of nuclei in the thin margin of the wall, two contiguous nuclei seldom being at exactly the same level; (2) in the variable size of nuclei; and (3) in the difference of their surface contour. With these three conditions present, it is easy to see that where the cells and nuclei begin to crowd each other closely, as at (*ep*), not only do the cells elongate, but also the nuclei arrange themselves serially. The serial accommodation is probably accomplished by the nuclei moving toward the inner or the outer surface, wherever pressure directs them. The formation of arches is one of the possible and apparent results of pressure on the nuclei so conditioned.

But these factors do not explain why the arches always take the form of evaginations, and seem never to construct invaginations. Perhaps another factor is physiological, in that the source of nutriment is from the outer surface where the blood-spaces of the septum transversum bathe the proton with nutrient fluid (Figs. 14 and 15, *sn*). That this conjecture may be of importance is supported by the fact that, in general, nuclei are in that part of the cell wherein physiological activity is greatest, and by the fact that the nuclei in the proton tend to be and are in large part near the outer extremity of their cells. The mechanical conditions of pressure on each side of the wall undoubtedly differ. On the lumen surface there is simply free fluid which presumably exerts an equal hydrostatic pressure at all points. On the other side there is not only fluid pressure, but also a framework of fixed tissue which furnishes some support at numerous points and at other places provides very little resisting power to counter pressure. Yet it seems that other factors are involved, because the *pars cystica*, developing under apparently similar conditions, does not form glandular structures.

The more advanced potential evaginations, such as stage 2 furnishes, are deeper, and more cells take part in their make-up (Figs. 8 and 17, *ep*). The cells of every advanced evagination, with the exception of those in the central axis of each, do not extend perpendicularly to the mural surfaces, but are disposed obliquely to them. They are oblique to the central axis, so that their outer ends are more distal to it than are their inner ends which are directed

toward it, and aid in filling with cytoplasm the cup-shaped cavity of the arch. The more mature the potential evaginations are, the more pronounced as a rule, is this obliquity of the peripheral cells and their nuclei. Where the axis of the evagination meets the inner surface of the proton, small, sharply-defined indentations sometimes occur.

Papilla-formation. Papillae, varying in form, project from the external surface of the pars hepatica, and perhaps also from contiguous areas of the pars cystica. Even in stage I a few very low rudimentary papillae are noticeable. These papillae are simply a higher development of the glandular structure. What have been observed to be potential evaginations are the prototypes of exuberant evaginations, the papillae. That is, the papillae or exuberant evaginations are the second morphologic aspect of the gland-formative process. Histologically, three modifications of the papillae are easily recognizable. Each represents a certain degree of maturity.

The least mature papillae (Fig. 7, *p*) differ from the potential evaginations only by virtue of their columnar or wedge-shaped cells being longer than the longest cells of the wall at its ordinary thickness. They exceed them in length by the extent that the papillae project from the outer mural surface.

The more mature papillae possess longer cells composing the core about their central axis. Often some of the cells are spatulate; their long, slender inner extremities reaching across the wall to its inner surface (Fig. 9, *p*²), converge more uniformly and sharply toward the central axis than in younger papillae. The most peripheral cells are long, wedge-shaped, or slightly spatulate. To reach the outer surface, they bend obliquely away from the central axis at that extremity, and are no longer straight (Fig. 9, *p*², *clw*).

The most mature papillae are longer than others (Fig. 18). The cells of the axial core are extremely long and spatulate. They are approximately straight and parallel with the papillary axis. Their long, slender inner ends often taper apparently to hair-like processes, and it is doubtful if those most centrally situated reach as far as the inner surface. In most sections some of them do not appear to. The change of cellular outline from wedge-shaped to spatulate has invaded the peripheral portion of the papillae from the axial core outward, and all cells, with perhaps the exception of a few most peripheral, are spatulate. The expanded outer extremi-

ties of the peripheral cells bend to a much greater degree than in the less mature papillae, and may be almost at right angles to their slender inner ends. There is a tendency for this bend to be sufficient for the cells to meet the curving papilla-surface at right angles.

The shape of the nucleus does not change appreciably when a cell develops from the wedge-shaped to the spatulate form. But in the expanded outer end of the spatulate cells which form the apices of the most mature papillae, the nuclei are somewhat spherical. All cells which, in later stages of normal development, are superposed on these apical spatulate cells, are polyhedral and possess spherical nuclei. Such polyhedral cells with spherical nuclei, are characteristic of the rods constituting the subsequent glandular structure of the liver. Their presence marks the end of the papilla form of evagination and the beginning of the rod-formation (Fig. 18). Perhaps the first few polyhedral cells are modified spatulate cells which have assumed this shape by a progressive shortening of their attenuated extremities.

Rod-formation. The ordinary growth of the rods, so far as traced, is characterized by cell-proliferation, and by the arrangement of these cells according to a certain type; by the extension of the rods into the septum transversum; by their branching; and by the resolution of these branches into a network of rods.

The size of the rods at their base depends very largely on the size of their antecedent potential evaginations and papillae. If a rod springs from a very wide papilla (Fig. 15, *pw*), the rod is broad. A cross-section of such a one shows a circloid area composed of twenty or more polyhedral, cuboidal, or short columnar cells, arranged in a single row about a common center. At the center a small lumen is often apparent. The nuclei of the polyhedral cells are spherical; of the columnar cells, slightly oval. They always tend to be distributed at the peripheral side of the cells. If a rod springs from a very slender papilla (Fig. 15, *ps*), it is correspondingly slender and has much the same structure in section that the broad rod exhibits.

Obstruction to growth modifies the form of the rods and of their cells. When a simple rod grows into the septum transversum between blood-vessels, where there is room for its unthwarted extension, it develops typically a straight cylinder with rounded distal extremity (Fig. 15, *r*). When its distal end rests against a

blood-vessel (Fig. 15, *r*), or between vessels offering obstruction to extension, this extremity is apt to be excessively thick, and the cells composing it are usually columnar instead of polyhedral. The longitudinal median section of a rod obstructed on one side by a vascular space is constituted on that side of well-developed columnar cells, whereas the opposite side, which suffers less obstruction, is composed of nearly cuboidal or polyhedral cells (Fig. 20).

After the simple rods have grown outward a short distance, they bifurcate. These branches also subdivide. By progressive extension and subdivision, each original simple rod grows into a dendritic system, of which it is the trunk.

In this tree-like system, the more distal the branches, the smaller they are. Some are merely strings of single cells placed side by side (Fig. 16, *r'*). Thus, branches may contain in a cross-section from a single cell to twenty or more. Most branches show from five to eight cells (Fig. 16, *rs*), about a very small central lumen. The central lumen can be traced very nearly to the internal surface of the protonic wall, in some instances (Fig. 20). The trunks of these dendritic systems and the more immediate branches of them, are more apt to contain columnar cells than are other branches.

Among the columnar cells of the large rods are often found potential evaginations and papilla-formations (Fig. 16, *re*). These phenomena incident to rod-outgrowths are common in certain parts of rods that have thickened by virtue of obstruction to extension.

The dendritic arrangement is never isolated and perfect. Before many bifurcations have occurred, the rods fuse end to end with those of the same and of contiguous systems, forming a net-work. In stage 4 the net-work is the most conspicuous portion of the developing liver (Fig. 14).

Relation of vascular spaces to glandular development.—The protonic wall is almost always separated from the blood-spaces by an interval filled with mesenchyme. Sometimes a vessel touches the proton, but never does one penetrate the wall in any degree (Figs. 15, 19, and 20). The papillae and simple original rods sustain a similar relation to the sinuses (Figs. 14 and 16).

When the network of rods is formed, its meshes enclose a network of blood-spaces, of which the larger near the protonic wall come in close contact with the rods at many points (Fig. 14, *m*). In the peripheral parts of the septum transversum the spaces are

small, capillary-like, and more numerous. Between them the separate distal branches of the rods lie. Here also the vessels and rods are separated by mesenchyme (Fig. 14, *sn*). As the development of the glandular net-work progresses, the vascular spaces near the proton seem to increase in caliber and come into closer relation with the rods (Fig. 14, *sn*).

The bifurcation of a rod seems always to be conditioned by the close proximity of a vascular space to its distal end (Figs. 14 and 16, *bf*). The two branches generally extend beyond the vascular space in V shape. Division generally occurs before the rod is in direct contact with the vascular space. When division occurs in proximity to a large vascular space such as the sinus venosus, the two resulting branches spread out at approximately right angles to the parent-stem.

Other authors on histogenesis, and comparisons

The most interesting deviation of the results of this research from those of other authors on mammalia devolves about the relationship of the vascular system in the septum transversum to the trabeculation of the glandular structures derived from the primitive protonic wall. A second important difference rests in the phenomena described concerning the method and direct results of the gland-formative proliferation. As to the method of the gland-formative proliferation, no details concerning the collective variations of form and arrangement peculiar to cells and their nuclei in the potential evaginations and in the papillae, have been described.

In regard to the direct result of proliferation from the proton, His describes the formation of a "kompakte Leberanlage" which is later formed into a net-work. Brachet confirms this statement by the terms "epithelialen Zellhaufen" and "kompakte Masse der Leberzellen" (vide extracts under "Morphogenesis"). Hammar also gives expression to the same idea.

But no "kompakte Leberanlage" has been evident in the embryonic pig liver as here described. The rods of cells are morphologically distinct from their incipency and, as a rule, remain separate. If a "kompakte Leberanlage" is evident on the wall of the proton, it is due to secondary fusion.

The relationship of the vascular system to the trabeculation of the gland-formative cells, as expressed by Shore (91) and by Brachet

(96), is that blood-vessels penetrate the "kompakte Leberanlage" and break it up into a net-work of rods. The following quotation from Brachet (96) illustrates the point in question:

"In der grossen Mehrzahl der Fälle entwickelt sich diese Netz durch ein Eindringen von Kollateralen, die den Gefässen der Nachbarschaft und zwar hauptsächlich den Venae omphalo-mesentericae entspringen, in die kompakte Masse der Leberzellen, die durch Proliferation aus der primitiven Leberanlage entstanden ist."

According to the results of this research, however, the net-work of rods in the embryonic pig is formed independently of the active intervention of vascular spaces. The rods springing from the protonic wall grow into the septum transversum apart from the direct contact of vascular spaces. Many times they grow out where there are no vascular spaces anywhere near. The rods extend between the vascular spaces already present in the septum, and thus are kept separate from one another. Their individuality is retained typically, except when some of their advancing extremities meet and fuse. The entrance of vascular spaces into the hepatic tissue plays no active part in trabeculation of the gland, because they never penetrate into the proton or into the individual rods derived therefrom. Furthermore, the organization of the glandular elements is seen within the original wall, before any external manifestations of them are visible.

The vascular spaces limit and determine the possible direction of rod growth. They are also passively concerned in making the network, in that they facilitate subdivision by offering obstruction at the free ends of rods, thus making it convenient for them to branch in order to extend themselves.

In short, the hepatic tissue, instead of being grown into by the vessels, grows out and extends among and around them, although by virtue of increases in caliber, the vascular spaces actively change the location of rods.

Fusion of rods: Collateral growth: Disorganization

The importance of the vascular spaces in keeping the rods separate is very obvious when it is noted how prone they are to fuse into a more or less homogeneous mass, where they run together in avascular areas (Fig. 14, *rc*).

That which, to some extent, resembles the "kompakte Leberanlage" of His is found in some embryos. It is best demonstrated in about stage 3 on the anterior wall of the proton, immediately posterior to the sinus venosus (Fig. 19). It is produced by the collateral outgrowth of a number of closely approximated rods into an almost avascular space. Since the region is practically avascular, and the rods contiguous, there arises a mass of tissue which produces a considerable thickening of the wall. But it is by no means a heterogeneous mass. It is a collection of contiguous rods. Their close approximation encourages fusion and more or less disorganization. In the figure cited, vascular spaces are apparently penetrating this collection. They are always between individuals of the collection. Therefore, they do not convert the outgrowth into rods, since the latter are already complete organizations, as can be observed by tracing each to its fundamental, histological arrangement within the protonic wall. The vessels simply separate the individuals from each other. Some of the evagination-formations at the bases of the rods are not illustrated as clearly in the figure given as in adjoining sections of the series.

Problems in trabeculation

There are some especially intricate problems in regard to the relation of the vascular system to the hepatic structures. Some of these problems could not be explained by direct demonstration. For instance, when a vessel is entirely surrounded by hepatic tissue it is often impossible to get a clew that will determine whether the vessel has grown into the hepatic structure, or has been surrounded by it. But, in certain cases, at a little distance from the circumference of the vessel, the site of the bifurcation of a rod has been seen; the two branches of the rod constituting the tissue which envelops the vessel. A very interesting example of a similar condition is conspicuous in cases (Fig. 10, 511), wherein a vessel at the outer border of the protonic wall is completely enveloped in a dense mass of hepatic tissue. That this vessel lies between two rods which were originally separated is demonstrated by the fact that in the wall on either side of the vessel are found the characteristic evagination-structures from which rods have sprung. The evagination to the right of the vessel discussed is not very evident in the figure, but is plain in an adjoining section of the series.

Whenever a rod becomes surrounded by a vascular space, it is impossible to decide whether the rod has pushed its way in, or whether the vascular space has expanded down over the end and sides of it (Fig. 15, r).

In case a vessel appears within a disorganized mass of rods, it is absolutely impossible to demonstrate what relation it has sustained to them.

Absence of the vaso-formative cells of Van der Stricht

Two forms of cells are described in the embryonic liver by Toldt and Zuckerkandl (75), and by Van der Stricht. One kind is the polyhedral cell with granular protoplasm. The other kind is a round cell with clear cytoplasm. The following quotation from Brachet (96) describes the two forms of which the round, clear type is said to be vaso-formative and the source of an intra-trabecular network of blood-vessels.

“Was nun den histologischen Aufbau der Lebertrabekel anlangt, so bestehen sie nach Toldt und Zuckerkandl aus zwei Zellarten. Die einen sind die eigentlichen Leberzellen von kubischer oder polyëdrischer Gestalt, mit granuliertem Protoplasma und grossem Kerne; die anderen sind klein, rund und besitzen kein gekörntes Protoplasma.

“Toldt und Zuckerkandl hatten diese letztere Zellform hauptsächlich im vierten Monat ausserordentlich reichlich angetroffen. . . .

“Van der Stricht und Kostanecki haben jedoch geltend gemacht, dass die runden, hellen Zellen Toldts und Zuckerkandls nichts anders als Erythroblasten sind, welche die Maschen des intratrabekulären Gefässnetzes behaupten.”

It was impossible to find any small, round, clear cells in the stages of development which were studied, with the exception of erythroblasts in the sinuses and capillaries.

The gall-bladder wall

The gall-bladder wall in the stages discussed partakes of a histological arrangement similar to that described under the simple smooth wall. It is relatively thicker than that portion of the proton constituting the pars hepatica, and the columnar cells are therefore longer.

LIST OF EMBRYOS CITED IN THE TEXT

Embryo	Protovertebrae	Corresponding Embryo of Keibel's Chart	Age
X ¹	19	8	17 days.
S	21	9	16½ "
J	21-23	10	16-17 "
P	26-27	10-11	16½ "
K	27-(28)	11	16½ "
F	28	11-12	16½ "
D	30-31	12	17½ "
G	32	12	17½ "
E	37	14	20 "

BIBLIOGRAPHY

BRACHET, A.

96. Die Entwicklung und Histogenese der Leber und des Pankreas. Anatomische Hefte, Bd. VI.

BRAUS, HERMAN.

96. Untersuchungen zur vergleichenden Histologie der Leber der Wirbelthiere. Habilitationsschrift mediz. Fakult. Jena.

BRUN, A. VON.

94. Leber und deren Entwicklung. Anatomische Hefte, Bd. IV.

FOSTER AND BALFOUR.

93. Elements of Embryology.

FELIX, WALTER.

92. Zur Leber und Pankreas-Entwicklung. Arch. für Anat. u. Entwickl.

HAMMAR, J. AUG.

97. Ueber einige Hauptzüge der ersten embryonalen Leberentwicklung. Anat. Anzeiger, Bd. XIII.

98. Zur Kenntniss der Leberentwicklung bei Amphioxus. Anatomischer Anzeiger, Bd. XIV.

HEISLER, J. C.

99. Elements of Human Embryology.

HIS, WILLIAM.

81. Zur Embryologie der Säugthiere. His' Archiv. (Quoted from C. S. Minot's Human Embryology.)

KEIBEL, F.

97. Normentafeln zur Entwicklungsgeschichte der Wirbelthiere, I.

KOSTANECKI.

92. Die embryonale Leber in ihrer Beziehung zur Blutbildung. Anatomische Hefte, Bd. I. (Consulted in Brachet's Resume, '96.)

KÖLLIKER, A.

79. Entwicklungsgeschichte des Menschen und der höheren Tiere. Zweite Auflage. (Consulted in Brachet's Resume, '96.)

MINOT, C. S.

97. Human Embryology.

98. On the Veins of the Wolffian body in the Pig. Proc. Bost. Soc. Nat. Hist., Vol. XXVIII, No. 10.

PETERSON, O. A.

99. The Early Development of the Liver in the Pig. Thesis, Library of the University of Nebraska. (Unpublished.)

SHORE, T. W.

91. Notes on the Origin of the Liver. Jour. of Anat. and Physiol.

TOLDT AND ZUCKERKANDL.

75. Ueber die Form und Texturveränderungen der menschlichen Leber während des Wachstums. Sitzungsber. d. Kaiserl. Akad. d. Wissensch. Wien. (Consulted in Brachet's Resume, '96.)

WLASSOW.

95. Zur Entwicklung des Pankreas beim Schwein. Morpholog. Arbeiten, herausg. von Schwalbe, Bd. IV.

EXPLANATION OF PLATES

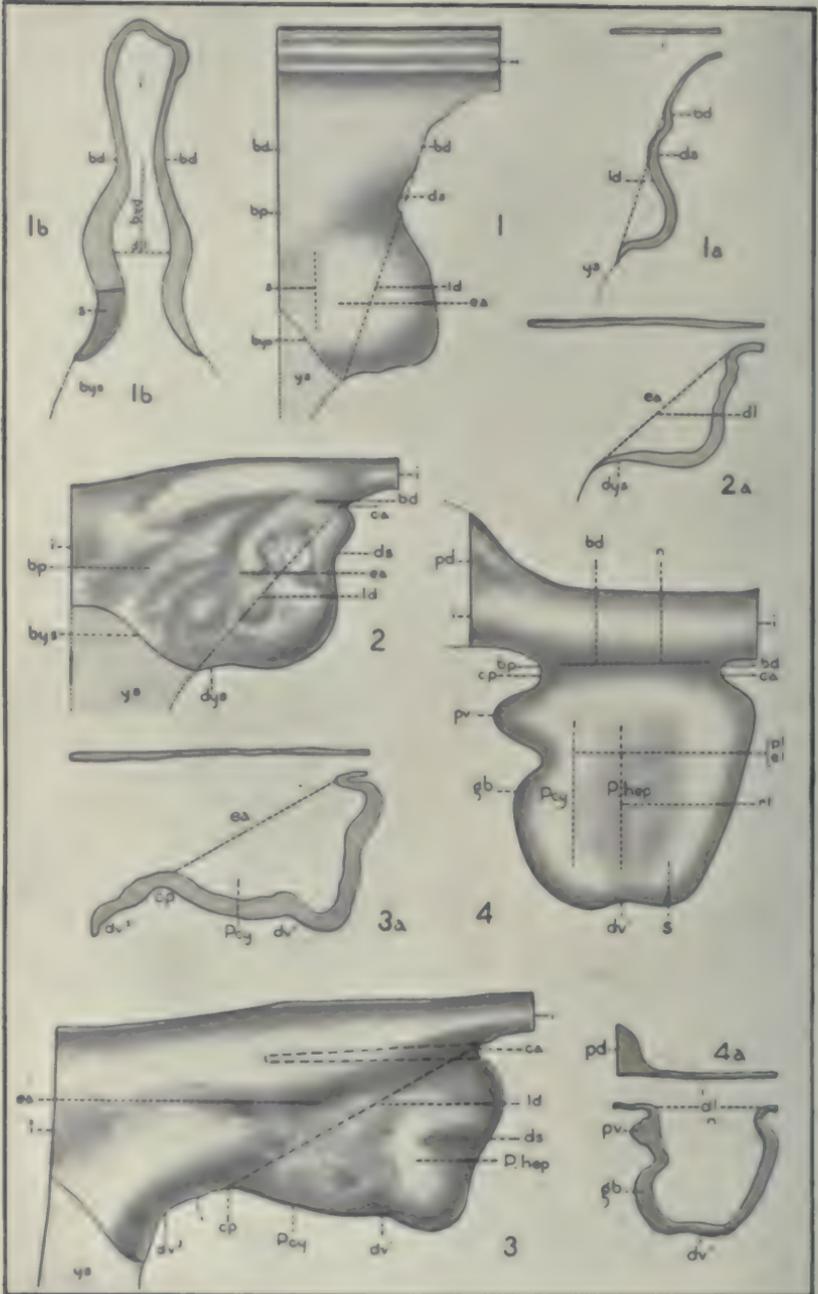
All drawings of sections were made with a camera lucida. The finest details were determined by a Zeiss microscope.

ABBREVIATIONS

<i>bd</i>	Dorsal border.	<i>n</i>	Neck of proton.
<i>bf</i>	Bifurcation.	<i>ni</i>	Nucleus of inner region.
<i>bp</i>	Posterior border.	<i>nm</i>	Nucleus of middle region.
<i>bys</i>	Yolk-stalk border.	<i>no</i>	Nucleus of outer region.
<i>ca</i>	Anterior constriction.	<i>p¹⁻²⁻³</i>	Papilla.
<i>cc</i>	Cuboidal cells.	<i>pd</i>	Dorsal pancreas.
<i>cm</i>	Mitosis-cells.	<i>ph</i>	Prehepaticus.
<i>clw</i>	Long wedge-shaped cells.	<i>P hep</i>	Pars hepatica.
<i>csw</i>	Short wedge-shaped cells.	<i>P cy</i>	Pars cystica.
<i>cp</i>	Posterior constriction.	<i>pl</i>	Papilla limit.
<i>d¹⁻²⁻³</i>	Diameters.	<i>ps</i>	Slender papilla.
<i>dl</i>	Lateral dimensions.	<i>pv</i>	Wide papilla.
<i>dvd</i>	Dorso-ventral dimensions.	<i>pv</i>	Ventral pancreas.
<i>ds</i>	Anterior (sinus) depression.	<i>r</i>	Rod.
<i>dv¹</i>	Anterior ventral depression.	<i>rc</i>	Collateral rods.
<i>dv²</i>	Posterior ventral depression.	<i>re</i>	Rod-evagination.
<i>el</i>	Evagination-limit.	<i>rs</i>	Rod-section.
<i>ea</i>	Alar extension.	<i>rl</i>	Rod-limit.
<i>ep</i>	Potential evagination.	<i>rt</i>	Right.
<i>gb</i>	Gall-bladder.	<i>s</i>	Section.
<i>ha</i>	Dotted line indicated in rabbit.	<i>sv</i>	Sinus venosus.
<i>ht</i>	Heart.	<i>sn</i>	Sinus-network.
<i>i</i>	Intestine.	<i>v</i>	Ventral.
<i>itr</i>	Transverse intestine.	<i>vs</i>	Umbilical vein.
<i>l</i>	Left.	<i>vv</i>	Vitelline vein.
<i>ld</i>	Division-line.	<i>ys</i>	Yolk-stalk.



PLATE III



86

PLATE IV.

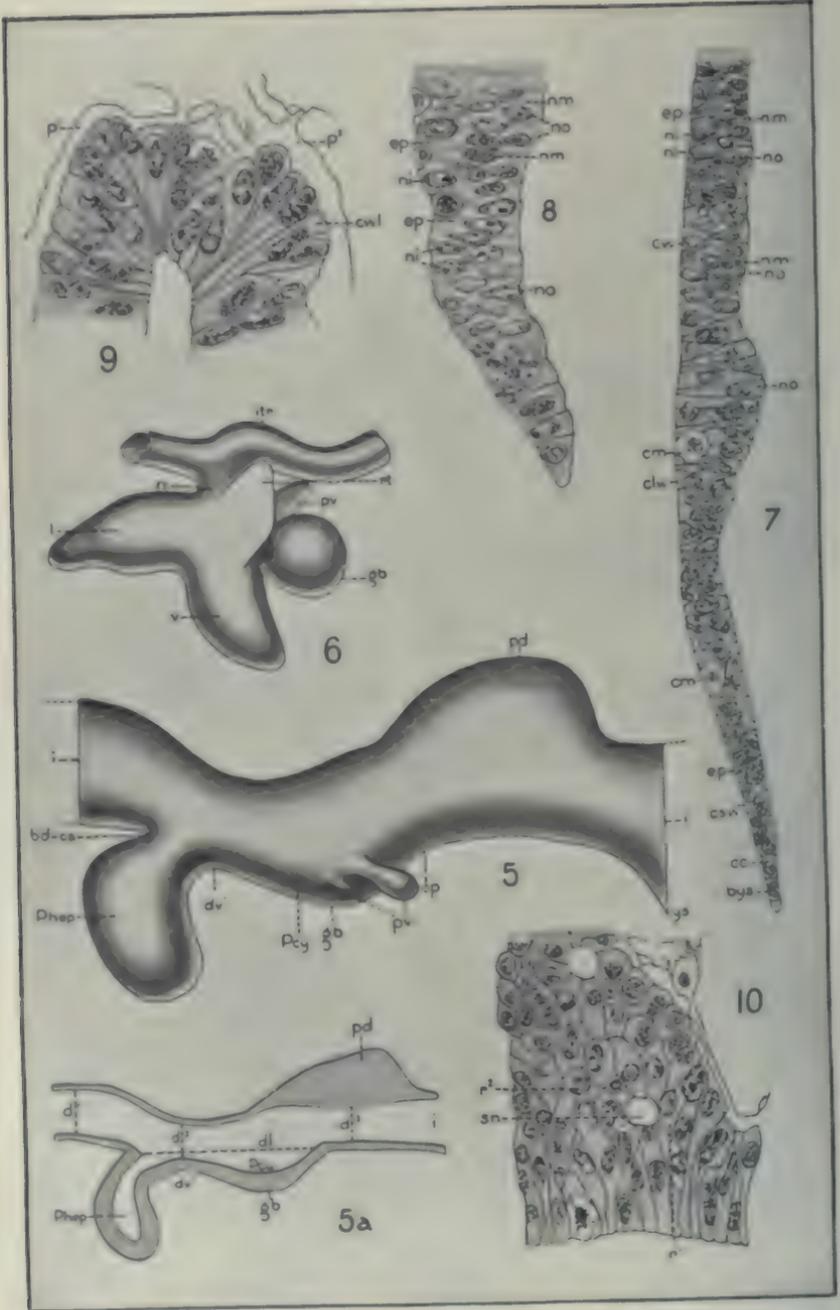


Plate III

Fig. 1. Lateral aspect of a model of the hepatic proton and adjoining intestine of embryo S, stage 2. About 50 X.

Fig. 1a. Median sagittal section of the same.

Fig. 1b. Transverse section of the same, taken at Fig. 1, s.

Fig. 2. Lateral aspect of a model of the hepatic proton and adjoining intestine of embryo J, stage 2. About 50 X.

Fig. 2a. Median sagittal section of the same.

Fig. 2. Lateral aspect of a model of the hepatic proton and adjoining intestine of embryo K, stage 3. About 65 X.

Fig. 3a. Median sagittal section of the same.

Fig. 4. Lateral aspect of a model of the hepatic proton and adjoining intestine of embryo G, stage 4. About 65 X.

Fig. 4a. Median sagittal section of the same.

Plate IV

Fig. 5. Lateral aspect of a model of the hepatic proton and adjoining intestine of embryo D, stage 4. About 75 X.

Fig. 5a. Median sagittal section of the same.

Fig. 6. Right anterior aspect of the model of the proton of embryo E. About 35 X.

Fig. 7. Median sagittal section of embryo X¹, through the central half of the proton, exhibiting histogenesis in stage 1. 400 X.

Fig. 8. Transverse section through the ventral portion of the left alar extension of the proton in embryo S, showing histogenesis in stage 2. 400 X. (The position of it is represented by Figs. 1 and 1b, s.)

Fig. 9. A transverse section of a fold in the protonic wall of embryo P, presenting cell-arrangement and incipient evaginations, 500 X.

Fig. 10. A portion of a median sagittal section of the proton of embryo K. 400 X.

Plate V

Fig. 11. Median sagittal section of embryo X¹, stage 1. 20 X.

Fig. 12. Median sagittal section of embryo J, stage 2. 20 X.

Fig. 13. Median sagittal section of embryo K, stage 3. 20 X.

Fig. 14. Transverse section through the protonic area of embryo G, presenting stage 4. 40 X.

Fig. 15. Transverse section of embryo P through its protonic area, illustrating the histology and morphology in stage 3. 100 X.

Fig. 16. Sagittal section of embryo D through its proton, stage 4. 100 X.

Plate VI

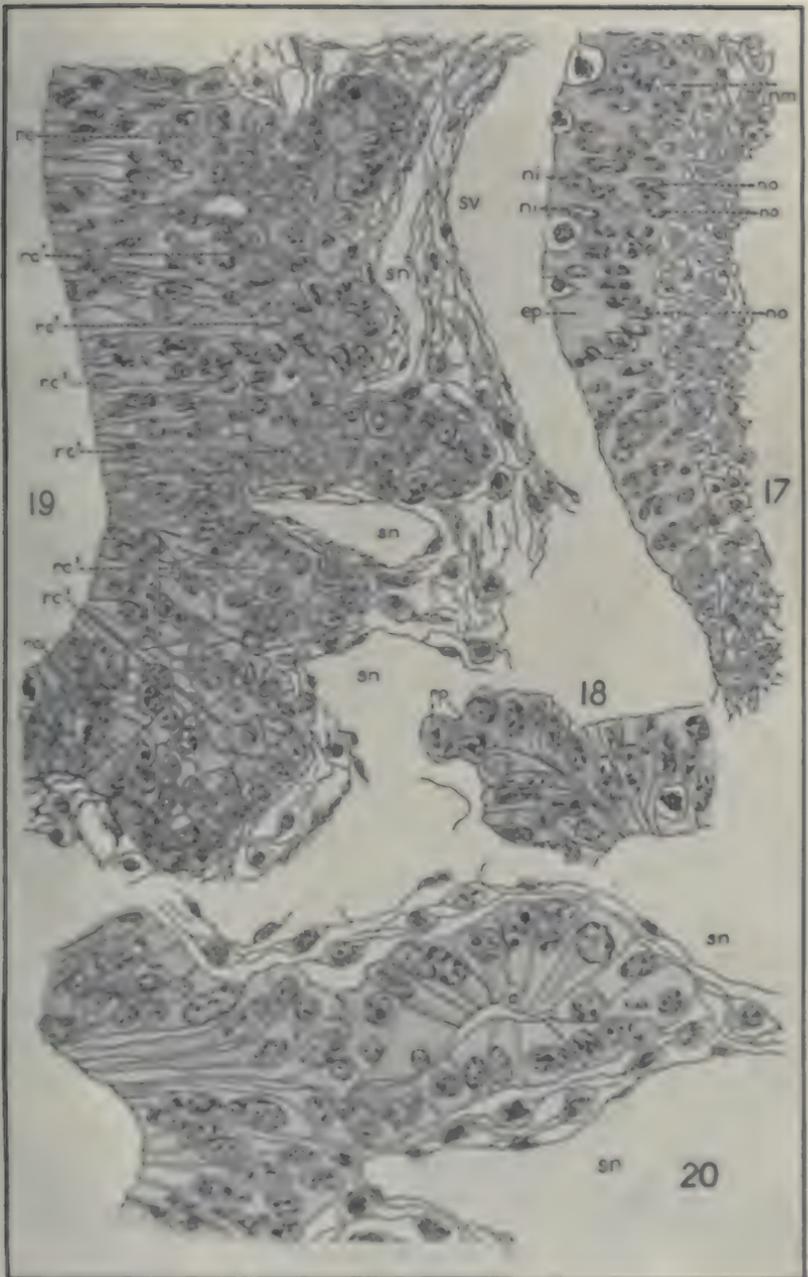
Fig. 17. A section similar to Fig. 8, taken slightly more anteriorly. 400 X.

Fig. 18. A transverse section from the protonic wall of embryo P, showing cell-arrangements in the period of transition from a papilla to an incipient rod. 500 X.

Fig. 19. A section similar to that of Fig. 10, taken immediately caudad and ventral to the sinus venosus. (The nearest approach to a "Kompakte Leberanlage.") 400 X.

Fig. 20. A transverse section of a portion of the protonic wall of embryo D, depicting a short rod, and exhibiting its relation as regards cell-arrangement and direction of growth to the near lying vascular spaces. 600 X.

PLATE VI.



CULTURAL STUDIES OF A NEMATODE ASSOCIATED WITH PLANT DECAY

By HAVEN METCALF

WITH ONE PLATE

It is well known that various nematodes are associated with plant disease; but aside from the gall-forming species, very few have been described from the standpoint of the plant pathologist. In descriptions of cases of root rot, joint rot, and "damping off," particularly such as are associated with fungi of the form-genus *Fusarium*, the presence of nematodes is frequently noted. The suspicion is often expressed that the nematode, rather than the fungus, may stand in a causal relation to the disease. But so far as I have been able to ascertain, no work has been done to demonstrate conclusively the relation of nematode to rot in any given case.

OCCURRENCE

My attention was first called to this species by Mr. J. L. Sheldon of the department of botany of the University of Nebraska, who noticed nematodes in great numbers in corms and young stalks of *Crocus*, which were affected with a soft rot; a *Fusarium* and bacteria were also present. In order to separate the fungus, poured plates were made with asparagus juice agar. To my surprise, not only the fungus and bacteria developed in the plate, but also, after about ten days, the nematodes. When first noticed, only three individuals were seen, but these multiplied until in about thirty days from the time of pouring the plate, the agar was fairly alive with nematodes, of all degrees of development. Trial inoculations of fresh tubes and plates showed that the nematodes could be grown readily by certain culture methods.

The same nematode was later isolated from cuttings of *Petunia*, *Coleus*, and *Geranium* which "damped off" in the green-house. In each case *Fusarium* was also found. In a number of sugar beets rotting with a characteristic bacterial rot nematodes were found

(Hedgcock and Metcalf, 1903); also in the late stages of the rot of potatoes caused by *Stysanus stemonitis* (Bessey, 1902). These potatoes were on sale in the markets of Lincoln, Nebraska, and were said to have been raised in Minnesota. The sugar beets were from Ames, Normal, and Grand Island, Nebraska. The bulbs and cuttings were from the green-houses of the University of Nebraska. Through the kindness of Mr. P. H. Rolfs, I have been able to examine certain *Coleus* plants from Miami, Florida, which were affected with some sort of root gall. From these galls no fungus nor animal parasite could be isolated, nor anything that would directly account for the abnormal growth. But about the galls considerable numbers of this nematode were found. Upon roots of the "iron pea" affected with a characteristic, but hitherto unstudied root rot, I have further found the same nematode in great numbers. The plants examined were from various points in Darlington, Orangeburg, and Oconee counties, South Carolina. The root rot in question is, in every case that I have observed, associated with a *Fusarium*, and the nematodes are always present. From these observations it seems probable that the nematode is widely distributed.

STRUCTURE AND CLASSIFICATION

Only female forms have been observed in cultures or in decaying plant tissue. Culture experiments show that these female forms are sexually self-sufficient; isolated specimens develop from the egg, and produce eggs, which develop normally. No histological studies have been made, hence it is impossible to say with certainty whether the form is hermaphroditic or parthenogenetic. Observations of living worms and those stained *in toto* have not revealed the presence of spermatozoa.

The size of mature individuals is subject to considerable variation. The maximum length observed was 1.034 mm.; but specimens only 0.6 mm. have been observed with living larvae inside. Measurements of isolated specimens show that growth in length does not cease when egg production begins. The escape of larvae into the body cavity, however, results in the death of the parent. Detailed measurements of a mature individual of average size are as follows: length, 0.87 mm.; maximum width, 0.072 mm.; length of oesophagus, 0.19 mm.; length from anus to posterior extremity, 0.085 mm.; length of eggs, 0.036 mm.; width of eggs, 0.021 mm.

As the measurements show, the form is rather plump. From the middle toward the anterior end it tapers gradually, but from the anus to the posterior end rather abruptly, ending in a point. This portion is noticeably more attenuated and proportionally longer in the larva than in the adult. No rings or wrinkles are perceptible in the cuticula, which is perfectly transparent. The head end is blunt, with three lips, upon each of which is one very minute papilla (Figs. 3, 5). The buccal cavity is rod-shaped, of equal diameter at all points. Back of the buccal cavity the oesophagus is of nearly equal diameter for one third its length, then swells into an elongated bulb, which tapers gradually until it is scarcely larger than the buccal cavity. This portion then swells abruptly into the large globular bulb, which is supplied with a valvular apparatus. The intestinal wall is transparent in the adult, bright by transmitted light, with distinct cell boundaries and nuclei. At the point of juncture with the proctodaeum is a conspicuous cluster of large gland cells (Fig. 4).

The vulva is a trifle cephalad to the middle of the body (Fig. 3). The genitalia are very variable in extent and arrangement in different individuals; but approximately symmetrical. Sometimes the distal ends are reflected back towards the vulva; quite as often not. The posterior portion is most frequently reflected. Usually this does not extend for more than half the distance from vulva to anus; while the anterior portion usually extends to the bulb.

Development has not been studied, although no object could be more favorable for such study. Eggs are deposited in all stages of development, or if not deposited, the larvae develop in the egg, break out into the body cavity, where they continue to grow at the expense of the parent; ultimately breaking through the body wall. I have not been able to see that this process takes place at any particular period in the life of the parent. But sooner or later it seems to occur in every individual. Not always, however, does the escape of the larvae into the body cavity precede the death of the parent form; in a number of cases, the worm has died from some cause, and the escape of the larvae from the decaying genitalia and finally from the body occurred as a matter of course. Several worms containing eggs I have killed by mechanical means; in every case the fully formed eggs have continued to develop normally. Whether within or without the parent body, the larva may attain a length of

0.15 mm. before breaking out of the egg. At about this time the larva moults (Fig. 1); once again at about the time egg production begins.

While this form does not exactly correspond to any written description that I have seen, it is closely related to, if not identical with, the form described and figured by De Man (1884) under the name of *Rhabditis brevispina* Claus. The figures and measurements given by De Man agree substantially with mine; his description differs in certain particulars. According to him, "Das Kopfende . . . wird von drei, wenig hervorragende Lippen gebildet, auf welchen sechs sehr wenig vorstehende Papillen gefunden werden"; I have observed only three papillae. The vulva is located in the middle or slightly cephalad of the middle of the body in all forms that I have examined; according to De Man, "Die weibl. Geschlechtsöffnung liegt ein wenig hinter der Mitte." I have seen no caudal papillae; but according to De Man, "Der Schwanz . . . trägt eine laterale Papillae ungefähr in seiner Mitte." Aside from these particulars De Man's description of the female applies perfectly to the form under consideration.

The original description by Claus (1862) of what he terms *Anguillula brevispinus*, is meagre; so far as it goes, his description of the female applies to the form which I have; and as papillae are not mentioned, it is in agreement with De Man's description. Regarding the position of the vulva, Claus says: "Die Geschlechtsöffnung liegt so ziemlich in der Mitte der Liebeslange."

Claus and De Man both describe male as well as female forms. Bütschli (1873) describes and figures a female form which he considers to be *Rhabditis brevispina* Claus. He says: "Der einzige bemerkenswerthe Unterschied, welchen ich auffand, ist, dass die Ovarien meiner Thiere bedeutend weiter nach vorn, respective nach hinten reichten, als dies von Claus angegeben." But between different individuals of the specimens which I have examined I have found greater differences in the arrangement and extent of the ovaries than is shown in the figures of Bütschli, Claus, and De Man. Regarding Bütschli's description De Man says: "Die, von Bütschli . . . als *brevispina* beschriebene Art ist eine andere und unterscheidet sich besonders durch die mehr beträchtliche Ausdehnung der Genitalien und einen verhältnissmässig kürzeren Schwanz." But a close comparison of the figures of the three authors shows

that the tail of the female in De Man's figure differs as much in form from that depicted by Claus as that in Bütschli's figure does in length. Of the three figures, that of De Man most closely depicts the form that I have, in this as in other respects.

The form figured by Claus exhibits distinct differentiation of ovary, oviduct, uterus, and receptaculum seminis, such as is not shown in the figures of Bütschli and De Man. In the form that I have studied, there is no proper differentiation of ovary and uterus; the egg-producing and egg-retaining portions vary greatly in extent in different individuals (see Figs. 3 and 6).

Whether the forms described by the three authors are identical, and whether the form which I have described is identical with one or all of them, must be left for some other investigator to settle.

CULTURES

My first cultures were made merely for following out the life history of the nematode; no attempt was made to keep the cultures pure. The original plates of asparagus agar, inoculated from rotting corms of *Crocus*, contained a *Fusarium* and one or more species of bacteria in addition to the nematodes. Culture slides of the ordinary pattern were prepared by placing distilled water in the slide, and a small quantity of agar on the cover glass. On each cover glass was placed a single worm or a single egg; and the cover glass was sealed to the slide with vaseline. On account of the large number of worms and eggs in the original culture, and their small size, it was not an easy matter to isolate an individual. It was accomplished by shaking a small portion of the culture in a few cubic centimeters of water in a small test-tube and pouring the whole out over the surface of a Petri dish. The worms and eggs, separated in this way, could be easily located with a lens, and picked up with a brush without injury.

Fungi and bacteria developed in the cultures. In the decaying mass the nematodes grew rapidly, and so far as could be judged by comparing with specimens in the rotten plant tissue, normally. The limited air supply seemed to cause no difficulty; at least no difference could be detected in the behavior of worms in these culture slides and in aerated Van Tieghem cells or in Petri dishes. The following are notes taken upon a typical preparation:

- March 1, 1902. One egg, unsegmented, placed in a culture slide.
- " 2. Egg unchanged.
- " 3. Egg unchanged.
- " 4. Egg segmented, apparently fourteen cells.
- " 5. Egg further segmented.
- " 9. Embryo distinctly formed.
- " 11. Embryo moving about actively in egg.
- " 12. Embryo broken out of egg.
- " 13. Embryo moulting; proton of genitalia visible; worm 0.18 mm. long.
- " 14. Moulting complete.
- " 17. Proton of genitalia 0.032 mm. long, of female type (Fig. 2, a); worm 0.34 mm. long.
- " 20. Worm 0.56 mm. long; genitalia 0.15 mm. long, recurved at anterior end. Skin loose at both extremities.
- " 22. Second moulting complete; worm 0.56 mm. long.
- " 24. Three unsegmented eggs formed; worm 0.65 mm. long.
- " 25. Three eggs segmenting; six others formed.
- " 26. Four eggs deposited; worm 0.73 mm. long.
- " 27. Three more eggs deposited.
- " 28. Two eggs in anterior branch of genitalia segmenting.
- " 30. Eggs further segmented.
- April 2. Embryos in eggs fully formed and active; eggs still within the genitalia.
- " 3. Embryos in eggs moving actively.
- " 4. Larvae broken through eggs and wall of genitalia, moving actively in posterior part of body cavity; parent worm not moving about, but alive and feeding as shown by characteristic motions of valvular apparatus of bulb. One larva measures about 0.15 mm. in length.
- " 5. Parent worm alive.
- " 6. Parent worm apparently dead; genitalia decaying; both larvae moulting.
- " 9. Both larvae still inside body of parent worm, of which only chitinous portions remain; both larvae have moulted; one measures 0.38 mm. in length; its genitalia extend one-sixth the length of the body.

- April 14. Both larvae escaped from skin of parent worm; the seven eggs deposited in the medium have developed; there are now nine worms in the culture; largest worm measures about 0.62 mm.; three worms have one or more eggs developing; preparation moist, but worms not moving very actively.
- " 15. Worms not moving or feeding; several coiled up.
- " 18. All worms more or less coiled; no motion.
- " 20. Condition unchanged.

Nothing further was done with this preparation. In another preparation where quiescence ensued in the same way, after forty-two days from the time the preparation was sealed, it was noticed that the worms were not dead,—at least they were not attacked by bacteria on the fifty-sixth day. Accordingly the preparation was opened and the worms transferred to a fresh Petri dish, where they revived and continued to develop and produce eggs. This quiescence has no relation to air supply, since after a certain time it ensued in Petri dishes and other aerated cultures. It is not improbably due to accumulation of waste products, *e. g.*, urea. Apparently nothing but new medium will revive the worms. This is probably to be correlated with the fact that the worms naturally move about over a large area, continually seeking a new substratum.

Up to the time that this quiescence begins to appear, the conditions in the cultures appear to be entirely normal. I have made elaborate comparisons of the nematodes in cultures with those growing under perfectly normal conditions in decaying plant tissue; apparently there is not a stage or condition occurring in cultures that cannot be matched, specimen for specimen, among those living naturally.

Methods of observation

The living worm is in constant motion, and is consequently difficult to observe with high powers of the microscope. On the other hand the living worm is transparent, while most killing media soon render some tissues opaque. Narcotizing the worms naturally suggests itself as a possible method of keeping the worms quiet for observation while retaining the transparency of life. With a 0.1 per cent solution of chloral hydrate and with a 1 per cent solution of cocaine hydrochlorate I had fair success; the only objection being

the slowness of action: worms treated with chloral do not entirely cease motion for thirty minutes. The most practicable method of preparing worms for observation was by treating them with a 0.01 per cent solution of mercuric chloride; death was practically instantaneous, and the worms did not begin to lose transparency for from thirty to forty-five minutes; allowing time for drawing and observations.

Obtaining sterile nematodes

In order to make inoculations upon living plants to determine whether the nematodes have any pathogenic power, it was first necessary to secure worms free from bacteria, fungi, or any other organisms. This proved to be by no means an easy matter. I first tried to free eggs from bacteria and fungus spores by making plates from them in the usual way, with asparagus agar. While by this process the germs were scattered, some bacteria or fungus spores remained so near the eggs that the latter could not be absolutely isolated. Various methods of sterilizing the eggs by chemical means were then tried: eggs were washed for varying lengths of time in various solutions of mercuric chloride, carbolic acid, thymol, copper sulphate, dilute hydrochloric acid; with the uniform result that whatever destroyed the plant organisms destroyed the eggs also. I then hit upon the method of washing eggs in sterile water, placing them in a watch glass, and changing the water repeatedly with a pipette. The eggs sink in water; so also do most bacteria, but spores of *Fusarium* and of terrestrial fungi in general float. Hence by this method the eggs were easily freed from fungus spores, but not from bacteria. But by repeated washings the surface of the eggs was largely freed from bacteria, and the number of bacteria in the water greatly reduced. Then the eggs were placed in liquefied agar tubes at low temperature, and poured plates made in the usual way. In the plates several spots of fungi appeared, and many bacterial colonies. But out of the twenty eggs used five were so situated that after two days' growth at room temperature no colonies were near enough to touch them. These eggs were then transferred to plates of sterile agar by using a special form of flat oese, a description of which will shortly be published. In this way eggs were secured free from all micro-organisms.

The sterile agar into which the eggs were transferred was a one per cent asparagus juice agar, sufficiently moist, but rather stiff. In

this medium the eggs developed, the larvae moulted, but after the first moult made very little growth. At first they moved about freely, but after from ten to fifteen days they curled up and became quiescent. That they were free from moulds and bacteria was conclusively shown by the fact that the agar remained uncontaminated.

As I was uncertain why the worms failed to develop, and was inclined to attribute the difficulty to injury received in the washing, I repeated the experiment twice, with similar results. It then occurred to me that the difficulty might be with the medium: that products of decay might be necessary food. Accordingly I inoculated a flask of one per cent asparagus juice agar with the *Fusarium* and bacteria of one of the original poured plates; after allowing the mass to decay for two weeks I heated the agar, filtered out the fungus fiber, and sterilized the filtrate. Sterile eggs were then placed in sterile plates of this agar; they developed rapidly and normally, and the worms produced eggs in their turn.

This decayed agar, however, was more nearly liquid than the normal agar. In order to show whether degree of solidity might not have as much to do with the behavior of the nematodes as presence of decomposition products, I placed other sterile eggs in a 0.25 per cent asparagus juice agar. These developed, not as rapidly nor as vigorously as those in the decayed agar; but quiescence did not ensue until several generations had developed. But as decayed agar was distinctly the best medium, it was used wholly in growing sterile worms for inoculation purposes.

I have already mentioned that these nematodes move about actively, and over considerable area if given range. Their food also passes quickly through the alimentary tract; it occurred to me that these facts might be utilized in devising a method of freeing the living worm from micro-organisms. To this end several rectangular Petri dishes were constructed, measuring three by fifteen centimeters; in these 0.25 per cent asparagus agar was placed; after this was sterilized, the dishes were slanted, so that the water collected largely at one end. Active worms were then placed in the upper end; they immediately began to move toward the moist end, reaching it in a few hours; when they were transferred to the next dish and the process repeated. It was expected that this continual passage through sterile medium would free the worms, inside and out, of germs. But such did not prove to be the case. Although the num-

ber of organisms in and about each worm was greatly reduced, as was shown by the number of colonies developing along the trail, no worms could be obtained entirely free from either bacteria or fungi. This suggested what later experiments have demonstrated, that these nematodes are efficient agents in disseminating micro-organisms.

Biochemical Relations

This nematode when grown in cultures exhibits peculiar and interesting relations to its substratum, which I have not worked out. The medium becomes more alkaline, probably in consequence of the considerable quantity that passes through the worms.

The frequent occurrence of the nematodes with *Fusarium* suggests some vital relation of that fungus or its products; whether or not there is such relation, it is certain that some other fungi exert a deleterious effect upon the nematodes. I noticed that the nematodes died in a culture which had become contaminated with a black *Aspergillus*. I inoculated two other plates of worms with this fungus with the same result; the bad effect of the fungus growth was unmistakable. No investigation was made of the by-products of this *Aspergillus*, which are probably poison. Might not the line of investigation here suggested be fruitful if followed out with reference to certain pathogenic nematodes? Nothing is known, for example, regarding the relation of gall-forming nematodes to plants other than their hosts.

To dryness the live nematodes are fairly resistant, but not so much so as might be expected; in agar cultures dried at room temperature for twenty-four days the nematodes have failed to revive. The eggs do not seem to be much more resistant than the living animal, a fact which may be correlated with their frequent internal development.

The nematodes are unaffected by sunlight. No attempt has been made to work out their relation to salts, disinfectants, or other chemical substances.

INOCULATIONS

Inoculations of pure cultures of nematodes have been made upon young *Coleus* and *Geranium* plants, upon sugar beets, and upon the iron pea. The standard methods of inoculation were employed, and each inoculation carefully checked; so the methods need not be described in detail. Suffice it to say that wounds were made on parts

of the plants under ground, and the nematodes placed on these spots. The wounds were kept moist. Although in every case the worms, or at least some of them, lived, decay of the plant tissue did not ensue in any case; instead, the wounds healed normally. Evidently, then, the nematodes alone have no pathogenic power.

More interesting results were obtained, however, upon using nematodes grown in pure cultures of the bacterium which causes the rot of sugar beets, already referred to. Some of these were placed on a wound in a live beet, with the prompt result of the decay of the beet by the bacterium. The experiment was also made of putting a quantity of nematodes from the same source on the surface of the soil around four potted beets. No decay ensued. But when the experiment was modified by wounding the surface of the beet *under the soil*, decay ensued in three out of four beets. The experiment was repeated with two other beets; both decayed; and examination of the decaying spots showed the nematodes to be present on the surface.

Cuttings of *Coleus* were placed in a pot of earth, and a large number of nematodes from a culture obtained originally from a *Coleus* cutting which had "damped off," were placed in the soil. *Fusarium* was present in the culture. Examination of the cuttings in ten hours showed that the nematodes had congregated around the cut ends of the plants. Later about one third of the plants "damped off." This led me to examine again fresh wounds of sugar beets, near which nematodes had been placed. Without exception the results showed that the nematodes gather about wounds; probably for the plant juices, upon which they seem to feed. Herein, then, lies their real relation to plant decay: they are carriers of germs of decay to wounded places. They are, however, necessarily from their structure, incapable of themselves producing the wounds.

SUMMARY

1. A nematode, *Rhabditis brevispina* (Claus) Bütschli or a closely related form, is commonly and widely associated with decay in certain plants.
2. The nematodes grow readily in agar cultures of plant juice if sufficiently fluid; better in decayed media. So far as can be determined by microscopical examination, the nematodes grown in cul-

tures are similar in all respects to those living under absolutely natural conditions.

3. Absolutely sterile cultures of the nematodes can be obtained by washing the eggs, and afterward making poured plates with them in the usual way.

4. In cultures the nematodes are killed by the presence of a certain species of *Aspergillus*.

5. The nematodes seek wounded places on the underground parts of certain plants, probably in order to feed upon the plant juices. If they bear spores of pathogenic organisms they necessarily inoculate the plants; and as they feed on decaying plant tissue, becoming covered with the germs of the decay, they readily transfer the disease from plant to plant.

ACKNOWLEDGMENTS

These studies have for the most part been carried on in the zoological laboratory of the University of Nebraska, and under the direction of Dr. Henry B. Ward, to whom I acknowledge many obligations.

BIBLIOGRAPHY

BESSEY, C. E.

62. The "brown disease" of potatoes. *Science*, N. S., XV, No. 372, p. 274.

BÜTSCHLI, O.

73. Beiträge zur Kenntniss der freilebenden Nematoden. *Nova Acta*, XXXVI, Nr. 5.

CLAUS, C.

62. Ueber einige im Humus lebende Anguillulinen. *Zeitschr. f. wiss. Zool.*, XII, S. 354.

DE MAN, J. G.

84. Die frei in der reinen Erde und im süßen Wasser lebenden Nematoden der Niederländischen Fauna. Leiden, 1884.

HEDGCOCK, G. G., AND METCALF, H.

03. Eine durch Bakterien verursachte Zuckerrübenkrankheit. *Zeitschr. f. Pflanzenk.*, XII, p. 321.

EXPLANATION OF PLATE VII

All figures drawn with Abbé camera lucida; 1, 3, and 6, from narcotized specimens, the remainder from specimens freshly treated with mercuric chloride.

Fig. 1. Larva at time of first moult. *a*, proton of reproductive organs.

Fig. 2. Portion of nematode from a culture sixteen days old. *a*, reproductive organs.

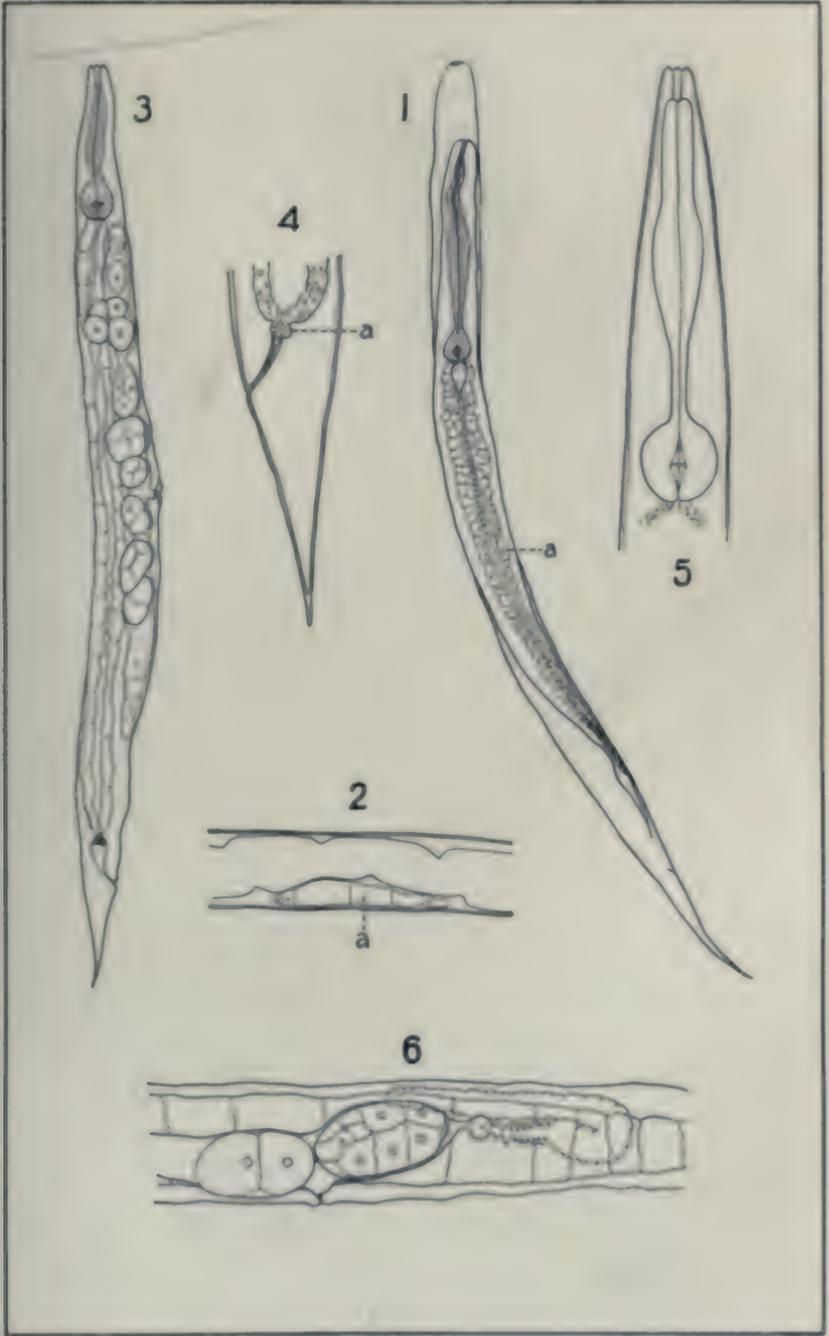
Fig. 3. Nematode from culture twenty-six days old.

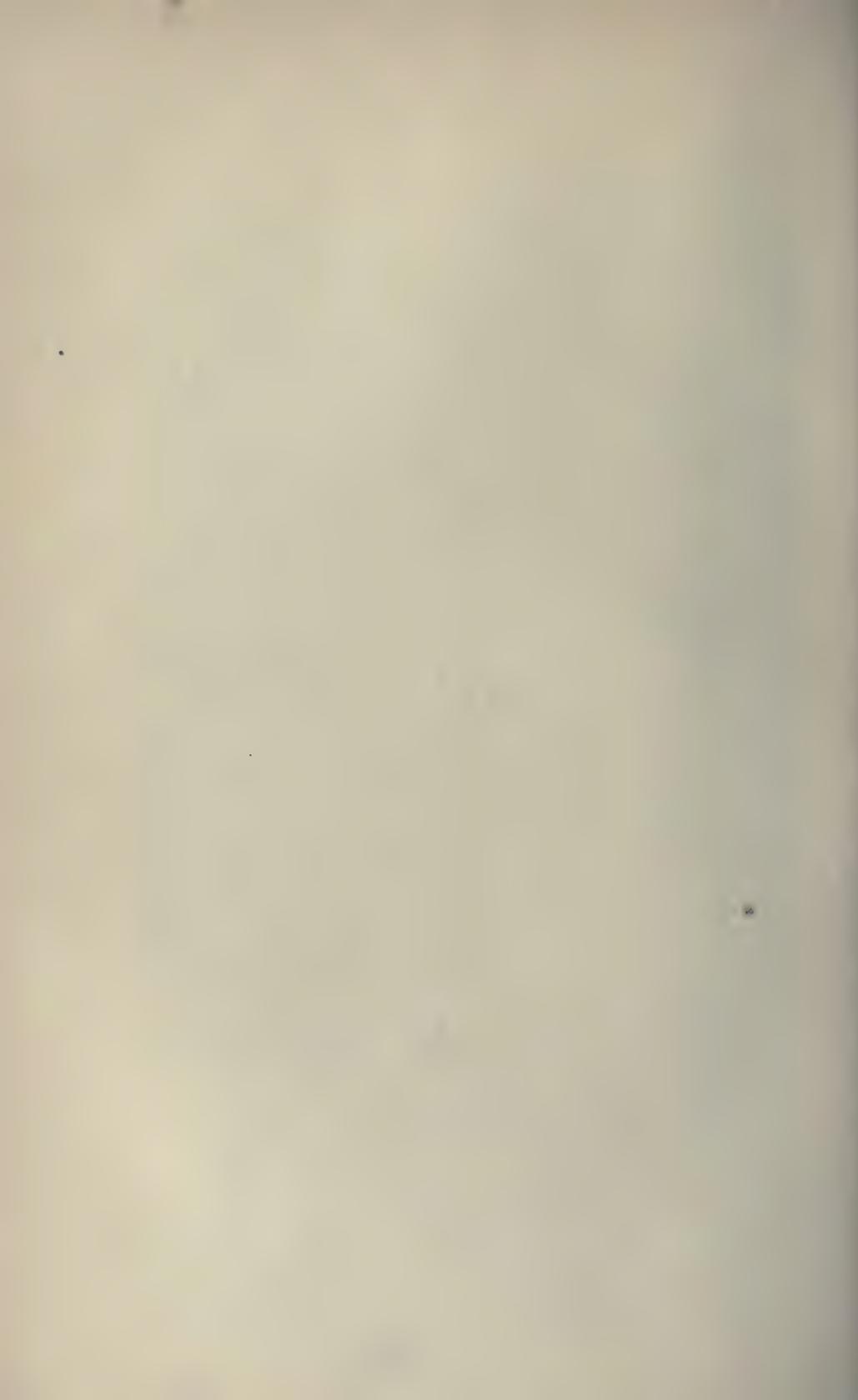
Fig. 4. Posterior end of adult nematode. *a*, gland cells.

Fig. 5. Anterior end of the same specimen.

Fig. 6. Portion of middle of nematode from a culture twenty-two days old, showing posterior branch of reproductive organs.

PLATE VII





DATA FOR THE DETERMINATION OF HUMAN ENTOZOA

BY HENRY B. WARD

WITH FOUR PLATES

The attention of the scientific world has been powerfully drawn to the endoparasites of man by recent discoveries demonstrating their great importance in the etiology of disease. Some notices regarding parasites from the human host have been found in the earliest records of disease. The occurrence of tapeworms and of the larger round worms is recorded not only in the first medical writings of the Greeks, but even in the earlier chronicles of the Hebrews and Egyptians; and in a few instances the records include accurate statements regarding the cause and remedy for the disease as well as the means of distinguishing different forms of such parasitic worms. These data cover, however, only the more conspicuous forms and are often confused by a mass of fables and superstitions, so as to weaken or destroy the value of the truth. With increased study of scientific subjects in general a larger number of such species came to be known. But even to-day they are not as a rule more than superficially known and it is only very recently that attention has been generally called to their number and the often serious effects which they produce in the human organism.

Thirty years ago Leuckart listed thirty species which had been found in man and, in company with Virchow and a long list of other investigators, called repeated attention to the deleterious effect certain species exert. Braun's more recent work (1902) discusses of certain and doubtful species fifteen Trematoda, twenty Cestoda and thirty-eight Nematoda, besides thirty to forty Protozoa, which have been recorded from the human host. In studies on the various groups which I have recently published this list is increased by two species although the interval between the publication of Braun's lists and my own is not a full year.

The various studies, however, have chiefly been made on forms found in the old world, and the well known species are in the main those of European countries. Within very recent times these studies have begun to be extended over other lands. All the new forms recorded during the last five years have been extra-European, either new species peculiar to other lands, or new regions within which known forms have been found to exist, so that one may say the greatest advance has been in knowledge of the geographical distribution of human parasites, although the life history of many species has also been strikingly elucidated. The previously recorded large number of isolated cases of the occurrence of certain species has been supplemented by other cases showing more general occurrence or wider distribution, the results of which have been to demonstrate that these parasites are far more common and widely distributed than was believed heretofore. The accompanying table which lists all human parasites of the various groups of worms heretofore recorded with a statement of the regions in which they are known to occur will be of value as indicating the present knowledge on the subject. It has seemed to me best to confine the list to the worms and to exclude the protozoan parasites for the double reason that the latter are very imperfectly known and it would be difficult to present a satisfactory list, and in the second place that they are also more difficult to determine, even by the professional microscopist, and present insuperable difficulties to the ordinary practitioner.

TABLE I.

Parasite and Organ Infested	Stage	Type of Parasitism	Geographical Distribution					Recorded Frequency as Human Parasite in Normal Habitat
			Europe	Asia	Africa	North America	South America	
<i>Skin and Subdermal Tissue:</i>								
Leptodera Niellyi	Larva	Accidental?	*					One
Gnathostome siamense	Adult	Occasional		*				One
Filaria medinensis	"	Normal	z	**	**	z	*	Abundant
Uncinaria duodenalis ¹	Larva	"	*	**	**	*	?	"
<i>Eye:</i>								
Cysticercus cellulose	Larva	Erratic	*					Rare
Echinococcus polymorphus	"	"	*			*		"
Filaria loa	Adult	Normal	z		**	z	z	Frequent
" lentis	Young	?	z	?	?			Uncertain
" conjunctivæ	Adult	Occasional	*					Rare

TABLE I.—Continued.

Parasite and Organ Infested	Stage	Type of Parasitism	Geographical Distribution					Recorded Frequency as Human Parasite in Normal Habitat
			Europe	Asia	Africa	North America	South America	
<i>Brain and Membrane:</i>								
<i>Paragonimus Westermanii</i>	Adult	Erratic	†	**		†		Rare
<i>Cysticercus racemosus</i> (= <i>C. cellulose</i>)	Larva	"	*			*		"
<i>Cysticercus acanthotrias</i>	"	"?	*			*		"
<i>Echinococcus polymorphus</i>	"	Erratic	*			*		"
<i>Connective Tissue:</i>								
<i>Fasciola hepatica</i>	Adult	"	**	†		†	†	"
<i>Paragonimus Westermanii</i>	"	"	†	**		†		"
<i>Bothriocephalus Mansonii</i>	Larva	Occasional		*				"
<i>Cysticercus cellulose</i>	"	Normal	**			*		Frequent
" <i>tenuicollis</i>	"	?				*		Once?
" <i>acanthotrias</i>	"	Normal	**			*		Rare
<i>Echinococcus polymorphus</i>	"	"	**			*	*	Frequent
<i>Filaria perstans</i>	Adult	"?	z		**		*?	Rare
" <i>loa</i>	"	"	z		**	z	z	Frequent
" <i>Ozzardi</i>	"	"?					*	Rare
<i>Muscles:</i>								
<i>Cysticercus cellulose</i>	Larva	"	**			*		Frequent
" <i>acanthotrias</i>	"	"	*			*		Rare
<i>Trichinella spiralis</i>	"	"	*	**	*		*	Abundant
<i>Heart:</i>								
<i>Filaria Magalhãesii</i>	Adult	?				*		Once
<i>Cysticercus cellulose</i>	Larva	Erratic	*			*		Rare
<i>Echinococcus polymorphus</i>	"	"	*			*		"
<i>Blood Vessels:</i>								
<i>Fasciola hepatica</i>	Adult	"	**	†		†	†	"
<i>Schistosoma hæmatobium</i>	"	Normal	z	z	**	z		Frequent
<i>Echinococcus polymorphus</i>	Larva	"	**			*	*	Rare
<i>Filaria immitis</i>	Adult	?	*?	†		†	†	Doubtful
" <i>romanorum-orientalis</i>	"	?	*			*		Once
" embryos (see Table II)	Larva	Normal	*	*	*	*	*	"
<i>Lymph Vessels:</i>								
<i>Filaria Bancroftii</i>	Adult	"	*?	**	**	*	*?	Abundant
" <i>volvulus</i>	"	"	z	*?	**			Rare
" <i>lymphatica</i>	"	Occasional	*					Twice
" <i>equina</i>	"	"	*					Twice
<i>Lungs:</i>								
<i>Fasciola angusta</i>	"	Erratic			†		z?	Once
<i>Paragonimus Westermanii</i>	"	Normal	†	**		†		Abundant
<i>Cysticercus cellulose</i>	Larva	"	*			*		Rare
<i>Echinococcus polymorphus</i>	Larva	Normal	*			*		"
<i>Strongylus spri</i>	Adult	Occasional	*					"
<i>Liver:</i>								
<i>Fasciola hepatica</i>	"	"	*	†		†	†	"
<i>Paragonimus Westermanii</i>	"	Erratic	†	**		†		Frequent
<i>Opisthobchia felineus</i>	"	Normal	*					"
" <i>sinensis</i>	"	"	*			z		"
" <i>noverca</i>	"	Occasional?	*					Once

TABLE I.—Continued.

Parasite and Organ Infested	Stage	Type of Parasitism	Geographical Distribution					Recorded Frequency as Human Parasite in Normal Habitat
			Europe	Asia	Africa	North America	South America	
<i>Metorchis truncatus</i>	Adult	Occasional		*				Once
<i>Dicrocoelium lanceatum</i>	"	"	*	†	*	†	†	Rare
<i>Cysticercus cellulosae</i>	Larva	Normal	*			†		"
<i>Echinococcus polymorphus</i>	"	"	**			*		Frequent
<i>Small Intestines:</i>								
<i>Fasciolopsis Buski</i>	Adult	"		**				Rare
<i>Fasciolopsis Rathouisi</i>	"	Occasional		*				Once
<i>Opisthorchis felineus</i>	"	Erratic	*	*				Rare
" <i>sinensis</i>	"	"		*		z		"
<i>Heterophyes heterophyes</i>	"	Normal		†	**			Frequent
<i>Dibothriocephalus latus</i>	"	"	**	**	*	z		Abundant
" <i>cordatus</i>	"	Occasional	*			*		Rare
<i>Diplogonoporus grandis</i>	"	"		**				"
<i>Dipylidium caninum</i>	"	"	*			*		"
<i>Hymenolepis nama</i>	"	Normal?	*	*	*	*?		Frequent
" <i>diminuta</i>	"	Occasional	*			*		Rare
" <i>lancoolata</i>	"	"	*					Once
<i>Davainea madagascariensis</i>	"	Occasional?			*		*	Rare
" <i>asiatica</i>	Adult	?		*				Once
<i>Taenia solium</i>	"	Normal	*	*	*	*		Abundant
" <i>serrata</i>	"	?			*			Twice?
" <i>saginata</i>	"	Normal	*	*	*	*		Abundant
" <i>africana</i>	"	"?			*			Once
" <i>confusa</i>	"	"?				*		Twice
" <i>hominis</i>	"	?		*				Once
<i>Strongyloides stercoralis</i>	"	Normal	*	**	**	*	*	Abundant
<i>Trichinella spiralis</i> ¹	"	"	*	**	*	*	*	"
<i>Strongylus subtilis</i>	"	"		*	*			Twice
<i>Uncinaria duodenalis</i>	"	"	*	*	*	*	*?	Abundant
" <i>americana</i>	"	"				**	*?	"
<i>Physaloptera caucasica</i>	"	?		*				Once
<i>Ascaris lumbricoides</i>	"	Normal	*	*	*	*		Abundant
" <i>canis</i>	"	Occasional	*			*		Rare
" <i>maritima</i>	"	"		*	*	*		Once
<i>Oxyuris vermicularis</i>	"	Normal	*	*	*	*		Abundant
<i>Gigantorhynchus gigas</i>	"	Occasional	*?			†		Rare
" <i>moniliformis</i>	"	"						"
<i>Echinorhynchus hominis</i>	"	?	*					Once
<i>Large Intestine:</i>								
<i>Gastrodiscus hominis</i>	"	Occasional?		*				Twice
<i>Trichuris trichiura</i>	"	Normal	*	*	*	*	*	Abundant
<i>Oxyuris vermicularis</i>	Female	"	*	*	*	*		"
<i>Kidney:</i>								
<i>Echinococcus polymorphus</i>	Larva	"	*			*		Rare
<i>Dioctophyme renale</i>	Adult	Occasional	*			†	†	"
<i>Bladder:</i>								
<i>Leptodera pello</i>	"	Accidental	*					Once
<i>Anguillula aceti</i>	"	"				*		Twice
<i>Filaria restiformis</i>	"	?				*		Once

TABLE I.

EXPLANATION OF SIGNS.

- ** Recorded from man ; autochthonous to region.
 * Recorded from man ; probably endemic, though often secondarily.
 † Recorded from man ; probably acquired elsewhere.
 ‡ Recorded from some other host, hence possible in man. This entry is without reference to the particular organ under consideration.
 ? Record open to question.
 † Distribution of larva after that of adult form.
 ‡ " " " adult " " " larval "

It may be confessed at the outset that the table is probably incomplete. The individual records are much scattered, and in such form as to demand extensive critical editing. It would be improbable, then, that, even with the great care which has been exercised, all records should have been included. So far as the list concerns Europe and the United States, however, I think it may be said that it is most nearly complete and includes all but the most obscure records up to the present date. It should nevertheless be borne in mind that one may certainly expect further evidence of the presence of some of these species in unrecorded regions and of the existence of new species in most of the regions of the world. Additional strength is given to this general premise by the discoveries which have been made within the past decade in these United States. Thus Thayer has demonstrated the existence here of the Indo-European *Strongyloides stercoralis*, White has discovered the Asiatic *Opisthorchis sinensis*, I have found the Asiatic Lung fluke, *Paragonimus Westermanii* and a new human tapeworm, *Taenia confusa*, while Stiles has in addition to records on the vinegar eel, *Anguillula aceti*, and other forms new as human parasites here, contributed the most important of all these studies, namely that on the widespread occurrence of a new hook worm, *Uncinaria americana*, which is of great etiological significance over large areas of our country.

The history of helminthology shows a characteristic vibration from one extreme of belief to the other regarding the importance to be attached to these forms from the clinical standpoint. In the belief of the medical profession two hundred years ago there was no disease, real or imaginary, which was not due to the presence and effect of some kind of parasite. Each ailment had its particular "worm" in its characteristic location. This was a direct result of

the endeavor to reduce every malady to some definite cause, and from a joining of the unknown sickness with the parasites of which they knew as little. Under the influence of study and of increase of knowledge regarding the parasites, such a theory was seen to be untenable, and the movement in the opposite direction began, a tendency which may be said by this time to have passed its height.

This opposite extreme has been manifested in our own land, since there has prevailed during recent years among the medical men of this country an exaggerated idea of the unimportance of human parasites. It has been very generally maintained that the country was less infested than the Old World, or that the forms, after all, were of little significance in the etiology of disease. I am of the opinion that the discoveries referred to furnish ample grounds for a modification of the position of indifference heretofore assumed, and in the treatment of disease call for more careful consideration of such forms as possible factors of etiological significance. The clinical importance of parasites is generally recognized in such cases as *Bothriocephalus* anemia, of which only a very few instances are on record in the United States, and for a few other species also, but similar significance has not been accorded to most forms.

It is true that internal parasites are very widely distributed and that scarcely any individual is entirely free from them. They are, however, usually present in limited numbers, and are believed to be harmless if infrequent or of small size. This does not seem to be strictly correct, for while it is doubtless true that the effect of a single parasite, or even of a considerable number of minute size, is small and difficult to measure or estimate, it is equally clear that even this is a certain drain on the host. Furthermore, the tax on the host is in proportion not only to the number and size but also to the habits of the parasites present. Thus there is a great difference whether the parasite is active and growing in the alimentary canal or some other cavity in the body of the host, or passively resting in the midst of the tissue of some organ.

While encysted parasites exercise a continued and sometimes serious pressure on adjacent tissue, yet the draft on the host by free parasites is much the greatest and manifests itself in three ways. The parasite requires a certain amount of food for its support; this it takes directly from the host, either from that which the latter has digested for its own use, if the parasite be in the alimentary canal,

or from material which the host has formed to perform certain work, as in the case of blood parasites, or from the tissue of the host, as some intestinal worms which feed on the cells composing the wall of the intestine. In any case the host expends at least the extra energy necessary to procure and digest the food taken by the parasite, and this extra labor will be directly in proportion to the amount of food taken, or in general to the size of the parasite and to its fertility.

In the second place the parasite occupies a certain amount of space and correspondingly reduces the calibre of the tube in which it lives. Unless a considerable number are present this is hardly a practical stoppage for the alimentary canal, although in several recorded cases death has followed occlusion of the canal by a mass of *Ascarids*, but in the case of the blood system a vessel may be closed or a clot formed by the presence of even a very few parasites.

In the third place, active parasites will, by their movements, give rise to a certain amount of irritation and inflammation of the membranes over which they move. This is in some ways, perhaps, the most serious trouble which a few parasites can cause, and it is much increased if in the special case the parasite obtains its food at the expense of the tissues of the host, that is, if it tears or consumes the walls of the cavity in which it lives. A secondary, though possible, result of this manner of living is the liability of rupturing some blood vessel, with consequent serious results as in the case of certain lung flukes which may chance upon some large blood vessel and in this way produce even fatal hemorrhage. In the alimentary canal a single *Ascaris* may perforate the wall and induce fatal peritonitis as has been observed several times in recent years. It is evident, then, that no more than a single active parasite may be dangerous, and that it is always some tax on the domestic economy of its host. Of course the effect of a microscopic worm in the alimentary canal of an elephant will be so small that it could hardly be calculated in any way; but this reasoning should not be extended too far. The disturbance produced in the human system by a single tape-worm is sufficient to call for prompt measures to remove it.

Recent studies, however, have demonstrated the presence of haemoglobin in the alimentary canal of many nematode parasites, the pathologic effect of whose activities must be counted much more important than heretofore estimated by reason of this blood sucking

habit. Thus in severe cases of uncinariasis the amount of blood lost from myriads of minute hemorrhages imparts a characteristic reddish-brown color to the feces, and is so extensive that fecal matter will leave a distinct blood stain on blotting paper. At the same time the intestinal wall becomes seriously affected, and affords places of easy attack for any pathogenic germs which may be present. This indirect damage may be very serious in the individual instance and may include primarily or secondarily undesirable regressive or progressive histological changes, inflammatory processes, and disturbances in the circulation.

Another source of danger from parasites is one which has long been surmised but only recently demonstrated. A number of investigators have shown that various Cestoda, Acanthocephala, and Eunematoda contain definite poisons (toxins) which, when extracted and employed experimentally, affect particularly the nervous system and the formation of blood. The continued formation and giving off of such substance would explain the apparently excessive results of parasitism in some instances, results which are shown prominently in reflex nervous symptoms. In a certain proportion of cases, pernicious anemia is the result of this toxic effect, and is accompanied by a considerable mortality, reaching seventeen per cent according to one report regarding *Bothriocephalus*. Whether the poison is elaborated by the parasite, or is produced by pathologic processes in the worm or by its death, as well as the ground for the variability in the toxic action of different specimens, are questions as yet undecided. It has been shown, however, that extracts from different species of helminthes vary considerably in toxic power. Vaulleuard has isolated two toxic principles, one of which acts upon nerve centers and the other upon muscles, and many symptoms produced experimentally by the injection of these substances are analogous to those manifested in parasitic disease. According to this chemical theory the troubles caused by parasites are due to the formation of toxic substances more rapidly than their elimination by the host, and their consequent accumulation in the system. A striking instance of the actual effects of parasitism on a large scale is set forth by Stiles (1902) in his description of the general anemic condition and the lowered physical and mental vitality of the families and communities where *Uncinaria americana* is common. These considerations are sufficient to show the greater numbers and more

serious effects of human parasites in our own country than has been conceded hitherto.

In view of these facts it would seem hardly necessary to emphasize the importance of the accurate identification of human parasites. They are by no means all of equal etiological rank; some are known to exert deleterious effects upon the human organism, regarding the action of some much doubt exists, and there are others which are believed to be indifferent to man. Some are short-lived, and from knowledge of their life history one may conclude that they are not likely to be met with in large numbers, while in other cases autoinfection renders a considerable increase in numbers probable as is the case with the pin worms, *Oxyuris vermicularis*, or threatens to infest the host with dangerous larval stages as in the pork tapeworm, *Taenia solium*. Furthermore, even of those whose injurious effects are unquestioned, the results on the hosts differ notably, and the line of successful treatment differs equally. It is evidently important then to determine accurately with what species the practitioner has to deal in the individual instance. To-day no one would be satisfied to accept the diagnosis of "fever" and how can the diagnosis of "worms" if made be regarded as more sufficient?

In reaching a precise determination of the forms which may be present, the physician has to deal usually with what is purely a microscopical question. The data which are essential are obtainable only by the use of the microscope, and yet they are very easily secured. They do not involve any complicated technique or the use of high powers and a series of time-consuming cultures is entirely unnecessary. The determination is most readily made from fresh material, and while it should be repeated several times in order to exclude all possibility of deception or accident, it requires only brief time, and the use of comparatively low magnification. A consideration of the factors involved will make the matter clearer.

Evidence of the presence of parasites will ordinarily be obtained by an examination of the blood, sputum, urine or feces. The first three are very frequently examined in the diagnosis of disease, and as a matter of fact they rarely furnish evidence of parasitism. So far as I have been able to learn fecal examinations are rarely made, and yet by them evidence of parasitism would be most largely furnished.

They are neither difficult nor in any conspicuous way disagreeable.

A quantity of fecal matter may be shaken up with water and by successive decanting and diluting the more solid portions including the parasitic material will be obtained in concentrated form. A small portion of the suspected feces may also be diluted with a few drops of water and after being broken up examined on a slide under the microscope to demonstrate parasitic specimens too small to be detected by the unaided eye. The negative evidence of a single such preparation can not be accepted as final but must be confirmed by a series of observations.

By means of such examination one finds sometimes specimens of the entire adult parasite, recognizable fragments of the same, its embryos or its eggs. It is comparatively rarely that one encounters specimens of the entire parasite, and unless the latter are very abundant such specimens may easily be overlooked if not of such size as to be visible to the naked eye. One is aided, however, in the detection even of small round worms by the definite form with its distinct contour, by the peculiar appearance and sometimes by the movements of living specimens. There is opportunity for confusion with fragments of undigested matter, particularly vegetable tissue which will be discussed later, and the diagnosis should be confirmed by careful microscopical examination of the suspected objects.

The identification of the parasite by some recognizable fragment of the body is regularly made only in the case of the tapeworm which is determined by the passing of segments or proglottids at stools. While the precise determination of the species of tapeworm from the separate proglottids is a matter of more difficulty than ordinarily believed, the cases of confusion resulting therefrom are not such as to introduce any difficulties in the accepted treatment. In passing it may be noted, however, that the determination of tapeworm proglottides as flukes on account of their active independent movements is a frequent error. The examination of such structures even with a hand lens will show the absence of features characteristic of the flukes.

The determination of embryos is not attended with difficulties so far as the different groups are concerned. The embryo of the flukes is oval or elongated, covered with a coating of cilia and so delicate that pressure of the cover glass will crush it completely into granular fragments. These embryos are not common and under normal circumstances do not desert the egg shell; but when brought under

conditions of varied osmotic pressure or chemical influence as when feces are diluted by water or urine is changed in acidity on standing, the shell may open and the embryo emerge. This may often be observed on the slide under the microscope.

The embryo of the tapeworm, known as an onchosphere, is precisely characterized by the presence of three pairs of small hooks which lie near one end of the spherical mass. Such embryos are not found free unless some accident has ruptured the membrane, or embryophore, by which each is surrounded.

The nematode embryo is elongate, or vermiform, and possesses a firm outer cuticular layer which is highly refractive and appears under the microscope as a clear structureless boundary. The surface often shows striations on careful examination, and spines or papillae are found near the mouth at the anterior end. The alimentary canal shows at least two distinct regions, an oesophagus or pharynx lined by inverted cuticula and a mid-gut without such lining. In the former various parts may often be made out. A clear area near the center of the worm, consisting of one or a few large cells is the proton of the reproductive system. The size and position of this genital area are of importance in the determination of the species although in many forms it has not been accurately described.

The characteristic features of individual species so far as known are sufficiently fully indicated in the annexed Table II. For the distinction of individual species of *Filaria* by means of the table the data are only partially satisfactory as these forms have been but little studied and are imperfectly known. These worms are probably rare in our fauna unless it be in the southern states and methods of distinguishing them are yet to be worked out.

If any evidence of parasitism is discovered, it is most frequently by the occurrence of eggs. And it is in dealing with these structures that the greatest difficulties in precise determination are experienced. This is in large part due to the inaccurate and insufficient knowledge concerning them. A comparison of the original sources with various manuals shows that serious errors in measurements have crept in and that mention of important and characteristic peculiarities has often been omitted. I have accordingly deemed it wise to include a critical review of these features with illustrations for all species known as human parasites.

The eggs of parasites may be distinguished on the basis of form,

TABLE II.
EMBRYOS OF HUMAN PARASITES.

Species	Form	Size in Microns	Surface	Head	Tail	Sheath	Present In						
							Blood	Sputum	Urine	Feces			
<i>Schistosoma hematobium</i>	Oval, changeable	60-90 X 40-50	Ciliated	Papilla	o	o							
<i>Strongyloides stercoralis</i>	Rhabditiform	300-500 X 16-22	Smooth	Lips	Sharp	o							x
<i>Strongyloides stercoralis</i>	Filariform	550 X 15	"	4 Lips	Taper	o							?
<i>Filaria diurna</i>	"	300 X 7.5	"	?	Sharp	Present							?
<i>Filaria nocturna</i>	"	300 X 7.5	"	6 Lips	† Taper	"							?
<i>Filaria perstans</i>	"	230 X 4.5	"	Papillated	† Truncated	Absent							?
<i>Filaria vulvus</i>	"	250 X 5	"	Rounded	† Taper	"							?
<i>Filaria Denaryuyi</i>	"	205-210 X 5	"	Retractile spine		"							?
<i>Filaria Ozzardi</i>	"	170-240 X	"		Sharp	"							?
<i>Trichinella spiralis</i>	Elongate	4-5 5-6	"	Blunt	Rounded	o							x

Explanation of signs.—x Positive record; ? Possible occurrence, or uncertain record; o Wanting or undescribed.

NOTE.—Small adult Nematoda may easily be distinguished from these embryonic forms by the presence of reproductive and copulatory organs which the latter do not possess.

Ciliated Protozoa should not be confused with larval forms.

size, texture, and other individual peculiarities. Any one of these elements is usually insufficient; but with the exception of a few forms of rare occurrence which are imperfectly known, the group of characters enables one to make a determination. In reaching a decision the observer should, however, keep in mind some general points.

All eggs are not mathematically uniform in size; the range of variation is in most cases small and the average readily obtained by measuring ten or a dozen specimens taken at random. In many cases only the average size, however, has been recorded. The same comparison of a number of specimens will serve to eliminate abnormalities of the individual egg and to give a correct idea of the typical structure.

The occurrence of constant differences in size between the specimens measured and the descriptions given for a species under consideration creates a prejudice at once in favor of the view that the two species are distinct, and some of the supposed wide variations in the eggs of certain species have been found to be due to the confusion of two or more closely related forms under a single specific name.

Errors in the general interpretation of these structures are also not infrequent. The eggs of distomes have more than once been diagnosed as coccidia to which they bear some superficial resemblance in external form. They are, however, usually larger and differ radically in texture and in internal structure as will appear on comparison of the descriptions or figures given in any good text. Thus Braun (1902, p. 75) states positively that the case diagnosed by Thomas (1899) as *Coccidium oviforme* in a brain tumor must certainly be interpreted in some other way and inclines to the view that the questionable bodies were distome eggs. In one case at least the eggs of a known fluke were duly baptized as a new genus and species of coccidia.

The eggs of the Trematoda, or flukes, may be characterized in general as ellipsoidal or ovoidal. The proportion of length to breadth varies so considerably in different species that the form may be that of a spindle in one case, or it may even approximate the sphere. In rare cases the egg is flattened on one side, as in the case of *Dicrocoelium lanceatum* according to Leuckart. One finds as a universal characteristic the presence of a lid which is absent in fact

only in a single case. The lid ordinarily conforms to the curvature of the shell, though in rare instances it appears more flattened. Only exceptionally does one find the opposite end of the shell prolonged into a filament of rudimentary character in this group. Where present such filaments constitute valuable criteria in the determination of species. Even in such genera as normally possess them, however, one may find them lacking at times. A knob-like thickening which is present at the lower pole of many fluke eggs may be regarded as the rudiment of a filament.

In appearance the trematode egg varies from light to dark brown in the extreme case reaching almost a mahogany color. When first formed in the body of the parent individual they are uniformly nearly transparent, a feature which is preserved permanently only by *Schistosoma haematobium*, whereas in other species the color begins to appear with the passage of the egg into the uterus, and has reached its final condition at the time when the egg is extruded from the body of the parent. The number of eggs produced by the trematodes which inhabit the human body is large, so that even in the presence of slight infection one finds considerable numbers discharged and their production is maintained over a considerable time. Special data regarding various species are given under the appropriate headings.

Gastrodiscus hominis is a human parasite which has been found only twice, and concerning which the data at hand are not extensive. Leuckart says that the eggs are of oval form, 0.150 mm. long, and 0.072 mm. broad. They are supplied with a firm shell, which at the attenuated anterior end is cut off in the form of a lid. Leuckart notes, moreover (1894, p. 458), that Giles, who was never able to demonstrate the eggs of the parasite in the excrement of the host, propounded the somewhat doubtful hypothesis that the eggs are set free only after the death or expulsion of the parasite.

The common liver fluke, *Fasciola hepatica*, has been studied by many observers. One of the best descriptions is given by Sommer (1880, p. 84). The large, well formed egg in the coils of the uterus (Fig. 12, Pl. IX) measures 0.13 mm. in length by 0.07 mm. in breadth, and up to a length of 0.142 to 0.150. The shell which is at first thin and transparent, is without irregularities save at the pointed pole where a few such occur frequently. The opposite end of the egg is provided with a lid and is regularly rounded or even

slightly flattened. When the egg comes to be deposited, it has acquired an intense brown color, which makes the investigation of the contents very difficult. Among them one may distinguish, however, in the earlier stage, a single homogeneous, clear, highly refractive mass of protoplasm, which is the single germ cell. It lies surrounded by a mass of opaque, granular cells, which constitute the yolk mass of the egg.

In *Fasciola magna*, the large American fluke, Stiles (1895, p. 242) who has investigated the species very carefully, says that the eggs (Fig. 11, Pl. IX) can hardly be distinguished from those of *F. hepatica*, although in general they are slightly larger.* In proof of this he gives the following table:

<i>F. magna</i>		<i>F. hepatica</i>		
Long mm.	Broad mm.	Long mm.	Broad mm.	
		0.105-0.145	0.066-0.090	(Blanchard)
		0.13 -0.14	0.075-0.09	(Leuckart)
0.109-0.168	0.075-0.096	0.13 -0.172	0.072-0.08	(Stiles)

It should be borne in mind that Stiles' measurements of *F. hepatica* were made from American specimens, and it is possible that a change of size may be found in such as have been produced under a different climatic environment. In case of the suspected presence of *F. magna* in man here where it may some time well occur, as does the closely related European species in numerous cases on record in Europe, Stiles' measurements are the most important. It has not yet been shown that the eggs differ in size when produced by parasites in different hosts, although it is well known that the parasites themselves undergo some modification in size and form.

Fasciolopsis Buski (Lank.) which has been hitherto little known has received careful examination within the last year at the hands of Odhner. Regarding the eggs this author says (1902, p. 578): The eggs which are much mixed with aborted specimens are present in large number and measure in length 0.12 to 0.126 mm. by a width of about 0.077 mm. They resemble in all respects the eggs of the

* This is not true of the figures given here (Pl. IX, Figs. 11, 12) as the illustration used for *F. magna* represents the *minimum*, rather than as should have been the *average* size for eggs of this species. On the other hand it is also doubtful whether the table quoted from Stiles actually supports his contention as to the relative magnitudes of the ova.

large liver fluke (*Fasciola hepatica*). Unfortunately the author does not give any representation of these structures.

The reports which have been published regarding the egg of *Paragonimus Westermanii* are considerably at variance. The original discoverer of the species Kerbert (1881) gives the measurement of those obtained from the tiger as 0.080 by 0.045 mm. The original account of the species in the United States (Ward, 1894, p. 356) states that the eggs vary from 0.096 by 0.048 mm. to 0.118 by 0.050 mm. with an average size of 0.102 by 0.053 mm.

According to Stiles (1900, p. 603) the average measurements of specimens taken from cysts in the lungs of Kentucky hogs are 0.078 to 0.096 mm. in length by 0.048 to 0.060 mm. in breadth, with an average size of 0.0856 by 0.0532 mm. The most recent investigation of the species by Katsurada (1900a, p. 508) gives the following data for eggs taken from the sputum of the human host: Minimum 0.0875 by 0.0575, maximum 0.1025 by 0.0525 mm. with an average size of 0.0935 in length and 0.057 in width. He says that the fully formed egg (Fig. 2, Pl. VIII) has an oval, clear yellowish brown, relatively thin shell, broad at one end, and somewhat tapering at the other; the tapering end has the thicker shell, and the other end shows a somewhat flattened small lid. The contents of the egg within the shell are covered by a thin membrane and in the space between the granular yolk masses, a clear viscous fluid is found.

The measurements as stated by different authors have been put together in an outline sketch which represents the differences in graphic manner (Fig. 1, Pl. VIII). It will be noted that there are only two wide variations from the general size as given by the majority of authorities. Regarding the eggs which are unusually large, according to the measurements of Baelz (1880), it may be said that the same author later (1883) gives lesser measurements for specimens obtained like the first from the sputum of man, so that one may suspect an error in the earlier record. On the other hand, the measurements given by Yamagiwa (1890, p. 455) were taken from sections of the brain and lungs of man. Their sub-normal size may be due to an error in measurement, or to a determination of the size from fragmented specimens, or to eggs situated obliquely in the section and consequently reduced in length. It is difficult to believe that all records can be correct as they stand, unless some other species is concerned.

The eggs of *Opisthorchis felineus* have been described by Braun (1902, p. 158) as oval, with sharply marked operculum at the pointed pole and containing an embryo in which cleavage is already well advanced. They measure 0.030 by 0.011 mm. (Fig. 8).

Opisthorchis sinensis has been investigated by a number of observers. Ijima (1887, p. 11) says: The eggs are unusually small, measuring 0.028 to 0.03 mm. in length and 0.016 to 0.017 mm. in breadth. In the anterior portion of the uterus, where the egg shells have assumed a dark brown or dark olive color, embryos are already formed (Fig. 6, Pl. VIII). In the interior three distinct remnants of yolk matter are seen in addition to scattered yolk granules. Embryos can be forced out of the shell by a sharp tap on the cover glass. Such have an elongated shape and measure 0.025 mm. in length. The body tapers slightly towards the posterior end, and there is an indication of head papillae. The posterior portion contains small clear cells, probably terminal and there are no eye-spots present.

Of the same species Katsurada says (1900, p. 481) that the previously published accounts agree well with facts, but cites as an especially accurate investigation that of Dr. Osafune, who measured 500 eggs from feces and found that the majority were from 0.027 to 0.030 mm. long, and 0.015 to 0.0175 mm. broad, exceptionally specimens were found with a length of 0.035 mm. and a breadth of 0.019 mm., and on the other hand such as were only 0.02 long and 0.0157 broad, or 0.0225 long and 0.015 broad were also present (Fig. 7, Pl. VIII).

The Egyptian Fluke, *Heterophyes heterophyes*, has been carefully studied by Looss (1894, p. 32) who speaks thus about the egg: The fully formed eggs which immediately after their formation, possess a completely transparent hyaline shell, are comparatively regularly oval, slightly more pointed at the lid pole than at the opposite. They possess a length of 0.03 mm. by a greatest breadth of 0.017 mm.; their shell is 0.001 mm. thick and has thus a relatively considerable strength. During the passage of the eggs through the uterus, the embryo is formed, so that the egg which has arrived at the end of this organ possesses in its interior a developed embryo (Fig. 9, Pl. VIII). The latter possesses, so far as one can determine through the egg shell, an elongated cylindrical form, and carries at the anterior end a weakly marked projection. The surface of

the body is covered in its entire extent with cilia which are most evident in the anterior region. In the posterior end large transparent spheres, 0.008 mm. in diameter, are the germ cells of the embryo.

In *Dicrocoelium lanceatum* (Fig. 3, Pl. VIII) the eggs are, according to Leuckart (1889, p. 376), ovoid in form, with the lid end notably flattened, while the same is true for one side of the shell (Fig. 4). In size, as well as in detail, there are many differences in form among the fully developed eggs. The length varies from 0.04 to 0.045 mm., and the breadth from 0.02 to 0.03 mm. When first formed, the egg is, as in many other cases, almost transparent, but during the passage of the uterus it becomes very dark brown. At the same time the embryonic development is being completed, so that the eggs when deposited contain an embryo which is already fully developed. Leuckart gives the length of this embryo according to his own measurements as 0.026 to 0.030 mm. and the breadth as 0.016. The embryo occupies exactly the center of the egg so that an even space intervenes between it and the shell everywhere. There is also a mass of granular matter, usually at one end, surrounding the head end of the embryo like a cap, and more or less completely concealing it.

Three other trematodes have been reported from the human host, namely *Opisthorchis noverca*, *Fasciolopsis Rathouisi* and *Fasciola angusta*. There is on record but a single case of each, and the eggs are not sufficiently well known to make them available for determination. Moreover in the case of such an exceptional species more than the evidence furnished by the egg would be necessary in order to establish its occurrence in the human host.

The eggs and embryos of *Schistosoma haematobium* have been carefully studied by Looss, whose observations are reported by Leuckart (1894, p. 521). According to this investigator, whose studies were made upon eggs discharged with urine, such either contain an embryo ready to hatch out, or are dead and calcified. The normal eggs are somewhat variable in form, though in general spindle shaped with median enlargement (Fig. 10, Pl. IX). At the posterior pole is a characteristic filament, often very inconspicuous, though universally found in the eggs taken from urine. Within the shell is a yolk membrane, with granules, surrounding the embryo. According to this author the eggs will not hatch, so

long as retained in the urine, but rather perish if permanently kept in that fluid. The addition of water even, in small amounts, brings about the opening of the egg. The enclosed embryo is exceedingly variable in form, with an insignificant cephalic papilla, a coating of cilia and the usual enclosed cell masses of the larval distome.

The eggs of the Cestoda, or tapeworms, are usually spherical, oval or elliptical, although occasional species are characterized by a polyhedral form. In general they manifest great constancy, although the outer membranes may be modified by shrinkage or the aspect of the egg may be changed by their absence, so as to produce decidedly variable effects. Frequently one finds filaments of various kinds which are projections of the shell, and are present either at one or both poles of the egg. Among human tapeworms they have a very rudimentary character and are demonstrable as a rule only in younger and smaller eggs. In color the tapeworm eggs are at first almost transparent, but later yellowish to brownish in tone.

Among the tapeworms one finds both such eggs as are possessed of a small lid, often difficult to demonstrate, and also those which are beyond doubt without such a structure. Among the higher forms, the eggs are small with delicate, colorless and often deciduous shell. By the formation of a number of embryonic membranes the embryo proper which is usually developed at the time when the egg is set free, is separated from the shell by a noticeable distance. The embryo itself is small, usually spherical, and regularly armed with six hooks arranged in three pairs near one pole. This six-hooked oncosphere, as it is called, is borne in an inner membrane of considerable thickness, and often prominent in appearance by virtue of its structure, and to this the name of embryophore has been given. It is of all the membranes the most constant in presence and appearance. Special characters of individual species are noted as follows:

For *Dibothriocephalus latus* (Figs. 13, 14, Pl. IX) the description given by Schauinsland (1886, p. 529) is as follows: The eggs possess a thick brown shell, and a small lid, which becomes especially distinct at the close of development. They contain a large amount of yolk substance, and do not increase in size. As in all *Bothriocephalids* the development is carried out in the water and not in the maternal body, so that the inconspicuous egg cell is only

rarely to be found in the mass of yolk cells which usually completely conceal it.

In the large Japanese tapeworm, *Diplogonoporus grandis*, the egg taken from the uterus possesses a deep brown shell (Fig. 15, Pl. IX) according to the account of Ijima and Kurimoto (1894). The shell is rather thick, the general form is oval, 0.063 mm. long and 0.048 to 0.050 mm. broad. The diameter of the operculum is 0.02 mm. and the contents of the shell consist of oil globules and a mass of cleavage cells.

In *Hymenolepis diminuta*, according to Blanchard (1891, p. 46), the egg is rounded or oval (Figs. 16, 17, Pl. IX). It measures from 0.060 to 0.070 or even 0.086 in diameter. The external membrane is yellowish, delicate, and manifests indistinct striation, the median membrane is doubled, the internal membrane or embryophore has ordinarily two polar knobs, to which are attached no filaments, however. The onchosphere is elliptical and measures 0.036 by 0.028 mm. Its hooks are 0.011 mm. long.

Of *Hymenolepis nana* (v. Siebold) von Linstow (1896, p. 575) says that according to his observations the eggs are in the rule spherical, more rarely also oval ones are present. They show two membranes, of which the external is delicate and irregular. The inner is regular and sharply doubly contoured. This shows at two opposed points an indistinct attachment from which a filiform appendage proceeds that is three to four times as long as the egg. Both these threads lie rolled up between the two egg membranes and may simulate a median third membrane (Fig. 18, Pl. X). The external membrane measures 0.039 mm., the internal 0.028 mm. in diameter. The hooks of the onchosphere measure 0.0092 mm.; in an especially elongated egg the external membrane was 0.043 mm. long and 0.031 mm. broad, the inner 0.029 and 0.024 mm.

The eggs of *Taenia saginata* have been described by a number of authors. The fullest comparison of the data thus obtained are given by Leuckart (1886) whose work in the main is followed here. These eggs are usually still covered by a thin yolk membrane, having a diameter of about 0.07 mm., which is frequently drawn out at two opposite points into long delicate projections, of which, however, only a single one may be evident (Figs. 19, 20, Pl. X). In eggs just formed in the uterus, which measures on the average 0.02 mm., the form is commonly oval, and the projections constant at the poles,

with a length about equal to the diameter to the egg. The embryophore is characterized by the considerable thickness or length of the rods which compose it, and measures in diameter approximately 0.03 mm., in which connection one should notice that the form of the same is commonly more oval than spherical. The embryo itself measures 0.02 mm. in diameter.

In *Taenia solium*, Leuckart (1886, p. 667) says that the embryophore, like that of *Taenia saginata* is thick and firm, brown in color, and covered with numerous rods, but more nearly spherical. In diameter these eggs measure 0.03 mm., while the onchosphere measures not more than 0.02 mm. The embryophore is often the only membrane present (Figs. 21, 22, Pl. X).

In *Taenia confusa* Ward, as described by Guyer (1898, p. 19), the eggs are oval in form in the ripe proglottis. They possess on the exterior a thin, transparent membrane, and within it a layer of little rods, side by side. Next within this is a thin space, or layer, the exact nature of which could not be determined. The elongated inner portion is of about the same outline, as the external covering of the egg, and is of different appearance in different specimens. In some there is a dark cap-like structure at one end; in others at both ends, and in still others along the side and one or both ends, while the entire center is usually dark. In no case could the pyriform apparatus, or tail-like processes, mentioned by Leuckart for the eggs of *Taenia saginata*, be determined. It is not unreasonable to suppose however, that since they are very delicate, they may have been present, but were destroyed through the poor preservation of the material. These eggs measure in general 0.039 mm. long and 0.030 broad. They are of whitish or yellowish color (Fig. 24, Pl. X).

In *Taenia africana* a new species recently described for the human host in Africa, the eggs are described by von Linstow (1900, p. 491) as very thick shelled. The shell is formed of a radially striated membrane which appears on the exterior finely granulated. These eggs measure 0.0312 to 0.0338 mm. in diameter. There are also present some oval specimens which are 0.0390 long and 0.0338 mm. broad. The six hooks of the onchosphere are very distinct and measure 0.0078 mm. in length (Fig. 23, Pl. X).

Two other species of cestodes, *Dibothriocephalus cordatus* and *Dipylidium caninum* also have been reported from the human host.

In the former case the eggs are not well known, and in the latter case they are cemented together in masses, which makes an individual description of little value. One of the latter species, however, is represented in Plate X (Fig. 25) after Diamare (1893). Much the same holds true of *Davainea madagascariensis*, while *Hymenolepis lanceolata* is apparently an occasional parasite merely and other forms definitely reported from man are in the larval condition in that host. Moreover, in the determination of cestodes in general the eggs are of secondary importance, since one will secure additional evidence in the form of the occurrence in the feces of single proglottids or groups of such which have been set free from the parent chain.

Among the round worms, or Nematoda, the greatest differences may be found in the character of the eggs. In a large number of cases, especially in the group of the Filariae, the forms are viviparous, and no eggs are known. Among such, however, as produce eggs, one finds wide variety in the character of this structure. In the one case it is thin shelled, and reduced it may be to a delicate membrane, containing an already well developed embryo. At the other extreme the shell is thick and impermeable, or surrounded by a mammellated albumen coat, which gives the structure a very characteristic appearance. In the case of the heavy shelled egg, development has usually not proceeded far, and the formation of the embryo takes place only at some time after the expulsion of the egg. The thick shell is here evidently a means for protection and nourishment of the embryo, a feature which is unnecessary in the case of those eggs deposited when the embryo is almost ready to carry on an independent existence. All differences between the two extremes may be found in different species. In addition to the Filariae which have no egg, and the small free living Rhabdites which are accidental parasites, several species of nematodes are so infrequent that we know little with regard to conditions respecting the egg. Such species are *Gnathostoma siamense*, *Strongylus apri*, *Physaloptera caucasica*, and *Ascaris maritima*. The ovoviviparous *Trichinella spiralis* may also be excepted from the list of those, the eggs of which are under discussion. In one case at least nematode eggs have been taken for coccidia (Cf. Braun, 1902, p. 68, footnote).

The eggs of *Strongyloides stercoralis* (Fig. 44, Pl. XI) have been

his description they are of elliptical shape, with a thin, clear yellowish shell, and granular contents, which were distinctly in cleavage. They measured about 0.0675 by 0.0375 mm. He calls attention to the fact that these measurements exceed those of the eggs of the parthenogenetic mother worm given by various authors, and cites Parona and Grassi (1879) who give the measurements as 0.06 by 0.04, while Braun (1902) and Railliet (1895) states them as 0.050 to 0.058 by 0.030 to 0.034 mm. Although authors are unanimous in stating that eggs are present at stools only with the greatest rarity, he gives good reasons for accepting the correctness of his observation, and calls attention to the agreement with the measurements of several other authors. At the same time he shows that the eggs described could not have belonged to the sexual intermediate generation.

In the whipworm, *Trichuris trichiura*, the eggs (Figs. 37, 38, Pl. XI) are easily recognized. They are ellipsoidal with a brown heavy shell, which is apparently perforated at both poles, while the orifices are closed by transparent plugs. Such eggs occur in the feces before cleavage has taken place and they measure 0.05 to 0.054 mm. in length by 0.023 in breadth.

In *Diocotophyme renale*, a rare human parasite, the egg has been well delineated by Balbiani whose figures (Figs. 26, 27, Pl. X) are copied here after Railliet (1895). The original description is not accessible.

In *Strongylus subtilis* Looss the ripe eggs (Fig. 43, Pl. XI) are described by that author (Looss, 1895, p. 169) as of oval form with a length of 0.063 mm. and a breadth of 0.041 mm. The shell is very thin and the content strongly granular, so that the nucleus cannot be recognized. At the same time Looss believes that cleavage does not take place in the interior of the female organs.

Investigating what is probably the same species in Japan, a year later Ijima writes (1896, p. 160) that he has found a larger number of eggs in the uterus, and that those which lay nearer the exit were in the process of cleavage. He also discovers a few free eggs exactly comparable to the uterine egg mentioned previously. These measured 0.08 mm. in length and 0.035 to 0.04 mm. in breadth, while the granular yolk was split into numerous cleavage spheres, 0.005 to 0.01 mm. in diameter, forming a solid morula-like mass. Yet at both ends of the egg there was a narrow unoccupied space

between this and the thin hyalin shell. Possibly this space explains the greater length of the egg as given by Ijima in comparison with the statements of Looss cited above.

In *Uncinaria duodenalis*, the eggs (Fig. 28, Pl. X) have been carefully investigated by Schulthess (1882, p. 215), who gives the following description: They reach maturity in the uterus, and are possessed of a thin, doubly contoured shell, oval in form, although one side is often flattened somewhat. He cites the following table regarding the size of the egg according to different observers:

	Length, mm.	Breadth, mm.
Leuckart	0.044-0.050	0.023-0.027
Perroncito	0.052	0.032
Hindenlang	0.0626	0.0319
Roth	0.064-0.072	0.032-0.024
Bugnion	0.059-0.060	0.040-0.041

According to Schulthess' own measurement the eggs vary from 0.0602 long by 0.0382 broad to 0.0674 long by 0.0359 broad, or 0.0602 long by 0.0449 broad. This author ventures also the remark that his investigations do not support the supposed considerable variations in size, and that his own figures give the extreme values for numerous measurements.

In the new American hook worm, *Uncinaria americana* Stiles, the description given by that author (Stiles, 1902, p. 193) records the size of the ova as 0.064 to 0.072 mm. long by 0.036 to 0.040 mm. broad, ellipsoidal in outline, in some cases partially segmented in the uterus, while in other cases they contain a fully developed embryo when deposited. The egg possesses a very thin shell without characteristic features (Figs. 29-32, Pl. X).

The eggs of the common round worm, *Ascaris lumbricoides*, are usually easily recognized by their characteristic mammelation. They present, however, certain variations which render confusion possible in some cases, as in that recently described by Miura and Nishiuchi (1902, p. 637), from whose account the following data are excerpted: The normal fertilized eggs are round to elliptical, with three-fold thick shell, and mammellated albumen covering of yellowish tone. The content of these fertilized eggs (Figs. 33, 34, Pl. XI) is finely granular, and round in form, so that at both poles between the content and the elongated shell one may distinguish a crescentic

space filled with a clear fluid. In the center of the spherical mass the nucleus may frequently be distinguished as a clear space.

On the other hand, the unfertilized eggs (Fig. 35, Pl. XI) are elliptical or oval with irregular contour and occasionally with lateral curvature of the shell. The form, however, manifests numerous variations, which are apparently due to the low resisting power of the shell, and to the irregular distribution of the albuminoid covering. The shell proper is doubly contoured, relatively thin, and with a less distinct internal boundary. The content of the shell consists of large, highly refractive bodies, which fill the entire space without evidence of the crescentic clear area near the poles, as in the fertilized egg. Such eggs measure on the average of numerous measurements 0.081 in length by 0.045 mm. in breadth, varying from 0.030 to 0.060 in transverse diameter, and from 0.063 to 0.098 in length. The fertilized eggs measure according to the same author 0.049 mm. in transverse diameter, and 0.065 mm. in longitudinal diameter, which is closely in accord with figures given except by French authors, who cite the length from 0.075 to 0.087 and the breadth as 0.058 mm.

The egg of the related species *Ascaris canis* from the cat and dog, also found occasionally in man, is represented (Fig. 36, Pl. XI) after Braun (1902).

The eggs of *Oxyuris vermicularis* are rarely met with in the feces. They are, however, of oval form, with very thin shell, measuring 0.05 by 0.016 to 0.02 mm. When deposited they contain an already well developed embryo (Figs. 39-42, Pl. XI).

Some of the Acanthocephala have rarely been reported as human parasites. Their eggs when fully formed possess three membranes, and have carried their development to the formation of an embryo in the body cavity of the female worm. In the case of *Gigantorhynchus gigas* the eggs found in feces are with the three membranes, of which the middle one is the thickest. The external measurements of the entire mass vary 0.08 to 0.1 in length (Fig. 45, Pl. XI).

It is necessary now to call attention to possible results of the examination in the way of non-agreement of the forms discovered with the data at present known regarding human parasites. The non-agreement may of course point to the discovery of a form new to the world, and most frequently has resulted in the description of the form under these conditions as a new species which has been

duly baptized. Unfortunately there are two other possibilities which are more frequently met with than the one just cited, and a disregard of them has led to great confusion. It may be in the first place that the species is new to the human host, but is one which is known from some other host. It consequently should not receive a new name, but should be discussed merely in the light of its occurrence under these conditions heretofore unknown.

Such a species may be normal to the human host as well as to that from which it was previously known, but a considerable range of cases must be brought forward in order to demonstrate this fact. In the case of a normal human parasite this will not be difficult after attention has once been drawn to its occurrence in a given region, and a failure to find further evidence of the occurrence of a new human parasite increases the probability that the form discovered falls into some other category always provided that the patient has not been in some other locality, in which of course the parasite may well have been acquired. Such cases throw an interesting side light on the dispersal of human parasites. The determination of a single case in a host of local habit inclines to the belief that it represents an instance of occasional or accidental parasitism; and this brings us to consider the possible types of parasitic existence.

One may recognize among human parasites those which occur in their normal host but in an unusual location, like the brain cysticerci or a liver fluke in a subcutaneous cyst and these may be spoken of as erratic; there are also many of the species listed which can not be regarded in any way as characteristic of the human host. Such are the occasional parasites which are species of true parasitic habit and can attain normal development in the human host but ordinarily do not find conditions favorable for their introduction. As an instance of such species may be mentioned *Fasciola hepatica*, the common liver fluke of the sheep which in many regions of the world is extraordinarily abundant. That it can thrive in the human system is demonstrated by the score or more cases of its occurrence there definitely recorded, but its infrequency is equal evidence of a general immunity on the part of man, lacking in these particular cases, or, of special features in its life history which make the infection of the human host difficult. That the latter is the probable explanation may be inferred from the fact that the cercaria larva, liberated from the intermediate host, encysts on plants and hence

could only reach the human alimentary canal under unusual circumstances. Similar examples may be taken from other groups of parasitic forms such as the rare occurrence in man of *Strongylus apri*, one of the commonest parasites of the pig in Europe, or of *Dipylidium caninum*, the cosmopolitan tapeworm of both dog and cat which has been reported only rarely from man.

Such occasional parasites often occur under abnormal conditions; thus, a fish nematode, *Ascaris clavata*, was discovered once in the hollow tooth of a man. Here the position was probably accidental, but in other cases it is the result of the action of the parasite itself. So the "red spiders," or "jigger" mites of the central states, bury themselves in the skin of man although such a position is so clearly abnormal that in fact it destroys the chance of further development and costs the parasite its life. A small leech, *Limnotis nilotica*, common in the circum-mediterranean area, is often drawn into the throat of men and other animals drinking at wayside pools. It usually retains its position, causing serious difficulty, until removed by operative interference; hence it has become an occasional parasite of man rather than as most leeches, a temporary parasite; or one may regard it as falling in the next following group of accidental parasites. This example shows most clearly the narrow and somewhat artificial limits which separate these groups of parasites from one another. Of the mites also which have been reported a few times as obtained living from stomach, bladder and rectum, it is difficult to say whether they are occasional or accidental parasites of man.

There are also rarely forms which commonly occur free living, but which by chance are introduced into some organ in which conditions are such that they can thrive. They became thus accidental parasites, a group difficult practically to distinguish from the last, the occasional parasites, and yet presenting somewhat different biological conditions. The recent discovery by Stiles and Frankland, as well as others, of the vinegar eel, *Anguillula aceti*, as an apparently successful colonizer of the bladder in a female patient illustrates the type under consideration. There is little doubt that this parasite was introduced through the use of vinegar in vaginal douches and effected a successful colonization, possibly by virtue of the trace of albumen present in the urine which furnished it with nourishment. Equally striking is the case of Scheiber who discovered *Pelodera*

pellio in the urine of a female patient in Hungary. This typical slime inhabiting nematode gained entrance no doubt through the application of mud poultices which are commonly employed by peasants in that region. It should be noticed that such accidental parasites are necessarily confined to those groups of animals which have free living forms. Such are Protozoa, Nematoda, and perhaps Insecta in the larval conditions, while Cestoda and Trematoda, which live only as parasitic forms in some host, would become rather occasional parasites of man should they stray into the human system in some chance manner and find favorable conditions for existence.

Quite distinct from the types just considered are pseudo-parasites which rank high in clinical importance. Among them one may recognize several very distinct classes. First, those which are actually free living animals, introduced by accident, usually in food or drink, into the human alimentary canal, and exciting there abnormal conditions which induce their more or less immediate and forcible expulsion. Thus Botkin found in the vomit of a Russian numbers of a small nematode which he wrongly believed to be a human parasite. In fact it lives normally in the onion and its introduction into the stomach with this food excited the untoward symptoms noted. Similarly, Blanchard records a case in which coleopterous larvae were found in the vomit of a child.

That such may be the result of introducing a true parasite from some other host is indicated by several cases like that of *Ascaris maritima* which Leuckart described from a single specimen vomited by a child in Greenland and which this author noted was very similar to *A. transfuga* of the brown bear. In all probability it was ingested with the viscera of some animal (seal?), though it may have been a species which had strayed into this unusual host only to make its appearance under the circumstances noted.

Of similar import are the cases of *Gordius*, the hair snake, which have been reported from man. In the adult condition this is normally a free living species but about a dozen specimens have been taken from man after a supposed sojourn of from a few hours to fourteen days. Some of these have been vomited and others passed per anum. This form has often been passed off upon the physician as a true parasite, and in one celebrated case at least as the Guinea worm.

In the same way one may find the explanation for other isolated cases of parasitism, even when the parasite is reported to have been passed from the alimentary canal. Thus Cobbold reported that larvae of *Blaps mortisaga*, the English churchyard beetle, were found in fecal discharges and many authors have recorded the presence of dipterous larvae in the alimentary canal.

The majority of such observers have inclined to regard the larvae as temporary endoparasites and to consider that they have accommodated themselves to the conditions present in the human host. The cases seem to show that these larvae live for some time in the canal and they often appear to evoke serious or even fatal disturbances; and yet the conclusions are open to grave doubt for Calandruccio experimented extensively on two families to which many of the supposed accidental parasites belong and found that the ingested larvae were regularly and promptly evacuated dead or dying and in no case secured a footing in the canal.

Among the Myriopods about forty recorded cases of pseudoparasitism have been brought together and discussed by Blanchard. In the large majority the animal was taken from the nasal fossae, though in a smaller number it was actually obtained living from the alimentary canal where it undoubtedly can exist for a brief time in spite of the untoward environment. The ingestion of such forms is purely accidental, the symptoms those of helminthiasis in general and their stay at most very limited. They never show any evidence of adaptation to the new environment.

In some such accidental fashion other forms are sometimes introduced into various organs not connected with the alimentary system. Thus Trouessart reported the occurrence of a species of detriticolous Sarcotids in the human testicle where the mites formed an old colony in a painless cystic tumor.

In contrast with the living animals of the types noted, the second class of pseudoparasites includes a large number of other structures which have been described as parasites. These may be considered conveniently in a few groups, the first of which includes bodies which are parts of the so-called host animal itself. Thus fragments of the arteria hyaloidea have been described as eye worms (*Filaria lentis*, *F. oculi-humani*, etc.), the organisms of whooping cough are nothing more nor less than ciliated tracheal cells torn from the wall and found in the sputum in distorted form, while groups of small

axillary and inguinal glands, hydatid moles, and Pacchionian bodies from the arachnoid have been frequently put on record as hydatid cysts.

Parts of substances used as food, both of plant and of animal origin, which have not been destroyed by the action of digestive juices are also among the pseudoparasites of man. The radulae of the common limpet have been reported several times from stools; the seeds of the mulberry were duly baptized as parasitic worms; and plant vessels and other similar undigested structures of peculiar appearance appear periodically as new helminthes. That a differentiation of such structures is not simple appears from the account given by Stiles of the partially digested banana fibers which closely simulate minute tapeworms. Wynn has found a good facsimile of tapeworms in blackened but undigested strips of cold slaw. Some years ago Leuckart entrapped a group of research students in helminthology with the pulp vesicles of an orange which were found in a fecal examination.

In all of the cases considered above it should be kept in mind that the animals or these other structures actually came from within the human body. It is necessary that the investigators have absolute evidence on this point, for there is another class of objects of which this cannot be said, and these call for brief mention here.

In determining the nature of unusual forms reported from man it should always be kept in mind that in the absence of positive personal evidence, suspicion in cases of neurasthenia at least favors the deceitful introduction of doubtful bodies. In many cases on record such things as earthworms, chicken entrails, etc., have been forcibly introduced into the rectum or vagina and have been subsequently reported by the attending physician as undoubted human entozoa of a remarkable character! Here as elsewhere the appearance of unusual structures should at once arouse the suspicion of the physician and call forth a most searching examination of the case in all its factors that any deceit be disclosed or that in event of the discovery of some rare parasite all conditions connected with its appearance be put on record for future use. Furthermore, it is important to preserve the fullest data in regard to any substances associated with the supposed parasite as well as concerning the food of the patient, whether usual or unusual, since in this way some hint as to the introduction of the questionable body may be found.

Finally, it is important to direct attention to the wisdom of preserving all material, whether new and doubtful or not, in considerable quantities, and both of the eggs and embryos as well as the adults, or as many thereof as can be obtained. In case of doubt regarding the identification of species, or possible question as to the source, it is important that the material, or some portion of it, should be referred to some expert helminthologist for examination and verification of the result attained. It is always a pleasure to have the opportunity of examining such material, and to assist one's colleagues in any way in connection with such studies. In most cases, in fact, and especially such as deal with the occurrence of rare forms, or such as are new, it is desirable that such corroborative evidence should be secured before publication, for in this way is often prevented the confusion which arises from incorrect descriptions or from the publication of new names which are merely synonymous with those already known to science. As a matter of fact, the practitioner can hardly hope to be acquainted with the entire range of parasitic species, and if to the accurate observations which he records regarding the clinical side of the question can be appended the notes of some helminthologist who is in position to give an expert opinion regarding the other side, the results are far more valuable to the world from their rounded scientific character and permanent value, than could be attained by the publication of either group of factors separately.

The large number of parasites in other animals which some unusual combination of circumstances may bring into the human system makes it imperative also that any supposedly new species be submitted to the judgment of a specialist before it is described as such. Only in this way can the discoverer avoid adding to the long list of synonyms which already burden the literature of this subject and render it so difficult for the investigator not a specialist in this particular line to find his way aright.

Reference has also been made to the grosser errors in determining the character of objects discovered in microscopical examinations. Some of these have been detected by virtue of evidence drawn from attendant circumstances; it may be equally positively asserted that many such have not been recognized though suspected and others still remain entirely unsuspected. To such errors in interpretation as well as to such as are due to faulty observation the scientific

world owes a long list of anomalous, inexplicable and often unthinkable occurrences listed in the chronicles of helminthology as in other fields of science. Progress depends upon the elimination of these errors and the substitution of more accurate methods.

BIBLIOGRAPHY

BAELZ, E.

1880. Ueber parasitäre Hämoptoë (*Gregarinosis pulmonum*). Centralblatt f. d. med. Wiss., XVIII., (39), pp. 721-722.
 1883. Ueber einige neue Parasiten des Menschen. Berl. klin. Wochenschr., XX., pp. 234-238, figs. 1-3.

BLANCHARD, R.

1891. Histoire zoologique et médicale des téniadés du genre *Hymenolepis* Weinland. Bibliothèque Générale de Médecine, Paris.

BRAUN, M.

1902. Die thierischen Parasiten des Menschen. Dritte Auflage. Würzburg.

DIAMARE, V.

1893. Il Genere *Dipylidium* Lt. Atti R. Accad. Scienze Napoli (2), VI., no. 7, 31 pp., 3 pl.

GUYER, M. F.

1898. On the Structure of *Taenia confusa* Ward. Zool. Jahrbücher., Abt. Syst., Geogr. und Biol., XI., pp. 469-492, plate 28.

IJIMA, I.

1887. Notes on *Distoma endemicum* Baelz. Journal of Science College, Imperial University, Japan, I., 12 pp., plate vii.
 1896. *Stronglyus subtilis* in Japan. Journal of Science College, Imperial University, Japan, VI., pp. 157-161.

IJIMA, I., AND KURIMOTO, T.

1894. On a New Human Tape-Worm (*Bothriocephalus* sp.). Journal of the College of Science, Imperial University, Japan, VI., pp. 371-385, Pl. xviii.

KATSURADA, F.

1900. Beitrag zur Kenntniss des *Distomum spathulatum*. Beiträge zur pathol. Anat. und zur allg. Pathol., XXVIII., pp. 479-505, Taf. xiii.
 1900a. Beitrag zur Kenntniss des *Distomum Westermanii*. Beitr. path. Anat. und zur allg. Path., XXVIII., pp. 506-523, Taf. xiv, xv.

KERRERT, C.

1881. Beitrag zur Kenntniss der Trematoden. Arch. f. mikr. Anat., XIX., 529-578, Taf. XXVI-XXVII.

LEUCKART, R.

- 1879-1886. Die Parasiten des Menschen und die von ihnen herrührenden Krankheiten. Leipzig und Heidelberg. Bd. I., 2. Aufl.
 1889. Die Parasiten des Menschen und die von ihnen herrührenden Krankheiten, 2. Aufl., I., 2. Abt., 4. Lief., pp. 97-440, figs. 61-191.
 1894. Ibid., 5. Lief., p. 441-736.

LINSTOW, O. VON.

1896. Über *Taenia (Hymenolepis) nana* v. Siebold und *murina* Duj. Jenaische Zeitschrift, XXX., pp. 571-582.
 1900. *Taenia africana* n. sp., eine neue Tania des Menschen aus Afrika. Centralbl. Bakt. und Par., I. Abt., XXVIII., pp. 485-490.

LOESS, A.

1894. Ueber den Bau von *Distomum heterophyes* v. Sieb. und *Distomum fraternum* n. sp. Leipzig. 59 pp., 2 pl.
 1895. *Strongylus subtilis* n. sp., ein bisher unbekannter Parasit des Menschen in Egypten. Centr. Bakt. u. Par., I. Abt., XVIII., pp. 161-169. 1 pl.
 1896. Recherches sur la faune parasitaire de l'Égypte. Mém. Inst. Égyptien, III. 252 pp., 16 pl.
 1899. Weitere Beiträge zur Kenntniss der Trematoden-Fauna Aegyptens. Zool. Jahr., Syst., XII., pp. 521-784, Pl. 24-32.

MIURA, K., AND NISHIUCHI, N.

1902. Ueber befruchtete und unbefruchtete Ascaridencier im menschlichen Kote. Centr. Bakt. u. Par., XXXII., Orig., 637-641.

ODHNER, TH.

1902. *Fasciolopsis Buski* (Lank.) [= *Distomum crassum* Cobb.], ein bisher wenig bekannter Parasit des Menschen in Ostasien. Centr. Bakt. u. Par., XXXI., Orig., pp. 573-581, 1 pl.

PARONA, C., AND GRASSI, B.

1878. Sullo sviluppo dell' *Anchilostoma duodenale*. Atti Soc. Ital. Sci. Nat., XXI., 6 pp., 1 pl.

RAILLIET, A.

- 1893-1895. Traité de zoologie médicale et agricole, 2^e. Ed. Paris.

SCHAUINSBLAND, H.

1886. Die embryonale Entwicklung der Bothriocephalen. Jenaische Zeitschrift, XIX., 520-572, 3 pl.

SCHULTHESS, W.

1882. Beiträge zur Anatomie von *Ankylostoma duodenale* (Dubini) = *Dochmius duodenalis* (Lkt.). Zeit. f. wiss. Zool., XXXVII., 163-230, 2 pls.

SOMMER, F.

1880. Die Anatomie des Leberegels, *Distomum hepaticum* L. Zeit. f. wiss. Zool., XXXIV., 104 pp., 7 pls.

STILES, C. W.

1894-1895. The Anatomy of the large American Fluke (*Fasciola magna*). Jour. Comp. Med. and Vet. Archives, Mar., 1894-May, 1895.

STILES, C. W. AND HASSALL, A.

1900. Notes on Parasites 51. The Lung Fluke (*Paragonimus Westermanni*) in Swine and its relation to Parasitic Haemoptysis in Man. Sixteenth Annual Report, Bureau of Animal Industry, U. S. Department of Agriculture, pp. 560-611, figs. 24-28 in text. Pls. xxiii-xxiv.

1902. The Significance of the Recent American Cases of Hookworm Disease (Uncinariasis, or Anchylostomiasis) in Man. Ann. Rept. Bureau An. Indust., XVIII., 183-222.

THAYER, W. S.

1901. On the Occurrence of *Strongyloides intestinalis* in the United States. Jour. Exp. Med., VI., 75-105, 1 pl.

THOMAS, J. J.

1899. A Case of Bone Formation in the Human Brain due to the presence of *Coccidium oviforme*. Jour. Bost. Soc. Med. Sci., III., 167-9.

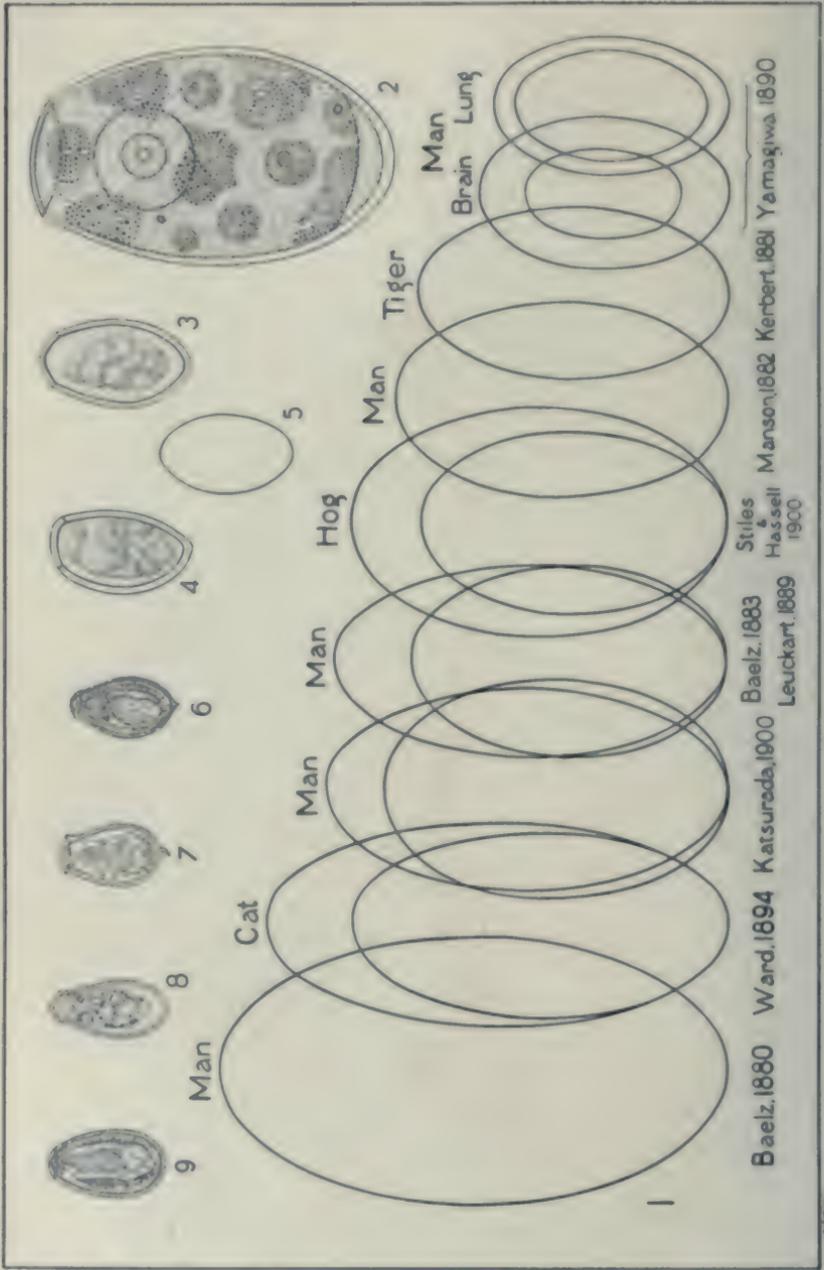
WARD, HENRY B.

1894. On the presence of *Distoma Westermanni* in the United States. Vet. Mag., I., pp. 355-359.

YAMAGIWA, K.

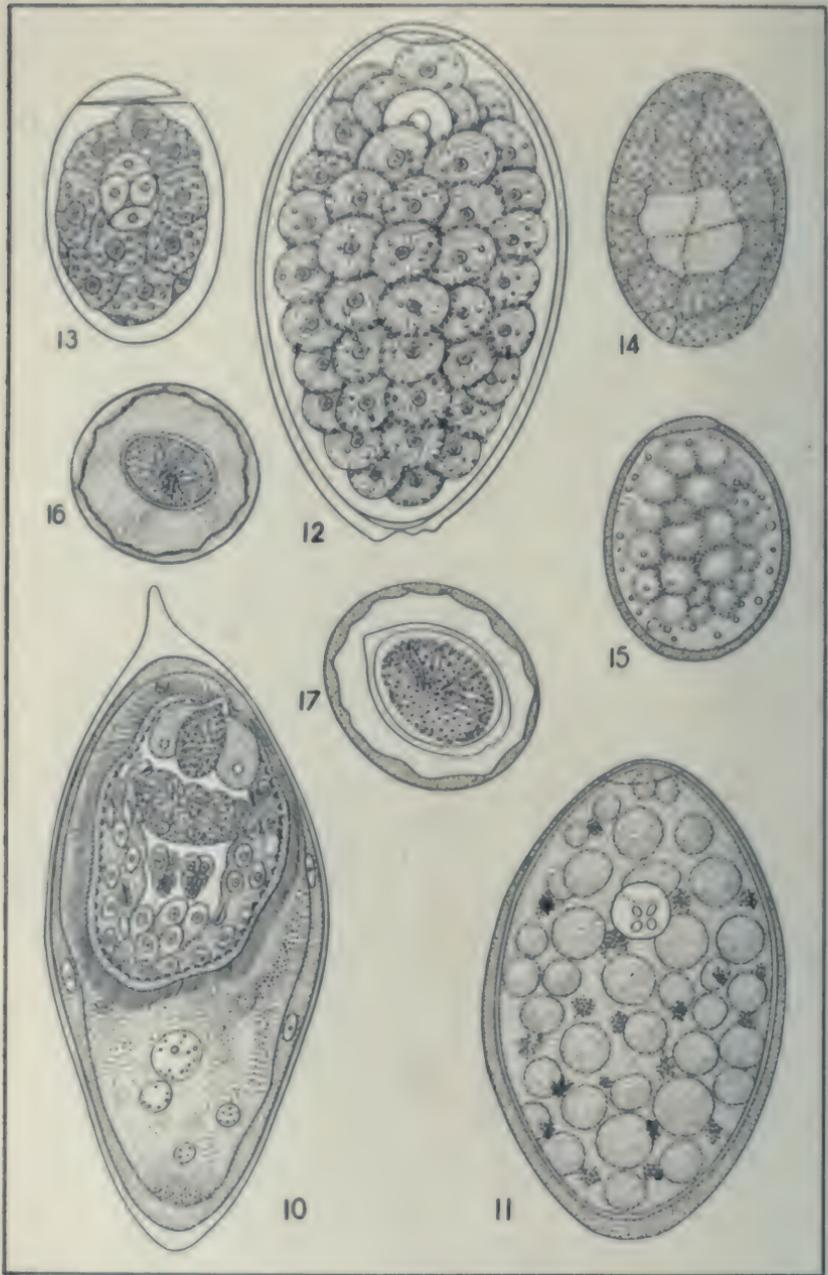
1890. Beiträge zur Aetiologie der Jackson'schen Epilepsie. Arch. f. Path. Anat. u. Phys. u. f. Klin. Med., CXIX. (2), 447-460, Taf. xl, figs. 1-3.

PLATE VIII



1282

PLATE IX



EXPLANATION OF PLATES

All of the figures have been reduced to the same scale in copying and the reproduction has brought all to the magnification of five hundred diameters. They usually represent the average size of ova in the given species.

Plate VIII

Fig. 1. Composite outline of the egg of *Paragonimus Westermanii* according to various authorities. The host is indicated above each outline; the author and date below. The outer oval gives the maximum, the inner the minimum of each observation.

Fig. 2. Egg of *Paragonimus Westermanii* from sputum of man. After Katsurada, 1900a, p. 507.

Fig. 3. Egg of *Dicrocoelium lanceatum* in surface view. After Braun, 1902, p. 168.

Fig. 4. The same in lateral aspect.

Fig. 5. Outline of egg of *Opisthorchis noveboracensis*.

Fig. 6. Egg of *Opisthorchis sinensis*. After Ijima, 1887, pl. 7, fig. 3.

Fig. 7. Egg of *Opisthorchis sinensis*. After Katsurada, 1900, pl. 13, fig. 8.

Fig. 8. Egg of *Opisthorchis felineus*. After Braun, 1902, p. 158.

Fig. 9. Egg of *Heterophyes heterophyes*. After Looss, 1896, pl. V., fig. 39.

Plate IX

Fig. 10. Egg of *Schistosoma haematobium* from the urine of man. After Looss, 1896, pl. XI., fig. 112.

Fig. 11. Egg of *Fasciola magna*. After Stiles, 1894, p. 227, fig. 4. This figure is drawn to the minimum, not to the average size of ova in this species.

Fig. 12. Egg of *Fasciola hepatica*. After Sommer, 1880, pl. VI., fig. 1c.

Fig. 13. Egg of *Dibothriocephalus latus* with operculum opening. After Schauinsland, 1886, pl. VII., fig. 31.

Fig. 14. The same, earlier stage. After Schauinsland, 1886, pl. VII., fig. 29.

Fig. 15. Egg of *Diplogonoporus grandis* taken from the uterus. After Ijima and Kurimoto, 1894, pl. XVIII., fig. 9.

Fig. 16. Egg of *Hymenolepis diminuta*. After Blanchard, 1891, p. 45.

Fig. 17. The same, elongated form.

Plate X

- Fig. 18. Egg of *Hymenolepis nana*. After von Linstow, 1896, p. 580, fig. IV.
- Fig. 19. Mature egg of *Taenia saginata*. After Leuckart, 1886, p. 568.
- Fig. 20. The same without external membrane. From human feces. After Leuckart, 1886, p. 186.
- Fig. 21. Egg of *Taenia solium*. After Leuckart, 1886, p. 667.
- Fig. 22. The same without external membrane. From human feces. After Leuckart, 1886, p. 186.
- Fig. 23. Egg of *Taenia africana*. After von Linstow, 1900, p. 489.
- Fig. 24. Egg of *Taenia confusa*. After Guyer, 1898, pl. XXVIII., fig. 11.
- Fig. 25. Egg of *Dipylidium caninum*. After Diamare, 1893, pl. I., fig. 18.
- Fig. 26. Egg of *Diocotphyme renale* in surface view. After Balbiani from Railliet, 1893, p. 421.
- Fig. 27. The same in optical section.
- Fig. 28. Egg of *Uncinaria duodenalis*. After Parona and Grassi, 1878, pl. II., fig. 6.
- Fig. 29. Egg of *Uncinaria americana* from human feces. After Stiles, 1902, p. 193.
- Figs. 30-32. Same with cleavage begun.

Plate XI

- Fig. 33. Egg of *Ascaris lumbricoides* from human feces. Seen in surface aspect. After Stiles, 1902, p. 202.
- Fig. 34. Same in optical section.
- Fig. 35. Unfertilized egg of *Ascaris lumbricoides* from human feces. After Miura and Nishiuchi, 1902, p. 638.
- Fig. 36. Egg of *Ascaris canis*. After Braun, 1902, p. 303.
- Fig. 37. Egg of *Trichuris trichiura* from uterus of female worm. After Leuckart from Stiles, 1902, p. 202.
- Fig. 38. Same in stage from human feces.
- Figs. 39-41. Eggs of *Oxyuris vermicularis* taken from uterus of female worm. After Leuckart from Stiles, 1902, p. 202.
- Fig. 42. Same in stage found in human feces.
- Fig. 43. Outline of egg of *Strongylus subtilis*. The larger oval and the cleavage cells from eggs free in stomach contents, after Ijima, 1896, p. 160; the smaller oval from eggs before deposition after Looss, 1895, p. 169.
- Fig. 44. Egg of *Strongyloides stercoralis* from human feces. After Thayer, 1901, pl. IX., fig. A.
- Fig. 45. Egg of *Gigantorhynchus gigas*. After Leuckart from Braun, 1902, p. 309.

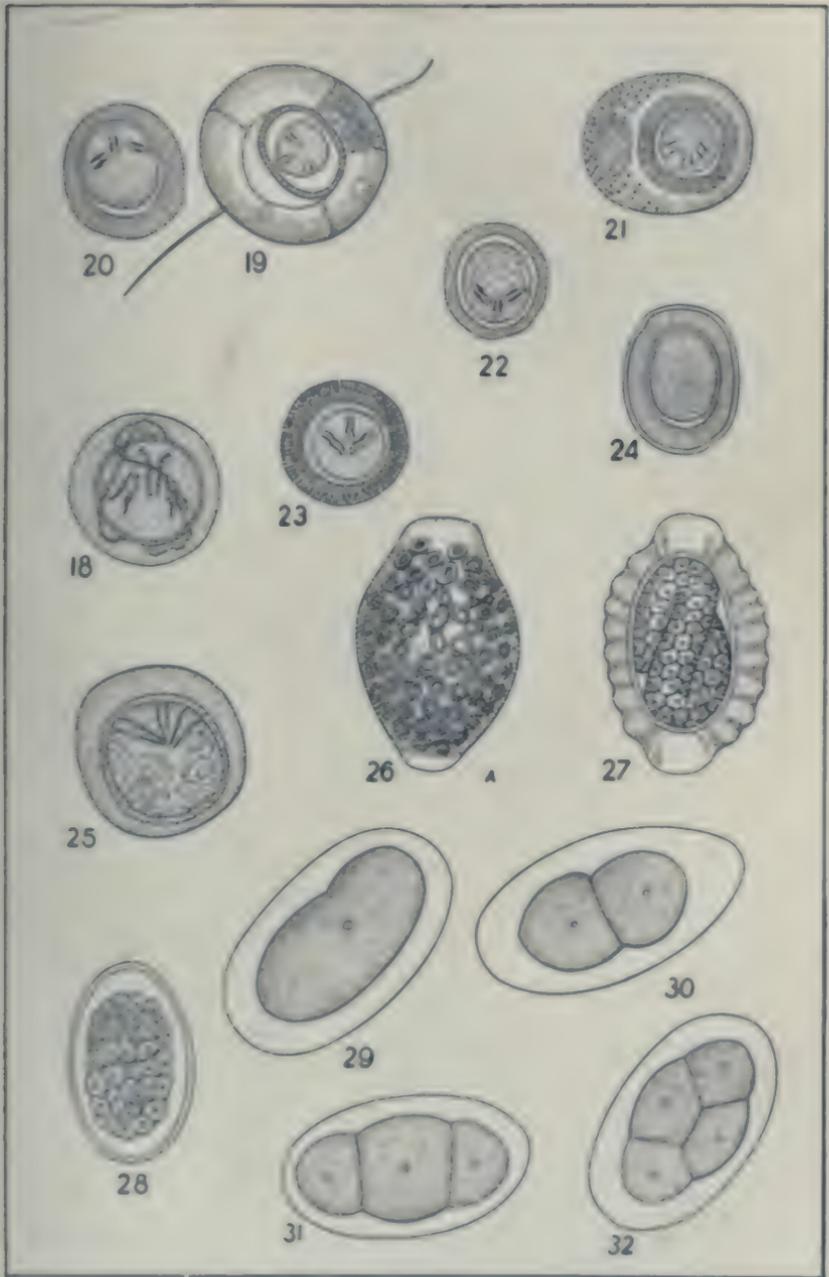
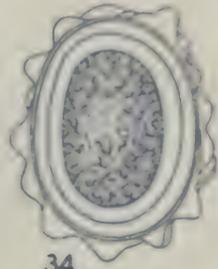


PLATE XI



36



THE NORTH AMERICAN SPECIES OF LIMNESIA

By ROBERT H. WOLCOTT

WITH TWO PLATES

I. INTRODUCTION

Though not numerous in species the genus *Limnesia* is quite universally distributed and almost always met with in collections. It may be recognized, in general, by its oval, highly-arched body; by the presence of two eyes on either side of the body anteriorly; by the absence of claws on the last pair of legs, which end in a sharply-pointed distal segment; and by the characters of epimera and genital area. The individuals are active and brightly-colored, of rather large size, and with pronounced cannibalistic tendencies, not only all other weaker forms of animal life present with it in an aquarium falling prey to its rapacity, but also most other mites, especially those of small size and with soft bodies.

The characters common to representatives of the genus may be enumerated more in detail as follows:

Size medium, but such as to rank them among the larger of the active, free-swimming forms. Form of body seen from dorsal or ventral aspect, oval, from the lateral, highly arched and with little tendency to dorsal pitting.

Body usually soft and epidermis marked with fine, wavy lines; sometimes a tendency to become papillose is observed, and in certain species a chitinous covering composed of a fine meshwork is developed. The glands are prominent, though not specially numerous, and surrounding each is a small chitinous ring bearing a fine hair.

The two eyes on either side, usually fused in adult hydrachnids, here remain separate, a considerable distance existing between those of the opposite sides. The anterior on each side is largest, with a spherical lens and an elongated pigment body, and is movable; the

posterior smaller and not movable. Below the eyes on the anterior surface of the body is a pair of antenniform bristles.

The maxillary organ is produced into a short snout at the end of which is the mouth opening, on the dorsal margin of this opening there being two hairs and on the ventral two more. The maxillary shield appears crowded between the anterior pair of epimera, while posteriorly on either side a short, broad ancoral process extends outward beneath these epimera.

The palpi vary considerably in different species, but in all the second segment is the stoutest, the fourth is longest and relatively slender, and the fifth quite pointed, the claws at its tip being small and inconspicuous. In most species there is, on the flexor surface of seg. 2 a prominent peg-like spine, usually inserted into the end of a projecting papilla, while toward the tip of seg. 4 on the flexor surface is a pair of fine long hairs borne on low papillae placed at the proximal end of an excavation varying in depth. In many species the spines on the palpi are pectinate.

The epimera are in four groups, the two anterior and the two posterior on either side being in apposition. The space between ep. II and ep. III is narrow, somewhat broader toward the lateral end where a gland opens. Ep. III is of the usual form, but ep. IV is characterized by its large size and triangular outline. Of the sides of this triangle the longest is lateral, the next in length is medio-posterior, and the shortest in medio-anterior, meeting ep. III. Leg IV is inserted at the posterior angle of this epimeron. The gland usually situated behind this last epimeron is here situated at its medial angle and is surrounded by a chitinous plate of considerable size which is set in between ep. III and ep. IV at the medial end of the suture separating them and which varies in different species in regard to its exact position with respect to the two epimera and to the degree to which it is fused with them.

The legs bear numerous spines, many of them, especially at the distal ends of the segments, being pectinate. Swimming-hairs are present on III and IV. The anterior three pairs are terminated by retractile claws, which are curved, sharply pointed, and bear, in addition to the principal tip, two others, one internal, the other external. The last segment of leg IV ends in a point bearing no claw but furnished with a long, slender spine inserted close to the tip.

The genital area is included in the space lying between the diverging medio-posterior margins of the last pair of epimera, and exhibits as a whole a more or less broadly and more or less regularly pyriform outline, the broader end being posteriad. The cleft is flanked and quite surrounded by two movable plates, each bearing three or four acetabula, and numerous spines, irregularly distributed.

The male is smaller than the female and the appendages are relatively larger. The spaces between the epimera are narrower. The most marked difference appears, however, in the genital area, which in the male is shorter and broader. The two genital plates show a tendency to fuse at their ends, forming a continuous plate about the cleft, and correlated with this is a change in the form of these plates; in the female the inner margins are straight and the plates of the two sides come together over the cleft, but in the male these inner margins are excavated, leaving a narrowly elliptical space about the cleft filled by its swollen lips. In front of the two flaps appears, in the female, a transversely-placed, narrow, arcuate plate.

Although there are certain species of *Limnesia* which may be at once recognized by some striking character, such as the chitinous covering of *L. lorca* Thor and *L. cornuta*, here described, the increased number of acetabula of *L. aspera* Koenike, a Madagascar species, and the very peculiar two-clawed hooks projecting from the anterior end of the genital plates of *L. armata* Koenike, an African form, other species of the genus are less easily recognized and the author has found it at times difficult to discriminate between them. The following characters serve in general, however, to distinguish the species: character of integument, form of palpi and character of spines and hairs, form of antenniform bristles, details in form of epimera, character of spines on the legs, and characters of the genital area. The characters seem to be fairly constant for each species, though there is some variation in the length of the papilla on palp. seg. 2, in the number of swimming-hairs, the distance between the acetabula, etc. In every case where specimens have been referred to a European species the author has found details in which his specimens do not entirely agree with printed descriptions, but our knowledge of variation in this group is not sufficiently accurate

yet, in the author's opinion, to furnish a satisfactory basis for the recognition of subspecies, varieties, or forms.

The genus possesses a wide distribution, species having been described from Europe, eastern Africa, Madagascar, South America, and Central and North America. Piersig (1901) recognizes twelve species and two have since been described, while Piersig also enumerates fourteen the status of which is uncertain. Of these three recognizable species and three questionable ones are referred to North and Central America.

Stoll, in the *Biologia Centrali-Americana* (87), described four species from Guatemala—*L. guatemalteca* (p. 13, 47, Pl. VII, f. 2), *L. longipalpis* (p. 13, 47, Pl. IX, f. 2), *L. puteorum* (p. 14, 48, Pl. VII, f. 3), and *L. lacta* (p. 14, 48, Pl. VIII, f. 2). Of these the first is a nymph; the second is a form allied to *L. histrionica*, but the name cannot stand as it had previously been applied by Koch to a European nymph. *L. puteorum* is most closely related to *L. connata* Koenike, a European species, coming among those forms in which the spine on the second palpal segment is not borne on a papilla. *L. lacta* is a species characterized especially by the absence of this spine on the flexor surface of pal. seg. 2, and also by the peculiar form of the genital area which is greatly broadened transversely and of an irregular outline.

Koenike (95b) discovered two species in material collected in Canada by Dr. J. B. Tyrrell, *L. undulata* (Müll) and *L. Koenikei* Piersig, the two being well-known European forms.

To these species hitherto recorded from North America the author now has the pleasure of adding five, of which two are new, and the list, together with the known distribution, becomes as follows:

1. *Limnesia lacta* Stoll—Guatemala.
2. *Limnesia cornuta* n. sp.—Michigan.
3. *Limnesia histrionica* (Herm.)—New Jersey, Michigan, Wisconsin, Illinois, Nebraska, Washington.
4. *Limnesia undulata* (Müll.)—New York, Michigan, Canada.
5. *Limnesia* sp. (*longipalpis* Stoll)—Guatemala.
6. *Limnesia paucispina* n. sp.—Michigan.
7. *Limnesia puteorum* Stoll (!)—Mexico, Guatemala.
8. *Limnesia Koenikei* Piersig—Canada.
9. *Limnesia maculata* (Müll.)—New York, Michigan.

In the preparation of this paper the writer has had not only the material collected by himself but also specimens received from Mr. E. W. Berry of Passaic, N. J., Mr. R. H. Johnson, until recently of Harvard College, Cambridge, Mass., Mr. J. B. Shearer of Bay City, Mich., Professor J. G. Needham of Lake Forest, Ill., Professor Trevor Kincaid of Seattle, Wash., and Dr. A. Dugès of Guanajuato, Mexico. To all of these gentlemen the writer desires here to express his deep obligation. Owing to the great kindness of Dr. Koenike of Bremen, Germany, he has also had for comparison European specimens of *L. histrionica*, *L. undulata*, *L. maculata*, and *L. Koenikei*.

The method of preparation and study has been the same as that described in previous papers on the group, and the same method of numbering segments and system of abbreviations are here followed, the context making apparent their meaning. Measurements are not made, as heretofore, along the middle of a segment, but along the extensor margin, since that seems to give more exactly the real length of an appendage when outstretched. Measurements of the distal segments of the legs do not include claws or the spine at the tip of seg. IV 6. Where the extremity of this last segment is oblique to the extensor margin the measurement is taken along a line continuing the latter to a point even with the farthest portion of the segment. The dorso-ventral diameter of a palpal segment is referred to as its thickness, the transverse diameter as its width.

No attempt has been made, in the paper, to deal with immature specimens.

II. DESCRIPTIONS OF SPECIES

1. *Limnesia cornuta* n. sp.

A species which may be recognized at once by the presence of a chitinous meshwork covering the body, by the length of the antenniform bristles, and by a plate on the dorsal surface of the body posteriorly.

The body is broad, evenly rounded anteriorly, truncate posteriorly and moderately high, with an evenly arched dorsal surface. The measurements of two female specimens are 0.95 mm. by 0.87 mm., and 0.98 mm. by 0.89 mm., respectively, while a male is 0.71 mm. long by 0.63 mm. broad.

The integument is distinguished by the presence of a chitinous meshwork made up of narrow trabeculae separating irregularly polygonal areas from $3\ \mu$ to $4\ \mu$ in diameter (Pl. XII, fig. 3). The glands scattered here and there are rather prominent, and there is a pair of long slender hairs borne on papillae, about 0.2 mm. apart, situated between and slightly in front of the eyes. Posteriorly on the dorsal surface is an elliptical area about 0.15 mm. by 0.12 mm. which shows prominently as a dark patch in a fresh specimen, and which seems to mark the position of certain glands beneath the surface. It apparently corresponds to the plate described by Koenike (98b: 402) as present in *L. scutellata*, and in a mounted specimen is seen to be a clearly defined plate with heavier trabeculae and much finer meshes than over the rest of the body.

There is a space of about 0.25 mm. between the eyes of the two sides while those of the same side are separated by a distance equal to twice the diameter of the lens of the anterior, which is rather small, measuring only $24\ \mu$. The finely serrate antenniform bristles (Pl. XII, fig. 2) are long, stout, and curved backward, standing nearly vertical on the papillae which bear them. In one female the length of these bristles is $64\ \mu$, in a male $87\ \mu$, while the distances separating the two are 0.13 mm. and 0.10 mm. respectively.

Corresponding to the deposition of chitin in the integument all hard parts are very heavily chitinized.

In length the palpi of the male exceeds by considerable half the length of the body, while in the female (Pl. XII, fig. 1) they fall a little short of the same measure; in width they are about equal to the first pair of legs. The spine on the flexor surface of seg. 2 is excavated toward the distal end, the two papillae in this excavation both equalling less than one-fourth the dorso-ventral diameter of the segment. Seg. 3 is in this direction nearly as broad as seg. 2; on its inner side near the extensor margin is a longer distal and a shorter proximal spine, while at the distal margin of the segment on the outer side is a pectinate spine between the other two in length. Seg. 2 has three spines on the inner side and two on the outer. Seg. 4 has a straight flexor margin for about two-thirds its length, then is excavated toward the distal end, the two papillae in this excavation bearing long, slender hairs; on the inner side at this end of the segment are a few very small hairs. The proportionate length of the palpal segments is as follows: 5, 27, 19, 38, 11.

The maxillary shield is triangular and extends back between the anterior pair of epimera nearly to their posterior extremities, where they are separated by a distance equal to a little less than their width at the end. The spaces between epimera are relatively narrow. The diverging medio-posterior margins of epp. IV form an angle somewhat greater than 90° , are undulating, and a line connecting the posterior angles passes, in the male, behind the whole genital area, while in the female it lies behind the middle acetabula. The gland plate at the inner end of ep. III occupies much of the end of the epimeron.

The legs are of moderate length, increasing in length from the first to the last pair, and only the last pair distinctly longer than the body. Spines are not numerous, but are stout and very many are pectinate, especially on legs III and IV. Swimming-hairs are few, there being only four on III 5 and four or five on IV 5.

The genital area in a female (Pl. XII, fig 4) 0.98 mm. long measures 0.21 mm. in length by 0.16 mm. in width; in a mounted male (Pl. XII, fig. 5) it is 0.18 mm. long by 0.21 wide. In both sexes it is pyriform in shape and resembles that of *L. Koenikei*, the greatest breadth being about two-thirds the way back from the anterior end. The acetabula are large, elliptical in form, of the usual number, and while in the male the distance between them is about the same and a little less than one-third the length of one of them, in the female the second and third are close together and the first and second are separated by a space not over one-half the length of the second.

Measurements from mounted specimens:

	MALE mm.	FEMALE mm.
Length of body.....	0.70 (estim.)	0.95
Width of body.....	0.63 (estim.)	0.87
Leg I.....	0.55	0.59
Leg II.....	0.66	0.72
Leg III.....	0.75	0.85
Leg IV.....	0.94	1.04
Palpus.....	0.43	0.44
Length of genital area.....	0.18	0.20
Extreme breadth of same.....	0.21	0.18

The color of the specimen from Charlevoix is stated in field notes to have been whitish, varied with dark; a red spot near the posterior

end of the body; eyes carmine-red, and legs and epimera tinged with the same. The others were all similar.

Types in the author's collection.

Of this species one female specimen was collected in Round Lake, Charlevoix, Mich., in bottom towing, July 10, 1894; a second female was secured in dredging on the bottom in 16 meters of water, in Lake Michigan, two miles northwest of Norwood, Mich., August 8, 1894; two males and a young female were taken in Softwater Lake, near Grand Rapids, Mich., August 19, 1895.

The name is in allusion to the appearance produced by the long antenniform bristles. This species is closely related to *L. lorea* Thor (99: 23), and in fact agrees with every detail in his brief description. He makes no mention, however, of the conspicuous posterior dorsal plate or of the prominent antenniform bristles, and his figures (Pl. VIII, figs. 86 a, 86 b, 87) show the following points of difference: The papilla and spine on the flexor side of palp. seg. 2 are longer in *L. lorea* than in *L. cornuta*; the other spines on the palpus are more numerous in *L. lorea*; the space between the anterior two acetabula is much wider in Thor's species and the acetabula are circular instead of elliptical; the space between the anterior epimera is wider and between the posterior narrower than in *L. cornuta*. The two are evidently closely allied but apparently distinct. *L. cornuta* resembles *L. scutellata* Koenike, from Madagascar, in the size of the antenniform bristles and in the possession of the dorsal plate, but differs in very many other details of structure.

2. *Limnesia histrionica* (Hermann)

Hydrachna histrionica Hermann, 04; 55, pl. II, fig. 2.

Limnesia fulgida Koch, 35; fasc. 2, fig. 19.

Limnesia maculata Krendowsky, 84; 304, pl. VII, figs. 4, 7, 8.

Limnesia longipalpis Soar, 97; 23, pl. III, figs. 6-9.

This well-known European species can be recognized by the faintness of the lines on its surface, the small size of its antenniform bristles, the length and thickness of its palpi, the length of the papilla on palp. seg. 2, and the character of the genital area.

It is one of the largest species of the genus, female specimens being commonly met with of lengths varying from 1.75 mm. to 2 mm. and breadths from 1.50 mm. to 1.70 mm., while the males

varying in length from 1 mm. to 1.25 mm. The body is broadly oval in dorsal view and highly arched in lateral view, but not evenly so, there being more or less well-developed anterior and posterior dorsal depressions; evenly rounded at both ends, sometimes slightly emarginate laterally behind the eyes.

The surface of the body is marked by very faint wavy lines which intersect forming elongated, irregular areas.

The eyes are relatively very small, in a female example selected at random and 1.90 mm. long by 1.59 mm. broad, the anterior lens being only 32μ in diameter. In the same specimen the distance between the anterior eyes of opposite sides is 0.48 mm. and the distance between the posterior 0.57 mm., while the two eyes on either side are 0.14 mm. apart. The antenniform bristles are very small, pointed, and borne on inconspicuous papillae; in the specimen just referred to they are about 24μ long.

The palpi (Pl. XII, fig. 6) are long, those of the female in length half that of the body, while those of the male may be two-thirds the body length; they are about twice as wide as the first pair of legs. The proportionate length of individual segments is: 4, 26, 17, 42, 11. Seg. 3 is nearly as thick as seg. 2, tapering toward its distal end, while seg. 4, is not only proportionately long but also noticeably slender, its thickness at the middle being only one-eighth its length and only two-sevenths the thickness of seg. 2. The papillae on the flexor surface of seg. 2 is very long, and though the peg-like spine at its tip is very short, the length of the two combined equals nearly half the thickness of the segment; the sides of the papilla are nearly parallel. On the inner side of seg. 2, toward the dorsal margin, is a row of about seven small spines, on the opposite side a row of three toward the proximal end and two, side by side, at the distal margin; on the inner side of seg. 3 are three spines and one at the distal margin, on the outer side one longer and three shorter ones. A very fine pectination can be seen on more or less of these spines except this longer one on seg. 3.

The maxillary shield is broad, relatively large, and extending well back, nearly even with the posterior ends of epp. I, which send narrow processes inward behind it, the processes from opposite sides meeting and fusing in the median line (Pl. XII, fig. 7). The spaces between the epimera are relatively wide. The medio-pos-

terior margins of epp. IV are widely divergent, forming an angle 125° to 130° ; anteriorly these margins are concave, posteriorly convex. The inner ends of epp. III and IV are produced, and the gland plate is set in opposite the inner end of the suture between them. The suture between this plate and ep. III is obliterated.

The legs are rather slender and leg II is nearly as long as leg III. In the case of the male these two legs approach the body-length and leg IV exceeds it by considerable, but in the female leg IV hardly equals this length. The distal segment in each leg is slightly curved. Hairs and spines are very numerous, relatively long, rather slender, and comparatively few are pectinate. On segs. III 4 and III 5 are five and eight to ten swimming-hairs respectively; on segs. IV 4 and IV 5 six and ten.

The genital area is so placed that a line connecting the posterior angles of epp. IV will in the female pass between the two anterior acetabula, in the male through the posterior. It is typical in form with rather large acetabula, of which the two anterior are in the female approximately circular, the posterior elliptical in outline, while in the male all are in general circular. The former are separated in the female (Pl. XII, fig. 7) by a space equal to half the diameter of each, while the posterior are closer together, and in the male the same is true. In the male, however, the whole area is slightly broader than long, while in the female it is about one-seventh longer than broad, being in one specimen, for example, 0.22 mm. wide and 0.25 long.

MEASUREMENTS

	MALE	MALE	FEMALE
	Lake St. Clair mm.	High Id. Harbor mm.	High Id. Harbor mm.
Length of body.....		1.24	1.90
Width of body.....		1.00	1.59
Leg I.....	1.17		1.04
Leg II.....	1.38		1.32
Leg III.....	1.39	1.16	1.35
Leg IV.....	1.81		1.82
Palpus.....		0.79	0.96
Length of genital area.....		0.21	0.26
Width of genital area.....		0.22	

The color varies greatly. Specimens from Reed's Lake, Grand Rapids, Mich., were "yellowish-white, tinged with greenish an-

teriorly between the bright red eyes; brownish-black patches and vermilion spots dorsally; below a clear white patch posteriorly; legs, palpi, etc., bright bluish green." Others from Twin Lakes, Charlevoix, Mich., were described in field-notes as "orange-red throughout, appendages paler; darker shadings; eyes purplish-brown." Specimens from Lake St. Clair were "yellowish-brown, whole surface with very fine whitish lines; spots of yellow, and two white patches on either side dorsally; legs bluish green."

Judging by previous experience this is the most common North American species of *Limnesia*, and an abundance of material is at hand. The following localities are represented:

New Jersey—Passaic, April, 1902, 1 female (E. W. Berry).

Michigan—Lake St. Clair, summer of 1893, 114 specimens, equally divided between males and females; Reeds's, Lamberton, and Softwater Lakes, and Grand River, Grand Rapids, summers of 1895, 1896, 1897, and 1898, 12 males and 7 females; Twin Lakes and Susan Lake, Charlevoix, August, 1894, 2 females; High Island Harbor, Northern Lake Michigan, August 18, 1894, 46 males and 16 females.

Wisconsin—Lake Winnebago, Oshkosh, August, 1897, 3 females.

Illinois—Pond at Galesburg, September, 1895, 5 males and 2 females (J. G. Needham).

Nebraska—Pond at Child's Point, Omaha, May, 1902, 2 males.

Washington—Seattle, March 10, 1902, 2 females (Trevor Kincaid). A total of 211 adult specimens.

This is a generally distributed European species, being recorded by Piersig (1901: 174) from Finland, southern Russia, Sweden, Norway, Germany, Austria, Switzerland, France, England, and Scotland.

3. *Limnesia undulata* (Müller)

Hydrachna undulata Müller, 1781; 80, pl. XI, fig. 1.

Hydrachna erythrophthalma Hermann, 04; 57, pl. III, fig. 3.

Limnesia pardina Neuman, 70; 109. Neuman, 80; 101, pl. I, figs. 3 a, 3 b, 3 c, 3 d.

Limnesia variegata Lebert, 79; 344.

Limnesia tessellata Lebert, 79; 349, pl. XI, fig. 2.

Limnesia triangularis Lebert, 79; 352, pl. XI, fig. 3.

Limnesia cassidiformis Lebert, 79; 355, pl. XI, fig. 4.

Limnesia calcarea Koenike, 81; 622.

Limnesia tigrina Krendowsky, 85; 303, pl. VII, figs. 5, 6.

Limnesia undulata Koenike, 95 b; 206, pl. II, fig. 48 (from Canada).

This species is very similar to the preceding, but can be told from it by the longer palpi, the smaller acetabula and the greater distance between the two anterior, as well as by other details of structure which will appear in the following description. It can best be described by comparing it directly with *L. histrionica*.

The form of body is similar to that of *L. histrionica* but, while a few specimens have been taken approaching in size the the largest of that species, the average of those in the author's collection is distinctly smaller. The lines on the surface are more evident.

The eyes are larger and the anterior lens is elongated. In a female specimen 1.17 mm. long and 1 mm. wide the anterior lenses are 53μ long by 34μ wide and are 0.33 mm. apart, while the posterior are situated closer to them than in the other form and slightly farther outside them. The antenniform bristles are here also small, slender and pointed, but are slightly longer; in the specimen just referred to the distance between them is 0.24 mm.

The palpi (Pl. XIII, fig. 9) are longer than in *L. histrionica*, nearly equalling the body-length, and not so thick, though nearly double in width the first pair of legs. They are relatively more slender, especially the fourth segment, which at its middle has a thickness less than one-ninth its length and one-third the thickness of seg. 2. The proportional length of the individual segments is 3, 25, 16, 44, 12. Seg. 3 is nearly the same thickness throughout and the flexor margin is very concave. On examining a number of specimens of both species, the length of the papillae on seg. 2 is found to vary considerably, but on the average that of *L. undulata* is relatively shorter than that of *L. histrionica* and usually does not equal more than one-third the thickness of the segment; it seems to be inclined more anteriorly than in the other species. The spines on segs. 2 and 3 are similar in number and position, though more noticeably pectinate, but the excavation at the distal end of seg. 4 is longer and the hair-bearing papillae are carried farther away from the tip.

The medio-posterior margins of epp. IV are less widely divergent. The spaces between all epimera are less wide.

The legs are much longer, somewhat stouter, with heavier spines, and more of these, especially on legs III and IV are prominently pectinate. Leg III is shorter than leg II in all specimens examined, although Piersig states that the contrary is true in the European *L. undulata*. III 4 has five to seven swimming-hairs, III 5, eight to ten, and the corresponding segments of leg IV about the same number.

The genital area, though relatively longer and narrower is so placed with respect to the last epimera that a line connecting their posterior angles will in both sexes pass behind the whole area; in one female specimen its length is 0.25 mm. and its width only 0.17 mm. The acetabula are nearly circular, relatively smaller and more widely separated. Between the two anterior of the female (Pl. XII, fig. 8) is a space equal to from one and a half to even two times their diameter.

MEASUREMENTS	MALE mm.	FEMALE mm.
Length of body..... (approx.)	0.75	1.19
Width of body..... (approx.)	0.60	1.02
Leg I.....	0.85	1.01
Leg II.....	0.97	1.20
Leg III.....	0.92	1.13
Leg IV.....	1.27	1.56
Palpus	0.77	1.01
Length genital area.....	0.15	0.25
Width genital area.....	0.17	0.17

The color of specimens taken at Lake St. Clair, Mich., was "grayish-white with dark patches and a white transverse band; eyes red; legs pale green." Specimens from Saginaw Bay, Mich., show indications of having been of a red color.

Specimens are at hand from Lake Chautauqua, N. Y., August, 1897, one male (R. H. Johnson); from Lake St. Clair, Mich., summer of 1893, 4 males, 5 females; from the Kawkawlin River, Mich., August, 1895, 19 males, 17 females (J. B. Shearer); and from Saginaw Bay, Mich., August, 1895, 5 females (J. B. Shearer). Koenike (95 b: 206) records the taking of 3 specimens by J. B. Tyrrell, in a "small lake near Pincher Creek," Canada.

This is also a generally-distributed European form, Piersig giving it as found in southern Russia, Sweden, Norway, Middle Europe, and England.

Note has been made of the fact that the length of legs, as given above, does not agree with that given by Piersig for *L. undulata*. Nor do the writer's specimens agree in that regard with specimens from Switzerland, received from Koenike. But after careful comparison there seems not to be sufficient reason to doubt their specific identity. And the author prefers to err on the side of conservatism in the matter of separating the American species from closely allied European forms.

4. *Limnesia paucispina* n. sp.

A species bearing a close resemblance to *L. histrionica* and *L. undulata* and evidently allied to them, but distinguished at once by the stouter palpi, with a very short papilla on the second segment, by the scarcity of spines on palpi and legs, and the character of the genital area.

The body of the single female specimen studied is broadly oval and evenly rounded at both ends; as far as can be judged it was only of moderate height. It is 0.87 mm. long by 0.70 mm. wide. The surface is marked by fine lines. The usual glands are present and for the most part they possess the very short, slender hairs found generally among species of this genus, but the pair of dorsal glands situated farthest posteriorly have very long slender hairs, projecting behind the body, and 0.11 mm. in length.

The eyes are very large and not only are the two of each side close together, but those of opposite sides are separated by a narrower interval than in the allied species, the anterior lenses being only 0.18 mm. apart, while the lenses themselves are over one-fourth as far across, being 48 μ in diameter. The antenniform bristles are similar to those of the allied species but longer than in either, measuring 33 μ ; they are 0.17 mm. apart.

The palpi (Pl. XIII, fig. 11) are over half the length of the body, much wider than the first pair of legs, and stouter, especially the two distal segments, than in the allied species. The proportional length of segments is 6, 26, 20, 37, 11; which shows that the distal segments are also relatively shorter. The total length of papilla and spine on seg. 2 is a little over one-third the thickness of the segment, but of this the spine, which is much longer than in the other species, furnishes four-fifths, the papilla being extremely short. On the inner side of seg. 2 are three small spines, and on the outer

only two, one toward the base and one at the tip; seg. 3 has two on the inner side and a longer and a shorter one on the outer. Seg. 4 is thicker than in either of the other two species with which this is compared, being one-fifth as thick as long and nearly one-half as thick as seg. 2; the excavation toward the tip is shorter and deeper. Seg. 5 is noticeably more blunt.

Maxillary shields and epimera bearing a close resemblance to those of *L. histrionica*. The sides of the first are straight, however, and the inner ends of epp. I behind it not so closely in apposition (Pl. XIII, fig. 10) and a little broader. The medio-posterior margin of ep. IV is more strongly sinuate.

The legs are relatively long, rather slender, and bear relatively very few spines and hairs, which are themselves, however, very long. At the tip of III 3 and also of III 4 is an extremely long, slender hair, and on III 5 are six swimming-hairs. On IV 4 are three swimming-hairs, two at the middle of the segment and one at the tip, while on IV 5 are three and one in the corresponding situations. On the tips of IV 4 and IV 5 are also two very peculiar spines, flat, spatulate, and with the pectinations long and confined to the tip.

The genital area (Pl. XIII, fig. 10) is quite different from *L. histrionica* and resembles that of *L. maculata* to some extent. All the acetabula are very large, but the anterior are the largest of all and are elliptical in form, while the distance between the first and second is equal to only half the diameter of the second. A line connecting the posterior angles of epp. IV passes through the last pair.

MEASUREMENTS

FEMALE

	mm.
Length of body.....	0.87
Width of body.....	0.70
Leg I.....	0.67
Leg II.....	0.83
Leg III.....	0.81
Leg IV.....	1.06
Palpus.....	0.51
Length of genital area.....	0.16
Width of genital area.....	0.13

Confused with other species when collected, no note of the color is available.

Type retained in the author's collection.

The single female specimen was taken in Powers' Lakes, Grand Rapids, Mich., August 9, 1895.

The name is in allusion to the scarcity of hairs and spines on the appendages, which is quite noticeable in contrast to the two preceding species.

5. *Limnesia puteorum* Stoll (!)

Limnesia puteorum Stoll, 87; 14, 48, pl. VII, fig. 3.

Limnesia puteorum Stoll seems to be characterized by the narrowness of the palpi, by the presence of a spine on palp. seg. 2 set directly upon the flexor surface and not borne upon a papilla, and by having a genital area similar to that of *L. maculata*. The species here described possesses all these characters and while the writer does not feel perfectly sure of the identification he prefers to consider the two as the same until comparison of material from the locality from which Stoll's species was described shall prove the identity or distinctness of the two.

The two female specimens to be described were received in a dry condition, the vial in which they were sent having been broken in transit, so it is only possible to make general statements in regard to a certain details. The form seems to have been broadly oval, the body about 1.3 mm. by 1.1 mm. in size, and the surface marked by lines.

The eyes are small, and the two lenses on either side widely separated, a space of $80\ \mu$ intervening between them; the anterior lenses of the two sides are separated by a distance equal to 0.32 mm., while the posterior are a little farther apart. The antenniform bristles are long, slender, and curved; they measure $80\ \mu$ in length and are 0.19 mm. apart.

The palpi (Pl. XIII, fig. 12) are about the width of the first pair of legs, and bear a close resemblance to those of *L. connata* Koenike, to which the species seems closest related, and also a certain similarity to the preceding species. The spine on the flexor side of seg. 2 is about $10\ \mu$ long, is slightly bent, is directed forward, tapers to a point, and about it the chitin of the integument is raised up to form a socket, although there is present no papilla of the character seen in the preceding forms. The spines are partly broken but their arrangement seems to be similar to those shown in Piersig's figure of *L. connata* (97: Pl. XXIII, fig. 58 d), except that there

are about six on the inner side of seg. 2. The excavation at the tip of seg. 4 is shallow and the two hairs seem to be placed the one midway between the other and the tip. Seg. 5 is short and relatively thick at the base. The proportional length of segments is 5, 26, 19, 40, 10.

Maxillary shield rather narrow, sides rounded; inner ends of epp. I produced inward, nearly meeting behind it. Spaces between epimera of only moderate width. Medio-posterior margins of epp. IV widely divergent, and convex throughout their length. A line connecting the posterior angles of these last epimera passes between the first and second acetabula.

The legs are short and rather slender, well provided with spines, of which few are pectinate. On III 5 appear to be from six to eight swimming-hairs, and on IV 4 and IV 5 about ten or eleven each, of which one or two are at the tip. Leg III is slightly longer than leg II, mostly due to the elongation of segs. 4 and 5.

The genital area (Pl. XIII, fig. 13) is very similar to that of *L. maculata*, but is slightly narrower.

MEASUREMENTS

FEMALE
MM.

Length of body.....	1.30
Width of body.....	1.10
Leg I.....	0.79
Leg II.....	0.92
Leg III.....	0.93
Leg IV.....	1.23
Palpus.....	0.61
Length of genital area.....	0.24
Width of genital area.....	0.17

Nothing can be said of the color.

The two females under examination were received from Dr. Alf. Dugès, and were collected at Guanajuato, Mexico. Stoll's specimens came from Guatemala.

This seems to be a very distinct species. The other forms lacking a papilla on palp. seg. 2 are *L. scutellata* Koenike and *L. lucifera* Koenike, both from Madagascar and both very different in very many respects, and *L. connata* Koenike, found in various parts of Europe, which it more closely resembles, but from which it differs especially in the character of the genital area.

6. *Limnesia maculata* (Müller)

Hydrachna maculata Müller, 1776; 191, no. 2289. 1781; 81, pl. XI, fig. 3.

Limnesia venustula Koch, 35, pt. 6, fig. 10.

Limnesia rutilata Koch, 35; pt. 6, fig. 11.

Limnesia phoenicea Koch, 35; pt. 6, fig. 12.

Limnesia attalica Koch, 35; pt. 6, fig. 15.

Limnesia cyanipes Koch, 35; pt. 6, fig. 19.

Limnesia vitellina Koch, 35; pt. 6, fig. 20.

Limnesia modesta Koch, 35; pt. 6, fig. 21.

Limnesia affinis Koch, 35; pt. 7, fig. 7.

Limnesia magna Kramer, 75; 312, pl. IX, figs. 21 a, 21 b.

Limnesia maculata can be at once distinguished by the smallness of its palpi and the abundance of long hairs and spines on the legs, including swimming-hairs, beside minor details of structure.

This is one of the largest of our species, specimens being numerous the lengths of which range from 1.6 mm. to 1.8 mm. and one under observation being 2.14 mm. long and 1.67 mm. in width. The body is oval, moderately high, quite evenly arched, and evenly rounded at both ends.

The integument is marked by fine lines. The eyes are small and very close together; in a specimen about 1.65 mm. long the diameter of the anterior lens is 55μ and the distance separating those of the opposite sides about 0.4 mm. The antenniform bristles are, in the same specimen, 0.35 mm. apart, are short, being only about 32μ long, and are stout, flattened, and pectinate.

The palpi (Pl. XIII, fig. 15) are very small, being not only very short but also hardly as wide as the first pair of legs. On seg. 2 the flexor surface in its distal half is projected to form a broad-based papilla equal in height to one-third the thickness of the segment and into the end of this is inserted, and directed ventrad and caudad, a short, blunt, fusiform spine. On the outer side of this segment are two long spines, on the inner four or five which are pectinate; while on seg. 3 are three spines on the outer side and two on the inner. From rather a narrow proximal end, seg. 4 gradually increases in thickness to just before the middle, where is its widest point; while the distal excavation begins at about the middle, extending to the tip. In this excavation are several hairs

springing from minute papillae while on the dorsal margin and on the two sides of the segment are several more very minute hairs. Just before the terminal claws on seg. 5, dorsally and ventrally, are two hairs. The proportional lengths of the segments are 5, 28, 17, 40, 10.

The maxillary shield is small, not over half the length of ep. I, and owing to its being crowded in between the anterior portion of these first epimera and the form of these epimera, the posterior half of their inner margins lie close together in the median line (Pl. XIII, fig. 14). The spaces between the epimera are moderately wide. The medio-posterior margins of epp. IV are nearly straight and diverge at an angle a little greater than 90° . The gland plate is small and entirely separate from epp. III and IV. A line connecting the posterior angles of epp. IV passes entirely behind the genital area in both sexes.

The legs are long, moderately heavy and very abundantly supplied with long hairs and spines. They increase in length from first to last but III is only slightly longer than II. The number of swimming-hairs is not uniform but they are much more numerous than in any other species examined. On III 4 and IV 4 are from eight to ten or even twelve of these, and on III 5 and IV 5 from ten to fourteen, while in IV 6 are from six to eight long hairs of which all but one or two have the length and fineness of swimming hairs. Few spines are pectinate.

The genital area of the female (Pl. XIII, fig. 14) is pyriform, and with the sides rather strongly excavated. The acetabula are large, the posterior circular and the first two slightly elliptical, and between the first two is a space equal to the diameter of one of them or a trifle less. In the case of the male, the two anterior acetabula are markedly elliptical and the distance between them is only about half their lesser diameter.

MEASUREMENTS	MALE	FEMALE
	mm.	mm.
Length of body.....	1.05	1.40
Width of body.....	0.83	1.22
Leg I.....	0.93	1.03
Leg II.....	1.35	1.46
Leg III.....	1.36	1.52
Leg IV.....	1.78	1.92
Palpus.....	0.48	0.52
Length of genital area.....	0.24	0.30
Width of genital area.....	0.27	0.26

Specimens from Lake St. Clair were, according to field notes, "dull-greenish with very narrow lines of light and six vermilion patches; eyes red and black; legs blue." Others were "yellowish with blackish patches; eyes purplish-brown; appendages greenish-blue." Still others from Charlevoix "pale yellowish-brown, marked with olive-brown and red; few white lines; appendages bright blue; eyes black." The red patches referred to were uniform in location and were placed as follows: One anteriorly and one posteriorly in the dorsal median line, the former one-third the way from the anterior margin, the latter near the posterior margin; two others, one on either side opposite the anterior dorsal; two more on either side even with the posterior dorsal.

Of *L. maculata* specimens are at hand from the following localities: Lake Chautauqua, N. Y., August, 1897, one male (R. H. Johnson); Lake St. Clair, Mich., summer of 1893, 4 ♂♂, 5 ♀♀; Reed's Lake, Grand Rapids, Mich., July 23, 1898, one female; Pine Lake, Charlevoix, Mich., July 24, 1894, one female; Les Chenaux Island, northern Lake Huron, August, 1895 (J. B. Shearer). It thus seems to be rather widely distributed, though not common.

It is one of the best-known European forms and Piersig records it from Finland, Russia, Sweden, Germany, Bohemia, Austria, Italy, Switzerland, France, and England.

III. TABLE FOR DETERMINATION OF SPECIES

The following table will serve for the determination of the described North American forms, the species described by Stoll as *L. longipalpis* being not placed.

- | | |
|---|------------------------------|
| 1. A prominent peg-like spine on the flexor surface of palp. seg. 2..... | 2 |
| No such spine present..... | <i>L. laeta</i> Stoll |
| 2. Body covered with a chitinous meshwork..... | <i>L. cornuta</i> n. sp. |
| Body soft and marked by fine lines..... | 3 |
| 3. Spine on flexor surface of palp. seg. 2 borne on a papilla..... | 4 |
| Spine on flexor surface of palp. seg. 2 borne directly on the surface, | |
| | <i>L. puteorum</i> Stoll (!) |
| 4. The papilla slender and chimney like..... | 5 |
| The papilla an outswelling of the whole distal half of the flexor surface | |
| of the segment..... | 7 |
| 5. The papilla very short and spine relatively long..... | <i>L. paucispina</i> n. sp. |
| The papilla very long and spine relatively short..... | 6 |
| 6. The two anterior acetabula of the genital area separated by a space less | |

- than the diameter of either. *L. histrionica* (Herm.)
 The same space in the female equal to from one and a half to two times
 the diameter of the acetabula; in the male this space is less, but still
 greater than in the preceding species. *L. undulata* (Müll.)
7. Spine on the palp. seg. 2 small, fusiform, set into tip of papilla, and directed
 somewhat backward. *L. maculata* (Müll.)
 Spine long, of nearly uniform calibre, and directed directly ventrad,
L. Koenikei Piersig

BIBLIOGRAPHY

- HERMANN, J. F.
 04. Mémoire aptérologique. Strasbourg, 1804.
- KOCH, C. L.
 35. Deutschlands Crustaceen, Myriapoden und Arachniden. Regensburg,
 1835-41 (40 parts).
- KOENIKE, F.
 81a. Revision von H. Lebert's Hydrachniden des Genfer Sees. Zeitschr.
 f. wiss. Zool., XXXV, pt. 4, 1881, 613-628.
 95b. Nordamerikanische Hydrachniden. Abh. des naturwiss. Ver. zu
 Bremen, XIII, 1895, 167-226, Pls. I-III. Also separate.
- KRAMER, P.
 75. Beiträge zur Naturgeschichte der Hydrachniden. Arch. f. Natur-
 gesch., XLI, 1875, 263-332.
- KRENDOWSKY, M. E.
 85. [Les Acariens d'eau douce (Hydrachnides) de la Russie meridionale].
 (Russian) [Arb. Naturf. Ges. Charkow]. XVIII, 1885, 209-358, 2 pls.
- LEBEY, H.
 79. Matériaux pour servir à l'étude de la faune profonde du lac Léman,
 par Dr. F. A. Forel. VI Série. Hydrachnides du Léman. Bull. Soc.
 Vaud. Sc. Natur., XVI, 1879, 327-377, 2 pls.
- MULLER, O. F.
 1776. Zoologiae Danicae prodromus, etc. Hafniae, 1776. (274 pp.)
 1781. Hydrachnae, quas in aquis Damiae palustribus, etc. Lipsiae, 1781.
 (88 pp., 11 pls.)
- NEUMAN, C. J.
 70. Vestergöthlands Hydrachnider. Öfvers. af Kongl. Vet.-Akad. Förh.,
 1870, no. 2, 105-110.
 80. Om Sveriges Hydrachnider. Kongl. Svenska Vet.-Akad. Hndlgr.,
 XVII. Separate, 1880. (123 pp., 14 pls.)

PIERSIG, RICH.

97. Deutschlands Hydrachniden. *Bibl. Zool.*, XXII. Stuttgart, 1897-1900. (601 pp., 51 pls.)

PIERSIG, RICH. [AND LOHMANN, H.].

1901. Hydrachnidae [und Halacaridae]. *Das Tierreich*, XIII. Berlin, June, 1901. (354 pp., 87 figs.) (Hydrachnidae by Piersig.)

SOAR, C. D.

97. British Hydrachnidae. Part VII. *Limnesia*. *Int. Jour. Micros. and Nat. Sci.*, 3d ser., VII., 23-26, Pl. III, figs. 1-9. (A series of articles ran from Vol. V, 1895, to Vol. VII, 1897.)

STOLL, OTTO.

87. Hydrachnidae. *Godman and Salvin's Biologia Centrali-Americana*, *Zool.*, part LIX, 1887, 9-15, 46-48, Pls. VII-XI.

THOR, SIG.

99. *Tredie Bidrag til Kundskaben om Norges Hydrachnider*. *Archiv. f. Math. og Naturv.*, XXI., no. 5. (64 pp., Pls. VII-XVII.)

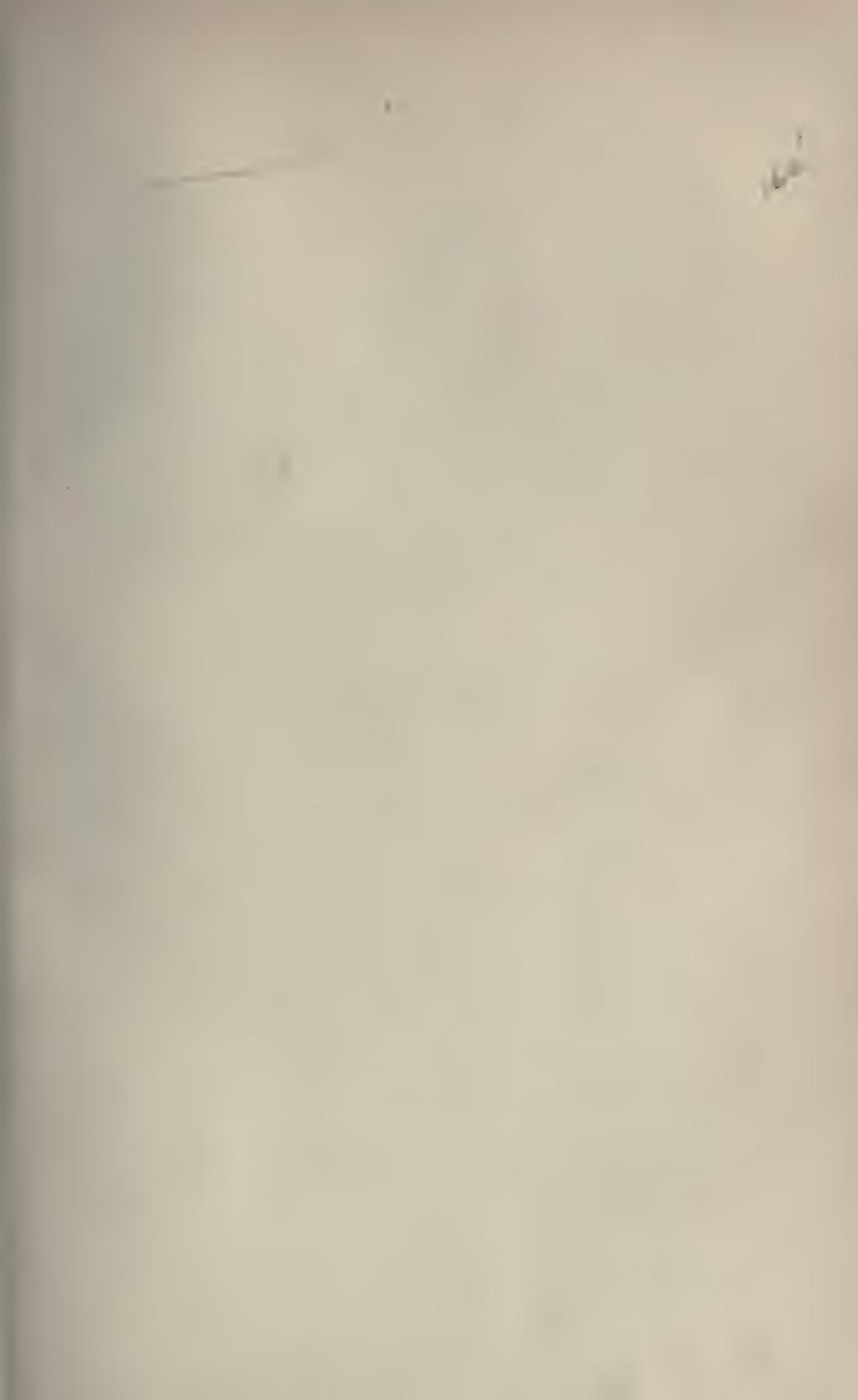
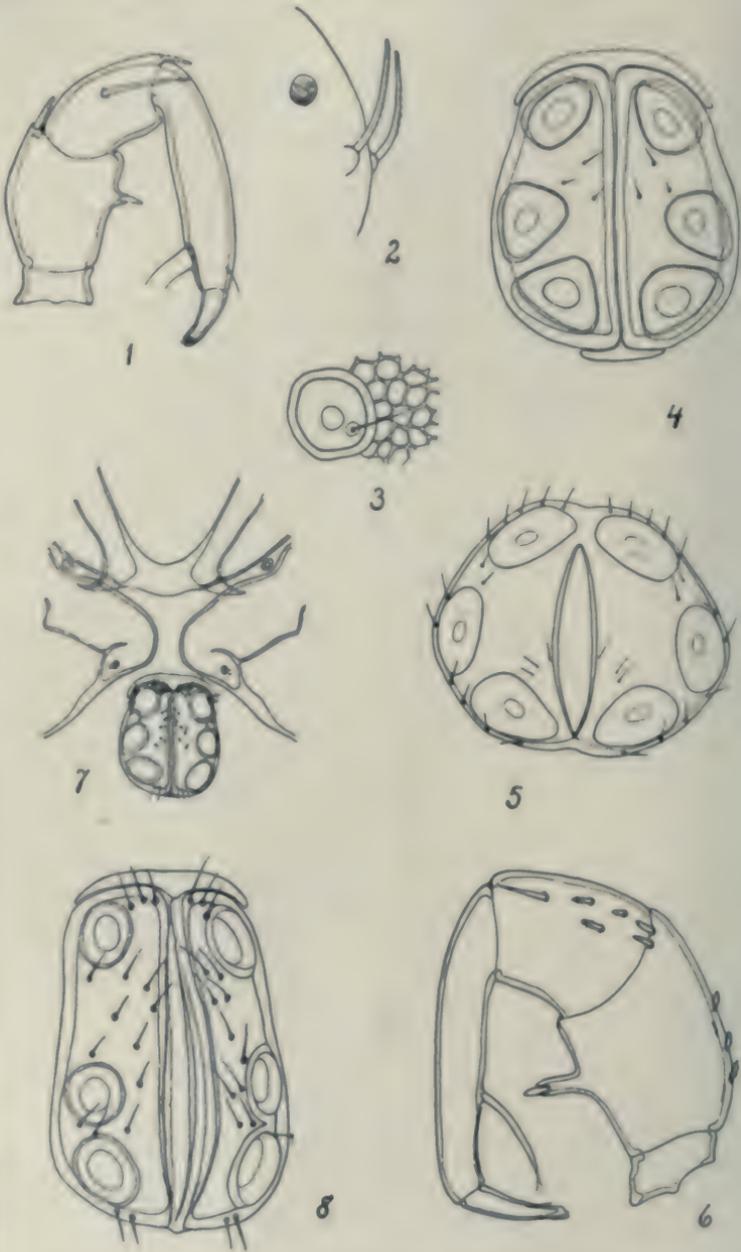
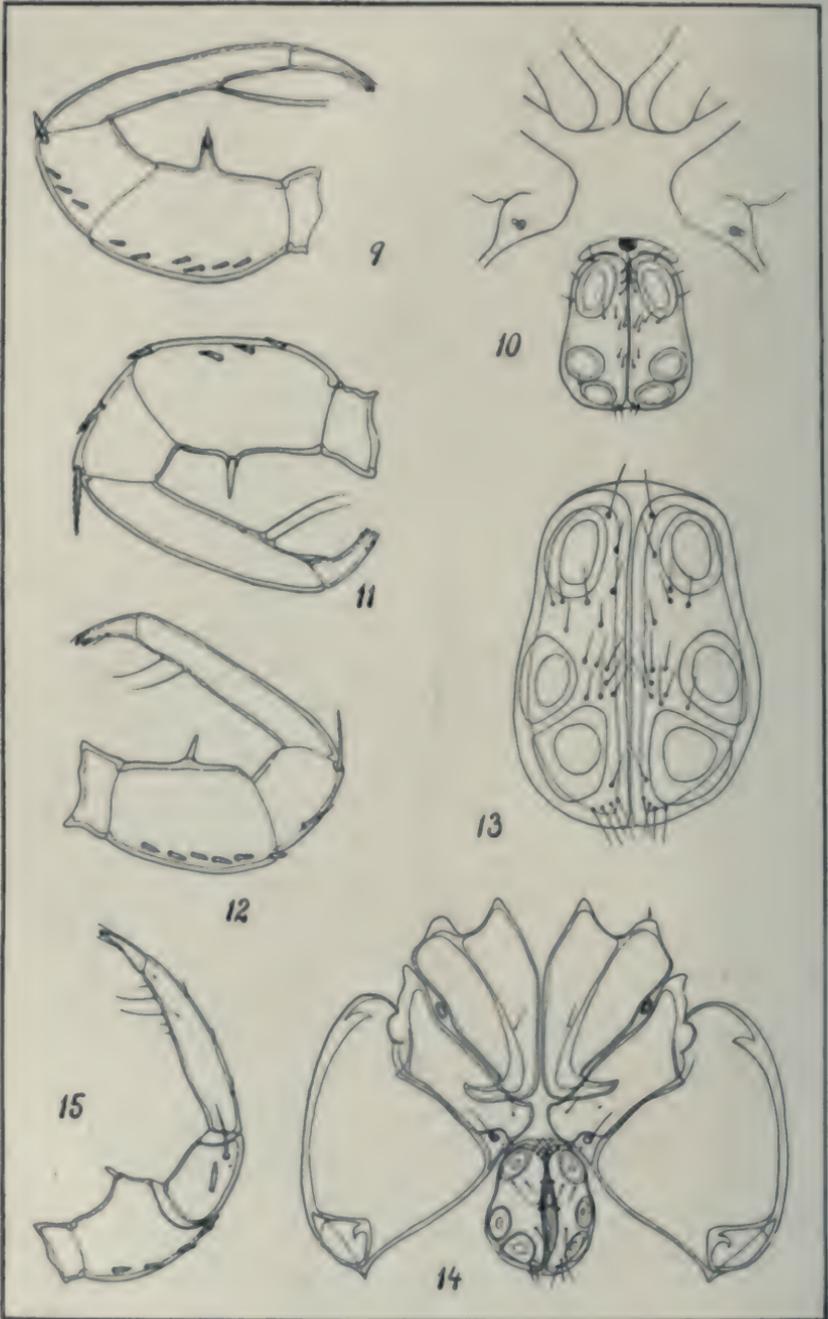


PLATE XII



100

PLATE XIII



EXPLANATION OF PLATES

All drawings made from slides and with the camera, unless otherwise stated.

Plate XII

FIGS. 1-5. *L. cornuta*

Fig. 1. Palpus of female, viewed from the outer side and slightly from the ventral aspect; $\times 185$.

Fig. 2. Antenniform bristles of male from Grand Rapids, Mich.; $\times 185$. From the unmounted specimen.

Fig. 3. Plate surrounding one of the epidermal glands, bearing a hair, together with a portion of the chitinous meshwork; \times about 500.

Fig. 4. Genital area of female; $\times 185$.

Fig. 5. Genital area of male; $\times 185$.

FIGS. 6, 7. *L. histrionica*

Fig. 6. Palpus of male, from outer side and also from ventral aspect; $\times 140$.

Fig. 7. Inner ends of epimera and genital area of female; $\times 60$.

FIG. 8. *L. undulata*

Fig. 8. Genital area of female; $\times 175$.

Plate XIII

FIG. 9. *L. undulata*

Fig. 9. Inner side of palpus of female; $\times 175$.

FIGS. 10, 11. *L. paucispina*

Fig. 10. Inner ends of epimera and genital area of female; $\times 130$. From the unmounted specimen.

Fig. 11. Inner side of palpus of female; $\times 185$.

FIGS. 12, 13. *L. pulecorum* (1)

Fig. 12. Inner side of palpus of female; $\times 130$.

Fig. 13. Genital area of female; $\times 185$.

FIGS. 14, 15. *L. maculata*

Fig. 14. Epimeral field and genital area of female; $\times 60$.

Fig. 15. Inner side of palpus of female; $\times 110$.

162



CHARLES M. VORCE

NECROLOGY

CHARLES MARVIN VORCE

OF CLEVELAND, OHIO

Charles Marvin Vorce was born in Pulaski, N. Y., November 10, 1843.

He possessed a naturally delicate, thoughtful, studious temperament and exceptional literary taste and ability, all of which were increased by exercise and study as long as he lived. To him education was an instinct, a mode of living, a necessary condition of existence, rather than a task to be performed under duress for a limited time and then dropped with a feeling of relief.

His course of life was interrupted by the breaking out of the Civil War, when he, at the age of eighteen years, devoted his life to the country's service from the call for three months' volunteers to the close of the conflict. His vigor was somewhat impaired by the hardships of war—including an attack of typhoid fever.

On January 27, 1868, he married Miss Evalyn C. Marshall, of Oregon, Illinois. He is survived by his widow and two sons aged 31 and 33 years.

As a man, his was a character of the strictest integrity and the highest honor. He was modest to a fault, making claim to only moderate merit and so fearful of seeming to seek notoriety that he would only accept it when forced upon him; which often prevented his being fully understood except by his most intimate friends. But his friendship was limited only by his opportunities. His hospitality was free and cordial, evidently one of his chief pleasures; and in return he keenly appreciated every act of kindness, however small. He was one of those rare and priceless friends, quiet, steadfast, generous, helpful, but never exacting, who, however much they may have been appreciated and rewarded, always leave their friends with a strong wish that they could have had opportunity to show more appreciation and to contribute more to their happiness before it was forever too late.

His education seemed to lean instinctively in the direction of physics and to means and methods of precision, which, in connection with his exceptional literary ability, may well have determined the choice of his profession and of his scientific specialty.

As an attorney he drifted in the direction of mechanics, chemistry, etc., and finally became a very prominent "patent lawyer."

He had distinctly scientific tastes, and was early fascinated with the rapid growth and vast possibilities of microscopy, which he almost unconsciously adopted as his second specialty, to give character and interest to his hours of leisure and periods of rest. His great versatility enabled him at first to gain a considerable familiarity with microscopy as a whole, and to take a wholesome interest in the labors of those who were cultivating its various branches. Such a character was most timely during that formative stage when microscopy was growing from an elegant and admirable recreation and a single specialty in science and art, into the large group of almost boundless specialties that it is now. But as the field outgrew even the superficial vision of any one person, he fixed his attention mainly upon portions of two divisions of the subject.

His work in biology was largely concerned with some of the lower forms, and especially in the direction of pond life, as it was then called. His study and writings, including the two studious and elaborately illustrated papers on the forms observed in the water of Lake Erie, in 1881-2, were pioneer work in the present revival of such studies under the name of limnology, a subject which has since then become the most prominent and important feature, not to say the specialty, of this Society; and it is reasonably hoped that the society may in the near future be fully recognized as the organ of the workers in this new and very important specialty, to the mutual advantage of both parties.

In economic microscopy, on the other hand, he did much of advanced work, mostly in the direction of jurisprudence, where it harmonized to advantage with his regular profession. He applied the microscope to good purpose in the detection of adulterations in food and medicines, of falsification in hand-writing, and in the detection and discrimination of blood stains. He participated in many of the important murder trials that were held in his county during the last quarter-century, and furnished much of the technical testimony that could be obtained only by expert microscopical investiga-

tion. As an expert he was, as ever, careful, thorough, precise, and perfectly candid. He was most skilled in recognizing the facts that were brought within sight by the microscope, and appreciating them at their true value, and applying them accordingly; but he was conservative and just, and incapable of making exaggerated claims or unjust inferences, or of expressing reckless or unwarranted opinions. His position as an expert was inflexibly judicial, and therefore one which the world would be greatly improved by following. His important paper on "Fees of Experts," in 1890, takes a stand in this same spirit. Micrometry, which was often a prominent and sometimes the principal feature in these studies, was one of his favorite departments, in which he greatly excelled. In connection with his studies of handwriting he contrived a special and useful microscope stand for that purpose, which was published in 1891, and which he used for his own work.

Many of his papers on these and similar subjects were introduced at the society meetings, and afterward published in the Proceedings or in other journals.

Every trait in Mr. Vorce's character led him irresistibly to join his friends and associates in their various society enterprises, and qualified him for the highest usefulness therein. He was one of the founders of the Cleveland Microscopical Society, of which he was secretary and afterwards president. He was also a Fellow of the Royal Microscopical Society of London, from 1881.

His most important participation was naturally in our own national body, the American Society of Microscopists, now American Microscopical Society, as the older members will remember with pleasure and gratitude.

He was a member of the National Microscopical Congress held at Indianapolis in August, 1878, where he was at once recognized as one of the leading spirits and one of the safest advisers. He was chairman of the nominating committee for permanent officers of the convention, and a prominent member of the committee on a permanent national organization; these being positions of greatest influence and responsibility in giving origin and character to the American Society of Microscopists. He was Second Vice-President at the first meeting of the fully organized society at Buffalo in 1879, and First Vice-President at the Pittsburg meeting in 1887, and the New York meeting in 1900. It might truly be added that only his

excessive modesty stood between himself and the Presidency; for he was often urged to accept the position, but as he happened to be a member of the nominating committee at the time no reasons or pressure could induce him to allow his name to be mentioned. Generally, however, he was barred from that office by the unwritten law, which was early adopted, that the President for the next meeting should always be chosen from among those present at the time of election, and the fact that his business engagements were so exacting that he could seldom be certain of attending two meetings in succession.

He labored strenuously, from first to last, to assist in building up and holding up the society. He was always a welcome associate, and often a chosen leader in any kind of committee work, where his quiet and unpretentious manners, thoughtful habits, scholarly attainments, and great organizing ability made him both congenial and efficient. Equally faithful was he in all the minor opportunities of membership. He was an early subscriber to the Spencer-Tolles fund for encouraging microscopical research, was as constant an attendant upon the meetings as the emergencies of business would allow, and often at a large sacrifice of profitable engagements. He presented numerous papers of every grade from little notes on useful details in technic to elaborate studies in natural history or economic microscopy in which he was a recognized expert. At the meetings he joined in discussions and his remarks were always practical, suggestive, and helpful. Among the special activities of the society, by which during its early years its members were interested and assisted, were the so-called "working sessions." These will be remembered by the older members as informal afternoon conferences, held during the "eighties" for demonstrations in technic. Mr. Vorce was always ready to contribute a share from his rich experience, presenting such important specialties as micrometry, photomicrography, detection of adulterations, etc. In planning for the Cleveland meeting in 1885, the executive committee requested him to take charge of that department. He accepted the very onerous duty and executed it with his usual thoroughness and good judgment. He prepared in advance a carefully considered scheme to make the best use of the available resources and engaged the participation of members able to contribute from their own specialties. Notwithstanding the inevitable disappoint-

ments from the inability of members to keep their engagements, demonstrations were given at thirty-eight tables, two of which were occupied with his own instructive illustrations in practical micrometry; and it is no injustice to other sessions, several of which were excellent, to call this the most complete and successful of the series. So highly was this instructive work appreciated that a resolution was enthusiastically offered, though evidently impracticable, that all the afternoons of the meetings be reserved for such work.

Mr. Vorce was always ready to do more than his share, both as an exhibitor and in committee, of the somewhat similar though more popular work at the various soirees, receptions, and exhibitions that were given from time to time.

At some of the earliest meetings an attempt was also made to stimulate the interest of the less active or experienced members by offering prizes for competition. The first prize was an objective offered by Mr. E. H. Griffith for the best mounts showing the application of the microscope to the detection of adulterations in food. At the Detroit meeting in 1880 it was awarded to an anonymous contributor, who proved to be Mr. Vorce, he having offered some of his ordinary work in that field, merely to assist in the enterprise by his participation, and without a thought of being a winner and thereby standing in the way of others. So disappointed was he at the result that he instantly insisted on presenting the prize to the society for further competition. His refusal to accept the prize was positive and evidently intended to be final; and only after the prize was duplicated by the offer of a like one for the next year could his friends induce him to accept the first as a compliment to himself.

At the Cleveland meeting in 1885 came the opportunity to entertain the Society in his own town, and he devoted himself to the work with a love and an aptness that was boundless. From the official address of welcome which it was his duty to give the arriving guests, till the closing vote of thanks to himself personally which was enthusiastically passed as the last act of an exceptionally delightful meeting, he was the virtual and recognized leader as well as the most tireless worker among the local entertainers. During more recent years his increasing business as a "patent lawyer" required long absences from home, or devotion to work in absorbing cases,

in a manner that interfered with his scientific work, and especially with attendance at the summer meetings. He however retained his interest throughout. It is noticeable that his last paper was an excellent obituary of his distinguished friend, and ours, the late Hon. J. D. Cox, for the 1900 meeting at New York.

Intimately connected with the American Microscopical Society, though independent in its inception, the National Committee on Micrometry was formed, on the initiative of the Troy Scientific Association. President F. A. P. Barnard of Columbia College, perhaps the leading theoretical metrologist of the world at that time, was chairman; and each of the societies connected with the Microscopical Congress was represented by a member on the committee. Mr. Vorce ably represented the Cleveland Microscopical Society. In this work he was in his native element. Everything that he could do was evidently a labor of love and a personal delight. During the period of the committee's activity his constant and untiring participation was a model of thoughtful, discreet, generous, and altogether successful committee work.

At the next meeting of the American Microscopical Society the committee was recognized by that body and authorized to continue as its representative. It was easy to decide on the metric system and the 0.001 mm. unit; but it required the work of years to be able to apply that unit, or any other one, to micrometry with any known degree of precision. The commercial micrometers in universal use were of as much authority as the carpenter's pocket rule, with no means of knowing which was the farthest wrong, or how much wrong was the nearest right.

Finally, with the cordial coöperation of Professor J. E. Hilgard, of the U. S. Bureau of Weights and Measures, an exquisitely ruled centimeter on a platino-iridium bar was obtained; and its actual relations to the standard meter of the U. S. Coast Survey and to several other meters of known value, and through them to the "Metre of the Archives" which had been adopted in 1870 by thirteen governments as the international standard, was obtained. Its subdivisions were studied at great length by Professor Wm. A. Rogers, then easily first in experience, skill, and success in such work, and by others of known aptness and experience, including Mr. Vorce. The precise relations of the various spaces to each other and to the standard meter were determined, so far as the microscope was able

to reveal them. Probably no centimeter of metal or of anything else has ever received as much, or a small fraction of as much, of high-class work as this. The plate was adopted as a national standard by the A. M. S. and so-called copies (having known degrees of correspondence with the standard) were prepared for use in testing and correcting the micrometers employed in actual work. As a result it is now possible to know the value of a working micrometer, with a definiteness and certainty unattempted before.

Mr. Vorce was also one of the organizers of the American Postal Microscopical Club. His altruistic spirit responded instantly and cordially to the idea of a correspondence society, not selfishly limited to a few experts or professionals who least of all needed encouragement or assistance, but open to all really qualified to participate profitably, where all could take an interest in the work of others along lines different from their own, and where those able to lead and teach could see exactly where their friendly words and helpful hints would be most useful. He was a manager for twenty years, from the foundation of the Club in 1875 to 1895, and Vice-President since that time. He soon organized a local circuit in his own town, and by his personal care made it for many years one of the strongest and best branches of the enterprise. There was nothing narrow-minded, selfish, or provincial in his principles, his interests, or his acts. A thorough cosmopolitan and a microscopist of the old school, like Quekett, and Beale, and Carpenter, and many others that might be mentioned, he cultivated and cherished microscopy in its broadest sense, both as a science and as an art. He was always ready to contribute facts or ideas from his own special lines to those working in other fields, and to take an appreciative interest in their own special undertakings; but he was pleased most of all to give friendly hints, needed information, and suggestive criticism to amateurs or beginners who were trying to enlarge their sphere of vision. In contributing to the circulating boxes, he always made a serious business of furnishing something having definite purpose connected with it, and in writing something worth reading about it. His circulating notes were models of general excellence and fitness for the purpose; being thoroughly accurate and scientific, but in conversational and readable style, free from needless technicalities of expression or ostentation of any kind, carefully, neatly, and closely written with fine pointed pen and suitable ink, giving a great deal

on a page but extremely legible and without appearance of crowding, and often accompanied with neat and illuminating pen drawings. He often added voluntarily to inadequately described slides from other contributors, not only casual remarks of importance but elaborate and carefully studied notes when required to make them useful. The Secretary knew him as one who, even in his busiest years, could be depended upon to write, on request, scholarly and instructive notes for difficult slides within his range of study. He will be greatly missed by his friends in the Club, and scarcely less by those members who knew him only by name as a very helpful educator. It is a singular coincidence that Mr. Vorce died almost at the same time as his neighbor and intimate friend, and long-time associate in microscopy and in the Club, Mr. L. A. Willson. Hearing of Mr. Vorce's death, the Secretary wrote to Mr. Willson asking for some information and assistance, only to receive from strange hands information that Mr. Willson had died three days before his friend.

Besides the records of his society work which found their way into the microscopical journals he was a frequent contributor of anything likely to be of use from the simplest hints in the technic of obtaining, examining, and mounting objects, to formal and thoroughly prepared papers along the lines which most attracted his attention. Not only were his contributions always more than welcome in all the American journals, but they were also appreciated abroad. They were often represented by reprints, extracts, abstracts, or references in the *Journal of the Royal Microscopical Society*, the unquestioned standard in microscopy, at least of the English-speaking world, in every volume of which, during the years of his greatest activity, they found place, often to the extent of several times a year.

Mr. Vorce's death was as remarkable as his life. On the morning of December 18, 1901, he started, well and happy, for his office, but telephoned that he would stop on the way to do some shopping. He entered one of the great department stores, made his way slowly through the holiday throng that crowded the aisles, and was quietly selecting Christmas gifts for his friends, when, without warning, he fell in a faint to the floor. But the rest that came so suddenly was eternal. His long overtaxed system had reached its limit. The gentle, courteous associate, the considerate and beloved friend, the eminently useful, modestly great man had finished his work.

R. H. WARD.

PROCEEDINGS
OF
The American Microscopical Society

MINUTES OF THE ANNUAL MEETING

HELD IN

PITTSBURG, PENNSYLVANIA, JUNE 27 AND 28, 1902

The twenty-fifth annual meeting of the Society was called to order by President Charles E. Bessey in the Phipps Botanical Laboratory, Pittsburg, Pa., at 3:00 P.M., Friday, June 27, 1902. Mr. Magnus Pilaum, Custodian of the Society, and chairman of the local committee, extended a welcome to the Society in the following words:

MR. PRESIDENT AND MEMBERS OF THE AMERICAN MICROSCOPICAL SOCIETY: This is the third time this city has been honored with your visit and the first time that the united body of scientists assembles in our midst. Not more than about ten years ago Pittsburg was known merely as a city of smoke, coal, and iron, as one of the many grimy manufacturing places of America. To-day it is the proud manufacturing center of the world, known wherever civilization rears its torch. But this city is not content with achievements merely material, but in the field of art, science, and education it longs also to be supreme. With gathered wealth its citizens have ceased confining themselves merely to accumulation, the period of generous disbursement has commenced, and with the example set by our Carnegie, Pittsburg indulges in the justifiable hope to lead at an early day with the largest and most complete public library system, and to have educational facilities, practical and theoretical, in all branches, second to none. We also have a working museum, yet an infant, but with such energy and activity promising soon to be a giant and the equal of any of the oldest institutions; and our efforts in music and fine arts are known in all art centers, a surprise to strangers and a pride to our people. On behalf of such city and its inhabitants,

in the name of the numerous committees of arrangement, and for the local members of this society I have the honor to bid you a hearty and sincere welcome.

When you visited us before you were the only guest; now you come in company with others. Then you received our whole attention; now it is divided, but not the less cordial, nor because entitled to diminished esteem. Your meeting before the main scientific body and leading, in point of time, in the great feast of knowledge and reason, is truly emblematical of the relation of microscopy to science at large. What matters it whether those critically inclined are right or wrong in denying to microscopy the rank of a science? Suppose the microscope has become merely a valued tool used and needed in every branch of practical and scientific investigation? Is not this wonderful tube and familiarity with its best use the door to the hall of knowledge, the sun to lighten dark and hidden places; in short, is it not the very eye of science? If this instrument has become domesticated in the different arts and branches of science, is not the credit for this domestication largely due to the stimulus given by this society to the use, methods of application, and improvements of the instrument? Whether this society has a function or fills a place is a question which can be answered from the shelves of almost every known scientific library.

And if microscopy be no science, what of microscopists? If painstaking, patient, unselfish, and unremitting labor, the last in every sense and meaning of the word, is not scientific effort, then there is no science.

Hence you may be assured that you and your work are duly appreciated. In the hope that your gathering here will be as pleasant and profitable to you as your visit is deemed an honor by this city, I again welcome you, each and all, with my whole heart.

The address of welcome was responded to in a felicitous manner by the President after which the usual order of business was taken up. The report of the Custodian was submitted and referred to a committee consisting of Messrs. Elliott and Ives for auditing. In the discussion of the report several members referred in strong terms to the valuable services rendered the Society on the part of the Custodian. It was on motion decided that the fiscal year should close October 1, and that the books of the Treasurer should then be forwarded to the auditing committee for examination, the result of

their examination to be published in connection with the report as made. The chair appointed Dr. Roscoe Pound and Dr. F. E. Clements as auditing committee.

The Secretary's report discussed the past volume of the Society and the increasing interest in its publication, which had been attained by the action of the executive committee in limiting papers to those which contained the results of original investigation and which were not printed elsewhere. Some suggestions were made regarding the increase in the membership and in the list of subscribers and with this end in view there was recommended the appointment of an Assistant Secretary. It was further reported that copies of the circular outlining the subscriptions to and disposal of the Spencer-Tolles Fund had been sent to each subscriber to that fund. It was further recommended that the fees of life memberships be placed at interest under the charge of the Custodian, and that the principal be held perpetually intact to constitute part of the invested funds of the society, that the Custodian should transmit to the Treasurer yearly the sum of two dollars or as much thereof as might be the interest earned by this fund, and that any balance of the income during the lifetime of the member, together with the entire income thereafter, should be included in the income of the research fund of the Society. On motion the recommendations of the Secretary were referred to the Executive Committee for final action. The amendments to the constitution proposed last year and printed on page 276 of the Transactions, Volume 23, were read and adopted in accordance with the recommendation of the Executive Committee.

The nominating committee consisting of Messrs. Krauss, Elrod, McMillan, Schoney, and Ward was elected.

The following papers were read:

On the comparative histology of animals: H. B. Ward, Lincoln, Nebr.; discussed by Messrs. Krauss, Pflaum, Schoney, and Elrod.

On the development of the liver in the pig: D. C. Hilton, Chicago, Ill.; discussed by Dr. Krauss.

On two growths of *Chlamydomonas* in Connecticut: F. S. Hollis, New Haven, Conn.; discussed by Messrs. Bessey and Ward.

The Society adjourned.

SECOND SESSION

At 8:00 P.M. the Society convened in the lecture hall at the Carnegie Institute and a large audience of members and guests listened

to the annual address of the President, Dr. Charles E. Bessey. After an appropriate vote of thanks for the admirable address the Society adjourned until the following morning.

THIRD SESSION

The Society met at 10 A.M., Saturday, June 28, in the lecture hall of the Carnegie Institute and listened to the reading of papers in connection with lantern demonstrations. The following papers were presented and discussed:

A new form of combined lantern and microscope for projection purposes: Mr. L. B. Elliott, Rochester, N. Y.

Stereoscopic photomicrography with high powers: Mr. F. E. Ives, Philadelphia, Pa., with demonstrations of the apparatus and the photographs.

Principles of microtome construction with illustrations of new forms of the instrument: Mr. L. B. Elliott, Rochester, N. Y.

The Society then adjourned.

FOURTH SESSION

At 2:00 P.M. the Society convened in the Phipps Botanical Laboratory and the following papers were read and discussed:

A method of staining glandular tissue: Professor M. J. Elrod, Missoula, Mont.

A rearrangement of the genera and species of the Phycomycetes: Dr. Charles E. Bessey, Lincoln, Nebr.

Data for the determination of human entozoa: Dr. Henry B. Ward, Lincoln, Nebr.

A method of concentrating plankton without net or filter: Professor B. L. Seawell, Warrensburg, Mo.

Prevention of the pedetic or Brownian movement in milk or other liquids with minute objects in suspension: Professor S. H. Gage of Ithaca, N. Y.

The following papers were then read by title and referred to the Executive Committee to print if found suitable:

Cultural studies of a nematode associated with plant decay: Professor Haven Metcalf, Clemson College, S. C.

Review of American species of *Limnesia*: Dr. Robert H. Wolcott, Lincoln, Nebr.

A memorial sketch of C. M. Vorce, one of the founders of the Society and a life-long worker in its ranks, was then read and ordered printed as a slight token of the appreciation felt by the Society for the faithful service of one who had been so unceasing in his efforts for the organization.

The informal report of the Limnological Commission was read by the Secretary outlining work being done at its instigation in various fields and announcing the preparation of a manual on Fresh Water Biology, by two of its members with the coöperation of a long series of specialists in various fields.

The following amendments to the Constitution of the Society were offered for consideration, referred to the Executive Committee for alteration in phraseology if necessary, ordered printed as approved by that committee, and in accordance with the rule laid on the table for one year.

To amend art. III by striking out all after the word "office" and substituting as follows: together with a Secretary, a Treasurer, and a Custodian, who shall each be elected for three years, be eligible for reelection and whose terms of office shall not be coterminous.

To amend art. IV by striking out after the word "presides" the words "of the Treasurer to act as custodian of the property of the Society" and substituting therefor: of the Custodian to receive and manage the property and permanent funds of the Society under the direction of the Executive Committee and in conjunction with a permanent committee to be called the Spencer-Tolles Fund Committee, and to make a full and specific annual report of the condition of all the property funds and effects in his charge.

To amend art. VII by adding thereto: But any person duly elected may upon payment of \$50 at one time, or in instalments within the same year, become a life member entitled to all the privileges of membership, but exempt from further dues and fees. All life membership fees shall become part of the Spencer-Tolles Fund, but during the life of such member his dues shall be paid out of the income of said fund. A list of all life-members and of all persons or bodies who have made donations to the Spencer-Tolles Fund in sums of \$50 or over, shall be printed in every issue of the Transactions. The income of said fund shall be used exclusively for the encouragement and support of original investigations within the

scope and purpose of this Society. The principal of the fund shall be kept inviolate.

A telegram was read from the Business Men's League of St. Louis, Mo., inviting the Society to hold its 1904 meeting in that city. The invitation was referred to the Executive Committee with power to fix the location of the meeting and to determine further whether the Society should join in the movement to hold mid-winter meetings in Convocation Week.

The nominating committee reported, recommending the following list of officers who were on ballot unanimously elected to serve for one year:

President, Dr. E. A. Birge, University of Wisconsin, Madison, Wis.

First Vice-President, Dr. Wm. H. Seaman, Washington, D. C.

Second Vice-President, Dr. A. M. Holmes, Denver, Colo.

Assistant Secretary, Dr. R. H. Wolcott, University of Nebraska, Lincoln, Nebr.

Elective members of Executive Committee: Mr. L. B. Elliott,

Rochester, N. Y.; Professor M. T. Elrod, Missoula, Mont.;

Dr. F. S. Hollis, Yale Medical School, New Haven, Conn.

A hearty vote of thanks was given the retiring President for his able administration, to Dr. W. G. Holland, Director of the Carnegie Institute, to the Local Committee, to the Director of the Phipps Botanical Laboratory for numerous courtesies, and to Mr. Magnus Pflaum for his work as head of the special local committee and for providing the handsome souvenir silver badges. Thereupon the Society adjourned subject to the call of the Executive Committee.

That evening the Society was entertained at a Summer Garden Opera party by the special local committee under the leadership of Mr. Pflaum. Those present enjoyed a delightful evening and were warm in expressions of appreciation for the hospitality extended to the Society.

HENRY B. WARD,

Secretary.

MID-WINTER MEETING, WASHINGTON, D. C., JANUARY 1, 1903

Pursuant to a decision of the Executive Committee the mid-winter meeting of the Society was called to order by President E. A. Birge in the lecture room of Columbian University Law School, Washington, D. C., at 4:00 P.M., January 1, 1903.

The Executive Committee recommended that a sum not to exceed \$50 be appropriated from the income of the Spencer-Tolles Fund, to assist in the publication of a paper by Mr. D. C. Hilton, on the development of the liver in the pig, which on account of the illustrations necessary could not be published otherwise. After an extended discussion as to the policy to be adopted by the Society in the use of the income of this Fund "for the encouragement of research" as specifically required by the terms of the Fund, it was voted that the publication of results which would otherwise remain unknown or imperfectly presented was clearly for the encouragement of research, and the recommendation of the Executive Committee was unanimously approved and adopted under the stipulation that the paper be designated beneath the title "Published under a grant from the Spencer-Tolles Fund."

The matter of mid-winter meeting was taken up and discussed *in extenso*. The action of the Executive Committee in calling such a meeting this year was approved and it was voted that for the present the Society continue to hold a general meeting in connection with the other organizations meeting in Convocation Week, but that in view of the large number of scientific programs already announced and of the financial inability of the Society to print more papers than it now does, it is unwise to have an extended scientific program prepared for the mid-winter meeting; if, however, the Executive Committee should deem it wise to change this plan at any time, such change should be approved.

It was then ordered further that the Executive Committee be instructed to provide for a summer meeting at some suitable point which would allow of demonstrations and field work with the view of determining the desire of members to take part in such meeting.

The matter of an official monthly organ having been brought before the Society by a communication regarding such a journal, it was voted to refer the matter for investigation of details to a committee consisting of Messrs. Ward, Eigenmann, and Pflaum. The committee was ordered to report at the summer meeting.

The Society then adjourned to inspect a demonstration of projection apparatus by Mr. L. B. Elliot.

HENRY B. WARD,
Secretary.

TREASURER'S REPORT

FROM OCTOBER 15, 1901, TO NOVEMBER 24, 1902

DR.		
To Membership dues, 1899.....	\$ 2 00	
To Membership dues, 1900.....	6 00	
To Membership dues, 1901.....	32 00	
To Membership dues, 1902.....	306 00	
To Membership dues, 1903.....	40 00	\$386 00
To Admission fees, 1902.....	\$ 21 00	
To Admission fees, 1903.....	24 00	45 00
To Subscribers, Vol. XXI.....	\$ 4 00	
To Subscribers, Vol. XXII.....	14 00	
To Subscribers, Vol. XXIII.....	54 00	72 00
To Advertising, Vol. XXII.....	\$ 8 00	
To Advertising, Vol. XXIII.....	104 00	112 00
To Volumes sold.....		54 55
To Balance due Treasurer.....		88 09
		<u>\$757 64</u>

CR.		
By Postage, Secretary.....	\$ 22 70	
By Postage, Treasurer.....	10 00	\$ 32 70
By Expressage, Secretary.....	\$ 41 08	
By Expressage, Treasurer.....	1 40	42 48
By Stationery, Secretary.....	\$ 25 50	
By Stationery, Treasurer.....	10 25	35 75
By Typewriting, Secretary.....		43 20
By Sundries, Secretary.....	\$ 12 00	
By Sundries, Custodian.....	2 00	14 00
By Bank Charges, Treasurer.....		2 50
By Printing Vol. XXIII.....	\$470 00	
By Plates Vol. XXIII.....	55 48	525 48
By Cash returned to Treasurer.....		61 53
		<u>\$757 64</u>

We hereby certify that we have examined the foregoing accounts, and the vouchers submitted therewith, and have found the same true and correct.

ROSCOE POUND,
FREDERIC E. CLEMENTS,
Auditing Committee.

CUSTODIAN'S REPORT FOR YEAR ENDING JULY 1, 1902

SPENCER-TOLLES FUND

Reported at Denver Meeting.....	\$1144 12
Dividends	93 24
Special Dividends	8 00
Sale of Proceedings.....	109 95
Contributions	63 93
Total amount invested	\$1419 24
Total increase during the year.....	\$ 275 12

ANNUAL GROWTH

Year	Increase	Total
1885.....		\$ 60 20
1886.....	\$ 25 00	85 20
1887.....	10 00	95 20
1888.....	52 66	147 86
1889.....	76 00	223 86
1890.....	30 00	253 86
1891.....	39 02	293 88
1892.....	19 12	312 00
1893.....	18 06	330 06
1894.....	19 32	349 38
1895.....	22 89	372 27
1896.....	50 77	423 04
1897.....	45 99	469 03
1898.....	86 43	555 46
1899.....	97 90	653 36
1900.....	102 65	756 01
1901.....	388 11	1144 12
1902.....	275 12	1419 24

MAGNUS PFLAUM, Custodian.

PITTSBURG, June 27, 1902.

We, the undersigned, hereby certify that we have carefully examined the accounts of the Custodian as given in the foregoing report, compared the same with vouchers, and found the same to correspond and to be correct.

M. J. ELROD,

F. E. IVES,

Auditing Committee.

CONSTITUTION

ARTICLE I

This Association shall be called the AMERICAN MICROSCOPICAL SOCIETY. Its object shall be the encouragement of microscopical research.

ARTICLE II

Any person interested in microscopical science may become a member of the Society upon written application and recommendation by two members and election by the Executive Committee. Honorary members may also be elected by the Society on nomination by the Executive Committee.

ARTICLE III

The officers of this Society shall consist of a President and two Vice-Presidents, who shall hold their office for one year, and shall be ineligible for re-election for two years after the expiration of their terms of office, together with a Secretary, a Treasurer, and a Custodian, who shall each be elected for three years and be eligible for re-election.

ARTICLE IV

The duties of the officers shall be the same as are usual in similar organizations; in addition to which it shall be the duty of the President to deliver an address during the meeting at which he presides; of the Custodian to take charge of the property of the Society, and of the Secretary to edit and publish the Proceedings of the Society.

ARTICLE V

There shall be an Executive Committee, consisting of the officers of the Society, three members elected by the Society, and the past Presidents of the Society and of the American Society of Microscopists who still retain membership in this Society.

ARTICLE VI

It shall be the duty of the Executive Committee to fix the time and place of meeting and manage the general affairs of the Society.

ARTICLE VII

The initiation fee shall be \$3, and the dues shall be \$2 annually, payable in advance. But any person duly elected may, upon payment of \$50 at one time, become a life member, entitled to all the privileges of membership, but exempt from further dues and fees.

ARTICLE VIII

The election of officers shall be by ballot.

ARTICLE IX

Amendments to the Constitution may be made by a two-thirds vote of all members present at any annual meeting, after having been proposed at the preceding annual meeting.

BY-LAWS

ARTICLE I

The Executive Committee shall, before the close of the annual meeting for which they are elected, examine the papers presented and decide upon their publication or otherwise dispose of them.

All papers accepted for publication must be completed by the authors and placed in the hands of the Secretary by October 1st succeeding the meeting.

ARTICLE II

The Secretary shall edit and publish the papers accepted with the necessary illustrations.

ARTICLE III

The number of copies of Proceedings of any meeting shall be decided at that meeting. But if not decided, the Secretary shall, unless otherwise ordered by the Executive Committee, print the same number as for the preceding year.

ARTICLE IV

No applicant shall be considered a member until he has paid his dues. Any member failing to pay his dues for two consecutive years, and after two written notifications from the Treasurer, shall be dropped from the roll, with the privilege of reinstatement at any time on payment of all arrears. The Proceedings shall not be sent to any member whose dues are unpaid.

ARTICLE V

The election of officers shall be held on the morning of the last day of the annual meeting. Their term of office shall commence at the close of the meeting at which they are elected, and shall continue until their successors are elected and qualified.

ARTICLE VI

Candidates for office shall be nominated by a committee of five members of the Society. This committee shall be elected by a plurality vote, by ballot, after free nomination, on the second day of the annual meeting.

ARTICLE VII

All motions or resolutions relating to the business of the Society shall be referred for consideration to the Executive Committee before discussion and final action by the Society.

ARTICLE VIII

Members of this Society shall have the privilege of enrolling members of their families (except men over twenty-one years of age) for any meeting upon payment of one-half the annual subscription (\$1).

ARTICLE IX

There shall be a standing committee known as the Spencer-Tolles Fund Committee to take general charge of the fund and to recommend annually what part of the income shall be expended for the encouragement of research, but the apportionment of the sum thus set apart shall be made by the Executive Committee.

The Spencer-Tolles Fund Committee shall also have general charge of the expenditure of such money as may be apportioned, under the conditions laid down by the Society for its use.

The Custodian shall be an *ex-officio* member of this committee.

ARTICLE X

The Executive Committee shall have the power annually to appoint two members to represent the Society on the Council of the American Association for the Advancement of Science, in accordance with the regulations of the latter organization.

Revised by the Society, June 27, 1902.

LIST OF MEMBERS.

LIFE MEMBER

BROWN, ROBERT.....Observatory Place, New Haven, Conn.

HONORARY MEMBERS

CRISP, FRANK, LL.B., B.A., F.R.M.S.,
5 Lansdowne Road, Notting Hill, London, England

DALLINGER, REV. W. H., F.R.S., F.R.M.S.,
Ingleside, Lee, S. E., London, England

HUDSON, C. T., A.M., LL.D., F.R.M.S.,
Hillside, Clarence Road, Shanklin, Isle of Wight, England

MADDOX, R. L., M.D., Hon. F.R.M.S. (died May 11, 1902),
Greenbank, 45 Belmont Road, Portswood, Southampton, England

SMITH, HAMILTON L., LL.D.....606 W. 115th St., New York City

WARD, R. HALSTED, A.M., M.D., F.R.M.S.....53 Fourth St., Troy, N. Y.

MEMBERS

The figures denote the year of the member's election, except '78, which marks an original member. THE TRANSACTIONS are not sent to members in arrears, and two years' arrearage forfeits membership. (See Article IV of By-laws.)

MEMBERS ELECTED DURING THE YEAR 1902

For addresses see regular list.

BYLES, D. E.	MATHER, E., M.D.
COATS, A. J.	MAYWALD, F. J.
ECHVERRIA, EMILIO, M.D.	METCALF, HAVEN, PH.D.
FERGUSON, MEADE, PH.D.	MICHENER, AVA, M.D.
FISCHER, ALFRED	PEARSE, A. S.
GILLET, JOHN, M.D.	POWERS, J. H., PH.D.
GRAY, R. S.	SIBLEY, E. R.
IVES, F. E.	WHITE, CHAS. H., M.D.

ANDERSON, ROBERT, M.D., '82.....327 James St., Syracuse, N. Y.

ALLEGER, WALTER W., M.D., '94.....949 T St., N. W., Washington, D. C.

ASPINWALL, JOHN, M.A., '00.....Newburg, N. Y.

ATWOOD, E. S., '79.....Highlands P. O., Monmouth Co., N. J.

ATWOOD, H. F., '78.....16 Seneca Parkway, Rochester, N. Y.

BARKER, ALBERT S., '97.....Twenty-fourth and Locust Sts., Philadelphia, Pa.

BARNSPATHER, JAMES, M.D., '91.....Sixth Ave. and Walnut St., Dayton, Ky.

- BARTLETT, CHARLES JOSEPH, M.D., '96.....150 York St., New Haven, Conn.
 BAUSCH, EDWARD, '78.....179 N. St. Paul St., Rochester, N. Y.
 BAUSCH, HENRY, '86.....Rochester, N. Y.
 BAUSCH, WILLIAM, '88.....St. Paul St., Rochester, N. Y.
 BEAL, PROF. JAMES HARTLEY, '96.....Scio College, Scio, Ohio
 BEARDSLEY, PROF. A. E., '97.....1412 Tenth St., Greeley, Colo.
 BELL, CLARK, ESQ., LL.D., '92.....39 Broadway, New York City
 BENNETT, HENRY C., '93.....Fourth Flat, 1692 Broadway, New York City
 BERING, J. EDWARD, '99.....Decatur, Ill.
 BESSEY, PROF. CHARLES EDWIN, Ph.D., LL.D., '98.....Lincoln, Neb.
 BEYER, PROF. GEO. E., '99.....Tulane University, New Orleans, La.
 BIRGE, PROF. E. A., S.D., '99.....University of Wisconsin, Madison, Wis.
 BISCOE, PROF. THOMAS D., '91.....404 Front St., Marietta, Ohio
 BLEILE, A. M., M.D., '81.....Ohio State University, Columbus, Ohio
 BODINE, PROF. DONALDSON, '96.....303 W. Main St., Crawfordsville, Ind.
 BOOTH, MARY A., F.R.M.S., '82.....60 Dartmouth St., Springfield, Mass.
 BOYER, C. S., A.M., '92.....3223 Clifford St., Philadelphia, Pa.
 BREDIN, GEO. S., '96.....Oil City, Pa.
 BROMLEY, ROBERT INNIS, M.D., '93.....Washington St., Sonora, Cal.
 BROWN, N. HOWLAND, '91.....33 S. Tenth St., Philadelphia, Pa.
 BRUNDAGE, A. H., M.D., '94.....1073 Bushwick Ave., Brooklyn, N. Y.
 BULL, JAMES EDGAR, ESQ., '92.....141 Broadway, New York City
 BURCHARD, E. A., M.D., '99.....6 Elm St., Lodi, San Joaquin Co., Cal.
 BURNER, NATHAN L., M.D., '96,
 Independent Chemical Co., Saginaw, W. S., Mich.
 BURRILL, PROF. T. J., Ph.D., '78.....Urbana, Ill.
 BURT, PROF. EDWARD A., Ph.D., '91.....Middlebury College, Middlebury, Vt.
 BYLES, D. E., '02.....114 W. Second St., Oil City, Pa.
- CARPENTER, THOS. B., M.D., '99.....533 Franklin St., Buffalo, N. Y.
 CARTER, JOHN E., '86..Knox and Coulter Sts., Germantown, Philadelphia, Pa.
 CLARK, GAYLORD P., M.D., '96.....619 W. Genesee St., Syracuse, N. Y.
 CLARK, GEORGE EDW., M.D., '96.....Skaneateles, Onondaga Co., N. Y.
 CLEMENTS, FREDERIC E., A.M., Ph.D., '98,
 University of Nebraska, Lincoln, Neb.
 COATS, A. J., '02.....University of Nebraska, Lincoln, Neb.
 COCKS, PROF. REGINALD S., '99...McDonogh High School, New Orleans, La.
 COFFIN, ROBERT, '00.....Bedford City, Bedford Co., Va.
 COOPE, A. F., M.D., '86.....114 Sycamore St., Oil City, Pa.
 COUCH, FRANCIS G., '86,
 Kalish Pharmacy, 100 E. Twenty-third St., New York City
 COX, CHAS F., F.R.S.M., '85.....Grand Central Station, New York City
 CRAIG, THOMAS, '93.....1013 Sherbrooke St., Montreal, Canada
- DAVIS, CHAS. H., '98.....Drawer 1033, Rochester, N. Y.
 DAVIS, F. L., M.D., '99.....209 Locust St., Evansville, Ind.
 DISBROW, WILLIAM S., M.D., Ph.G., '01.....151 Orchard St., Newark, N. J.

- DORR, S. HOBART, Ph G., '95.....907 Seventh St., Buffalo, N. Y.
 DRESCHER, W. E., '87.....Box 1033, Rochester, N. Y.
- ECHEVERRIA, EMILIO, M.D., '02.....San José, Costa Rica
 EIGENMANN, PROF. C. H., '95.....630 Atwater St., Bloomington, Ind.
 ELLIOTT, PROF. ARTHUR H., '91.....4 Irving Place, New York City
 ELLIOTT, LUTHER B., '98.....219 Fulton Ave., Rochester, N. Y.
 ELBROD, PROF. MORTON J., M.A., M.S., '98,
 University of Montana, Missoula, Mont.
 ELSNER, JOHN, M.D., '83.....1014 Fourteenth St., Denver, Colo.
 ELWELL, A. T., '89.....16 Pearl St., Council Bluffs, Iowa
 EWELL, MARSHALL D., M.D., LL.D., '85.....59 Clark St., Chicago, Ill.
 EYRE, JOHN W. H., M.D., M.S., F.R.M.S., '99,
 Embankment Chambers, Villiers St., London, W. C., England
- FEIHL, ADOLPH, M.D., '81.....520 E. Main St., Columbus, Ohio
 FELL, GEO. E., M.D., F.R.M.S., '78.....72 Niagara St., Buffalo, N. Y.
 FELLOWS, CHAS. S., F.R.M.S., '83.....925 Guaranty Bldg., Minneapolis, Minn.
 FERGUSON, MEADE, M.S., Ph.D., '02.....Blacksburg, Va.
 FERRIS, PROF. HARRY B., M.D., '96.....118 York St., New Haven, Conn.
 FINDER, WM., JR., M.D., '98.....2 Union Place, Troy, N. Y.
 FISCHER, ALF., '02.....646 Broadway, Milwaukee, Wis.
 FISCHER, MAX, '93.....Zeiss Optical Works, Jena, Germany
 FISHER, REV. STOKELY S., '99.....Pleasantville, Ohio
 FLINT, JAMES M., M.D., '91....."The Portland," Washington, D. C.
 FOOTE, J. S., M.D., '01.....422 So. Twenty-sixth St., Omaha, Neb.
 FORDYCE, CHARLES, B.S., A.M., Ph.D., '98,
 Nebraska Wesleyan University, University Place, Neb.
 FOSTER, EDWARD, '99.....P. O. Box 405, New Orleans, La.
 FRAKER, H. C., M.D., '99.....342 Ohio Ave., Columbus, Ohio
 FULLER, CHAS. G., M.D., F.R.M.S., '81.....Reliance Bldg., Chicago, Ill.
- GAGE, PROF. SIMON H., B.S., '82.....Cornell University, Ithaca, N. Y.
 GAGE, MRS. SUSANNA PHELPS, '87.....4 South Ave., Ithaca, N. Y.
 GALLOWAY, PROF. T. W., '01.....McMillen University, Decatur, Ill.
 GATES, ELMER, '96.....Chevy Chase, Md.
 GILLET, JOHN, M.D., '02.....Sparta, Kent Co., Mich.
 GRAY, R. S., '02.....1427 Eighth Ave., East, Oakland, Cal.
 GRAYBILL, H. W., B.Sc., '01.....University of Nebraska, Lincoln, Neb.
 GROSSKOPF, ERNEST C., M.D., '99.....Wauwatosa, Wis.
- HAAG, D. E., M.D., '86.....Liberty Center, Ohio
 HALL, VICTOR S., '01.....1911 Webster St., San Francisco, Cal.
 HANAMAN, C. E., F.R.M.S., '79.....State and Second Sts., Troy, N. Y.
 HATFIELD, JOHN J. B., '82.....313 N. Arsenal Ave., Indianapolis, Ind.
 HERTZLER, ARTHUR A., M.D., '96.....Halstead, Kan.
 HERTZOG, MAXIMILIAN, M.D., '01.....174 E. Chicago Ave., Chicago, Ill.

- HIGGINS, F. W., M.D., '98.....20 Court St., Cortland, N. Y.
- HILL, HERBERT M., Ph.D., '87.....24 High St., Buffalo, N. Y.
- HILTON, DAVID CLARK, A.M., M.D., '01...146 S. Campbell Ave., Chicago, Ill.
- HOFFMAN, JOS. H., M.D., '96.....111 Steuben St., Pittsburg, Pa.
- HOLLIS, FREDERICK S., Ph.D., '99....Yale Medical School, New Haven, Conn.
- HOLMES, A. M., M.D., '98.....205 Jackson Block, Denver, Colo.
- HOSKINS, WM., '79.....Room 55, 81 S. Clark St., Chicago, Ill.
- HOWE, W. T. H., Ph.D., '00.....Evansville, Ind.
- HOWLAND, HENRY R., A.M., '98.....217 Summer St., Buffalo, N. Y.
- HUMPHREY, PROF. O. D., Ph.D., '95....State Normal School, Jamaica, N. Y.
- HYATT, J. D., '78.....69 Burling Lane, New Rochelle, N. Y.
- IVES, FREDERIC E., '02.....550 W. Twenty-fifth St., New York City
- JACKSON, DANIEL DANA, B.S., '99.....941 President St., Brooklyn, N. Y.
- JAMES, FRANK L., Ph.D., M.D., '82.....514 Century Bldg., St. Louis, Mo.
- JAMES, GEO. W., '92.....108 Lake St., Chicago, Ill.
- JOHNSON, FRANK S., M.D., F.R.M.S., '93.....5221 Prairie Ave., Chicago, Ill.
- JOHNSON, WM. D., M.D., '98.....Batavia, N. Y.
- JONES, MRS. MARY A. DIXON, M.D., F.R.M.S., '98,
249 E. Eighty-sixth St., New York City
- JUDAY, CHANCEY, '00.....720 Marine St., Boulder, Cal.
- KELLOGG, J. H., M.D., '78.....Battle Creek, Mich.
- KERR, ABRAM TUCKER, JR., M.D., '95.....61 Waite Ave., Ithaca, N. Y.
- KINGSBURY, BENJ. F., A.B., M.S., '98.....125 Dryden Road, Ithaca, N. Y.
- KINLEY, JOS. B., M.D., '01.....1405 Welton St., Denver, Colo.
- KIRKPATRICK, T. J., '93.....701 E. High St., Springfield, Ohio
- KOFOID, CHARLES A., Ph.D., '99.....University of California, Berkeley, Cal.
- KOTZ, A. L., M.D., '91.....32 S. Fourth St., Easton, Pa.
- KRAFFT, WILLIAM, '95.....411 W. Fifty-ninth St., New York City
- KRAUSS, WM. C., B.S., M.D., '90.....479 Delaware Ave., Buffalo, N. Y.
- KUEHNE, F. W., '79.....19 Court St., Fort Wayne, Ind.
- LAMB, J. MELVIN, M.D., '91.....910 T St., N. W., Washington, D. C.
- LATHAM, MISS V. A., M.D., D.D.S., F.R.M.S., '88,
808 Morse Ave., Rogers Park, Chicago, Ill.
- LAWTON, EDWARD P., '88.....3 Linden Ave., Troy, N. Y.
- LEIPPE, J. HARRY, '96.....336 Pine St., Reading, Pa.
- LEWIS, MRS. KATHARINE B., '89.."Elmstone," 656 Seventh St., Buffalo, N. Y.
- LEWIS, IRA W., '87.....408 S. Galena St., Dixon, Ill.
- LOCKE, JOHN D., '93.....P. O. Box 129, Haverhill, N. H.
- LOMB, ADOLPH, '92.....48 Clinton Place, Rochester, N. Y.
- LOMB, HENRY, '84.....48 Clinton Place, Rochester, N. Y.
- LOOMIS, CHANDLER H., '87....Atlantic Dredging Co., 31 Pine St., N. Y. City
- LOVE, PROF. E. G., F.R.M.S., '91.....80 E. Fifty-fifth St., New York City
- LYMAN, R. A., A.M., '01.....1205 Pacific St., Omaha, Neb.
- LYON, HOWARD N., M.D., '84.....828 Wheaton Ave., Wheaton, Ill.

- MANTON, W. P., M.D., '85.....32 W. Adams Ave., Detroit, Mich.
 MARSH, J. P., M.D., '01.....1828 Fifth Ave., Troy, N. Y.
 MARSHALL, COLLINS, M.D., '96.....2507 Penn. Ave., Washington, D. C.
 MARSHALL, W. M., JR., '92.....Coudersport, Pa.
 MASTERMAN, ELMER E., '97...Rural Mail Delivery No. 2, New London, Ohio
 MATHER, E., M.D., Ph.D., '02.....80 Park Place, East, Detroit, Mich.
 MAYFIELD, FREDERICK J., '02.....1028 Seventy-second St., Brooklyn, N. Y.
 McCALLA, ALBERT, Ph.D., '80,
 414 Monadnock, Dearborn and Jackson Sts., Chicago, Ill.
 MCKAY, JOSEPH, '84.....259 Eighth St., Troy, N. Y.
 MCKIM, REV. HASLETT, '85.....9 W. Forty-eighth St., New York City
 McMILLAN, R. M., M.D., '00.....35 Twentieth St., Wheeling, W. Va.
 MEADER, LEE DOUGLAS, M.D., '96.....2651 Gilbert Ave., Cincinnati, Ohio
 MELLOR, CHAS. C., '85.....319 Fifth Ave., Pittsburg, Pa.
 MERCER, A. CLIFFORD, M.D., F.R.M.S., '82,
 324 Montgomery St., Syracuse, N. Y.
 MERCER, FREDERICK W., M.D., F.R.M.S., '83...2540 Prairie Ave., Chicago, Ill.
 MERCER, W. F., Ph.D., '90,
 Biological Laboratory, Ohio University, Athens, Ohio
 METCALF, HAVEN, A.M., Ph.D., '02.....Clemson College, S. C.
 MICHENOR, AVA, M.D., '02.....State Training School for Girls, Geneva, Ill.
 MILES, MRS. C. S., '01.....1544 Franklin St., Denver, Colo.
 MILLER, JOHN A., Ph.D., F.R.M.S., '89.....44 Lewis Block, Buffalo, N. Y.
 MILNOR, CHAS. G., '86.....318 Highland Ave., Pittsburg, Pa.
 MOCKETT, J. H., SR., '01.....Burr Block, Lincoln, Neb.
 MOODY, ROBERT O., M.D., '91.....Hearst Anatomical Laboratory,
 University of California, San Francisco, Cal.
 MYERS, BURTON, D., '97.....89 N. Tioga St., Ithaca, N. Y.
- NUNN, RICHARD J., M.D., '83.....5 York St., Savannah, Ga.
- ORTEL, T. E., M.D., '92.....Med. Dept., Univ. of Ga., Augusta, Ga.
 OHLER, W. H., '91.....18 Locust St., Portland, Me.
 OLSEN, ALFRED BERTHIER, M.D., '96.....Sanitarium, Battle Creek, Mich.
- PARK, ROSWELL, A.M., M.D., '94.....510 Delaware Ave., Buffalo, N. Y.
 PANNER, HORATIO N., '99.....Board of Health, Montclair, N. J.
 PATRICK, FRANK, Ph.D., '91.....601 Kansas Ave., Topeka, Kan.
 PEARSE, ARTHUR S., B.Sc., '02.....2623 N. Twenty-fourth St., Omaha, Neb.
 PEASE, FRED N., '87.....1307 Third Ave., Altoona, Pa.
 PENNOCK, ED., '79.....3609 Woodland Ave., Philadelphia, Pa.
 PFLAUM, MAGNUS, ESQ., '91.....449 Diamond St., Pittsburg, Pa.
 PIWONKA, THOS., ESQ., '97.....243 Superior St., Cleveland, Ohio
 POUND, ROSCOE, A.M., Ph.D., '98.....Lincoln, Neb.
 POWERS, JAS. H., A.B., Ph.D., '02.....Doane College, Crete, Neb.
 PYBURN, GEORGE, M.D., '86.....1011 H St., Sacramento, Cal.

- RANSOM, BRAYTON H., '99.....1362 B St., S. W., Washington, D. C.
 REED, RAYMOND C., Ph.B., D.V.M., '79.....120 W. Hudson St., Elmira, N. Y.
 REYBURN, ROBERT, M.D., '90.....2129 F St., N. W., Washington, D. C.
 RICHARDS, ELIAS, '99.....1722 Calhoun St., New Orleans, La.

 SAMPSON, ALLEN W., M.D., '96.....Penn Yan, N. Y.
 SARCAR, HEM CHUNDR, M.B., '01,
 Listerpet, Rajamundry, District Godawari, India
 SCHONEY, L., M.D., '98.....23 W. 135th St., New York City
 SEAMAN, WM. H., M.D., '86....1424 Eleventh St., N. W., Washington, D. C.
 SEAWELL, BENJ. LEE, B.S. (Edin.) '01..308 E. Grover St., Warrensburg, Mo.
 SHANKS, S. G., M.D., '00.....547 Clinton Ave., Albany, N. Y.
 SHEARER, J. B., '88.....809 Adams St., Bay City, Mich.
 SHULTZ, CHAS. S., '82.....Seventh St. Docks, Hoboken, N. J.
 SIBLEY, E. R.,.....902 Pine St., Philadelphia, Pa.
 SIEMON, RUDOLPH, '91.....195 Calhoun St., Fort Wayne, Ind.
 SLOCUM, CHAS. E., Ph.D., M.D., '78.....Defiance, Ohio
 SMITH, J. C., '96.....131 Carondelet St., New Orleans, La.
 STAUFFER, REV. T. F., '01.....200 Eleventh St., Sioux City, Iowa
 STEBBINS, J. H., JR., Ph.D., M.D.....80 Madison Ave., New York City
 STEDMAN, PROF. J. M., '95.....Mo. Experiment Station, Columbia, Mo.
 STONEY, ROBERT J., JR., '96.....424 Fifth Ave., Pittsburg, Pa.
 SUMMERS, PROF. H. E., '86.....Ames, Iowa

 TAYLOR, GEO. C., LL.D., '99.....Poydras, St. Bernard Parish, La.
 THOMAS, ARTHUR H., '99.....Twelfth and Walnut Sts., Philadelphia, Pa.
 THOMAS, PROF. MASON B., '90.....College Campus, Crawfordsville, Ind
 TIMMINS, GEORGE, '96.....1410 E. Genesee St., Syracuse, N. Y.
 TWINING, FREDERICK E., '96.....29 Patterson Block, Fresno, Cal.

 ULRICH, CARL J., B.S., '01.....Central High School, Duluth, Minn.

 VANDERPOEL, FRANK, M.E., Ph.D., '87.....153 Center St., Orange, N. J.
 VEEDER, M. A., M.D., '85.....12 Queen St., Lyons, N. Y.
 VREDENBURGH, E. H., '84.....60 Plymouth Ave., Rochester, N. Y.

 WARD, HENRY B., A.M., Ph.D., '87....University of Nebraska, Lincoln, Neb.
 WEBER, PROF. HENRY A., Ph.D., '86.....1342 Forsyth Ave., Columbus, Ohio
 WEEKS, JOHN ROCKWELL, '99.....Weather Bureau, Macon, Ga.
 WRIGHTMAN, CHAS. H., '86.....5859 Michigan Ave., Chicago Ill.
 WELCH, GEO. O., M.D., '91.....Box 416, Fergus Falls, Minn.
 WELLINGTON, CHARLES, '99.....403 Pringle Ave., Jackson, Mich.
 WENDE, ERNEST, M.D., F.R.M.S., '91....471 Delaware Ave, Buffalo, N. Y.
 WHEELER, E. J., Ph.D., '00.....79 Chapel St., Albany, N. Y.
 WHELPLEY, H. M., M.D., Ph.G., F.R.M.S., '90,
 2342 Albion Place, St. Louis, Mo.

- WHIPPLE, G. C., '99.....Director Mt. Prospect Laboratory,
Flatbush Ave. and E. Parkway, Brooklyn, N. Y.
- WHITE, CHAS. H., M.D., '02.....Center Sandwich, N. H.
- WHITLEY, JAMES D., M.D., F.R.M.S., '85.....405 S. Main St., Petersburg, Ill.
- WIARD, MARTIN S., '86.....21 Walnut St., New Britain, Conn.
- WILLSON, LEONIDAS A., ESQ., '85.....112 Public Square, Cleveland, Ohio
- WOLCOTT, ROBERT HENRY, A.M., M.D., '98,
University of Nebraska, Lincoln, Neb.
- YOUNG, AUGUSTUS A., M.D., '92..22 E. Miller St., Newark, Wayne Co., N. Y.
- YOUNG, L., '00.....High School, Evansville, Ind.
- ZENTMAYER, FRANK, '91.....209 S. Eleventh St., Philadelphia, Pa.

SUBSCRIBERS

- PUBLIC LIBRARY.....Detroit, Mich., one copy
 FIELD COLUMBIAN MUSEUM.....Chicago, Ill., one copy
 COLUMBIA UNIVERSITY LIBRARY.....New York City, one copy
 NEW YORK PUBLIC LIBRARY.....New York City, one copy
 DULAU & Co.....37 Soho Square, London, England, two copies
 CARNEGIE LIBRARY.....Pittsburg, Pa., one copy
 SYRACUSE CENTRAL LIBRARY.....Syracuse, N. Y., one copy
 ACADEMY OF NATURAL SCIENCES...Logan Square, Philadelphia, Pa., one copy
 NEW YORK ACADEMY OF MEDICINE,
 17 W. Forty-third St., New York City, one copy
 THE MISSOURI BOTANICAL GARDEN.....St. Louis, Mo., one copy
 SCIENTIFIC LIBRARY.....U. S. Patent Office, Washington, D. C., one copy
 N. Y. STATE VETERINARY COLLEGE, Cornell University, Ithaca, N. Y., one copy
 U. S. MEDICAL MUSEUM AND LIBRARY,
 Surgeon General's Office, Washington, D. C., one copy
 NEW YORK STATE LIBRARY.....Serial Section, Albany, N. Y., one copy
 BOSTON SOCIETY OF NATURAL HISTORY..Berkeley St., Boston, Mass., one copy
 DR. JOS. H. LINSLEY,
 Director of Hygienic Laboratory, Burlington, Vt., one copy
 LIBRARY OF THE OHIO STATE UNIVERSITY.....Columbus, Ohio, one copy
 LABORATORY OF HISTOLOGY AND EMBRYOLOGY,
 University of Minnesota, Minneapolis, Minn., one copy
 LIBRARY OF THE UNIVERSITY OF NEBRASKA.....Lincoln, Neb., one copy
 JOHN CRERAR LIBRARY.....Chicago, Ill., one copy
 LIBRARY OF THE ILLINOIS STATE LABORATORY OF NATURAL HISTORY,
 Urbana, Ill., one copy
 NEW HAMPSHIRE STATE LIBRARY.....Concord, N. H., one copy
 MEDICAL LIBRARY.....McGill University, Montreal, Canada, one copy
 S. C. FULLER.....Westboro Insane Hospital, Westboro, Mass., one copy
 LIBRARY OF THE COLORADO STATE NORMAL.....Greeley, Colo., one copy
 LIBRARY OF THE UNIVERSITY OF MONTANA.....Missoula, Mont., one copy
 PUBLIC LIBRARY.....Plainfield, N. J., one copy
 SAN FRANCISCO MICROSCOPICAL SOCIETY.....San Francisco, Cal., one copy
 LIBRARY OF THE UNIVERSITY OF WISCONSIN.....Madison, Wis., one copy
 LIBRARY OF THE STATE NORMAL.....Warrensburg, Mo., one copy

BIENNIAL INDEX

FOR VOLUMES XXIII AND XXIV¹

*Acanthocephala, Some Points in the Structure of the, H. W. Graybill.	191
*American Microscopy, The Debt of, to Spencer and Tolles, W. C. Krauss	19
*Amount of Oxygen and Carbonic Acid Dissolved in Natural Waters and the Effect of these Gases upon the Occurrence of Microscopic Organisms, On the, G. C. Whipple and H. N. Parker.	103
*Apparatus, Modification of some Standard, to facilitate the Work of the Histologic and Embryologic Laboratory, Simon H. Gage.	259
*Beardsley, Arthur E., Notes on Colorado Entomostraca.	41
*Beardsley, Arthur E., Notes on Colorado Protozoa, with descriptions of new species.	49
*Bessey, Charles E., The Structure and Classification of the Conjugatae with a revision of the families and a rearrangement of the North American genera	145
Bessey, Charles E., Evolution in Microscopic Plants.	5
Bessey, Charles E., The Structure and Classification of the Phycomycetes, with a revision of the families and a rearrangement of the North American genera	27
Brownian Movement, Prevention of, in Milk or other Liquids with Minute Objects in Suspension, Simon H. Gage.	21
*Carbonic Acid, On the Amount of, Dissolved in Natural Waters, and the Effect upon the Occurrence of Microscopic Organisms, G. C. Whipple and H. N. Parker.	103
<i>Chlamydomonas</i> , Two Growths of, in Connecticut, Frederick S. Hollis	13
* <i>Cittotonia</i> , Studies on the Genus, R. A. Lyman.	173
*Classification of <i>Hymenolepis</i> , On <i>Hymenolepis cariaca</i> (Magalhaes) and <i>Hymenolepis megalops</i> (Nitzsch) with remarks on the, B. H. Ransom	151
*Classification of the Conjugatae, The, with a revision of the families and a rearrangement of the North American genera, Charles E. Bessey	145
Classification of the Phycomycetes, The, with a revision of the families a rearrangement of the North American genera, Charles E. Bessey.	27
*Claypole, E. W., Obituary Sketch of, Robert O. Moody.	267
*Colorado Entomostraca, Notes on, A. E. Beardsley.	41
*Colorado Protozoa, Notes on, with descriptions of new species, A. E. Beardsley	49
*Conjugatae, The Structure and Classification of the, with a revision of the families and a rearrangement of the North American genera, Charles E. Bessey.	145

¹References to Volume XXIII are starred.

Connecticut, Two Growths of <i>Chlamydomonas</i> in, Frederick S. Hollis..	13
*Constitution and By-Laws.....	283
Constitution and By-Laws.....	181
*Contribution to the Subterranean Fauna of Texas, A. C. J. Ulrich....	83
<i>Crenothrix</i> , A New Species of (<i>C. manganifera</i>), D. D. Jackson.....	31
Cultural Studies of a Nematode associated with Plant Decay, Haven Metcalf	89
* <i>Curvipes</i> , The North American Species of, Robert H. Wolcott.....	201
*Custodian's Report, 1900-01.....	282
Custodian's Report, 1901-2.....	179
Data for the Determination of Human Entozoa, Henry B. Ward.....	103
*Debt of American Microscopy to Spencer and Tolles, The, W. C. Krauss	19
*Eel Question, The Solution of the, C. H. Eigenmann.....	5
*Effect of Oxygen and Carbonic Acid Dissolved in Natural Waters upon the Occurrence of Microscopic Organisms, D. C. Whipple and H. N. Parker.....	103
*Eigenmann, Carl H., The Solution of the Eel Question.....	5
*Elrod, M. J., A New Hydra.....	257
*Embryologic Laboratory, Modification of some Standard Apparatus to facilitate the Work of the, Simon H. Gage.....	259
*Endothelium, The Morphogenesis of the Stigmata and Stomata occur- ring in Peritoneal and Vascular, A. E. Hertzler.....	63
*Entomostraca, Notes on Colorado, A. E. Beardsley.....	41
Entozoa, Human, Data for the Determination of, Henry B. Ward....	103
Evolution in Microscopic Plants, Charles E. Bessey.....	5
*Fauna, Subterranean of Texas, A Contribution to the, C. J. Ulrich....	83
*Gage, Simon Henry, Modification of some Standard Apparatus to facili- tate the Work of the Histologic and Embryologic Laboratory.....	259
*Gage, Simon Henry, Laboratory Photographic Apparatus.....	263
Gage, Simon Henry, Prevention of the Pedetic or Brownian Movement in Milk or other Liquids with Minute Objects in Suspension.....	21
*Gases, Dissolved in Natural Waters, Effect of Oxygen and Carbonic Acid upon the Occurrence of Microscopic Organisms, G. C. Whipple and H. N. Parker.....	103
*Graybill, H. W., Some Points in the Structure of the Acanthocephala..	191
*Hertzler, Arthur E., The Morphogenesis of the Stigmata and Stomata occurring in Peritoneal and Vascular Endothelium.....	63
Hilton, David C., The Early Morphogenesis and Histogenesis of the Liver in <i>Sus scrofa domesticus</i> , including notes on the Morphogen- esis of the Ventral Pancreas.....	55
Histogenesis of the Liver in <i>Sus scrofa domesticus</i> , The Early, David C. Hilton	55
*Histologic Laboratory, Modification of some Standard Apparatus to facilitate the Work of the, Simon H. Gage.....	259
Hollis, Frederick S., Two Growths of <i>Chlamydomonas</i> in Connecticut..	13
Human Entozoa, Data for the Determination of, Henry B. Ward.....	103
*Hydra, A New, M. J. Elrod.....	257

* <i>Hymenolepis cariosa</i> (Magalhaes) and <i>Hymenolepis megalops</i> (Nitzsch) with remarks on the Classification of the Group, On, B. H. Ransom	151
*Indiana, Lake Maxinkuckee, The Plankton of, Chancey Juday	61
Ives, F. E., Stereoscopic Photomicrography with High Powers	23
*Jackson, D. D., A New Species of <i>Crenothrix</i> (<i>C. manganiifera</i>)	31
*Juday, Chancey, The Plankton of Lake Maxinkuckee, Indiana	61
*Krauss, William C., The Debt of American Microscopy to Spencer and Tolles	19
*Laboratory, Modification of some Standard Apparatus to facilitate the Work of the Histologic and Embryologic, Simon H. Gage	259
*Laboratory Photographic Apparatus, Simon H. Gage	263
*Lake Maxinkuckee, Indiana, The Plankton of, Chancey Juday	61
<i>Limnea</i> , The North American Species of, Robert H. Wolcott	139
Liver, The Early Morphogenesis and Histogenesis of, in <i>Sus scrofa</i> <i>domesticus</i> , David C. Hilton	55
*Lyman, Rufus Ashley, Studies on the Genus <i>Cittotaenia</i>	173
*Maxinkuckee Lake, Indiana, The Plankton of, Chancey Juday	61
*Members, List of, 1901	287
Members, List of, 1902	185
Metcalf, Haven, Cultural Studies of a Nematode associated with Plant Decay	89
Method of Concentrating Plankton without Net or Filter, A. B. L. Seawell	17
*Microscopic Organisms, The Effect of Oxygen and Carbonic Acid Dis- solved in Natural Waters upon the Occurrence of, G. C. Whipple and H. N. Parker	103
Microscopic Plants, Evolution in, Charles E. Bessey	5
*Microscopy, The Debt of American, to Spencer and Tolles, W. C. Krauss	19
Milk, Prevention of Pedetic or Brownian Movement in, Simon H. Gage	21
*Minutes of Twenty-fourth Annual Meeting	275
Minutes of the Twenty-fifth Annual Meeting	171
Minutes of the Mid-Winter Meeting, January, 1903	176
*Modification of some Standard Apparatus to facilitate the Work of the Histologic and Embryologic Laboratory, Simon H. Gage	259
*Moody, Robert O., Obituary Sketch of E. W. Claypole	269
Morphogenesis of the Liver in <i>Sus scrofa domesticus</i> , The Early, David C. Hilton	55
*Morphogenesis of the Stigmata and Stomata occurring in Peritoneal and Vascular Endothelium, The, A. E. Hertzler	63
Morphogenesis of the Ventral Pancreas in <i>Sus scrofa domesticus</i> , Notes on, David C. Hilton	55
*Necrology, E. W. Claypole, Robert O. Moody	269
Necrology, Charles M. Vorce, R. H. Ward	163
Nematode, Cultural Studies of a, associated with Plant Decay, Haven Metcalf	89
*New Hydra, A. M. J. Elrod	257
*New Species of Colorado Protozoa, descriptions of, A. E. Beardsley	49

*New Species of <i>Crenothrix</i> (<i>C. manganifera</i>), A. D. D. Jackson.....	31
*North American genera of Conjugatæ, a rearrangement of the, Charles E. Bessey	145
North American genera of Phycomycetes, A rearrangement of the, Charles E. Bessey.....	27
*North American Species of <i>Curvipes</i> , The, Robert H. Wolcott.....	201
North American Species of <i>Limnesia</i> , The, Robert H. Wolcott.....	139
*Notes on Colorado Entomostraca, A. E. Beardsley.....	41
*Notes on Colorado Protozoa, with descriptions of New Species, A. E. Beardsley	49
*Obituary of E. W. Claypole, Robert O. Moody.....	260
Obituary of Charles M. Vorce, R. H. Ward.....	163
*Occurrence of Microscopic Organisms, the Effect of Oxygen and Carbonic Acid Dissolved in Natural Waters upon the, G. C. Whipple and H. N. Parker.....	103
*Officers for 1900-01, and Executive Committee.....	2
Officers for 1901-02, and Executive Committee.....	2
*Oxygen, On the Amount of, Dissolved in Natural Waters, and the Effect upon the Occurrence of Microscopic Organisms, G. C. Whipple and H. N. Parker.....	103
Pancreas, Ventral, Notes on Morphogenesis of, in <i>Sus scrofa domesticus</i> , David C. Hilton.....	55
*Parker, Horatio N., and Whipple, George C., On the Amount of Oxygen and Carbonic Acid Dissolved in Natural Waters and the Effect of these Gases on the Occurrence of Microscopic Organisms.....	103
Pedetic or Brownian Movement, Prevention of, in Milk or other Liquids with Minute Objects in Suspension, Simon H. Gage.....	21
*Photographic Apparatus, Laboratory, Simon H. Gage.....	263
Photomicrography, Stereoscopic, with High Powers, F. E. Ives.....	23
Phycomycetes, The Structure and Classification of, with a revision of the families and a rearrangement of the North American genera, Charles E. Bessey.....	27
Fig. The Early Morphogenesis and Histogenesis of the Liver, including Notes on the Morphogenesis of the Ventral Pancreas, David C. Hilton	55
Plankton, A Method of Concentrating, without Net or Filter, B. L. Seawell	17
*Plankton of Lake Maxinkuckee, Indiana, The, Chancey Juday.....	61
Plant Decay, Cultural Studies of a Nematode associated with, Haven Metcalf	89
*President's Address, 1901.....	5
President's Address, 1902.....	5
Prevention of the Pedetic or Brownian Movement in Milk or other Liquids with Minute Objects in Suspension, Simon H. Gage.....	21
*Protozoa, Notes on Colorado, with descriptions of New Species, A. E. Beardsley	49
*Ransom, B. H., On <i>Hymenolepis carioca</i> (Magalhaes) and <i>Hymenolepis megalops</i> (Nitzsch) with remarks on the Classification of the Group	151

Seawell, B. L., A Method of Concentrating Plankton without Net or Filter	17
*Solution of the Eel Question, The, C. H. Eigenmann.....	5
*Some Points in the Structure of the Acanthocephala, H. W. Graybill....	191
*Spencer, The Debt of American Microscopy to, W. C. Krauss.....	19
*Spencer-Tolles Committee, Report.....	265
*Spencer-Tolles Fund, List of Subscribers to the.....	267
*Spencer-Tolles Fund, Report.....	282
Spencer-Tolles Fund, Report.....	179
Stereoscopic Photomicrography with High Powers, F. E. Ives.....	23
*Stigmata, The Morphogenesis of the, occurring in Peritoneal and Vascular Endothelium, A. E. Hertzler.....	63
*Stomata, The Morphogenesis of the, occurring in Peritoneal and Vascular Endothelium, A. E. Hertzler.....	63
*Structure of the Acanthocephala, Some Points in the, H. W. Graybill....	191
*Structure of the Conjugatae, The, Charles E. Bessey.....	145
Structure of the Phycomyces, The, Charles E. Bessey.....	27
*Studies on the Genus <i>Cittotaenia</i> , R. A. Lyman.....	173
*Subscribers, List of, 1901.....	294
Subscribers, List of, 1902.....	192
*Subterranean Fauna of Texas, A Contribution to the, C. J. Ulrich.....	83
*Texas, A Contribution to the Subterranean Fauna of, C. J. Ulrich.....	83
*Tolles, The Debt of American Microscopy to, W. C. Krauss.....	19
*Treasurer's Report, 1900-01.....	281
Treasurer's Report, 1901-02.....	178
Two Growths of <i>Chlamydomonas</i> in Connecticut, Frederick S. Hollis....	13
*Ulrich, Carl Jost, A Contribution to the Subterranean Fauna of Texas..	83
Vorce, Charles M., Obituary Sketch of, R. H. Ward.....	163
Ward, Henry B., Data for the Determination of Human Entozoa.....	103
Ward, R. H., Obituary Sketch of C. M. Vorce.....	163
*Waters, Natural, On the Amount of Oxygen and Carbonic Acid Dissolved in, and the Effect upon the Occurrence of Microscopic Organisms, G. C. Whipple and H. N. Parker.....	103
*Whipple, George C., and Parker, Horatio N., On the Amount of Oxygen and Carbonic Acid Dissolved in Natural Waters and the Effect of these Gases on the Occurrence of Microscopic Organisms.....	103
*Wolcott, Robert H., The North American Species of <i>Curzipes</i>	201
Wolcott, Robert H., The North American Species of <i>Limnesia</i>	139

TRANSACTIONS
OF THE
American Microscopical
Society

ORGANIZED 1878 INCORPORATED 1891

EDITED BY THE SECRETARIES

Twenty-Sixth Annual Meeting

HELD AT

WINONA LAKE, INDIANA, JULY 29, 30 AND 31, 1903

VOLUME XXV

AND INDEX TO VOLUMES I TO XXV INCLUSIVE

PRINTED BY
THE NEW ERA PRINTING COMPANY
LANCASTER, PA.

1904

OFFICERS FOR 1903-1904

<i>President</i> T. J. BURRILL.....	Urbana, Ill.
<i>Vis-Presidents</i> H. A. WEBER.....	Columbus, O.
E. W. KURNE.....	Fort Wayne, Ind.
<i>Secretary</i> HENRY B. WARD.....	Lincoln, Neb.
<i>Assistant Secretary</i> R. H. WOLCOTT.....	Lincoln, Neb.
<i>Treasurer</i> J. C. SMITH.....	New Orleans, La.
<i>Custodian</i> MAGNUS PFLAUM.....	Pittsburg, Pa.

ELECTIVE MEMBERS OF THE EXECUTIVE COMMITTEE

CHAS. F. COX.....	New York City
L. B. ELLIOTT.....	Rochester, N. Y.
J. M. STEDMAN.....	Columbia, Mo.

EX-OFFICIO MEMBERS OF EXECUTIVE COMMITTEE

Past Presidents still retaining membership in the Society

R. H. WARD, M.D., F.R.M.S., of Troy, N. Y.,	
at Indianapolis, Ind., 1878, and at Buffalo, N. Y., 1879	
H. L. SMITH, LL.D., of Geneva, N. Y.,	
at Detroit, Mich., 1880, and at Cleveland, O., 1885.	
J. D. HYATT, of New York City,	
at Columbus, O., 1881.	
ALBERT McCALLA, Ph.D., of Fairfield, Ia.,	
at Chicago, Ill., 1883.	
T. J. BURRILL, Ph.D., of Champaign, Ill.,	
at Chautauqua, N. Y., 1886.	
GEO. E. FELL, M.D., F.R.M.S., of Buffalo, N. Y.,	
at Detroit, Mich., 1890.	
FRANK L. JAMES, Ph.D., M.D., of St. Louis, Mo.,	
at Washington, D. C., 1891.	
MARSHALL D. EWELL, M.D., of Chicago, Ill.,	
at Rochester, N. Y., 1892.	
SIMON HENRY GAGE, B.S., of Ithaca, N. Y.,	
at Ithaca, N. Y., 1895.	
A. CLIFFORD MERCER, M.D., F.R.M.S., of Syracuse, N. Y.,	
at Pittsburg, Pa., 1896.	
W. C. KRAUSS, M.D., of Buffalo, N. Y.,	
at Columbus, O., 1899.	
A. M. BLEILE, M.D., of Columbus, O.,	
at New York City, 1900.	
C. H. EIGENMANN, Ph.D., of Bloomington, Ind.,	
at Denver, Col., 1901.	
CHARLES E. BENNEY, LL.D., of Lincoln, Neb.,	
at Pittsburg, Pa., 1902.	
E. A. BIRGE, LL.D., of Madison, Wis.,	
at Winona Lake, Ind., 1903.	

The Society does not hold itself responsible for the opinions expressed by members in its published Transactions unless endorsed by a special vote.

TABLE OF CONTENTS

FOR VOLUME XXV

The Annual Address of the President, The Thermocline and its Biological Significance, by E. A. Birge, with Plates I and II,.....	5
The Finer Structure of the Heart Muscle of the Dog, by Gertrude A. Gillmore, with Plates III to V.....	35
Additional Notes on the Cladocera of Nebraska, by Chas. Fordyce, with Plate VI	45
Upon the Occurrence of Haemosporidia in the Blood of <i>Rana Catesbiana</i> , with an Account of their probable Life History, by Jas. H. Stebbins, Jr., with Plates VII and VIII.....	55
Outline of the Tube Plan of Structure of the Animal Body, by J. S. Foote, with Plates IX to XIV.....	63
The Classification of Protophyta, Including a Revision of the Families, and a Rearrangement of the North American Genera, by Chas. E. Bessey	89
River Pollution and Purification, by T. J. Burrill, with Plates XV to XVII	105
<i>Synchaeta bicornis</i> : A New Rotifer from the Brackish Waters of Lake Pontchartrain, Louisiana, by J. C. Smith, with Plate XVIII.....	121
A Biological Reconnoissance of some Elevated Lakes in the Sierras and the Rockies, by Henry B. Ward, with Reports on the Copepoda by C. Dwight Marsh, and on the Cladocera by E. A. Birge, and with Plates XIX to XXX.....	127
Necrology, Richard L. Maddox, with Plate.....	155
Bushrod W. James, with Plate.....	160
Oscar C. Fox, with Plate.....	163
J. C. Millen, with Plate.....	165
Minutes of the Annual Meeting.....	167
Minutes of the Mid-Winter Meeting.....	170
Custodian's Report, Spencer-Tolles Fund.....	172
Treasurer's Report	173
Constitution	175
By-Laws	176
List of Members.....	179
List of Subscribers.....	186
Index to Volumes I to XXV, Inclusive.....	187
Advertisements	I

5

TRANSACTIONS
OF
The American Microscopical Society

TWENTY-SIXTH ANNUAL MEETING, HELD AT WINONA LAKE,
INDIANA, JULY 29, 30 AND 31, 1903

THE ANNUAL ADDRESS OF THE PRESIDENT

THE THERMOCLINE AND ITS BIOLOGICAL
SIGNIFICANCE

By E. A. BIRGE

WITH TWO PLATES

It is my misfortune that my studies do not enable me to speak to this Society on a subject which is immediately connected with its name. To me, as to many biologists, the microscope has been an aid to work rather than an object of study in itself, and in preparing an address which shall deal with a topic of general scientific interest it has been necessary for me to select a subject which has but little direct relation to the microscope, although that instrument is the main aid to the student in working out the biological problems which the subject presents. However, it is not inappropriate that we should consider a topic relating to the biology of a lake when we meet, as we do to-day, on the shore of a sheet of water at once so beautiful and the subject of so much scientific investigation as is Winona Lake.

The term *thermocline* was introduced by myself in 1897, as an equivalent for the German term *Sprungschicht*, by which is meant that comparatively thin stratum in the water of a lake, situated below the surface, in which the temperature falls rapidly—much more rapidly than in strata of similar thickness above or below it.

It is a well known fact that in summer the temperature of a fresh-water lake is much higher at the surface than at the bottom. The surface water may have a temperature anywhere from 20° to 30° C., while the bottom temperature varies in different lakes between 4° C. in deep bodies of water—the temperature of the maximum density of water—and a temperature very close to, or equal to that of the surface, in large and shallow lakes. Ordinarily, however, the difference is considerable. In small lakes, even though they are but 10 m. to 15 m. in depth, there is usually a temperature difference of 10° to 12° between the surface and the bottom.

When this fall of temperature is distributed to the several strata of the water between surface and bottom, it is seen that the decline is by no means uniform. Ordinarily there will be found a surface stratum of water, varying in different lakes from 2 m. to 12 m. in thickness, whose temperature is very nearly that of the surface. If at this season temperatures are taken in a lake like Winona in the early morning, before the sun has had an opportunity to warm the surface water, a stratum 5 m. to 6 m. in thickness may possess a temperature almost absolutely uniform. Immediately below this stratum comes another—the thermocline—in which the fall of temperature is very marked and very rapid. The temperature usually declines as much as 2° or 3° in the course of a meter and the fall may be much more rapid than this. A drop of 5° or 7° , or even 9° has been found in a single meter and in certain lakes a decline as great as 5° or 6° in the course of a meter may be ordinarily expected. This stratum, the thermocline, varies in thickness in different lakes and in the same lake under different circumstances, but may be from 2 m. or 3 m. to 5 m. in thickness. Its upper surface is pretty sharply marked and can usually be defined within the limits of a few decimeters. In its lower part, however, the thermocline passes more or less gradually into the region below and it is not possible to mark its lower surface by any exact level, though it is usually considered as ending where the decline in temperature becomes less than 1° per meter. Below the thermocline the rate of decline in temperature becomes rapidly smaller and soon amounts to only a few tenths of a degree per meter. As the depth increases the change in temperature becomes still less until perhaps, in the deepest lakes, the temperature of 4° , that of the maximum density of water, is reached, and below this point there is no further change.

This distribution of temperature in various lakes is illustrated by the following diagram (Plate I), which shows the distribution of temperature in three Wisconsin lakes on May 30 and September 2, 1878. These lakes are Garvin—a small pond having an area of about 8 hectares (20 acres) and a depth of about 11 m.; Okauchee Lake with an area of 4.4 sq. km. (1.7 sq. mi.) and a depth of 27 m.; and Lake Mendota, whose area is 39 sq. km. (15 sq. mi.) and whose depth is slightly over 24 m. These lakes are in the same general region: Garvin being immediately adjacent to Okauchee Lake, and both of these about 50 miles east of Lake Mendota. On May 30 Garvin Lake showed a strongly marked thermocline, whose upper surface lay at a depth of 4 m. and showed a fall of 7° in about half a meter. Okauchee Lake showed a thermocline extending from about 6 m. to 11 m., while Mendota on this date showed nothing that could fairly be called a thermocline. Thus the smallest lake showed a well-marked thermocline and the largest displayed a much more even distribution of the heat. The surface temperatures were lowest in Mendota and highest in Garvin. This would naturally follow from the greater influence of the wind in distributing the heat of the sun to greater depths in the larger lake. The bottom temperatures of the respective lakes showed the effect of the wind; Garvin at a depth of 11 m. being more than a degree lower than Okauchee at a depth of 27 m., while Lake Mendota, at a depth of 24 m., was nearly 2° higher than Okauchee Lake.

On September 2 all lakes showed well-marked thermoclines, which lay at a greater depth in the larger lakes. The variations in the surface temperatures on this day were due to the fact that the temperature of Lake Mendota was taken earlier in the morning, while the other lakes were visited later in the day; the temperature in Garvin Lake not being read until nearly noon. The bottom temperatures had increased comparatively little during the three months. Okauchee Lake indeed showed an apparent loss of 0.4° , which was probably due to an irregular stratification of the water on the earlier date. Garvin Lake at a depth of 11 m. had gained but half a degree, while Lake Mendota at the same depth had gained nearly 7° , and Okauchee about 1° .

This singular distribution of temperature was first noticed by Simony in Germany over fifty years ago. His observations were

entirely forgotten and in 1885 Buchanan¹ observed the same phenomena in Loch Lomond, and Forel² about the same time in Lake Geneva. Their observations and explanations remained unnoticed and in 1891 Richter³ gave new and careful investigation to the subject and applied the term *Sprungschicht* to the stratum of rapid change of temperature. His name for the stratum has been generally adopted, as also his explanation of the phenomena, although the latter is not wholly correct. Since this time the thermocline has been observed by all the very numerous students of lake temperature and much has been written regarding its nature and origin.

It is worth our while to spend a few minutes in considering the way in which the thermocline is formed, or rather, since the problem is really a more general one, to consider the explanation of the shape of the peculiar curve which represents the vertical distribution of temperature in a lake. (Plate II, fig. 2.) In all lakes of the northern United States, with which alone we are concerned, the temperature of the lake at freezing is but little above the temperature of 0° C. Ordinarily the bottom water, even in a lake 30 m. to 50 m. deep has a temperature of not more than 1° to 2°, and in lakes whose depth is 20 m., or more, it may easily be lower than 1°. During the winter the water under the ice is warmed, mainly by the action of the sun, and at the time of the melting of the ice in the spring the water has reached a temperature of 2° to 4° C., and usually is nearer the higher figure. When the ice has disappeared the water of the lake is freely exposed to the action of the weather. Practically all of the heat received by the water comes directly from the sun. Small amounts may be absorbed from the air and by reflection from the shores of the lake, but these are so insignificant in amount that they require no special consideration. The rays of the sun as they fall upon the lake are, in part, reflected; in part, used in evaporating the water of the surface; in very small part, employed for chemical operations in the plants and animals of the open water; and the remainder of the

¹ J. Y. Buchanan. On the distribution of temperature in Loch Lomond during the autumn of 1885. Proc. Royal Soc. Edin., Vol. XIII, 1886, pp. 403-428.

² F. A. Forel. Le Léman. Vol. II, p. 362, footnote.

³ E. Richter. Die Temperaturverhältnisse der Alpenseen. Verhandl. d. neunten Geographentages zu Wien, 1891, pp. 176-189.

sun's energy, passing into the water, is there converted into heat. By far the greater portion of this energy is absorbed by the stratum of water immediately at the surface. Nearly one-half of the sun's energy is in the form of waves too long to be visible as light, and these are absorbed by the first centimeters of water through which they pass. Probably 30%, or more, of the energy present as light is absorbed by the first meter, so that even in distilled water not more than 30% to 35% of the energy which enters the surface of the water is transmitted to the second meter. In natural water, which is always rendered more or less turbid by the presence of suspended inorganic matter and of algae and plankton animals, the absorption is much greater, and in lakes whose water, when filtered, is clear and which are not at all exceptional in the amount of plankton which they may contain, only 3% or 4% of the sun's energy may be transmitted to the second meter; 95%, or more, being reflected or absorbed by the surface meter. If, therefore, the surface of the lake were not disturbed by the wind, the lower strata of water would be warmed during the course of the year very little, if at all. The surface strata would be greatly heated during the day; they would cool at night, to be again warmed as day returned, but the entire play of summer temperatures in the lake would take place in a shallow layer near the surface and the water at a very moderate depth would be slightly or not at all warmed above 4° C.

But the lake is exposed not only to the action of the sun, but to that of the wind, and the wind is the chief agent for the distribution through the body of water in the lake of the heat derived from the sun. This heat is distributed, in part, by the waves as they move, and especially as they break in whitecaps on the surface, but much more effectively by the currents which the wind causes on the surface of the lake.

Imagine a lake receiving no heat from the sun but exposed to the action of a wind which is blowing steadily in one direction. The surface water will not only be lifted into waves but will be driven by the wind across the lake. As it reaches the leeward side, it must return in some way, either around the edges of the lake, or across the bottom, and, since almost all lakes are very shallow in proportion to their breadth, a wind, such as is described, would finally set the entire mass of the water of the lake into a sort of rotation, completely mixing the surface and deeper water. Such a mixture as

this actually occurs in late fall, after the lake has become homothermous. This is shown by the fact that even in lakes more than 70 m. in depth the temperature of the bottom water before the lake freezes falls below 4° , or the temperature of maximum density, and, further, during this period of cooling below 4° the difference of temperature between the surface and bottom water rarely exceeds 0.2° or 0.3° C.

If, however, the lake is exposed to the action of both sun and wind the influence of the wind becomes modified. The surface water, warmed by the sun, is driven across the lake but since the water becomes lighter as its temperature rises, there is produced a thermal resistance to the mixture of the water and the rotation described can not be set up unless the wind is very powerful. Instead of mingling with the lower water and returning easily by deep currents, the warmed water tends to remain on or near the surface and to accumulate on the leeward side of the lake. There is thus produced a sort of wedge-shaped layer of warm water, thickest on the leeward side and gradually tapering until it becomes very thin on the windward side. This wedge-shaped mass is, of course, in a condition of unstable equilibrium because of its shape and density. Equilibrium may be restored in various ways. The warmed water may, in small part, mingle with the cooler water by means of lateral diffusion currents. At night, as the temperature of the warmed surface falls, the thermal resistance to mixture declines and the task of the wind is rendered easier. On the cessation, or reversal, of the wind, the warmed water may flow back toward the leeward side, thus producing a surface layer of uniform thickness. If the wind is strong enough or if the action of the sun and wind continue long enough, the warmed water may flow back to the windward side along the shore, or beneath the surface and on top of the cooler water, thus producing a warmed surface layer of nearly uniform thickness. It is obvious that by one or all of these ways there could be produced on the surface of the cooler water of the lake a layer of warm water with a transition layer immediately below it—the thermocline.

If this were the entire story, the thermocline would be formed permanently very early in the spring and the bottom water would be only slightly warmed above 4° . But, as a matter of fact, while a warm surface layer is frequently produced during the day in spring, many days are so cool and cloudy that the small amount of heat

gained is readily distributed to the depths of the lake. The long cool nights so reduce the surface temperature and diminish the thermal resistance to mixture that the winds may easily mix the surface water with all of that which lies below it. Almost always, too, during the spring there occur periods of cold weather and high winds, during which the entire stratum of warmed surface water will be cooled and mingled with the mass of the water of the lake. By these means the entire mass of the water of the lake may become warmed during the spring and the bottom temperature raised considerably above 4° . In Lake Mendota, whose area is 39 sq. km. (15 sq. mi.), the bottom temperature may rise to 10° or 12° at a depth of 24 meters. In Okauchee lake (4.4 sq. km.; 1.7 sq. mi.) the temperature at the same depth is 6° to 8° .

The distribution of the heat of the sun through the water of the lake is thus dependent on the mutual relation of two forces: first, the action of the wind, which tends by waves and currents to mingle the surface water with that which lies below it; and, second, the thermal resistance to mixture offered by the surface water as it is warmed. The influence of the wind is proportional to its velocity and duration. The thermal resistance is greater when the sun is shining; it is diminished at night, as the surface cools, and by cloudy or cold weather. The depth and extent to which the distribution of the warmth will take place depend on what may be called the algebraic sum of these two forces. The nocturnal cooling of the surface, and cooling due to periods of cloudy and cold weather are important aids to the distribution of heat, because they diminish the thermal resistance and thus give the wind an opportunity of mingling the water and so making the temperature of the lake more nearly uniform.

As the spring advances, the sun gets higher in the heavens, the days become longer and warmer, the nights shorter, and the influence of the sun upon the surface becomes greater. Under these circumstances there will come a time for each lake when even the strongest winds are unable completely to overcome the thermal resistance and when the action of the most violent and steady wind is able only to mingle the surface water with a small portion of that which lies below. Under these circumstances, a stratum will be formed on the surface nearly uniform in temperature and whose thickness will depend on the depth to which, under the prevailing temperature con-

ditions, the ordinary winds are able to affect the water of the lake, especially at night, when the thermal resistance is least. Then the permanent thermocline will be formed and in the stratum above the thermocline the diurnal play of temperature will go on.

The result of this action is to divide the water of the lake into two main regions, with a transition zone between them. These are: first, a surface layer in which take place the diurnal changes of temperature—a stratum whose temperature is high and fairly uniform, though ordinarily declining somewhat below the surface; second, a transition stratum—the thermocline—in which the temperature falls rapidly to that of the cooler water of the lower part of the lake; and, third, below the thermocline and separated from it by no distinct line, lies the mass of the cooler water of the lake.

These thermal regions of the lake are very different in thickness in different lakes. In large and shallow lakes, indeed, there may be only one region, corresponding to the upper of the three regions named. In Wisconsin, for example, there is Lake Winnebago—a sheet of water more than 33 km. (20 mi.) in length, and perhaps 20 km. (12 mi.) in greatest width, with a maximum depth of 8 m. to 10 m. This body of water is so large and so shallow that the wind easily stirs it up to the bottom and the warmed surface strata are rapidly mingled with the entire mass of the water. As a result, the temperature of Lake Winnebago is ordinarily uniform from top to bottom in the morning, although at night the surface strata will usually be warmer, unless the day has been very windy. In lakes which are in the same geographical region and whose depth in relation to area is of a more common type, the thickness of the warmed surface layer will vary with the area of the lake. In July the stratum may be as little as 2 m. or 3 m. in thickness in lakes whose area is from 8 to 10 hec. (20 to 30 acres). In lakes whose area is 3 or 4 sq. km. (one or more sq. mi.) the stratum may be from 5 m. to 7 m. in thickness. In lakes whose area is from 15 to 30 sq. km. the warmed stratum may be from 9 m. to 12 m. thick. In any case, it is true that the larger the lake the thicker the warm layer, or, in other words, the deeper lies the thermocline. This fact is a necessary result of the formation of the layer by the action of the wind, since in the larger body of water the wind has a greater opportunity to act upon the surface. It ought also to be said that the *effective* area of the lake should be con-

sidered, and the figures which I have given relate to lakes of fairly simple outline. A very irregular body of water, mainly consisting of narrow arms extending in various directions, would, of course, be much less influenced by the wind than a lake of simple outline. A similar statement might be made for a lake a large share of whose area is occupied by islands.

In different lakes the thermocline appears as a permanent feature at very different dates. In the smallest lakes—those in which the wind has the least effect—it no doubt may be permanent as early as the latter days of April, although I have never observed it earlier than the first week of May. In larger lakes it appears later, since the wind is able to mingle the surface water with the lower strata of the lake for a much longer time during the spring. In lakes whose area may be measured in square miles the thermocline is not likely to appear before the middle of June, and in Lake Mendota it can hardly be said to have a well-defined and permanent existence much before July. It should be noted, however, that it frequently appears temporarily at an earlier date and that the thermocline, in general, is by no means a phenomenon of late summer and autumn, as some of the earlier observers supposed. Other things being equal, the time of its appearance is conditioned upon the area of the lake—the date being earlier in the smaller body of water.

After the formation of the thermocline, the direct gains of heat are confined to the stratum of water above it. By this means the lower water is preserved in a cooler condition than would otherwise be the case. If the lake received its heat in smaller doses, as it were, such that the wind could mingle surface and deeper water, the temperature of the latter would rise far higher than it does. Okauchee Lake, for instance, has an area of about 4.4 sq. km. (1.72 sq. mi.) and a maximum depth of about 30 m. In 1898 the temperature of the water at the bottom had reached 6.5° by April 25; it was 7° on May 6; and after that date no perceptible rise was made until October. After the 1st of May the heat came so rapidly that the wind could not distribute it. Thus the lower water remained cool—much cooler than in a lake of larger area and equal depth. In small lakelets the sun produces little effect directly, even at depths which are very moderate. In one case the temperature at a depth of 11 m. rose only about 0.2° C. (4.33° to 4.55°) in 40 days, July 27 to September 5. A meter deeper no perceptible rise took place.

(Plate II, fig. 2.) The sun's effect is similarly confined to a small depth in the larger lakes, but the influence of the wind is so much greater as to prevent any direct proof of the fact by ordinary temperature observations. Thus a very low summer temperature may be maintained in comparatively shallow water if the area of the lake is small, and if it receives little or no ground water. It is obvious also that a cool spring, with its necessary alternations of warmth and cold, leads to the distribution of more heat to the lower water than does a warm season. Thus in Winona Lake in 1901 the bottom temperature was about 8°, while at the present time it is 2.5° higher.

It should also be added that the only periods when the entire mass of water in a lake is circulated freely are during late fall, after the lake has become homothermous, and the very brief period in the spring before the water reaches the temperature of 4° C. Thermal resistance prevents free circulation in the spring, and its effective opposition begins at a very early date.

By the first, or middle, of July, at latest, a warmed stratum has been formed on the surface of the lakes in this region of the United States and the thermocline is to be found at a depth which varies with the area of the lake but which is, in the same lake, about the same in successive years. For some weeks very little change occurs in the depth at which the thermocline lies. The surface of the lake is still gaining from the sun more heat than it radiates to the air, and the thermal resistance is such that it takes a very violent wind to mix the water to a depth greater than that at which the thermocline lies. Indeed, as one studies the temperature of the lake, he is surprised at the force of this thermal resistance. Squalls of very considerable violence and the strong winds which accompany summer showers, and which may last for many hours, may temporarily depress the thermocline on one side of a large lake perhaps 2 m. or 3 m., but they have very little effect in permanently lowering the thermocline, which rises almost to its former position when the wind ceases. One who follows the temperature of a lake with daily observations and notes the great oscillations of the upper surface of the thermocline and its very slow sinking in early and midsummer comes almost to feel that the upper surface of the thermocline offers such a resistance to the mixture of water as a thin elastic layer of rubber might do in the same position. In Okauchee Lake, for example, in 1898 the

upper surface of the thermocline lay at 7 m. below the surface on June 28. Two and a half months later the upper surface was still at the same level, and the temperature of the upper stratum of water was not very different from that at the earlier date. In other lakes the same conditions are found. In Lake Mendota the upper surface of the thermocline at the middle of June, 1898, lay between 6 m. and 7 m. below the surface. Early in July it reached 8 m. and sank little more than a meter during July and August. In other years, as might be expected, the sinking is somewhat more rapid, but is always very slow during July and early August. In Garvin Lake, in the same year, the upper surface of the thermocline lay at 4 m. on June 28, and did not sink below that level in more than two months.

With the passing of the summer, as the nights increase in length and the gains from the sun become smaller, the thermal resistance to mixture decreases, and with the cool days and nights which often come in August and early September, there is brought about an equalizing of the temperature of the warmed layer. Under these circumstances, the wind more easily mingles this stratum and the upper part of the thermocline, and thus, as the temperature of the surface water falls, the thickness of the warmed layer increases, or, in other words, the position of the thermocline moves downward during the late summer and the early fall. As this process goes on, the thermocline is apt to sink with increasing rapidity, since the thermal difference between the upper and the lower water becomes smaller as the upper stratum cools, and the task of the wind, therefore, becomes easier. Usually the complete mingling of the water of the lakes comes in connection with a storm. In Lake Mendota, for instance, where most of my studies have been carried on, we have a lake about 10 km. (6 mi.) in length by 6.5 km. (4 mi.) in width, and with a maximum depth slightly exceeding 24 meters. The thermocline gets very near the bottom by the latter part of September, at which time the surface temperature may be about 18° and that of the bottom about 15°. Frequently the complete mixture of the water takes place during the gales which are wont to occur at the close of that month, or in early October. Should these not come, however, the equalizing of the temperature may not be brought about until late in October or in November. In smaller or deeper lakes the process of equalization lasts until later, and undoubtedly in the deepest lakes the homothermous condition is brought about more by the cooling

of the surface water than by the overturning of the mass of water in the lake by the action of the wind.

This, then, is a brief sketch of the thermal history of any of our northern lakes. Starting in the spring, at a condition of thermal homogeneity, there is developed a condition by which the lake becomes separated into two very distinct thermal regions—a shallow, warm, surface layer resting on and ordinarily considerably thinner than the cooler bottom portion of the lake. These are connected by a transition stratum, the thermocline. During late summer and fall the warm layer loses heat and also gains in thickness by mixture with the subjacent water, until finally at some time during the autumn thermal homogeneity is reestablished.

These thermal changes must have a considerable effect on the physical conditions of life in a lake. The change of temperature at the thermocline is itself a factor which may influence directly the vertical distribution of life in a lake. Still further, change of temperature is accompanied with other physical changes. The cooler water is denser, and, therefore, plankton plants and animals may float in this denser water, which would sink in the warmer water above. Ostwald¹ has very recently pointed out that the viscosity of water increases as its temperature declines, and increases at a much more rapid rate than does its density. This increase of viscosity must affect the rate of sinking of plankton animals and plants, and so their vertical distribution. As yet, however, no experimental work in this direction has been published. Undoubtedly this newly suggested factor is a real one and its influence must be studied and evaluated. The initial influence of the viscosity of water is still unknown and it is, therefore, difficult to see how great the value of its increase will be. It appears also that it will not be easy to distinguish between the effects due to increased density and those due to increased viscosity.

Besides these more direct effects of the change in temperature at the thermocline, there are others less direct, but even more important in their influence on distribution. After the thermocline has been established, the water below is cut off from any direct access to the air. It is also deprived in great measure, though not entirely, of the effects which come from circulation induced by the wind.

¹ W. Ostwald. Theoretische Planktonstudien. Zool. Jahrbücher, Abt. für Systematik, Vol. XVIII, 1903, pp. 1-62.

The movements of the warmed stratum occasion slow movements in the lower water, but these are very small and feeble as compared with the vigorous movements in the upper stratum. It is obvious also that the gaseous contents of the lower water are likely to become quite different from those of the upper stratum. All of the leaves blown into the lake, all organic debris washed into it, all of the plankton plants and animals, as they die, sink into the lower water and are there decomposed. Oxygen is consumed in this process and may almost entirely disappear from the lower water, as it is supplied only slowly to this water by diffusion from the upper stratum. The gases formed by decomposition escape also slowly, partly because of the lack of circulation, and partly because of the distance through which diffusion has to take place. The extent of this influence on gases and the substances dissolved in the lower water will depend on the amount of plankton or other organic matter present in the lake, on the volume of the water in the lower stratum, and on the temperature of the bottom water, which regulates the rate of decomposition. In large and deep lakes little, or no, influence of this kind can be detected. In small ponds, where the organic content is great and the bottom temperature high, the lower water may become very foul, ill-smelling, and discolored by the products of decomposition. All possible gradations between these extremes may be observed.

Another result of this thermal stratification of the lake is to produce like temperature conditions in the upper water of lakes in the same region, and so to render uniform the conditions of life near the surface. Very numerous observations have shown that lakes differing very greatly in area and depth and distant perhaps 100 miles from each other, differ no more in the temperature of their upper water than does the same lake at different times of the day. It might be thought that the warmed layer of the smaller lakes, being shallower, would be much more highly heated by the sun than is the thicker stratum of the larger lake. Yet this is not the case. The diurnal changes are somewhat greater in the smaller lake; and at noon of a hot day, with a slight breeze, the temperature of the surface in very small lakelets is higher than in the larger body of water. Yet a lake whose area is a sq. km. or even less has a surface temperature essentially the same, for biological purposes, as one of 50 times that area. There is then a general uniformity of temperature

conditions at the surface. Different lakes in the same region differ far more widely in the thickness of the stratum above the thermocline than they do in its temperature, and for biological purposes, this stratum may be regarded as essentially identical. The temperature of the subthermocline in different lakes differs much more widely, as also does that of the water at the bottom.

During the summer, then, our typical northern lakes really consist of two lakes, one superposed on the other: first, the lake above the thermocline, whose temperature is high and whose water is kept in active movement by the wind; and below this, the stagnant mass of water below the thermocline, having a low temperature, denser and more viscous than the upper water, in which the gaseous and other products of decomposition are accumulating and from which they are only slowly and partially discharged.

Let us now turn from this general consideration of the physical conditions produced in the lake by the summer temperatures, and ask what effect this stratification of the water has upon the plants and animals of the plankton. We must say frankly at the outset that comparatively little is known in detail regarding this subject. As soon as investigation begins, it appears that we have not before us a simple problem which can be promptly solved, but that the question of the relation of the thermocline to life is one factor in the extremely complex subject of the vertical distribution of animal and vegetable plankton. What I have to say, therefore, will be much more in the way of suggestion than of presenting final results.

The following account of the biological influence of the thermocline on the vertical distribution of the plankton is based upon observations made upon lakes in Wisconsin. By far the most numerous and continuous observations were made upon Lake Mendota, which is immediately adjacent to the grounds of the University of Wisconsin. During the summer of 1898 observations were made about once in two weeks upon five smaller lakes in the Oconomowoc district, some 40 miles from Madison, and observations fewer in number, not exceeding two or three in a season, were made on more than 30 other lakes, chiefly in southern and central Wisconsin. The material from Lake Mendota comprises several hundred sets of observations. There are something more than 100 sets of observations from the other lakes. These, while sufficient to give a general idea of the vertical distribution of the animals and plants referred to, are not sufficient,

except in Lake Mendota, to allow accurate conclusions to be drawn regarding the several species. My studies on Lake Mendota make it plain that in order to discuss the succession and distribution of forms in any lake with sufficient accuracy, it is necessary to follow them through at least one season with observations made as often as two or three times a week. This task, however, involves so great an amount of work that it is practically impossible to perform it for more than one or two lakes. The student must choose between obtaining a general view of many facts and an accurate knowledge of a few.

The relation of the thermocline to the vegetable plankton may be briefly stated. In general, the thermocline produces little direct effect upon vegetable life. The algae of the lake are so dependent upon sunlight that the greater part of the active vegetation is contained in the upper water which lies above the thermocline. Undoubtedly, the surface meter contains far more than its proportion of these algae. In lakes of considerable size, where the thermocline is 10 m., or more, below the surface, there would naturally be very little active plant development at its level. In the lakelets of small size, where the thermocline lies only 3 m. to 5 m. from the surface, the thinness of the stratum of warm water may exert an influence on the amount of algae in the lake and so on the amount of animal life which it can support. In lakes which are not peculiarly transparent green plants may grow from the bottom at a depth of 6 m., or more, and in lakes whose transparency is such that Secchi's disk can be seen to a depth of 5 m. to 6 m., there should be light enough to permit the active growth of algae at a depth of at least twice that distance. When, therefore, the temperature of the water at 6 m. or 7 m. is as low as 12° or 15° , there must be exerted an unfavorable influence on the total amount of vegetable life which the lake will support. So far as I know, however, no studies of this influence have been made, and it would probably be very difficult to distinguish this among the other, and mainly unknown, forces which make the difference between a lake rich in plankton and one containing little.

In another way, however, the thermocline has a very interesting relation to the algae. The fact is well known that in any lake the forms of algae appear in succession and each occupies the upper water almost to the exclusion of other species, then gradually passes

away and its place is taken by another form. As any species of alga declines in number and dies out, it sinks gradually and it is found that under these circumstances the dying algae frequently accumulate in great numbers at the thermocline, so that at certain periods, lasting for as much as two days, the stratum included in the thermocline may contain a larger share of the alga-life of the lake than any other stratum of equal thickness. So far as my experience goes, this pausing of the sinking plants at the thermocline is more marked with the diatoms, such as *Fragilaria*, *Melosira*, and *Diatoma*, than with the blue-green algae. Botanists now tell us that the structures which keep these diatoms in suspension in the water are not certainly known. However this may be, it is clear that they are maintained in suspension by vital and not by mechanical means. They have none of the long spines which constitute the *Schwebverrichtungen* of such genera as *Rhizosolenia* or *Atheya*. Those who have collected *Fragilaria* know that it very promptly settles to the bottom of a vessel when taken out from the lake, although it will remain for days, or even for weeks, suspended in the open water.

A moment's thought will show that the halting of these sinking algae at the thermocline is not a physical phenomenon, due to the decline of temperature and the increasing density of the water. If this were the case, the halting would only last long enough for the diatoms to acquire the temperature of the water, and, while their downward progress would be delayed, the halting would not extend beyond a very few minutes, although the sinking in the cooler water might be slower. Probably the cool water checks the progress of senescence and prolongs for a time the decaying life of the alga.

These diatoms are among the favorite food of the crustacea and indeed are preferred by most of the crustacea to the blue-green algae. At such times, therefore, as the successive crops of diatoms are found in the region of the thermocline, they are frequently accompanied by large numbers of crustacea, which then find more abundant, or more appetizing, food in that region than nearer the surface of the lake.

Under the conditions of plant life which have been thus described the number of algae found in the water of the subthermocline is ordinarily very small. This fact is not due to the distance from the surface and the consequent diminution of light, for the water close to the thermocline in Lake Mendota always has an abundant popu-

lation of algae, which follows the thermocline downward as it descends and which in the autumn occupies the whole of the water, to the depth of 25 m., after it has become homothermous. In summer the algae, as they sink, seem to delay at the thermocline until they are dead, or so nearly dead that they fall rapidly to the bottom after passing that level. The crustacea which follow them to the thermocline do not go further with them; thus showing that other causes than lack of food prevent the occupation of the subthermocline by animals. Occasionally, therefore, large quantities of algae may be obtained from the lower water, with almost no crustacea or rotifers. Such periods are short and infrequent and usually the net brings up very little of either animal or vegetable life from this region.

In lakes whose lower water is habitable, the great masses of algae common in Lake Mendota are not often found. Yet the algae of such lakes also halt at the thermocline as they sink, and thus give occasion to accumulations of food at this point, and are probably one of the causes of the swarms of crustacea not infrequently found in that region.

In still another way, the thermocline may have an important indirect effect on vegetable life. Whipple¹ has pointed out that the products of decomposition, all of which accumulate in the subthermocline, constitute a sort of nutritive medium for the growth of algae, which can not be utilized because of the absence of sufficient light and warmth. As the thermocline moves downward, this nutritive material is distributed to the upper water, where it becomes available for plant food. He says also that when the thermocline disappears in the autumn and the water of the lake is "overturned" a large and sudden addition of plant food may be made, which will cause a great development of algae. He correlates with this overturning the appearance of large crops of algae in the autumn. This relation undoubtedly exists in the bodies of water which he observed, but in none of the lakes which I have studied is the accumulation of the products of decomposition anything like as great as that described by Whipple, and the addition of nutritive substances to the upper water by the overturning of the lake has not been great enough to produce any observable effects.

In addition to these relations of the thermocline to vegetation, the

¹ H. A. Whipple. *The Temperature of Lakes*. Trans. Am. Soc. Civil Engineers, 1895.

change of temperature at this level must also produce other effects. The increase in density of the water as its temperature declines must have an influence on the sinking of those algae whose specific gravity is only slightly greater than that of the warmer water in which they live. This is especially true of the blue-green algae, whose density during life hardly, if at all, exceeds that of the water. As these die and gradually sink, they must tend to linger at the thermocline, in consequence of the increased density of the water. The same effect must be produced by the increased viscosity of the water due to decreased temperature. Neither of these changes, however, appears to have any considerable influence on the rate of sinking of the ordinary plankton diatoms, whose specific gravity is considerably greater than that of water. Experiments show that they will pass in a very brief space of time an artificial thermocline considerably sharper than that in any lake. A greater effect may be produced on plants too small to be seen by the unassisted eye and these changes in density and viscosity may determine their position.

The relation of the thermocline to the vertical distribution of animal life is a far more complex matter than its relation to the algae. The change of temperature at this point may affect animals directly or indirectly. In the first case, the decline of temperature itself limits the downward movement of the plankton animals, or the rapid increase in warmth forms a barrier to their migration into the upper strata of the lake. Indirectly the change of temperature modifies the action of other forces, such as light, which are effective in determining the relation of the plankton animals to the surface. The stagnation of the lower water, which results from the thermocline, with the attending chemical changes, may also indirectly limit distribution. The increase in density and viscosity of the water, which accompanies the decline in temperature, will also exert an influence on the rate at which the plankton animals sink, and it may be found that these alterations are sufficient to permit animals to float at this level, which would sink in the warmer water above. This possibility holds especially for nauplii and other young forms. The adult crustacea and the rotifers which are large enough to be seen by the naked eye sink quite rapidly, both in the water above the thermocline and in the cooler water below.

It is not easy to trace any direct influence on vertical distribution of the change of temperature at the thermocline. Other factors than

temperature are so much more important that the influence exerted by this one can hardly be detected and in few cases does it appear probable that temperature determines the position of animals. The best example of an animal whose position seems to be determined by the temperature of the water is furnished by the well known member of the Cladocera, *Diaphanosoma*, or *Daphnella*. This genus exists in two closely allied species; one inhabiting weedy water and marshes where the water is, of course, very warm; the other is limnetic in its habits. The latter species is more narrowly limited by temperature in its seasonal distribution than any other important member of the plankton crustacea. It appears later in the season and disappears earlier than any other form and while it is present, it is always confined to the region above the thermocline. Occasionally a few specimens may be captured from below the thermocline, but a large majority of such straggling individuals are diseased or have been unable to complete the shedding of the skin, or are in some way obviously disabled. Within the warm water above the thermocline the distribution of these animals is determined by various factors, which need not be discussed. The species differs so widely from other genera of plankton crustacea in never seeking the cooler water below the thermocline that it is not unfair to conclude that temperature is the most important factor in confining it to the superthermocline. It must be granted that light may also have its influence, but, as *Diaphanosoma* reacts negatively to a very bright light, and as the species occupies the whole of the warm water, whether 4 m. or 12 m. in thickness, the lower limit of its distribution seems to be set primarily by temperature.

There are two other forms of crustacea which it is possible may also be confined to the superthermocline for the same reason. There are *Ceriodaphnia lacustris* and the copepod *Epischura*. The former crustacean has been found only in the superthermocline but has appeared in small numbers and in few lakes, so that I hesitate to make any general proposition regarding it. *Epischura* was found only in the superthermocline of Green Lake by Marsh. I have never found it in sufficient numbers in other lakes to warrant any definite statement regarding its distribution. In Lake Mendota, where it has sometimes appeared in considerable numbers, it has ordinarily been found in the deeper water during the day, but this has been in the fall when the thermocline had moved far down. In Winona Lake it

has been found to live in the thermocline by day and to move upward at night.

There is no rotifer which has been shown to be excluded from the thermocline by temperature. I am somewhat disposed to think that *Conochilus* may be such a form, but as I have found it in large numbers in Lake Mendota only, I can make no positive assertion, for reasons which follow.

The stagnation of the water below the thermocline, with the accompanying changes in its gaseous contents and dissolved matters, may become a very important factor in excluding the plankton animals from this region. Lake Mendota is an example of a lake whose subthermocline is almost uninhabitable. In that lake the entire mass of the water of the lake is freely occupied by crustacea and rotifers during April and May, and also late in the autumn. As the thermocline begins to be formed and the lower water becomes stagnant, the animals are gradually driven out of it, and after the early part of July the subthermocline is practically devoid of plankton animals. The few crustacea and rotifers which are found there are evidently diseased or feeble and are gradually sinking to the bottom. The suddenness with which the animal life disappears at the thermocline is very remarkable. I give a diagram (Plate II, fig. 1) showing the condition of the vertical distribution on September 8, 1896. At that date the thermocline began at 13 m.; at 12 m. nauplii were found at the rate of more than 220,000 per cubic meter; at 12.5 m. the number had fallen to 108,000; at 13 m., to 22,000; and at 13.5 m. and below, none were found. The adult crustacea ended with almost equal suddenness, though the absolute numbers were not nearly so great—something more than 10,000 per cu. m. being found at a depth of 12.5 m.; 2,000 at 13 m.; 400 at 13.5 m.; below which only an occasional straggler was found. Thus within the limits of a meter to a meter and a half at the thermocline the plankton population suddenly ceased.

It should be understood that this sharp limitation of the vertical distribution of the plankton animals is not due to the change of temperature at the thermocline. This fact is shown plainly by the relations in other lakes in which the vegetable plankton is less abundant, or the bottom water greater in quantity and colder, and in which the animals are freely distributed to all depths. It is the rule in the smaller lakes of Wisconsin that the animals occupy the whole

mass of the water and only in three or four of the lakes has a relation been found similar to that in Lake Mendota. All of these lakes have abundant plankton and a comparatively small amount of water beneath the thermocline. They are of all sizes, however, the smallest being only 8 hectares (20 acres) in extent, and the largest 39 sq. km. (15 sq. mi.).

The subthermocline in these lakes is not entirely devoid of animal life. In Lake Mendota the mud is inhabited by *Cyclas*, and also by a few worms. These animals have not been found in the other lakes, where the conditions of bottom life are perhaps not as favorable as in Lake Mendota. The water of the subthermocline is inhabited by insect larvae, chiefly the larva of *Corethra*. This active and rapacious larva is well known to all students of fresh-water plankton as one of the largest, most transparent, and most beautiful of the creatures which the lakes contain. It is one of the animals which has a well-marked diurnal migration, moving down into the subthermocline during the day and passing the night in the warmer water above the thermocline. It will be remembered that the animal breathes by tracheae and that it contains two air sacs, so that even though the supply of oxygen in the subthermocline is deficient, it has no difficulty in remaining there for a considerable length of time. So far as my observation goes, it is most numerous in those lakes with abundant plankton and whose subthermocline is not inhabited by the crustacea and rotifers. In such lakes it not infrequently happens that the absolute number of *Corethra* larvae caught from the subthermocline exceeds that of the crustacea and rotifers together. Under these circumstances, it is evident that the larvae must do most of their feeding at night, since during the day there is hardly anything in the water surrounding them on which they can feed. It is probable that the action of light determines the position of these larvae, yet, although it is easy to understand the possibility of their passing the day in the water of the subthermocline, it is difficult to see why their habits should not have become adjusted to a continuous existence in the warmer water which they do not find uncomfortable at night, and in which their food is so much more plentiful than in the deeper water.

In lakes of the type of Lake Mendota only the upper water is occupied by plankton animals during the summer. In other words, of the two lakes into which the body of water is divided, only one is habit-

able. This fact exerts a considerable influence on the total quantity of animal life supported by the lake during the summer, as the number of animals is limited by the shallowness of the stratum to which they are confined. In each of the years during which the crustacea of Lake Mendota were studied, a midsummer minimum was found in the number of these animals. This was probably caused, in part, by the high temperature of the water, and, in part, by the exclusion of crustacea from the thermocline. Still further, the autumnal increase in the number of crustacea in this lake comes almost wholly from the progressive occupation of the lower water. As the thermocline moves downward, the population of the upper strata increases only very slightly, or, if any considerable temporary increase is found, it is due to the appearance of swarms of young, which live near the surface at their first appearance. The lower water, however, contains in the fall an abundance of algae in a healthy condition and supports a large population of plankton animals until the decrease of temperature in November causes a decline to their winter numbers.

We now turn from these lakes whose subthermocline is not habitable by the plankton animals, to those in which the lower water is abundantly supplied with oxygen and is, therefore, capable of supporting animal life. The first question which arises is the reverse of that which we have answered for the superthermocline; namely: are there animals which are confined to the subthermocline during summer because they are unable to endure the high temperature of the upper water? This is very probably the case with some of the crustacea found only in very deep lakes. In Green Lake, Wisconsin, which is more than 70 m. deep, there is an abyssal fauna, closely corresponding with the deep water fauna of Lake Michigan. It contains *Mysis* and *Pontoporeia*, the latter one of the amphipods. Whatever may be the cause which first drove these crustacea into the deeper water, it is certain that they always remain here, and, so far as is known, do not appear in the warmed surface water, either by day or by night. Besides these representatives of the higher crustacea, there is also found in the depth of the lake the copepod *Limnocalanus*, which, Marsh reports, is confined to the deep water during summer. The animal, however, has appeared in surface collections made by night in Lake Geneva, so that it is not absolutely confined to the subthermocline.

One member of the Cladocera has appeared only in collections from the bottom water of the lakes. This is *Daphnia longiremis*—a form belonging to the hyaline section of this genus and distinguished, as the name implies, by extremely long antennae. This species has been found in a few lakes only, whose waters are deep in proportion to their area and consequently are cold. In these lakes it was always found close to the bottom. It has never appeared in numbers throughout the subthermocline but has been aggregated within a few meters of the bottom and in largest numbers just above the mud. Its position here is very possibly determined by the presence of food and there is no reason to suppose that temperature alone determines its position. This species has never appeared at the surface in collections made by night, yet the observations on this subject have not been sufficiently numerous to warrant me in asserting positively that it never comes to the surface. We are, however, warranted in stating that, so far as is known, this is the only member of the common genera of plankton crustacea which, by preference, occupies a position at the bottom of the deeper lakes in the coldest water to be found—water whose temperature ranges from 6° to 8° C.

The most interesting of the animals found, by preference, in the subthermocline, is *Daphnia pulicaria*. This is a large, stout *Daphnia*, belonging to the *pulex* group. It is found in many lakes and during the summer is regularly an inhabitant of the subthermocline. It might be supposed that temperature immediately determined the position of this creature, yet such is not the case. The animal responds negatively to light, and this fact appears to determine its position in the lake, the lower temperature of the water of the thermocline being effective in lessening or reversing the negative action of the light. It is well known that many of the plankton animals respond negatively to light, moving downward in the water to varying distances according to their sensitiveness to this influence. This negative action of light is greatly increased as the water becomes higher in temperature and when the temperature of the water is lowered the animals may become indifferent to light, or may move toward a light which would repel them were the temperature higher. Such seems to be the case with *Daphnia pulicaria*. It is found at the surface in the spring and until the water reaches its summer temperature. It also has a period of active reproduction late in the autumn, when the water has cooled, and then occupies the water at

the surface, as well as at all depths. In winter it may often be seen in great numbers immediately below the transparent ice. In summer, however, it moves downward below the thermocline and is found there alone, though occasionally a few straggling individuals may be captured in the warm water.

That the position of *Daphnia pulicaria* is determined by light rather than by temperature appears from the fact that in certain lakes it comes to the surface at night, moving upward into water often as much as 15° C. warmer than that which it occupies by day. This upward movement is probably in search of food and the absence of light is a condition and not a cause of the migration. The species has been found to appear at the surface about two hours after sunset and it disappears before sunrise, while the sky is still dark. If temperature alone determined its position in the subthermocline, it would not move upward into the warmer water at all.

While this species may be found throughout the subthermocline of the lakes which it inhabits, the largest numbers are wont to stay in the immediate neighborhood of the thermocline. This is probably due to the fact that this stratum contains a larger amount of food, for reasons which have already been stated, than does any other equally thick stratum of the lake below the surface. Possibly the action of the light becomes positive in the cooler water. Yet the animals are so generally distributed in the subthermocline as to render this hypothesis improbable. In Lake Mendota, whose subthermocline is not habitable by the plankton crustacea, *Daphnia pulicaria* is present and in summer is forced to occupy a very narrow space just at the thermocline. Almost all of the members of the species are ordinarily found in a stratum of water not much more than a meter thick, at the junction of the thermocline with the warmer water above; the temperature preventing it from rising into the warmer water, and the nature of the subthermocline making it impossible for the animal to descend into it. In this lake no vertical migration of the species at night has been detected.

When now we turn to the other species of crustacea and rotifers comprising the great mass of the plankton animals, we have to do with forms which are not confined to any one thermal region of the lake, and we can speak only of a preference for this or that region. We find also in different lakes and on different occasions in the same lake a varying distribution of the same species. It is evident that

other factors than temperature are the principal forces which determine the vertical distribution. The most important of these factors are light and food, yet these affect different species in very different degrees and the thermocline has a marked influence on the distribution of most forms.

The two genera of Copepoda which contribute most to the plankton are *Cyclops* and *Diaptomus*. The former genus is more uniformly distributed through the water than any other of the plankton animals. It is comparatively indifferent to light, and temperature has no noticeable influence upon it. *Diaptomus* responds much more definitely to light and a larger proportion of individuals is usually found in the upper strata of water. In neither genus is any sharp break in distribution regularly made by the thermocline. At times there are found large aggregations of both of these genera at the thermocline. In some lakes *Diaptomus* seems to be driven by sunlight into the thermocline by day, rising into the warm water at night. The same statements may be made for the nauplii as for the adults of both these genera of Copepoda. In the illustration which I give of the distribution in September, the majority of the nauplii were aggregated just above the thermocline. I have never found these aggregations, which may be very great, elsewhere than at the surface and thermocline. In the case of the adult Copepoda, the swarms, as they become old, are wont to move downward in the lake and occasionally large numbers of adults are found close to the bottom. This is evidently the result of old age. The aggregations at the surface and thermocline are probably, although not certainly, due mainly to the food which is present at these places, either in large quantities or in forms which are especially desired. The surface meter and the thermocline are the two regions of the lake in which great crowds of plankton animals may be found, and it rarely happens that some species or other is not present in unusual numbers at the thermocline.

The member of the group of Cladocera which is universally present in the plankton is *Daphnia hyalina*. The distribution of this species corresponds very closely with that of *Diaptomus*. Like that genus, it is ordinarily most numerous in the upper water, but it is also true that large aggregations of the species may be found at the thermocline—a fact which again is probably attributable to food.

A large number of species of rotifers are, in like manner, dis-

tributed through the waters of the lakes; aggregated occasionally in great numbers at the thermocline, at the surface, or at the bottom, or again, more uniformly distributed through the entire depth of the water. Many more observations would be needed on these animals, as well as on the crustacea, in order to work out in detail the laws of their distribution. Yet so far as my observations extend, certain preferences in position are indicated. Among the common rotifers which are ordinarily, though not exclusively, found in the warm surface water of the lakes in summer are *Asplancha*, *Polyarthra*, *Conochilus*, *Mastigocerca*, and *Anuraea cochlearis*. Those found by preference in the cooler bottom water are *Anuraea aculeata* and *Notholca longispina*. In all of these rotifers the distribution was, in general, as indicated, yet not without exception. In several cases swarms were found at the bottom, even of the deepest lakes. Yet in these cases the animals were all adult and it appears probable that these constituted the last part of a generation-cycle. In all cases, too, there were found some exceptions to the general rule of distribution; the rotifers which ordinarily belong below the thermocline being above it in certain lakes, and *vice versa*. These exceptions, however, were few in number. In no case does it appear probable that the change in the temperature of the water constitutes in itself an important barrier to the movements of these animals. Yet we are also warranted in saying that the preference of one set of species is for the warmer water and of the other is for the cold. This is especially noticeable in the case of the closely allied species *Anuraea cochlearis* and *A. aculeata*. These are found in the same lakes and frequently in considerable numbers, although the former species is ordinarily by far the more abundant. In no case where the two species were found together was the arrangement other than that which was indicated; *A. cochlearis* occupying the upper water, although extending into the subthermocline; and the majority of the individuals of *A. aculeata* coming from below the thermocline.

From this account we may fairly infer that the thermocline constitutes a critical point in the distribution of the plankton in the water below the surface. No single factor within the water itself compares with it in importance. The direct influence of the change of temperature is not very great and in this respect the difference of temperature in the lake corresponds to temperature differences in general. Most plants and animals of temperate regions are not par-

ticularly sensitive to a change of a few degrees of temperature. For some species, however, the change from warm to cool water constitutes the factor which determines their vertical distribution. Indirectly, the effect of the thermocline is far greater. The stagnation of the lower water, with its attendant chemical results, causes a sharp limitation on the distribution of the animal life in many lakes. The thermocline in these lakes marks the limit of the thriving of algae and thus directly limits the distribution of plants and indirectly that of the animals which feed upon them. In all lakes the thermocline has an evident influence upon distribution, and, although it is by no means an impassable barrier, most species of plankton animals live, by preference, either above or below it. The fact that the thermocline is the one stratum below the surface where large numbers of the plankton animals are often aggregated is sufficient to indicate its importance.

The thermocline is, however, only one factor in the complex of forces which determine the position of plants and animals in the water of our lakes. Some of these, as light and food, density and viscosity, have been named, but these, with temperature, are not the only factors. Others, like gravitation, have an effect difficult to trace, but none the less real. Competing species and plants of the plankton which are not edible have an influence which the observer can feel but whose value he finds it even more difficult to estimate. Each of these forces is independent of the others, both in the direction and the intensity of its action. They differ in their effect on the individuals of different species and their influence on the same animal may change as it passes from youth to maturity and old age. Still more, these forces are affecting animals of highly complex organization, whose reactions are not always marked by the directness and uniformity of a unicellular animal.

Thus the problem of the vertical distribution of plankton animals becomes very complicated and requires for its full solution far more numerous and careful studies than those on which this address is based. It was an investigator and a lake of Indiana that suggested the phrase: "The lake as a unit of environment." The years which have passed since that phrase was uttered have shown, on the one hand, its essential truth, and, on the other, have partially revealed to the student of lake biology the great inner complexity of this unit, and the amount of research which its problems demand. This ques-

tion of vertical distribution on which I have touched is among the simpler problems of the lake. Yet we have no accurate knowledge of the effects of any one of the factors which determine it, nor do we know how these factors influence any one species of the plankton. Here is a wide field open to the investigator. I say "open" because any student may work in it. Complicated apparatus and difficult processes are not demanded; at any rate, for the present. Patient and intelligent observation by day and night with pump, plankton net, and microscope, will be rewarded by large additions to knowledge. By these means we may hope to make a beginning in unraveling the tangled story of the interrelations of the inhabitants of this "unit of environment." We may hope thus to trace, in part, their relations to the lake in which they live and to the forces of the larger world which act on them with an apparent simplicity, all the more provoking as it masks a real complexity so great that the increase in our knowledge of the facts seems thus far to bring little more than increase in ignorance of principles. Each lake and lakelet, almost each species in each lake, seems thus far to be a peculiar case and to have its own singularities so marked that it is difficult, or impossible, to unite them in any general statement. Only a large body of most careful observations can furnish material which will show in what sense each lake is "a unit of environment," and how each furnishes but a special case in the larger statement of the laws of lake biology.

PLATE I

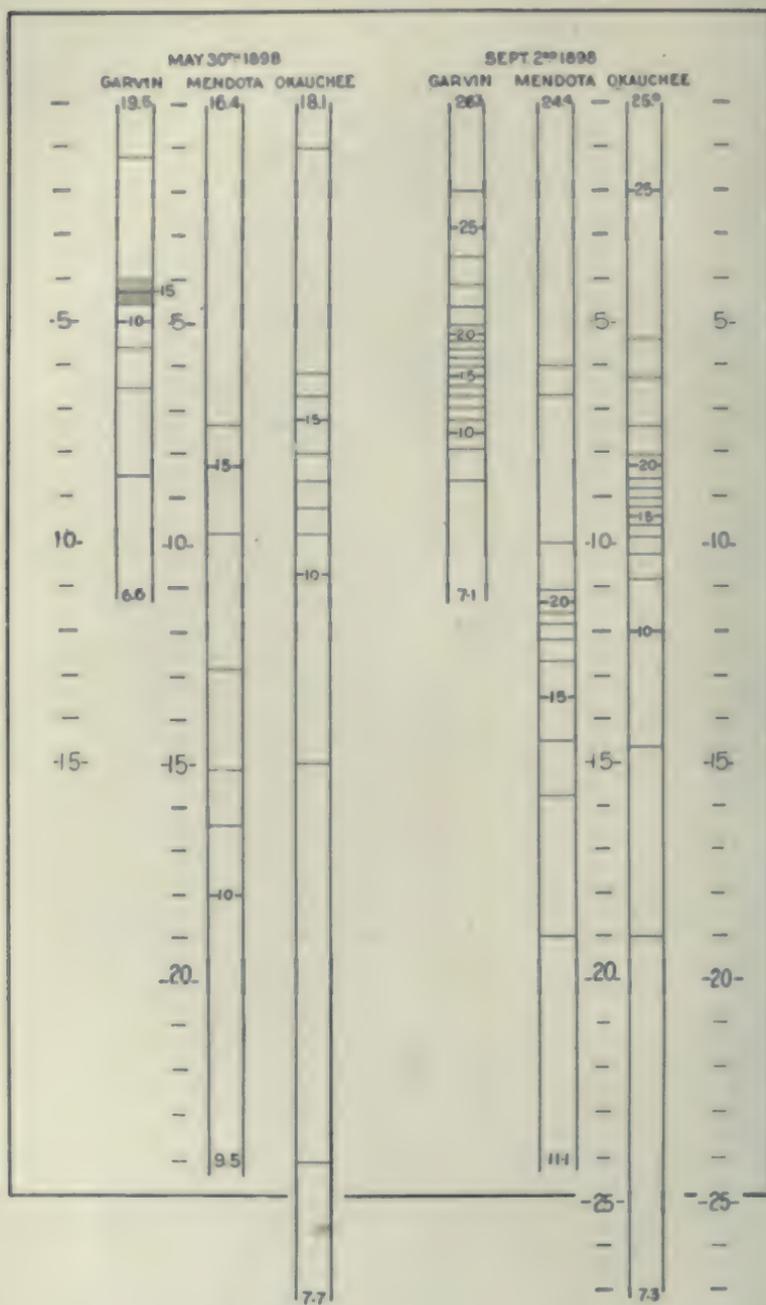
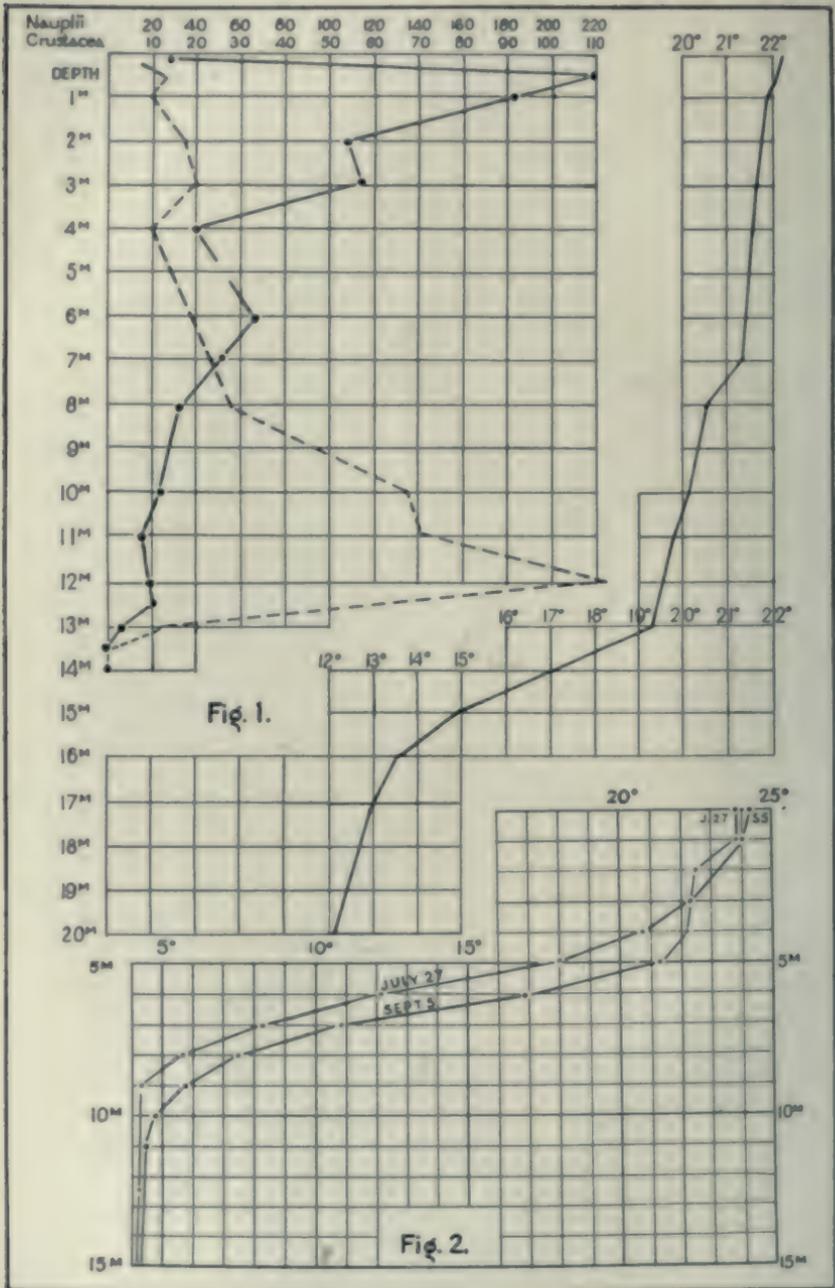




PLATE II



EXPLANATION OF PLATES

Plate I

Temperature diagrams of Lakes Garvin, Okauchee, and Mendota on May 30 and September 2, 1898. The depth is indicated by a scale placed beside the columns on which is platted the distribution of temperature. For further explanation see text.

Plate II

Fig. 1. Curves showing the vertical distribution of adult crustacea of all kinds, of copepod nauplii, and of temperature, in Lake Mendota September 8, 1896. Each space on the vertical scale indicates one meter in depth. On the horizontal scale each space represents 10,000 crustacea per cubic meter of water, or 20,000 nauplii per cubic meter, or 1° of temperature. The distribution of the crustacea was determined by the pump at the depths indicated by dots on the line representing the number of crustacea present. The numbers indicate the rate of the population of crustacea or nauplii at the depths indicated and not the number found between the successive levels of one meter. The temperature curve shows a slight surface warming, a secondary thermocline between 7 m. and 8 m. due to warm weather several days earlier, and the permanent thermocline beginning at the depth of 13 m.

Fig. 2. Temperature curves of Beasley Lake, Wisconsin, on July 27 and September 5, 1898. These curves show the amount of sinking of the thermocline during the 40 days between the dates named. They show also the very slight change in temperature below the depth of 11 m.

THE FINER STRUCTURE OF THE HEART MUSCLE OF THE DOG

By GERTRUDE A. GILLMORE

WITH THREE PLATES

During the winter of 1900-1901, the writer began the investigation of the finer structure of the heart muscle with a view to the elucidation of the relation and meaning of the discs. At that time, with the exception of the papers by MacCallum, little or no detailed work on the finer structure appeared to have been done. One found substantially the same brief descriptions and drawings repeated again and again. From these descriptions little information could be gained beyond that of the shape and anastomosing of the cells, the position of the nuclei, presence of the cell cement, the existence of striations, and the supposed absence of sarcolemma. Even the continuity of Krause's membrane was not generally understood. There seemed, therefore, a need of more detailed work on the finer structure of heart muscle.

The facts here given were substantially worked out during the winter of 1901 while in the department of Histology and Embryology of Cornell University, but were not published.¹ Now, that Heidenhain has published such important results, it is hoped confirmation and comparison of some points will not be unwelcome. After a year's unavoidable delay, the writer, through the kindness of Dr. Whitman, has been able to continue her work at the Marine Biological Laboratory, Wood's Holl, Massachusetts.

The heart assigned for study was that of a dog, with comparative work on the hearts of the cat, sheep, rabbit, frog, necturus, and amphiuma. In this report only the first part of the problem will be treated, *i. e.*, the fine structure of heart muscle as illustrated in the heart of a dog.

The material used was obtained from a young dog instantly killed by an accident. Pieces of the heart wall were put into various

¹ An informal report of the results embodied in this paper was given before the Histological Seminary, Cornell University, May 7, 1901.

fluids: Zenker, Flemming, micro-aceto-sublimate, picric alcohol, 67% alcohol, Perenyi, and others. Of the fixatives used, Flemming and micro-aceto-sublimate have proved the most satisfactory. The material was carefully dehydrated, imbedded in paraffin, and cut into sections of from 3 to 5 microns in thickness. Some of the material was stained with Heidenhain's haematoxylin, and some with Wotter's haematoxylin, first mordanted in vanadium chloride. The latter stain was the more satisfactory. The sections were mordanted for three hours in a solution consisting of two parts of a 10% solution of vanadium chloride and ten parts of a 5% solution of acetate of aluminum. They were then stained for three-quarters of an hour, instead of the longer period recommended in Lee. The material was differentiated in absolute alcohols acidulated with $\frac{1}{2}\%$, $\frac{1}{3}\%$, $\frac{1}{4}\%$, and $\frac{1}{5}\%$ of hydrochloric acid. While the sections were transferred successively through the four differentiators, they were carefully watched every two minutes. They were then cleared in bergamot oil and mounted in balsam. The new methods recommended in Heidenhain's last paper ('01) have not been used, since much of my material was prepared several months prior to that publication. Any later use is now precluded by his request that no one publish any results obtained on muscle by his new methods until his complete work appears. The effect of iron haematoxylin on muscles is well known. With vanadium chloride and haematoxylin the transverse disc, Krause's membrane, and a dark line crossing the cell cement are stained a bright blue. The sarcolemma is faintly tinted a light blue. Since this stain is much more brilliant than iron haematoxylin and tinges more structures, it has proved the more satisfactory one to use.

In the writer's well-fixed preparations of heart muscle few wide breaks occur in the tissue and these breaks are filled with connective tissues, or capillaries. One does not find the commonly figured wide spaces between the fibers, but a mass of fibrils from the formerly so-called cells, whose existence is now doubted by Ebner, Heidenhain, and others, appear to blend together and form other fibers. (See figs. 1 and 3.) Heidenhain has found the same condition in the human heart ('99). He thinks that one does not find cells anastomosing by lateral branches, but that the "general type of lateral connection is by broad regions of fusion between parallel fibers." From a glance at the right of figs. 1 and 3, one sees that by the confluence

of two masses of fibrils from two adjacent cells a third so-called cell is formed which lies in a line intermediate between the other two cells. Repeatedly these masses of fibrils appear to blend in a plane above or below that on which one's sections were cut. (See fig. 3.) Frequently small breaks occur parallel with the fiber but extending only for a short distance, *i. e.*, between two cement bands. (See figs. 2 and 3.) Evidently these separations between fibrils can hardly indicate cell boundaries, for frequently they are only a few fibrils apart. Often any wide lateral break between cells is two or three fibers apart. But in these spaces several small, more or less parallel breaks may occur. In consequence of these conditions, it seems to the writer difficult, or even impossible, to give distinct lateral boundaries for cells. However from a careful comparison of long and cross sections of the fibers, one usually finds near its center nuclei at more or less regular intervals. Occasionally one finds two nuclei close together. In every case there is some cytoplasm surrounding the ellipsoidal nucleus and extending out from it, often in a more or less cone-shaped mass. (See fig. 2.) The areas enclosed between two cement bands are variable; occasionally they are shorter than the length of a nucleus, usually several times its length. (See the extreme upper and lower portions of fig. 3.) In the dog's heart, the writer has never found the bands less than three or four segments apart. Heidenhain, however ('01), states that in the human heart one sometimes finds one segment ($Z-Z$)¹ enclosed between two bands. This fact, together with the already observed continuity of the fibrils through the cement—Ebner ('00), Hoyer ('01), Heidenhain ('01), and figure by Szymonowicz ('01)—he thinks argues against the cement bands being considered as distinct cell boundaries. Godlewski ('01) has also come to the conclusion that the cells of the myocardium develop as a syncytium. The writer has also found in the dog's heart indications of this same continuity of the fibrillae. This point will be discussed more fully later when the cement bands are described in detail. The more one studies heart muscle the less does the idea of separate cells seem tenable.

Wherever large or small breaks occur in the muscular tissues of the heart of the dog, cat, sheep, or amphiuma, one finds along the

¹ Throughout this paper the writer will use Heidenhain's nomenclature: Z = Krause's membrane; q = transverse disc; $q\dot{h}$ = the light area which separates the transverse disc into two parts; J = lateral disc; and M = the middle disc.

edge of the fiber a distinct sarcolemma. The presence of this structure in heart muscle was reported by Hoyer ('01), recently by Heidenhain and others. MacCallum ('97) has described in the human heart a condensation of the sarcoplasm, but does not seem to consider it the same as the sarcolemma of skeletal muscle. He thinks each fibril is surrounded by such a condensation. Sometimes between two adjacent fibrils it is double. It then appears raised in folds. At other times between two fibrils there is a single layer with no wavy outline. Heidenhain, on the other hand, having so recently thoroughly studied the human heart, describes the same structure as a sarcolemma. Where this structure appears in successive parallel breaks, which are only a few fibrils apart, he thinks indicates the presence of partially developed fibers. In the hearts studied by the writer, the sarcolemma appeared as a narrow, usually wavy band of homogeneous, hyaline sarcoplasm. (See figs. 2 and 3.) In this band Krause's membrane terminates. When the sarcolemma is raised in waves *Z* ends in the depressions between the waves. One wave extends from *Z* to *Z*. This arrangement seems to be usually the case, except possibly where the cement intervenes. The height of successive waves, where the discs are in like phases, appears to be the same. In thin sections of the hearts of the dog, sheep, and cat the relation of *Z* to the sarcolemma is very apparent. Where the fibrils border the cytoplasm surrounding the nucleus, one finds again the sarcoplasm raised in arches, at the base of each of which *Z* ends. It is interesting to note that in insects where so much muscular effort is put forth, one finds a sarcolemma like that in the heart muscles of vertebrates. The relation of this structure to the cement bands will be described later.

The cement bands extend occasionally across a fiber, but usually one finds the staircase appearance fully described by Heidenhain ('01). (See figs. 1 and 2.) The steps seem to lie edge to edge and seldom to overlap. They may go up and then down, or each step may be one or several segments higher than the one below. Occasionally there appears to be in the dog's heart some slight variability in the breadth of the bands. Usually they are slightly narrower than the area from *Z* to *Z*, but occasionally as broad. In the same section there is little or no variation in the bands. The number of fibrils which are crossed by one of the steps may vary from those which constitute half or three-quarters of a fiber to a single fibril.

The discs crossing the segments just above or just below a step become continuous with those crossing other fibrils which are crossed by other steps. When the cement bands in the dog's heart are examined more carefully, they appear to be composed of rod-like bodies, each of which lies in the same straight line as a fibril. To the writer each rod seems to be a continuation of a fibril. These rods, as shown in figs. 5*c* and 5*d* (Pl. V), do not extend straight across the band, but often either separate or come close together towards the middle of the cement area. Extending across the center of the cement band is a dark blue line. (See fig. 4.) This line stains as does *Z*. Where small breaks occur between fibrils and cement bands, one often sees such a condition as shown in fig. 5*b*, where Krause's membranes appear to become continuous with this blue line. Where a wide break occurs and the single blue line can be seen, the sarcolemma appears to arch down in the middle of the cement band and the blue line to end in the depression. Again one sometimes finds the cement band crossed by two blue lines which are quite close together. One then finds that both lines appear to terminate in the sarcolemma (see fig. 5*a*), or as already shown in fig. 5*b*, each blue line appears to become continuous with an intermediate disc (*Z*) lying just beyond the cement band and the one nearest on a level with the blue band. From a more careful examination of the band, it would look as if the blue might be produced by the staining of the delicate threads which seem to weave in and out between the rods of which the cement seems to be composed. After comparing the writer's sketches of cement areas with those of Szymonowicz ('01) and MacCallum, it was evident that they resemble more closely the latter author's illustrations of the cement bands in the human heart. He states, however, that he was only able to find in the human heart a single line crossing the cement (MacCallum, '97). At first the writer thought that probably the two blue lines were Krause's membranes, which are supposed to border each side of the cement bands. This explanation seemed probable, since the lines ended in the sarcolemma and stained as did *Z*. But of this point the writer is uncertain. If these lines are Krause's membranes, why does one so frequently find the cell cement crossed in the center by a single blue line? Is this effect caused by a slight obliquity in the cutting of the sections? If this is the case, the obliquity was not apparent. Since these lines both stain and

bear the same relation to the sarcolemma as does *Z*, they would seem to be of the same nature. But are they really the same structure? The writer is confident that in the dog's heart one may find the cement band crossed sometimes by one, and sometimes by two blue lines. What they are it seems impossible to say, especially since the nature of the cement band is not fully understood. MacCallum and Przewoski ('93) consider the bands intercellular bridges. Ebner thinks they are contraction areas; and Heidenhain ('01), in his last article, has attempted to disprove both hypotheses and has claimed that they are growth areas; that these segments are being formed as the heart increases in size. Whatever hypothesis one may hold, it is interesting to note that all the discs between the two cement bands appear to the writer to be in like phases. When the discs appear to change their forms, a cement band intervenes.

From a glance at figs. 4*a* to 4*c*, one sees that all the discs, except perhaps *M*, found in skeletal muscle, occur in the heart muscle of the dog: Krause's membrane (*Z*), the lateral disc (*J*), the transverse disc (*q*), the light area which separates *q* into two parts (*qh*), and possibly the middle disc (*M*), is present. *Z* takes a deep blue stain with haematoxylin, does not seem to vary in thickness, and extends as a continuous membrane not only from fibril to fibril across one fiber, but also appears to cross continuously two or even three and possibly more fibers. It is interesting to examine places where fibrils have been pulling a short distance apart, for there one sees Krause's membrane stretching across the intervening space. The relation of *Z* to the sarcolemma has been dwelt upon. On each side of *Z* is the lateral disc (*J*). It is isotropic, more fragile, and less deeply stained than *q*. It appears a little darker than the ground substance, but lighter than *qh*. It does not stain with haematoxylin. The width of *J* varies greatly, as will be seen from figs. 4*a* and 4*b*, but it never entirely disappears. The transverse disc is anisotropic and stains deeply with haematoxylin. It varies greatly in width and outline. In fig. 4*a* it extends almost the entire length of the segment. The outline in long section is then distinctly that of an oblong. As *J* decreases in size, the edges of *q* round off and one gets the bead-like forms shown in fig. 4*b*. In figs. 4*c* and 4*d*, one sees *q* crossed by the light area, thus forming *qh*. Whether one can consider that in fig. 4*c* the narrow area is *M*, seems difficult to determine if one is unable to stain it. Heidenhain, by his later methods, is able to

color this disc and shows that M is present in the human heart muscles. He considers it the complete analogue of Z , but more delicate in nature. As q grows narrower, J increases in width. Heidenhain ('99) thinks that J and q stand in the closest connection with the function of contraction. The bead-like appearance of q he considers due to the contraction of the contour lines. Since the transverse discs crossing one fiber lie in the same straight line as those crossing parallel neighboring fibers, one may often trace row after row of these discs extending straight across the field of the microscope. All parallel fibers do not always show like discs in like phases, as is evident from fig. 3, although they are often in like phases.

Whether the various appearances of the transverse and lateral discs indicate extraction of the stain or whether they indicate phenomena of contraction, the writer does not know. As already stated, the indications are that between two cement bands all like discs show like phases, unless the conditions of the discs on the lower edge of fig. 2 is an exception. If the fibers are continuous and if the phases of the discs indicate contraction phenomena, why does the wave contraction stop at the cement band? Why does the impulse gradually die out?

From what has been said one sees that in the dog's heart, as in the human heart, the fibers are packed close together. Fibrils from adjacent cells blend together to form new fibers; the whole making a complex network. Again, where spaces occur between fibrils, one sees along the fiber's edge a narrow, wavy condensation of sarcoplasm resembling the sarcolemma of insect muscle. In this structure terminates Krause's membrane. Near the center of the fibers at more or less even distances apart lie the nuclei. Occasionally two nuclei lie a short distance apart and are connected by a slender column of cytoplasm. The cement bands resemble a series of blocks crossing the fibers. The distance between the bands and the number of fibrils crossed by a portion of a band, or step, may vary greatly. The cement area appears to be crossed by rods which look as if they were the ends of the fibrils. Through the center of the cement area extends one, or occasionally two, blue lines. These lines give indications of becoming continuous with Z . In places, also, these lines appear to end in the sarcolemma as does Krause's membrane. At times, in very thin sections, one gets the appearance of an interlacing network crossing the rods. Between two cement areas all the discs

appear in like phases. The discs which the writer has found present are *Z*, *J*, *q*, and *qh*. *M* may be present. *Z*, or Krause's membrane, is of uniform thickness, stretches continuously from fibril to fibril, crossing often more than one fiber, and terminates in the sarcolemma. If the sarcolemma is wavy, *Z* terminates in the depressions between the waves. *J* and *q* vary in size but never entirely disappear; as the one increases, the other decreases in size; frequently *q* is bead-like in form; and it is often crossed by a light area, *qh*, which cuts the transverse disc into two parts. The breadth of *qh* varies. As it increases in width, the parts of the transverse disc become bead-like.

The writer wishes to acknowledge her indebtedness to Professor S. H. Gage and Professor B. F. Kingsbury. To the former she is indebted for encouragement and assistance in the preparation of material; to the latter for his many helpful suggestions and ready sympathy.

WORKS CITED

EBNER, V.

00. Ueber die Kittlinien der Herzmuskelfasern. Sitzungsber. der Wien. Akad., math.-nat. Kl., Bd. 109, Abt. III.

GODLEWSKI, E.

01. Ueber die Entwicklung des quergestreiften musculösen Gewebes. Bull. der Krakauer Akad.

HEIDENHAIN, M.

99. Structur der contractilen Materie. Structur des quergestreiften Muskels. *Ergeb. der Anat. und Entwicklungsges.*, Bd. VIII.

01. Ueber die Structur des menschlichen Herzmuskels. *Anat. Anz.*, Bd. XX, p. 33.

HOVER, H.

01. Ueber die Continuität der Fibrillen in den Herzmuskelzellen. Bull. der Krakauer Akad.

MACCALLUM.

97. On the Histology and Histogenesis of the Heart Muscle Cell. *Anat. Anz.*, Bd. XIII, No. 23.

PRZEWSKI, M.

93. Sur le mode de réunion des cellules myocardiques de l'homme. *Archiv. des Sci. Biologiques de St. Petersburg.* Tome II, p. 287.

SZYMONOWICZ.

01. Histologie. Also Szymonowicz and MacCallum. *Histology and Microscopic Anatomy*, Phila. and N. Y., 1902.

EXPLANATION OF PLATES

Plate III

Fig. 1. Heart muscle of the dog showing the interblending of fibrils, the relative position and shape of the cement bands, and cross striations.

Fig. 2. Same as fig. 1, but showing the relation of the sarcolemma to the muscle fiber and to Krause's membrane.

Plate IV

Fig. 3. Shows cross striations in detail and their relation to those of neighboring fibers and to the cell cement.

Plate V

Fig. 4. Various appearances of the discs. *4a*. The segment, Z-Z, nearly filled by the transverse disc, *q*. *4b* and *4c*. Variation in the relation of the transverse disc to the later discs. Two bead-like forms which *q* may assume. *4d* and *4e*. The transverse disc crossed by the light area forming *qh*.

Fig. 5. Cell cement. Relation of blue lines crossing the cement to Krause's membrane. *s*, sarcolemma; *x*, cell cement; *y*, blue lines; *z*, Krause's membrane. *5a*, cement crossed by one blue line. *5b*, cement crossed by two blue lines.

Fig. 6. Appearance of the cement band and the relation of the blue lines and the sarcolemma to the band. *x*, rods; *y*, blue lines; *z*, Krause's membrane; *s*, sarcolemma.

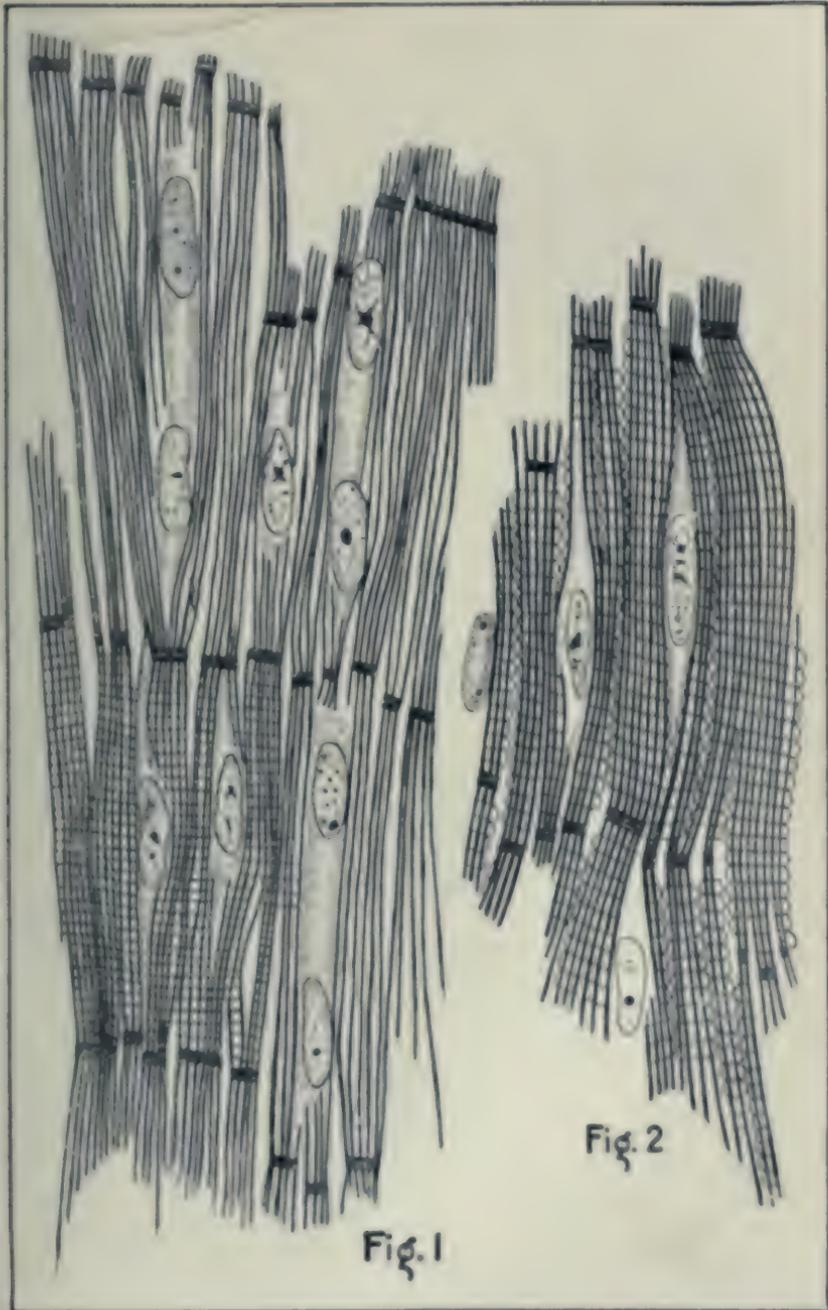


Fig. 1

Fig. 2

522

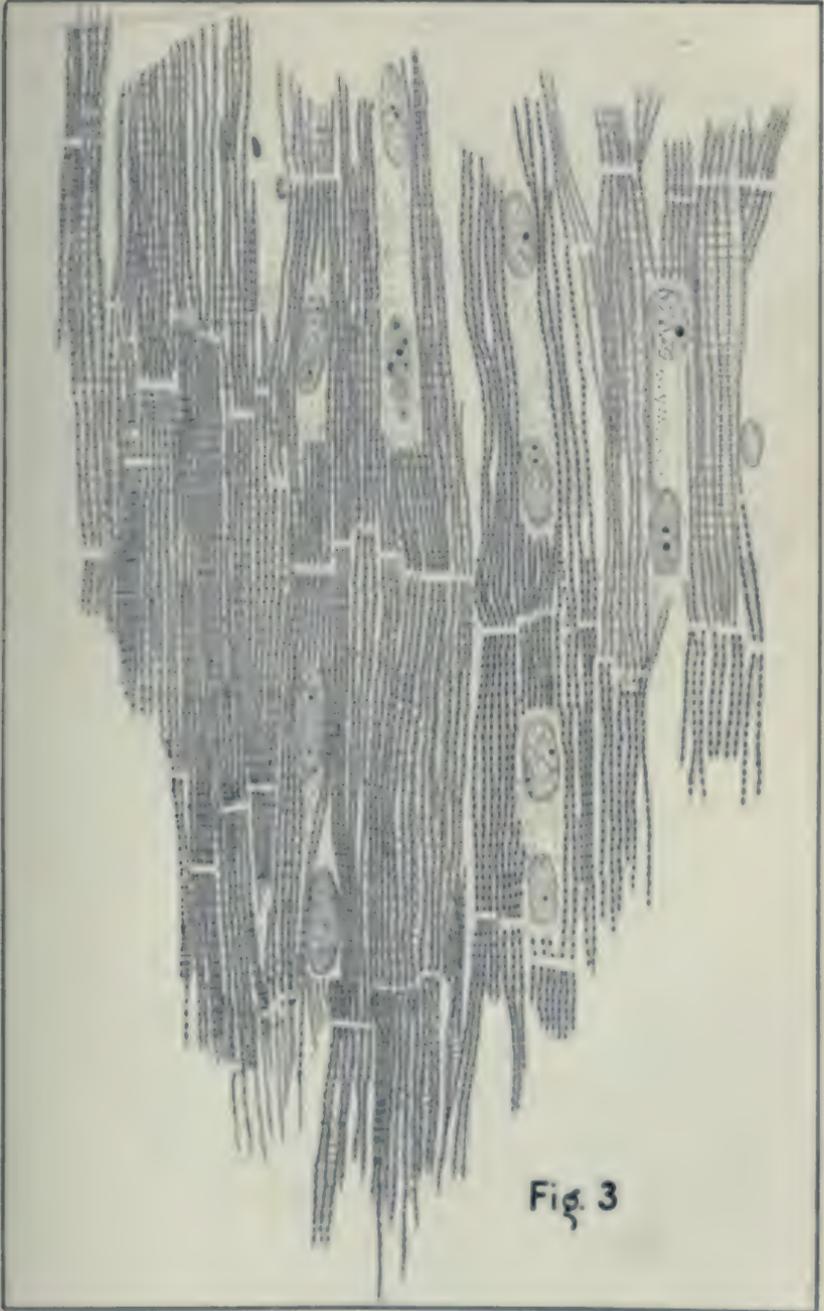


Fig. 3



Fig. 4a

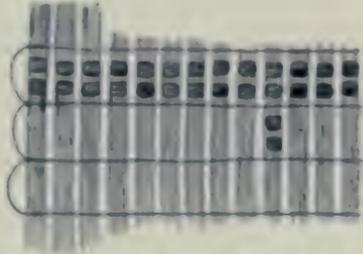


Fig. 4d



Fig. 4b

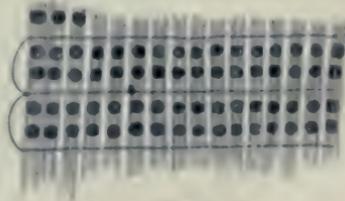


Fig. 4e

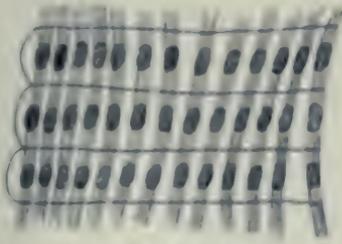


Fig. 4c



Fig. 6

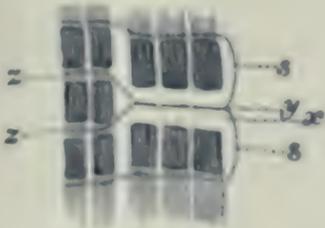


Fig. 5a

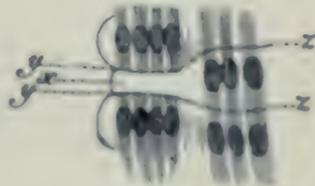


Fig. 5b

ADDITIONAL NOTES ON THE CLADOCERA OF NEBRASKA

By CHARLES FORDYCE

WITH ONE PLATE

Since the appearance of the first paper on the Cladocera of Nebraska (Fordyce, 1901), the author has been extending his survey of the state and making collection in localities not covered in the previous report; aside from the material obtained by personal effort, acknowledgments are due to Dr. R. H. Wolcott and Miss Caroline E. Stringer for some valuable collections furnished by them. An examination of the material reveals nineteen species in addition to the twenty-six with which the former paper dealt, making a total of forty-five species thus far reported from Nebraska. These additional species are distributed among the following two families: Daphnidæ 9, and Lynceidæ 10.

BIOLOGICAL CONDITIONS

The bodies of water from which these collections were made vary greatly in their characteristics. The station at Valentine is in the form of a large mill pond on the Minichaduza River, located about two miles north of the village. The water is cold, clear and has a depth varying from two to five meters. The phytoplankton and the higher aquatic plants are abundant. The pond is well located and especially adapted for zooplankton, but for the fact that the stream is swift, giving the water found in the mill dam an appreciable current which doubtless carries away many of the forms. Not only the species shown in the subjoined table, but many reported in the table of 1901, flourish here.

Little Alkali Lake lies about thirty-five miles south of Valentine in one of the most interesting lacustrine districts of our state. The elevation here is about fourteen hundred meters above the sea level. The lake is about five hundred meters in diameter, and attains the depth of two to three meters. The plant life is not abundant; a few clusters of cat-tails and rushes represent the higher aquatic plants,

while the algae are confined to a few Volvocinae and to a few Diatomaceae.

Hackberry Lake is a broad sheet of water lying three miles northwest of Little Alkali Lake. It has an average diameter of about four thousand five hundred meters and a depth of from one to two meters. The water contains an abundance of higher aquatic plants, as well as the lower forms; *Spirogyra*, *Zygnema*, and other types of filamentous algae are in great abundance.

St. Mary's Lake is located seven and one-half miles south of Aurora. It has a diameter of about four hundred and fifty meters with a depth rarely exceeding one meter. The bed is composed of rich alluvial soil with an abundant growth of rushes and other higher plants. The phytoplankton is scarce; *Closterium* among the desmids, and two or three types of Volvocinae are the leading representatives.

The collecting ground at Sidney is a small shallow lake one and a half miles southwest of town. The region is generally sandy with a vegetable plankton confined almost wholly to diatoms. The zooplankton is represented by two genera, *Alona* and *Chydorus*.

The material from York was found in a small turbulent pond on the east side of the city. The water is poorly lighted and almost destitute of plant life. *Moina brachiata* is the only cladoceron in the collection; this is not abundant.

Pilger Lake is a body of water in the form of a "cut-off" on the Elkhorn River at a point one mile east of Pilger. The lake contains many higher plants, and among the lower *Fragillaria* and *Oscillaria* are very abundant; the Rotatoria are also very numerous. The zooplankton is rich in numbers.

Stringer's Lake is a small sheet of water, located two miles east of Wayne. The lake is spring fed, comparatively cold, and very poor in vegetable plankton. The animal plankton, like the vegetable plankton, is limited.

The following table indicates the geographic distribution of species found so far as these are new to Nebraska; *Pleuroxus uncinatus* Baird is new to this country and the following are new to science:

Daphnia magna var. *americana*.

Leydigia trichura.

DAPHNIDAE		Valentine	Little Alkali Lake	Hackberry Lake	York	St. Mary's Lake	Sidney	Pilger's Lake	Stringer's Lake
1.	<i>Daphnia pulex</i> , var. <i>nasutus</i> Herrick.....					•			
2.	<i>Daphnia magna</i> var. <i>americana</i> n. var.		•						
3.	<i>Daphnia schoedleri</i> Sars.....			•					
4.	<i>Daphnia carinata</i> King.....		•						
5.	<i>Simosephalus serrulatus</i> Koch.....								
6.	<i>Ceriodaphnia censors</i> Birge.....			•					•
7.	<i>Ceriodaphnia megops</i> Sars.....					•			
8.	<i>Ceriodaphnia reticulata</i> Jur.....	•							
9.	<i>Moina brachiata</i> Jur.....				•				
LYNCEIDAE									
10.	<i>Alona costata</i> Sars.....								
11.	<i>Alona intermedia</i> Sars.....	•					•		
12.	<i>Alonella excisa</i> Fisch.....					•			
13.	<i>Alonopsis media</i> Birge.....					•			
14.	<i>Alonopsis latissima</i> Kurz.....	•							
15.	<i>Camptocercus rectirostris</i> Schoedlr.....							•	
16.	<i>Leydigia quadrangularis</i> Leyd.....							•	
17.	<i>Leydigia trichura</i> n. sp.....					•		•	
18.	<i>Pleuroxus uncinatus</i> Baird.....			•					
19.	<i>Chydorus globosus</i> Baird.....	•					•		•

DAPHNIA MAGNA var. AMERICANA n. var.

Plate VI, fig. 1

Daphnia magna Strauss is described quite in detail by Richard (96:192-197; Pls. 20, fig. 1; 24, figs. 6, 13); the species is very generally distributed over the Old World, but up to this time, as far as can be learned, is not reported from America. Since this species has very pronounced variations dependent upon food and the different biological conditions under which it has been found it is not without hesitation that the writer suggests a new variety; the representatives of the species here are, however, so remote and under such different environmental conditions from their kindred in the Orient that such wide variations in characteristics as have been found are not unexpected.

The female has an average length of 3.5 to 4.5 mm. and a height of 2.5 to 3 mm. The carapace is very distinctly sculptured with fine, quadrate areas: the caudal spine is in the line of the dorsal mar-

gin and spinulose, while in many specimens it curves ventrad (fig. 1): in length it is very variable and in old females absent. The ventral margin is decidedly more convex than the dorsal, both being armed from near the middle posteriad with spinules of increasing length: the spinules of the ventral series are continued on the caudal margin, where they are very thickly set: along the middle of the ventral margin for an interval equal to about one-tenth its total length is found a series of very fine plumose hairs. There is no appreciable sinus between the head and the body. The upper and anterior margins of the head are uniformly curved, there being a slight projection below and in front of the eye and a noticeable concavity in the ventral margin between the head and the beak. The antennae of the first pair are conical and reach the extremity of the beak; the sensory hairs are coarse, short and rarely exceed seven in number. The fornix is very prominent, the eye medium in size with large distinct lenses; the pigment fleck is small and triangular. The antennae of the second pair are strong and spinulose, the apical end of the basilar joint, as well as each articulation of the rami, is furnished with short teeth; the dorsal margin of the ventral ramus and that of the distal articulation of the dorsal are provided with long sparsely set hairs. The swimming setae are biarticulate and densely plumose, the hairs being set almost perpendicularly to the shaft. The digestive canal is of the usual daphnid type with the gastric caeca long and convoluted: the most characteristic feature of this species is the post-abdomen, the dorsal margin of which is interrupted near its lower part by a sinuosity: there are from nineteen to twenty-three anal teeth, of which seven to nine lie below the sinuosity and twelve to fourteen above; these teeth decrease in length dorsad in each series; besides these teeth the post-abdomen is densely studded with sharp spinules which are in the lower half grouped in twos and threes. The terminal claws are long, distinctly curved, and provided with two combs of fine secondary teeth on the proximal half and a series of fine spinules on the distal. There are four abdominal processes, the anterior being long, slender and curved forward, the second is heavy conical and about half as long as the first; the last two are short nodules and like the second distinctly spinulose. The abdominal setae are short and biarticulate, with the distal portion plumose.

The males are about half as large as the females, measuring 2 to 2.75 mm. long and 1 to 1.4 mm. high. The plumose hairs of the

ventral margin extend forward to the head. The eye is comparatively larger than it is in the female and is set farther forward, giving the anterior margin of the head in some instances a prominent bulging outwards. The antennae of the first pair are large, club-shaped and provided at the antero-distal point with a long curved flagellum, whose outer half is thickly beset with fine hairs. The sensory hairs emerging from the middle of the distal end of the antenna are few and very coarse; the body of the antenna is slightly serrate. The claw of the first foot is extremely long, having the length of 0.7 to 1 mm.; this foot is furnished also with a long flagellum. The post-abdomen is curved forward on its anterior margin and has a deeper sinuation in the posterior margin than is seen in the female. The teeth on this posterior margin differ from those in the female, there being only eleven above the sinuation, while there are fourteen to sixteen very small ones below.

Comparisons

<i>D. magna</i> Strauss.	<i>D. magna</i> var. <i>americana</i> n. var.
1. Valves often as broad as long.	Never.
2. Size—female 4 to 5 mm. long.	Size 3.5 to 4.5 mm.
3. Forehead not prominent.	Prominent.
4. Anterior margin of head straight.	Convex.
5. First antenna does not reach the extremity of the beak.	Reaches extremity.
6. Abdominal processes all hairy.	Posterior three only.
7. Post-abdominal teeth of	
(a) distal series 4 to 6,	(a) 7 to 10,
(b) proximal series 10 to 12.	(b) 12 to 14.
(c) Teeth equal in length.	Decreasing dorsad.

LEYDIGIA TRICHURA n. sp.

Plate VI, figs. 2, 3

Female.—This species attains a length of 0.8 mm. and a height of 0.55 mm. The general form is elliptical and very similar to *L. fimbriata* Fordyce (61: 161-162, Pl. 23, figs. 11 to 14). The dorsal margin of the carapace is nearly straight in its middle third: the margins of the rest of the valve are uniformly curved (fig. 2). The ventral margin is ornamented through its entire length with

densely set plumose hairs: the ventral fourth of the posterior margin is provided with short, fine spinules. The valves are indistinctly marked by longitudinal striae. The head is comparatively large and projects obliquely downward, the forehead being nearly straight. The eye is small and approaches the anterior margin of the head, the crystalline lenses are buried in the pigment; the pigment fleck is triangular, about fifty per cent larger than the eye and is above the middle point between the eye and the rostrum. The antennae of the first pair are prominent, fusiform, and inserted immediately under the pigment fleck; they extend considerably below the extremity of the rostrum. The sensorial hairs are few and about half as long as the body of the antenna, from whose anterior margin long, straggling, stiff hairs emerge. The antennae of the second pair are robust and when flexed reach nearly two-thirds the distance to the posterior margin of the carapace. They are ungraceful in appearance, having a stunted basilar joint much constricted at the proximal end. The rami are almost equal in length, each having three apical, biarticulate, and sparsely plumose swimming setae; a strong sharp thorn accompanies each set of setae. A brush of similar thorns diverges from the antero-distal part of the first and second articulations of the ventral ramus, two appear on the anterior margin of the first article of the ventral ramus and one emerges from the extero-distal end of the first article of the dorsal ramus.

The digestive canal is convoluted and has a very narrow lumen. The post-abdomen is very prominent, having both the anterior and posterior margins convex, the latter being conspicuously curved and armed with several series of spines and thorns. From the distal half of this margin there come eight or nine long curved spines decreasing in length dorsad (fig. 3); each is fortified at the exterior side of its base by one or two short curved spines. The series of long spines is continued dorsad by a row of fifteen to sixteen shorter straight ones. The series of anal spines just mentioned is set in considerably from the margin. The interval immediately along the dorsal edge between the lateral rows of spines is densely studded with sharp, stout thorns which extend to a slight sinuosity found at the beginning of the upper third of the dorsal margin: from this point extends a row of spinules followed by a number of nodules from the largest of which the long abdominal setae emerge. Each side of the anterior margin of the post-abdomen is marked by three

equally distributed combs of spinules, each comb embracing from seven to ten spinules.

The terminal claw is long, slightly curved, and armed by a row of very fine denticles, there being one small secondary tooth near the middle of the claw. There are four nodular abdominal processes, each furnished with a brush of stiff spines, the anterior more prominent process being provided with a larger cluster of spines. No males are found in the collection.

DAPHNIA PULEX var. NASUTUS Herrick

The animal described and figured by Herrick (84: 57, Pl. N. figs. 1 to 4) under the above name is found in St. Mary's lake. It has an average length of 1.1 to 1.2 mm. The peculiarity of the beak, suggesting to Herrick the appearance of the "Roman nose" is noticeable in the forms examined. The abdominal processes are hairy and the two anterior ones less divergent than is indicated in the original figure. There are twelve anal teeth curving upward. The claw is rather strongly curved and armed at its proximal half with twelve short, sharp teeth that decrease dorsad. Five eggs were seen in many of the females; no males appear in the collection.

DAPHNIA SCHOEDLERI Sars

Scarcely any two writers agree on the description of this species. My specimens approach most nearly Stingelin's diagnosis (95: 196-197). The forehead however is prominent, while Stingelin describes it as without prominence. The eye lies so near the margin as to give a slight projection immediately in front. The beak is long and pointed, projecting obliquely downward; there is a slight concavity between the forehead and the end of the beak. The specimens measured have an average of 1.7 mm. in length and only 0.95 mm. in height; in other respects the animal agrees with that of Stingelin.

SIMOCEPHALUS SERRULATUS Koch.

Our specimens differ from the described forms, particularly Birge's *S. serrulatus* which he formerly called *S. americanus* (78: 82-84, Pl. 1, fig. 6) in having the antero-frontal portion of the head to which the thorns are attached rounding rather than in the form of an acute angle. The caudal teeth emerging from the truncated portion of the post-abdomen are, in the animals observed, fourteen in number,

gradually decreasing in size from the claw posteriad; in other regards our form does not differ from those described.

MOINA BRACHIATA Jur.

A few of these were found in a small pond at York. It is with some doubt that they are referred to this species as they do not answer exactly to the characteristics of any of the *Moina* group, but they approach so nearly Stingelin's diagnosis (95: 219-220, fig. 20) that I venture to put them under the above name rather than to assign them a new place. The shell is indistinctly marked by lines crossing each other irregularly, very similar to the sculpturing of the shell in *M. Lilljeborgii* Schoedl. as figured by Lilljeborg (53: 38, Pl. 2, fig. 4f). The males bear a striking resemblance in outline and in form of the antennule to the male of *M. affinis* Birge (93: 290-291, Pl. 10, fig. 7). Our species departs from Stingelin's description in the following particulars:

	Swiss forms	Nebraska forms
Length—female	1.2-1.6 mm.	1.5-1.65 mm.
male	0.8 mm.	0.88 mm.
Caudal teeth	10	11-12

ALONA COSTATA Sars

This form approaches very closely to the diagnosis and figure of Steuer (01: 124, Pl. 5, fig. 17). It differs, however, in having only ten anal teeth and in having above these a row of very closely set spinules. In points of comparison with *A. guttata* Sars our specimens correspond to Steuer's description.

ALONOPSIS LATISSIMA Kurz

These are abundant in the collections from St. Mary's Lake, Aurora: the average length is 0.45 mm. The general form agrees with that of Herrick and Turner (95: 232-233, Pl. 61, fig. 9) and with Birge's description under *A. media* (78: 108, Pl. 1, figs. 14, 15). By these men no mention is made of the fact that the lower three anal spines are decidedly larger than the others; this is characteristic of the Manitoba specimens of Ross (97:162), as well as of those found here.

PLEUROXUS UNCINATUS Baird

A few typical representatives of this species, not hitherto reported in this country, were found among the collections from Hackberry

Lake. The animal agrees in general with Baird's description (50: 135, Pl. 17, fig. 4) but differs in having the posterior margin of the carapace truncate instead of rounding and sinuate at the lower margin, as given in Baird's diagnosis. The beak is less procurved than is indicated by the description and the original figure.

The general outline of the body approaches Baird's description of *P. trigonellus* (50: 134, Pl. 17, fig. 3). Baird does not give the length of his specimens but Steuer finds the average length to be 0.538 to 0.568 mm. (01: 126-7, Pl. 5, fig. 23 *a, b*), while our representatives measure from 0.7 to 0.8 mm. in length.

CHYDORUS RUGULOSUS Forbes

This little animal reported in my former paper (01: 169, 170) as quite generally distributed over Nebraska, but as differing in some particulars from Forbes' description (90: 712), has been found among the collections from Sidney; the specimens of recent collection show exact conformity to Forbes' diagnosis and figure.

OTHER SPECIES

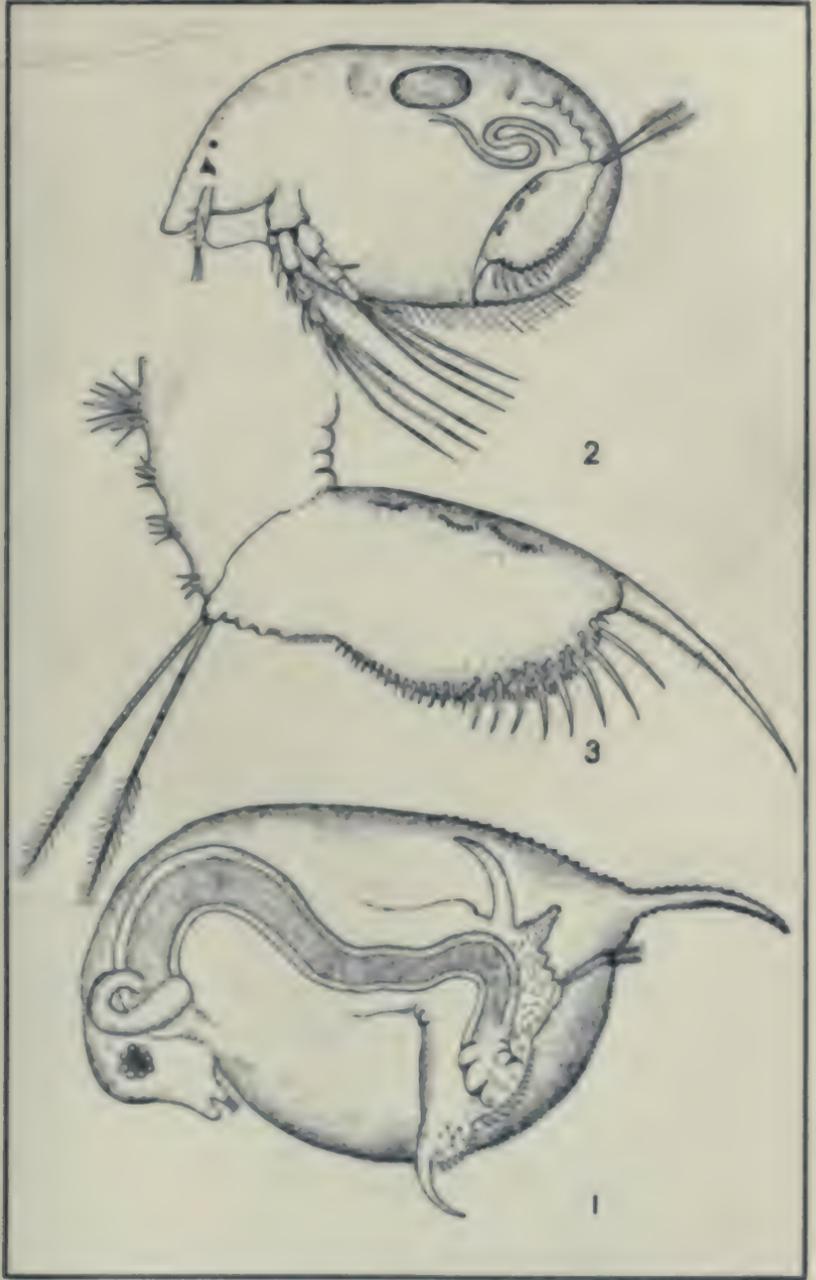
The other species of this report not referred to in the above notes, agree so perfectly with the descriptions and figures of American and European writers as to make comment upon them quite unnecessary.

WORKS CITED

- BAIRD, W.
50. The Natural History of the British Entomostraca. Ray Soc.
- BIRGE, E. A.
78. Notes on Cladocera. Trans. Wis. Acad. Sci., IV, 77-110, 2 pl.
93. Notes on Cladocera, III. Trans. Wis. Acad. Sci., IX, 275-317, 4 pl.
- FORBES, S. A.
90. On Some Lake Superior Entomostraca. U. S. Comm. of Fish and Fisheries, part 15, Report for 1887, 701-718, 4 pl.
- FORDYCE, CHAS.
01. The Cladocera of Nebraska. Trans. Amer. Mic. Soc., XXII, 119-175, 4 pl.
- HERRICK, C. L.
84. A Final Report on the Crustacea of Minnesota included in the Orders Cladocera and Copepoda. 12th Ann. Rep. Geol. and Nat. Hist. Survey, pt. V, 191 pp., 30 pl.
- HERRICK, C. L., and TURNER, C. H.
95. Synopsis of the Entomostraca of Minnesota with descriptions of related species comprising all known forms from the United States included in the orders Copepoda, Cladocera, Ostracoda. Zool. Ser. II, State Geol. Nat. Hist. Survey Minn., 525 pp., 81 pl.
- LILLJEDORG, W.
53. De Crustaceis ex ordinibus tribus: Cladocera, Ostracoda et Copepoda, in Scania occurrentibus.
- RICHARD, J.
96. Revision des Cladoceres, II. Ann. Sci. Nat., zool., Ser. 8, II, 187-363, 6 pl.
- ROSS, L. S.
97. Some Manitoba Cladocera with Description of one New Species. Proc. Iowa Acad. Sci., IV, 154-162.
- STEUER, A.
01. Die Etomostrakenfauna der "alten Donau" bei Wien. Zool. Jhrb., Syst., XV, 168 pp., 12 pl.
- STINGELIN.
95. Die Cladoceren der Umgebung von Basel. Rev. Suisse Zool., III, 161-274, 4 pl.

EXPLANATION OF PLATE VI

- Fig. 1. *Daphnia magna* var. *americana*, lateral view of female. $\times 20$.
Fig. 2. *Leydigia trichura*, lateral view of female. $\times 90$.
Fig. 3. *Leydigia trichura*, post-abdomen of female. $\times 300$.



UPON THE OCCURRENCE OF HAEMOSPORIDIA IN
THE BLOOD OF RANA CATESBIANA, WITH
AN ACCOUNT OF THEIR PROBABLE
LIFE HISTORY

By JAMES H. STEBBINS, Jr.

WITH TWO PLATES

Twenty-four small bullfrogs captured last fall on Long Island, N. Y., furnished the material for this investigation. Upon examination these frogs were found to be quite heavily infected with haemosporidia, while in several of the number trypanosoma were also found. The blood was examined in the fresh and stained conditions, and several forms of parasites were found to be present, which for convenience of reference will temporarily be referred to by number.

One of the parasites which we will designate as No. 5 differs so considerably from any of the others that I consider it to be a distinct species, and will therefore exclude this one, and confine my remarks to a description of the other four forms which will be shown to belong to one and the same species, only in different stages of their life history.

Parasite No. 1.—This parasite was found very plentifully in the red blood corpuscles of the frogs examined, but also is occasionally found in the leucocytes. It is a small gregarine-like organism, somewhat crescent-shaped; pointed at both ends, though at times some may be found pointed at one extremity, and slightly enlarged, and rounded at the other.

It is provided with a nucleus, nearly centrally located, consisting of chromatin granules arranged either in the shape of a ring, irregularly in clumps, or scattered over the body of the parasite. The body cytoplasm contains numerous fine chromatoid granulations, and occasionally the parasite may be found with a vacuole on either side of the nucleus. The length is 18.5μ , and the diameter 4.6μ .

The organism stains faintly with the Wright stain, but, strongly with the Goldhorn polychrommethylene blue and eosin stain, the latter staining the body protoplasm a light pink, and the chromatin granules a strong and fiery red.

This parasite (PL VII, fig. 2) which I have christened *Haemogregarina catesbiana*, and which later will be shown to be the asexual organism, exerts but little if any action upon the invaded erythrocytes. Occasionally a red cell may be found whose nucleus has been displaced to one side, but as a rule they are not displaced, nor have I ever noticed any other injurious action upon the same. There may be multiple infection with one, two, or three parasites. The organism may be found within the red corpuscles completely elongated, curved up crescent-fashion, with the ends folded up U-shape, or rolled up into a spherical form, depending upon what stage of the asexual cycle it has entered.

Parasite No. 2, or Cytocyst.—(Plate VII, figs. 5 and 8.) Strictly speaking, this is not a distinct or separate parasite, but merely one of the transformation forms of the previously described organism, and represents the encystation stage of the same. This cyst, properly speaking cytocyst, varies considerably in shape and size, though the spherical shape seems to predominate, but it is sometimes found of an ovoid shape. It is surrounded with a thick membrane, which stains of a deep purplish brown color with the Goldhorn stain, while the body of the cytocyst takes a light pinkish shade.

This cytocyst, in reality a schizont, during the later stages of its growth, will be found to contain numerous small merozoites, surrounding a small amount of residual protoplasm, which stain of a fiery red color with the Goldhorn stain (Pl. VII, figs. 5 and 8). The erythrocytes are subject to multiple infection, as many as four schizonts in one corpuscle having been observed. The nuclei of the invaded red cells are usually displaced a little to one side in order to make room for the schizont, but they may frequently also be seen with the nuclei in their normal position. Apart from this displacement of the cell nucleus, no other pathological condition was observed. The diameter of this form is 7.18μ .

Merozoites.—(Pl. VII, fig. 1.) In addition to the foregoing, a very small ovoid to spherical organism with a fiery red chromatin granule centrally located, was frequently encountered in a free state in the blood plasma, and was usually found quite close to the peri-

phery of a red corpuscle. These bodies are the merozoites, which have escaped from the before-mentioned cytocysts after segmentation.

Parasite No. 3, or Microgametocyte.—(Plate VIII, figs. 1-3.) This parasite is found free in the blood plasma. It is a straight or somewhat curved gregarine-like organism, sharply pointed at one end, but, somewhat more rounded at the other, or anterior end. It swims with its blunter anterior end forward. The average length is $14.45\ \mu$ and the diameter is $3.98\ \mu$. The body cytoplasm is slightly granular, and stains of a pale pink color with the Goldhorn stain. The parasite may be found with a centrally located nucleus, consisting of a conglomeration of chromatin granules, as in Pl. VIII, figs. 1 and 2, or with the latter scattered throughout the body of the parasite, as in Pl. VIII, fig. 3. It is very motile, and glides through the blood plasma quite rapidly with an even undulating motion. It is also capable of exerting considerable force, sufficient to easily push any blood corpuscles aside which may happen to be in its path.

One of the most striking peculiarities of this parasite is the ease with which it is able to enter and leave the blood corpuscles. By carefully watching one of these organisms, it may be seen to glide up to a red blood cell with its rounded end first, and immediately proceed to penetrate it, and this is achieved so rapidly that up to the present time I have been unable to discover how it is accomplished. All that can be observed is a slight indentation of the cell protoplasm at the point of contact, when the latter seems to yield to the pressure exerted by the parasite, and before one can realize it, the vermicule has completely buried itself within the corpuscle, leaving as a rule no other sign of its presence within other than a slight writhing motion, and distortion of the cell protoplasm, but at other times its movements may be easily followed. After a varying length of time the parasite will leave its temporary abode, and when this is about to occur, a protuberance will be formed upon the side of the corpuscle from which it is going to emerge. This protuberance gradually increases in length until the erythrocyte is drawn out, pear-shaped. By this time the parasite has practically emerged from the cell, but is still connected with the same by a long, very fine, and nearly invisible thread, with which it tows the corpuscle around for some distance before it is eventually ruptured. It not infre-

quently happens that the parasite when emerging from the blood corpuscle, tears away portions of the same, which it may carry around with it for some time attached to the before-mentioned hyaline thread. This parasite I take to be the microgametocyte of *Haemogregarina catesbiana*. (Pl. VIII, figs. 1, 2 and 3.)

Parasite No. 4, or Macrogametocyte.—(Pl. VIII, figs. 4 and 5.) This parasite exists both in the free state in the plasma, and within the red blood corpuscles. Its length is 9.98μ and its diameter 5.06μ . In the free state it is usually bean-shaped, fairly pointed at one end, but bluntly rounded at the other. Its cytoplasm is quite coarsely and heavily granular, with a well defined nucleus centrally located, or nearly so, and a vacuole on either side of the same, about midway between the nucleus and each pole.

The parasite takes the Goldhorn stain very readily, its cytoplasm staining of a light pink, and the chromatin of the nucleus of a fiery red color. It is not nearly as motile as the microgametocyte. This organism I believe to be the macrogametocyte of *Haemogregarina catesbiana*.

The intra-corpuscular parasite is met with in several forms, depending upon which stage of its life-cycle it has entered. (Pl. VIII, figs. 6–10.) It may be either bean-shaped, ovoid, or spherical, the latter form representing its encystation stage. The nucleus of the intra-corpuscular parasite, or macrogametocyte, is considerably larger than that of the extra-corpuscular organism. In the undivided state it occupies the greater part of the body of the parasite, and stains of a deep fiery red color, with the Goldhorn stain. At times a small vacuole may be found at either pole, but this is not of common occurrence. The cysts, in reality oocysts, are mostly spherical, but vary occasionally, and are sometimes seen of an ovoid shape. They are surrounded by a dense, heavy membrane, which stains of a deep purplish red color. (Pl. VIII, fig. 10.)

It has been an undecided question for some time, how cold-blooded animals like frogs, turtles, snakes, etc., are infected with haemosporidia, some taking the ground that infection is caused by the bite of a blood-sucking insect of some sort, while others believe that infection is induced by taking the parasites through their food into the digestive tract, and from there into the blood.

From my own observation, I know that the latter mode of infection is possible, as will be seen from what is to follow, though this

by no means excludes the other mode of infection, but personally I have been unable to discover any blood-sucking insects or animals likely to carry infection.

A giant bullfrog (*Rana catesbiana*) which I had under observation for over a year, and which was known to be absolutely free from infection of any kind, one day swallowed a small infected bullfrog, which I had carelessly placed in the same aquarium. In about six weeks the large bullfrog's blood was examined, and then found to be infected with the same parasites as discovered in the blood of the small frog. This I think is fairly good evidence that infection may take place through the digestive tract, by means of the food ingested.

An attempt will now be made to show in what is to follow, that both schizogony, and sporogony take place within the blood corpuscles of the same host, though it has usually been assumed that in cold-blooded animals, like the frog, etc., schizogony takes place within the blood corpuscles, while sporogony occurs in the epithelial cells of either the stomach, intestine, liver, or spleen of the same host. In advancing my present views upon this subject, I feel that I am treading upon dangerous ground; nevertheless, as all my observations point in this one direction, I believe that I am justified in the following remarks:

Asexual Cycle of *Haemogregarina catesbiana*.—The cytocyst after segmentation (Pl. VII, fig. 6) discharges its merozoites or spores into the blood plasma, and these after wandering around attach themselves to the blood corpuscles which by some means they manage to penetrate. As soon as this has occurred, the young organism begins to grow, and is converted into a small worm-shaped trophozoite, or schizont (Pl. VII, fig. 7) and this process is continued until the schizont has reached its full growth, when it will have the characteristics previously alluded to. (Pl. VII, fig. 2.) It now begins to fold over on its self, gradually assuming a U-shape. (Pl. VII, figs. 3 and 4.) The two loops of the U now begin to curve inwardly until they meet and coalesce, thus forming a sphere, in which the line of suture is at first visible, but which eventually disappears.

The schizont now surrounds itself with quite a heavy membrane forming a true cyst (Pl. VII, figs. 5 and 8), and the chromatin granules of the fragmented nucleus in turn become surrounded with

a small body of protoplasm, at the expense of the cyst protoplasm, thus forming the merozoites or spores lying about a small amount of residual protoplasm. These after reaching full maturity, rupture the cytocyst, and escape into the plasma, when they are once more ready to invade fresh blood corpuscles. The foregoing represents fairly accurately I believe the asexual cycle of *Haemogregarina catesbiana*, which closely resembles the conditions obtaining with *Lankesterella ranarum*, discovered in the blood of *Rana esculenta*,¹ and whose life history has been described in full by Hintze,² in 1902.

Sexual Cycle of *Haemogregarina catesbiana*.—By analogy with the haemosporidia of other cold-blooded animals on the one hand, and with the acystosporidia on the other, it is believed that after many generations of schizogony, the sexes become differentiated into micro- and macrogametocytes, and that sporogony takes place somewhat as follows:

The nucleus of the motile, extra-corpuseular parasite, or microgametocyte (Pl. VIII, figs. 1 and 2), contains a number of chromatin granules. In the course of time the nucleus becomes fragmented, and its chromatin granules divide, and become scattered throughout the body of the parasite. (Pl. VIII, fig. 3.) According to Hintze (*loc. cit.*) the chromatin granules of the fragmented nucleus now become the nuclei of microgametes, which are not separated off simultaneously, but one by one in an irregular manner. This I have been unable to verify in the case of *Haemogregarina catesbiana*, though I suspect that some mode of fertilization must exist.

The unfertilized macrogametocyte which is found free in the blood plasma (Pl. VIII, figs. 4 and 5) is likewise supplied with a nucleus containing a number of chromatin granules. After fertilization, whether this occurs in the manner suggested by Hintze (*loc. cit.*) or by some other mode of conjugation, the macrogametocyte enters a red blood corpuscle, and then prepares for its final encystation, by undergoing a number of changes. It first becomes more ovoid in shape, while the nucleus at the same time is considerably enlarged. (Pl. VIII, fig. 6.) It now begins to divide, or segment (Pl. VIII, fig. 7), and its chromatin granules become scattered throughout the body of the parasite. (Pl. VIII, figs. 8

¹ Lankester, Quart. Journ. Mic. Sci., n. ser., Vol. 11, 1871, p. 387.

² Zool. Jahrb., Abth. f. Anat., XV, 4, pp. 693-730, 1902.

and 9.) The sporont now becomes more spherical in shape, and surrounds itself with a membrane, thus being converted into an oocyst.

The chromatin granules of the fragmented nucleus now appropriate a certain quantity of the cyst-protoplasm, and then become sporoblasts, and these in turn are gradually changed into small rod-shaped bodies, or sporozoites (Pl. VIII, fig. 10), which when fully mature rupture the oocyst, and escape into the plasma (Pl. VIII, figs. 11 and 12), when they in turn will seek out and invade fresh blood corpuscles. Such I believe to be the sexual cycle of *Haemogregarina catesbiana*, as it now appears to me, but it is possible that after further study I may be forced to change my views.

SUMMARY

Haemogregarina catesbiana is found in the blood of *Rana catesbiana* in several forms, among which may be mentioned, the merozoite or spore; the trophozoite, and cytocyst of the asexual cycle; the micro- and macrogametocytes, oocyst, and sporozoite of the sexual cycle, in which the microgametocyte is extra-corpuseular, while the macro-gametocyte is both extra- and intra-corpuseular.

Infection may be induced by the food taken into the animal's digestive tract, though this does not exclude infection from other causes.

Schizogony and sporogony occur in the red blood corpuscles of the same host.

In the asexual cycle, multiplication of the species is brought about by segmentation, or sporulation.

After many generations of schizogony, the sexes become differentiated into macro- and microgametocytes, and conjugate by some means yet undiscovered.

The extra-corpuseular macrogametocyte after fertilization, penetrates a red blood corpuscle, and becomes encysted, forming an oocyst. The chromatin granules of the fragmented cyst-nucleus appropriate a certain quantity of protoplasm, and become sporoblasts, which in turn are converted into germinal rods, or sporozoites, which when mature rupture the oocyst, and escape into the plasma, when they in turn are ready to invade fresh blood corpuscles.

EXPLANATION OF PLATES**Plate VII**

Asexual cycle of *Haemogregarina catesbiana*. Magnification about 930 diameters.

Plate VIII

Sexual cycle of *Haemogregarina catesbiana*. Magnification about 930 diameters.

PLATE VII

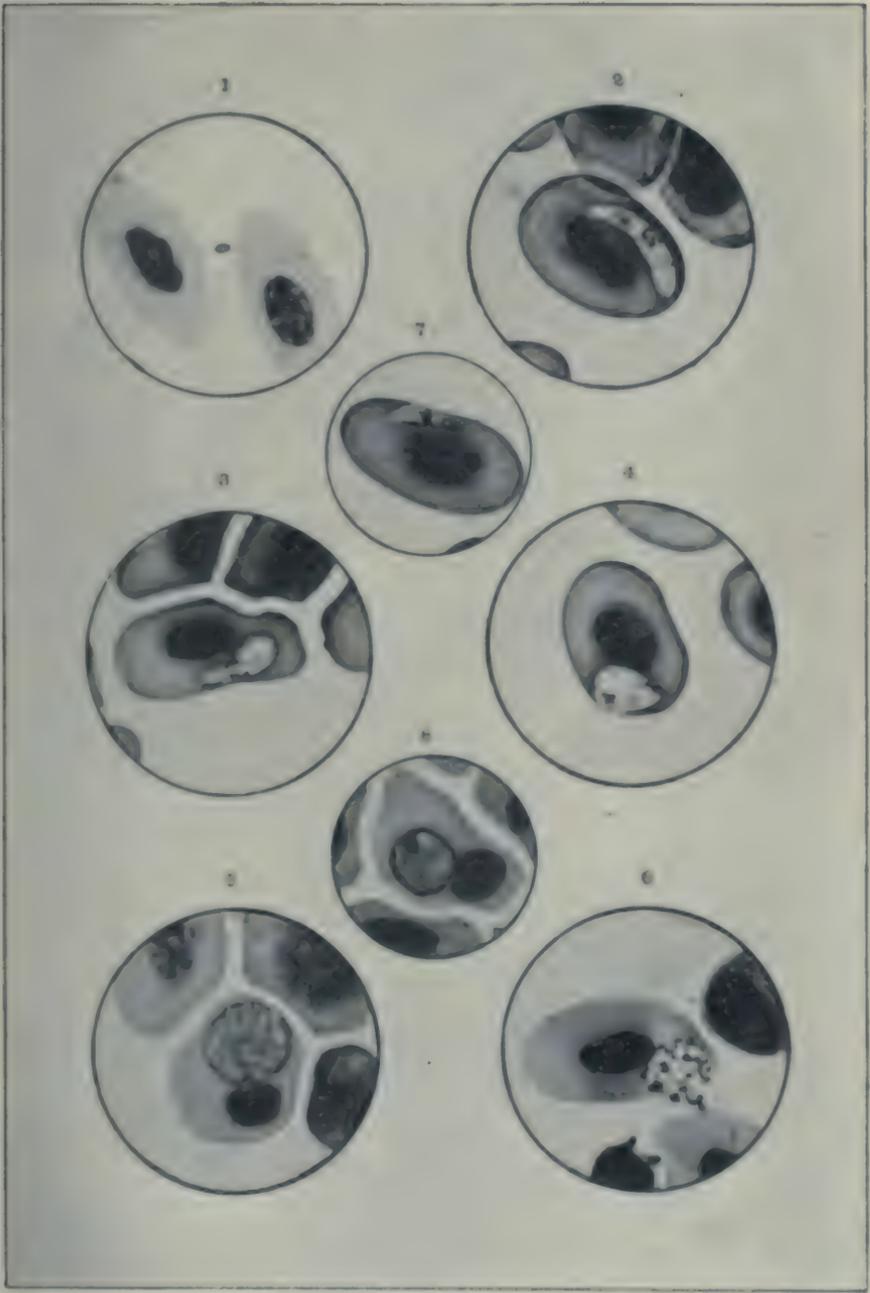
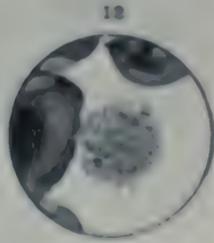
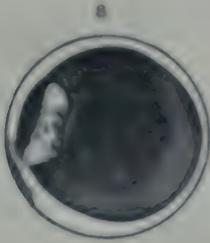
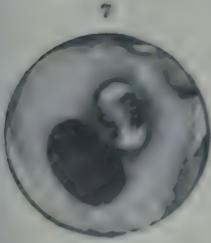


PLATE VIII

62



OUTLINE OF THE TUBE PLAN OF STRUCTURE OF THE ANIMAL BODY

By J. S. FOOTE

WITH SIX PLATES

The recognition of a definite plan underlying minute structures is as essential to the understanding of body construction as to that of the tissues themselves. Tissues and cells do not exist separately in the body, but are associated together as a cooperative community, each one bearing some particular relationship to all the others. If design is omitted they are confusing and difficult to remember; but if the design is known their various positions and varieties become reasonable and easy to fix in the mind.

It will simplify matters very much if there can be found some one plan of structure which is sufficiently common to the greater number of organs of the body to become a fundamental constructive unit in their formation. This plan of structure is to be found in the tube. The development of the vertebrate kingdom of animals calls attention to this fact. The small dimensions of the Protozoa enabled them to continue themselves and exhibit their phenomena of life without the presence of a central cavity; but as physiological division of labor advanced in accordance with an increase of animal mass a time came when a central cavity was necessary for the nutrition of the animal and from that time the tube became the basis of structure. It was foreshadowed as far back as *Euglena viridis*—a single-celled organism in which there was a slight indentation in the anterior end of the creature and this was set aside as a food tube of entrance to the small body. This simple tube in the low forms of life developing into a complex system in the higher and highest forms indicates the line of ascent along which animal progress has made its way, and we find that the worm, tunicate, fish, amphibian, reptile, bird, and mammal—chief divisions of the animal kingdom—all present the tube as the fundamental structure of the body and of most of its viscera.

Embryological development also reveals the tube plan in all its phases. After fertilization has occurred and the blastoderm has been formed the whole period of prenatal life is concerned with the tube formations and adjustments and when the creature is born, it is born as a large tube within which are arranged in the form of viscera a vast number of small tubes of all magnitudes. Both racial and individual developments are tube developments and the kind of tube produced depends upon the functional requirements of the animal. The vertebrate animals are all practically constructed on the same plan. They are composed of two tubes: the larger one containing the thoracic and the abdominal viscera separated by the diaphragm; the other, the smaller, enclosing the brain and spinal cord.

THE VISCERA COMPOSED OF SYSTEMS OF TUBES

By a simple dissection we may satisfy ourselves that most of the great system of the body are large tubes, as, for example, the respiratory, digestive, genital, urinary, vascular. By further analysis these large tubes or systems are found to contain many small ones: these small tubes are joined together in various ways by connective tissue and form the organs. Thus the respiratory system is composed of a large tube, the trachea, which divides and subdivides into a great number of small tubes, the ultimate terminations of which are the alveoli of the lungs. The digestive system is composed of a large tube, the alimentary canal, the functional lining of which is arranged in the form of simple and compound tubular glands which are small tubes. The genital system is composed of a large tube containing in its different divisions many small ones. The urinary system is composed of a large tube some parts of which exhibit a most complex system of small ones. The vascular system is composed of a large tube which gradually decreases in size and forms small ones. The secretory system is composed of large tubes which ultimately terminate in a vast number of small ones, the acini. The viscera then are for the most part aggregations of tubes and in many instances the structure and function of one of them is sufficient for the whole. If we can understand the structure and function of one air cell we can understand the structure and function of the lung. If we know the structure and function of one lobule of the liver or of any secreting or excreting gland we know the structure and function of any of those glands taken as a whole.

THE VISCERAL TUBES ARRANGED IN FIVE CLASSES

The numerous visceral tubes vary somewhat in their structure as they do in their function. But if we examine them all and classify them on the basis of structural agreement, we will find that nearly all the tubes of the different viscera may be arranged under five classes. These five classes will be found to differ from each other by the presence or absence of some definite structure. The thickness of the wall of any tube depends upon what is required of it. It may be thick like the uterus or thin like a capillary, but in any case the walls are composed of some combination of the tissues arranged in the form of coats which may be divided into layers. For the sake of convenience we may begin with that class which has the greatest number of coats, which is four, and by a process of subtraction arrive at a class with three coats—then two—then one—then one layer. These tubes may be designated as four-coated, three-coated, two-coated, one-coated, and one-layer tubes. In each tube structure the coat numbered 1, is the outside coat and the tube section is so placed that its inner epithelial lining is uppermost. The coats of the five tube classes are given below:

COATS OF A	{	4. Epithelial.	
FOUR-COATED TUBE.		3. Subepithelial.	
		2. Muscular.	
		1. Connective tissue.	
COATS OF A	{	3. Epithelial.	
THREE-COATED TUBE.		2. Muscular.	
		1. Connective tissue.	
COATS OF A	{	2. Epithelial.	
TWO-COATED TUBE.		1. Connective tissue.	
ONE-COATED TUBE.	{	b. Epithelial.	} Two layers.
		a. Basement.	
ONE-LAYER TUBE.		b. Epithelial.	

It is thought that the coats and hence the structure of these tubes will be better understood if they are based upon the functions of the tubes.

In microscopical sections the purpose of the structures seen does not appear and so no particular reason for the existence of any coat is apparent and the coats are meaningless to the observer. If the object of the tube is known then the structure becomes reasonable and consequently more easily remembered. Structure does not indicate function. For example there is nothing about a specimen of muscle to show that it ever contracted nor would it be possible by an examination of it carried even to the limits of microscopical investigation to prove that it could contract. But knowing that it does contract its ultimate structure then becomes a reasonable one. The same is true concerning any other structure. The various tube structures or coats may be considered from this viewpoint.

FOUR-COATED TUBE

The alimentary canal is the only tube of this class.

1. *Connective tissue coat.*—This is a thin layer of connective tissue in the form of a serous membrane which surrounds the tube for the most part from the lower end of the oesophagus to the rectum. This coat of the oesophagus consists of the connective tissue which supports the tube and may or may not be considered a distinct coat. By means of this coat the tube is supported by attachments to the skeleton and provided with a blood and lymph circulation.

2. *Muscular coat.*—This is composed of two layers of muscle throughout the whole length of the alimentary canal except at the cardiac end of the stomach, where there are three. In the upper half of the oesophagus the muscle is striped voluntary, in the other portion smooth. Here a motor tube is required because progressive motion of the contents in a certain direction is necessary. This can be accomplished only by a contractile tissue and this must be arranged according to some definite plan. In most motor tubes, two layers of muscle are sufficient, an external longitudinal and internal circular. In a few tubes three layers are found. Of the two layers the external longitudinal by contraction shortens the tube and makes it rigid while the internal circular by a wave of contraction from above downward propels the contents toward the lower end of the tube. In the cardiac stomach the internal oblique layer of muscle is composed of a few radiating strands over the fundus, the effect of which is not important. The layers of muscles are joined together by a thin connective tissue which carries small blood and

lymph vessels and a plexus of nerves called the plexus of Auerbach. In the pyloric end of the stomach the internal circular layer is thickened to form the *sphincter pylori*. The character of the contents of a tube governs the amount of muscle which it contains and when the contents consist of a small amount of liquid, ciliary motion is sufficient. The contents of the four-coated tube are large. There is no force behind them and therefore a well-developed muscular apparatus must be provided in order to move the contents from one end of it to the other.

3. *Subepithelial coat*.—This is composed of areolar tissue which joins the muscular and epithelial coats and contains blood vessels, lymphatics, a plexus of nerves called the plexus of Meissner, and in two places, *viz.*, oesophagus and duodenum, secreting glands. While this coat unites the epithelial and muscular coats it allows freedom of motion of the former upon the latter on account of its areolar character. It is widest in the stomach and the epithelial coat is more freely movable than in other parts. It contains parts of Peyer's patches which are confined to the lower portion of the small intestine and which extend into the epithelial coat.

4. *Epithelial coat*.—This coat is also called mucous membrane or *mucosa*. The term epithelial coat is preferred because it does not lead one to think that its chief function is mucin producing, but may be any secreting function. It is made up of a *muscularis mucosae* which is composed of two very thin layers, an external longitudinal and internal circular, of smooth muscle, and of a connective tissue base, containing in some places diffuse masses of lymphoid tissue, as in the stomach, in others, as small and large intestines, solitary glands and parts of Peyer's patches, blood and lymph vessels. Resting upon the latter is a stratified pavement epithelium as in the oesophagus, or embedded within it gastric glands as in the stomach, crypts of Lieberkühn and villi as in the small intestine, crypts of Lieberkühn with many goblet cells as in the large intestine, and lymphoid tissue in which are incomplete crypts as in the vermiform appendix. The *muscularis mucosae* distinguishes this type of tube from all others. In the examination of a section if we find it we know we are examining a four-coated tube and that this belongs only to the alimentary canal.

The *muscularis mucosae* is required in this tube for the proper adjustment of the epithelial structure to the moving contents and for

the purpose of shortening the villi of the small intestine, as a result of which the contents of the central lacteals are set in motion. There is perhaps no other tube in which the adaptive function of the *muscularis mucosae* would be of any advantage to the tube because there is no other tube having the same character of contents. If there was no *muscularis mucosae* in the alimentary canal the epithelial lining would be pouched by the driving force of the muscular coat and having no means of withdrawing itself would be torn.

The four-coated tube then is a motor tube adapted to the progressive motion of its contents and also to the application of its epithelial lining to the contents. The various organs which belong to this tube together with their structures are given in the following outlines. (Table A.)

CONSTRUCTIVE METHOD

Since so many of the organs of the body are tubes and the walls of the tubes are composed of coats and layers, a constructive method of learning these structures may be employed. The various coats and layers are all drawn on the same curve, printed and cut out of suitable material. By placing these parts together according to the arrangements in the outlines the different organs of the tube formation may be constructed. It is believed that the actual construction of an organ by means of its parts fixes it in the mind as a reality. The simple matter of handling the coats and layers and placing them in the positions which they naturally occupy discloses a plan of structure and furnishes a reason for many of their actions.

Thus, referring to Plate IX, if we take 14, 11, 8, 4, 6, 9 and 10, and arrange them according to the outline of a four-coated tube we shall have the pyloric end of the stomach. (See Plate XIV, fig. 1.) In a similar manner any tube may be constructed. The numbers at the ends of the coats in the plates are for convenience in the illustration of the method and the order is not significant; thus fig. 11 indicates the external longitudinal smooth muscle. The fine details of structure are to be worked out in the laboratory. The object of this method is to give as much prominence to the plan of formation as to the tissues and cells, and this can be accomplished better by the building process than by any other. Connective tissue, smooth muscle, epithelium, blood vessels, nerves, and lymphatics do not make a stomach unless they are arranged according to a definite design,

and the design is as important as the tissues. The models are made on a general formula, that is, the connective tissue coat, smooth muscle, *muscularis mucosae*, and subepithelial coats may be used to build up any tube containing these parts. The teacher will call attention to variations. After constructing the tubes according to the outlines the microscopical section is examined in detail. The outlines give a word picture of the structure, the models the design of the structure, and the microscopic section the real structure. From the structure and function of the four-coated tube it is evident that some variation in structure will be necessary in order to adapt other tubes to different functions. There is no other class of tube in which a *muscularis mucosae* is necessary, inasmuch as the contents of all other tubes are small in amount and liquid in character, without undissolved masses, except perhaps the uterus in labor, and therefore the adaptation of the epithelial lining would not be required.

OTHER TUBE CLASSES

If the *muscularis mucosae* is taken from the four-coated tube there is nothing to separate the epithelial coat from the sub-epithelial and hence the epithelial coat with the connective tissue coat underneath it may be considered as one. This makes a three-coated tube. It is a three-coated tube in function as well as structure. It is still a motor tube and has two sets of motor apparatus, *viz.*, smooth muscular coat and cilia. The muscular coat may have one, two, or three layers. The uterus, vas deferens, lower ureter, and bladder have three layers; the Fallopian tube, vagina, epididymis, seminal vesicle, upper ureter, and any large duct, have two layers; the artery, vein, and large lymphatic, one. The larger blood vessels do not have the definite coated arrangement, but have smooth muscle and elastic tissue intermixed. The Fallopian tube, uterus, epididymis, vas deferens, and bronchus have cilia and hence are provided with the two sets of motor apparatus. The presence of a muscular coat in the walls of these tubes shows that their contents are continually or intermittently in motion and that considerable force may be required to move the contents. The presence of a ciliated lining in some of them shows that the contents may be very small and very little force is required to move them. The presence of both muscle and cilia shows that the contents may be large and moved with difficulty, or small and easily moved. The circulatory tubes differ from other tubes in this re-

spect—that their contents are propelled by a force from behind and hence the muscular coat arrangement is not necessary. In none of these tubes would a *muscularis mucosae* be of any use. In the blood vessels and bladder a hydrostatic pressure exerted in all directions would not demand local adaptation of the enclosing surface. In the genital and respiratory tubes, epithelial adaptation to contents at ordinary times would do nothing and at the times when the muscular coat was at work could accomplish nothing. The epithelial coat has a connective tissue foundation and carries blood vessels, nerves, and lymphatics; but in no case, secreting glands. The epithelium varies according to the location of the tube. Nearly all varieties are found. The outside connective-tissue coat may contain plates of hyaline cartilage and secreting glands as in the bronchi. Here open tubes are required. The systems and organs which belong to the three-coated tube may be found in the following outline: (See Table B.)

The eye is a modified adaptation of the three-coated tube. Its diameters are nearly equal as the organ is nearly spherical. It is a combination of the segments of two spheres of different curvatures. It is not a motor tube and therefore has no regular muscular coat. However the three-coated tube arrangement is still preserved, as appears in the table following. (Table C, upper part.)

Plate X represents the structures in the outline of a three-coated tube. These organs may be built up by using the coats and layers of both plates. For example, place in order of outlines, Pl. IX, figs. 14, 11, 8; Pl. XI, figs. 25, 31, and the organ will be the epididymis. (See fig. 2, Pl. XIV.)

This completes the muscular tubes. If all the muscular layers be taken from the three-coated tube there will remain the epithelial and connective tissue coats. If C-shaped rings of hyaline cartilage are introduced into the connective tissue coat which also contains secreting glands, a two-coated tube will be formed. To this class belong the trachea and large bronchi, as is seen in the outline which follows. (Table C, lower part.)

These organs may be built up as follows: Pl. X, fig. 15, and Pl. XI, figs. 33 and 27. (See fig. 3, Pl. XIV.) The essential requirements of this class of tubes are that it be constantly kept open, and that the very small liquid contents be moved toward the upper end. The first requirement is made possible by cartilaginous rings, the second by the ciliated epithelial lining. Between the ends of the

cartilage rings, a very little smooth muscle is found arranged in longitudinal and transverse layers. This muscle however evidently takes no part in the propulsion of the contents. If the cartilage is taken from the two-coated tube a single coat of two layers will remain which may be designated as a one-coated tube. This tube is composed of an epithelial layer on a basement membrane or upon a base of connective tissue containing blood vessels, nerves, and lymphatics, with or without secreting glands. These tubes are generally small and constitute the structural units of many organs. They may be united by connective tissue and form organs such as the kidney, testicle, ovary, secreting glands, lung, or may be in large expanded areas as in the skin and serous membranes, or may be in the form of a prolonged tube enclosed in a bony canal as in the ear. They form the *tubuli seminiferi*, Graafian follicle, *tubuli uriniferi*, capsule of Bowman, alveoli of lungs, acini of secreting glands, small ducts, skin, hair follicle, serous membranes, and vestibule, utriculus, sacculus, semi-circular canals, and cochlea of the ear. The ear may be considered a coiled tube mostly enclosed in bone. This type of tube is adapted by structure to the function of secretion and special sense. Secreting glands are all constructed upon the same plan, *viz.*: a basement membrane with the circulation on one side of it, and epithelium on the other. This brings the epithelium as near as possible to the blood, a condition of structure absolutely essential for the act of secretion. A structureless basement membrane represents the smallest supporting structure which can be placed between a cell and its blood supply. What is true in regard to glandular structure is also true concerning structures of special sense. It is as essential that neuro-epithelium should be close to the blood stream as it is that secreting epithelium should be. All highly organized cells require such positions. The various organs which belong to this tube are given in the following outline: (See Table D.)

Place in the order of the outline of a one-coated tube, Pl. XI, fig. 33, and Pl. XIII, fig. 60, and the organ will be a secreting gland (see Pl. XIV, fig. 4). If the basement membrane and connective tissue are taken from the single-coated tube, the epithelium remains and this is always simple pavement and forms the single layer class of tube. It is the simplest tube in the body and to it belong the blood and lymph capillaries. It is composed of one layer of pavement epithelial cells which are united by cement (see Pl. XIV, fig. 5).

This is the thinnest structure which can be placed between two liquids and hence is best adapted to osmotic conditions and the processes of cell nutrition. (See outline which follows. Table D, latter part.) Looking over these five classes of tubes it may be seen that structurally

A four-coated tube minus a *muscularis mucosae* is a three-coated tube.

A three-coated tube minus its muscular coat and plus cartilage rings is a two-coated tube.

A two-coated tube minus its cartilage is a one-coated tube.

A one-coated tube minus its basement structures is a one-layer tube; that is, the *muscularis mucosae*, muscular coat, cartilage rings, and basement structures are the differentiating structures in the walls of tubes. There still remain certain parts of the body which apparently, at least, do not conform to the tube plan of structure. These parts are the nervous system, thymus, spleen, lymph nodes, and adrenals.

"In the development of the cerebro-spinal system the rudimentary part is formed from the thickened medullary parts of the involuted epiblast, the ridges of which rising from the surface of the epiblast, are united dorsally along the middle line so as to form a hollow medullary tube. This tube is wider at its anterior or cephalic extremity and this dilated portion is divided by partial constrictions into three primary cerebral vesicles which represent the anterior, middle, and posterior divisions of the brain. The spinal portion retains a more uniform cylindrical shape. The continuous cavity enclosed within the primitive medullary tube is the same with that which constitutes the central ventricles of the brain and central canal of the spinal cord." (Quain's Anatomy.) Thus the brain during its early existence is the dilated anterior portion of the primary medullated tube derived from an indentation of the epiblast and the spinal cord is the remainder of that tube. In the adult the central ventricles of the brain and canal of the spinal cord still remain, showing that a tube plan is the plan of formation, although many structural additions and modifications have been made. The ventricles and central canal are lined with simple ciliated epithelium (fifth ventricle lined with simple pavement). Structurally then the brain and cord are covered on the outside by a connective tissue layer (*pia mater*) and are lined with a simple epithelium like certain other

tubes. Functionally the tubular character is not so clearly marked. The brain is composed of an external layer of gray matter which generates impulses and an internal core of white matter which conducts those impulses. In the spinal cord this arrangement is reversed. Both are enclosed with a covering of bone. If both the brain and cord were solid, that is, had no central canal, an increased or decreased blood supply would produce pressure upon nervous tissue and inhibit their actions and cause a termination of nervous phenomena. A central canal is essential to the volumetric increase and decrease of these organs; so that, although the functions of these organs do not depend upon the specific character of the tube as in other organs of the five tube classes, yet structurally the tube plan is essential to the successful performance of function.

The thymus in its early development is almost like an epithelial gland and during that stage of development would be classified among the tube structures of the body like any other true gland: but about the end of the second year following birth it begins to retrograde and when the age of puberty is reached an adenoid structure has displaced the epithelium and atrophy reduces the organ to an inactive condition. Therefore during its active period it belongs to the secreting glands and to the one-coated tubes. During its retrogressive period it is not tubular.

Apparently the spleen does not belong to the tube organs. However it seems to be a vascular body structurally and functionally, for if its vascular tubes are not considered in its plan of structure the remaining parts are reduced to blood cells. Its trabeculae of smooth muscle suggest a relationship of force pump to the liver and the spleen would belong to the three-coated tubes.

The lymph nodes are composed of masses of lymphoid tissue around which are channels through which the lymph passes. These channels or sinuses are lined with endothelium which also lines the inner surface of the capsule and outer surface of the trabeculae; so that the channels are widened parts of the lymph vessels within the nodes. This places them under the one-layer tubes. As far as function is concerned the parts outside of the channels are reduced to the functions of lymphoid tissue or leucocytes.

The adrenals are composed of cells arranged in different ways according to the zones which characterize the structure. A tube plan is not sufficiently apparent in these organs to place them under a tube system.

CONCLUSIONS

That a proper conception of a tube is essential to the comprehension of an organ.

That design is as important as tissue or cell.

That most of the organs of the body can be arranged under five tube classes, *viz.*: four-coated, three-coated, two-coated, single-coated, and one-layer tubes.

That four-coated tubes are adapted to the progressive motion of their contents and to the application of their epithelial structures to the contents.

That three-coated tubes are adapted to the progressive motion of their contents when necessary.

That two-coated tubes are adapted to conditions which require open tubes.

That single-coated tubes are adapted to functions of secretion and special sense.

That one-layer tubes are adapted to osmotic conditions.

That these tubes can be constructed by models and the constructive process is a great help to the beginner.

TABLE A

		System	Four Coats	Organs		Duodenum					
				Upper Half of the Oesophagus	Lower Half of the Oesophagus						
<p>Characterized by an epithelial structure on a connective tissue base and a <i>muscularis mesenter</i> — a sub-epithelial coat enclosing blood and lymph vessels, nerves, with or without secreting glands, a muscular coat of two or three layers, and a connective tissue coat</p> <p style="text-align: center;"><i>Four-coated Tube</i></p>	<p>Alimentary</p>	<p>4. Epithelial</p> <p>3. Sub-epithelial</p> <p>2. Muscular</p> <p>1. Fibrous serous</p>	<p>3. <i>Stratified pavement epithelium</i></p> <p>2. Connective tissue base, blood and lymph vessels</p> <p>1. <i>Muscularis mucosa</i></p>	<p>3. <i>Stratified pavement epithelium</i></p> <p>2. Connective tissue base, blood and lymph vessels</p> <p>1. <i>Muscularis mucosa</i></p>	<p>4. <i>Villi</i></p> <p>3. <i>Crypts, goblet cells</i></p> <p>2. Connective tissue base, blood and lymph vessels, lymphoid tissue, solitary glands</p> <p>1. <i>Muscularis mucosa, two layers</i></p>	<p>4. <i>Villi</i></p> <p>3. <i>Crypts, goblet cells</i></p> <p>2. Connective tissue base, blood and lymph vessels, lymphoid tissue, solitary glands</p> <p>1. <i>Muscularis mucosa, two layers</i></p>					
							<p>2. Muscular</p>	<p>2. Internal circular <i>striated voluntary</i></p> <p>1. External longitudinal <i>striated voluntary</i></p>	<p>2. Internal circular <i>smooth</i></p> <p>1. External longitudinal <i>smooth</i></p>	<p>2. Internal circular <i>smooth</i></p> <p>1. External longitudinal <i>smooth</i></p>	<p>2. Internal circular <i>smooth</i></p> <p>1. External longitudinal <i>smooth</i></p>
							<p>Connective tissue</p>	<p>Connective tissue</p>	<p>Connective tissue</p>	<p>Connective tissue</p>	

TABLE A, Continued

		Organs				
Four Coats		Cardiac End of the Stomach	Pyloric End of the Stomach	Jejunum and Ileum	Large Intestine	Verriform Appendix
Four-coated Tube (Continued)	4. Epithelial	3. Compound tubular glands { Short necks and Long parietal cells } Chief and Short bodies alone 2. Connective tissue base, blood and lymph vessels, and lymphoid tissue 1. Muscularis mucosae, two layers	3. Compound tubular glands { Long necks } Chief cells alone 2. Connective tissue base, blood and lymph vessels, and lymphoid tissue 1. Muscularis mucosae, two layers	4. Villi 3. Crypts, goblet cells 2. Connective tissue base, blood and lymph vessels, solitary glands, and Peyer's patches 1. Muscularis mucosae, two layers	3. Crypts, goblet cells 2. Connective tissue base, blood and lymph vessels, solitary glands 1. Muscularis mucosae, two layers	3. Incomplete types 2. Large amount of lymphoid tissue in nodules and diffuse masses 1. Muscularis mucosae
	3. Sub-epithelial	Loose areolar tissue, enclosing blood vessels, lymphatics, and nerves	Loose areolar tissue, enclosing blood vessels, lymphatics, and nerves	Areolar tissue, enclosing nerves, blood vessels, and lymphatics	Areolar tissue, enclosing nerves, blood vessels, and lymphatics	Areolar tissue, enclosing nerves, blood vessels, and lymphatics
	2. Muscular	3. Internal oblique smooth 2. Middle circular smooth 1. External longitudinal smooth	2. Internal circular thick smooths 1. External longitudinal smooth	2. Internal circular smooth 1. External longitudinal smooth	2. Internal circular smooth 1. External longitudinal smooth	2. Internal circular smooth 1. External longitudinal smooth, poorly developed
	1. Fibrous Serous	Connective tissue	Connective tissue	Connective tissue	Connective tissue	Connective tissue

TABLE B

	Systems	Three Coats	Fallopian Tube	Organs	Vagina
<p>Characterized by an epithelial structure on a connective tissue base containing blood and lymph vessels, nerves, with or without secreting glands; a muscular coat of one, two, or three layers, and a fibrous coat with or without cartilage and secreting glands</p> <p><i>Three-coated Tube</i></p>	<p>Large genital, urinary, respiratory, vascular, eye</p>	<p>3. Epithelial</p> <p>2. Muscular</p> <p>1. Fibrous</p>	<p>2. <i>Simple ciliated epithelium in folds</i></p> <p>1. Connective tissue cellular base, blood vessels, nerves, and lymphatics</p>	<p>2. <i>Simple ciliated epithelium in tubular glands</i></p> <p>1. Connective tissue cellular base thick, blood vessels, nerves, and lymphatics</p>	<p>2. <i>Stratified pavement epithelium, which also lines one half of the cervix uteri</i></p> <p>1. Fibrous and elastic tissue, with secreting glands</p>
			<p>2. <i>Internal circular, smooth</i></p> <p>1. <i>External longitudinal, smooth</i></p>	<p>3. <i>Internal longitudinal, smooth</i></p> <p>2. <i>Thick, middle, vascular circular, or oblique smooth</i></p> <p>1. <i>External longitudinal, smooth</i></p>	<p>2. <i>Internal circular, smooth</i></p> <p>1. <i>External longitudinal, smooth</i></p>

Connective tissue or serous coat

Connective tissue serous

Connective tissue, or serous coat

Connective tissue

TABLE B, Continued

		Organs				
Three Coats		Vasa Efferentia of Testicle	Epididymis	Vas Deferens	Ureter	Bladder
3. Epithelial	{	Stratified ciliated, alternating with stratified columnar epithelium	2. Stratified columnar ciliated epithelium	2. Partly simple ciliated and partly stratified ciliated columnar epithelium	2. Stratified transitional epithelium	2. Stratified transitional epithelium
			1. Fibrous and elastic tissue	1. Fibrous and elastic tissue	1. Areolar tissue with nerves, blood vessels, few lymphatics	1. Areolar tissue with nerves, blood vessels, few lymphatics
2. Muscular	{	2. Internal circular, smooth	2. Internal circular, smooth		2. Internal longitudinal, smooth	
			1. Thin external longitudinal, smooth		1. External circular, smooth	1. External longitudinal, smooth
1. Fibrous	{	Connective tissue	Connective tissue	Connective tissue	Connective tissue, serous	Connective tissue, serous
			Connective tissue	Connective tissue	Connective tissue, serous	Connective tissue, serous

Three-coated Tube (Continued)

TABLE B, Continued

		Organs				Bronchus Less Than 3 mm. in Diameter
Three Coats	Artery	Vein	Lymphatic	Medium Bronchus		
3. Epithelial	3. Endothelium	3. Endothelium		3. Stratified ciliated epithelium		
	2. Connective tissue base	2. Very thin base of connective tissue	2. Endothelium	2. Basement membrane	2. Ciliated epithelium gradually changing to respiratory as the bronchus approaches the air cell	
2. Muscular	1. Penetrated membrane of Henle	1. Incomplete fenestrated membrane of Henle	1. Connective tissue base with few elastic fibers	1. Areolar tissue with blood vessels, nerves, lymphoid tissue	1. Basement membrane	
	A single circular layer of smooth muscle, which in the aorta and large vessels is arranged in alternating layers of elastic tissue and smooth muscle	A thin circular layer of smooth muscle	A single layer of smooth muscle circularly and obliquely arranged	1. Areolar tissue, enclosing nerves, blood vessels, lymphatics, and secreting glands	Single layer of smooth muscle	
1. Fibrous	Connective tissue	Connective tissue	Connective tissue	Fibrous tissue enclosing plates of hyaline cartilage	Connective tissue	

Three-coated Tube (Continued)

TABLE B, Continued

	Three Coats	Organs		
		Large Ducts	Seminal Vesicles	Corpus Spongiosum of Penis
Three-coated Tube (Continued)	3. Epithelial	2. <i>Simple columnar epithelium</i>	2. <i>Pseudo-stratified columnar epithelium</i>	Prostatic— <i>Transitional epithelium</i>
		1. Connective tissue with blood vessels, nerves, lymphatics	1. Connective tissue with blood vessels, nerves, lymphatics	Membranous— <i>Stratified columnar</i>
	2. Muscular	2. <i>Internal circular, smooth</i>	2. <i>Internal circular, smooth</i>	Meatus— <i>Stratified potential</i>
		1. <i>External longitudinal, smooth</i>	1. <i>External longitudinal, smooth</i>	<i>Erectile tissue, consisting of trabeculae, connective tissue, elastic fibers, and smooth muscle, enclosing a communicating system of spaces</i>
1. Fibrous	Connective tissue	Connective tissue	Dense connective tissue	

TABLE C

A Modified Adaptation of the Tube		Organs
Three Coats	System	Two Coats
<p>Eye</p> <p>3. Epithelial</p> <p>2. Musculo-vascular</p> <p>1. Fibrous</p>	<p>Ratna</p> <p>Choroid</p> <p>Sciera</p> <p>Connective tissue</p>	<p>Trachea and Large Bronchi</p> <p>Trachea, large bronchi</p>
<p>10. Pigment layer of epithelium</p> <p>9. Layer of rods and cones</p> <p>8. External limiting membrane</p> <p>7. Outer nuclear layer</p> <p>6. Outer molecular layer</p> <p>5. Inner nuclear layer</p> <p>4. Inner molecular layer</p> <p>3. Layer of nerve cells</p> <p>2. Layer of nerve fibers</p> <p>1. Internal limiting membrane</p>	<p>4. Vitreous membrane</p> <p>3. Lamina choriocapillaris</p> <p>2. Lamina vasculosa</p> <p>1. Lamina suprachoroidea</p> <p>Ciliary body</p> <p>5. Pigmented epithelium</p> <p>4. Ciliary processes</p> <p>3. Ciliary muscles</p> <p>2. Blood vessels</p> <p>1. Connective tissue</p> <p>5. Simple cubical epithelium</p> <p>4. Posterior elastic lamina</p> <p>3. Tunica propria</p> <p>2. Anterior elastic lamina</p> <p>1. Stratified pavement epithelium</p>	<p>3. Posterior vitreous layer</p> <p>2. Connective tissue and ciliary muscle</p> <p>1. Anterior epithelium</p> <p>Iris</p> <p>3. Stratified ciliated epithelium</p> <p>2. Basement membrane</p> <p>1. Areolar tissue, in which are blood vessels, nerves, lymphatics, masses of lymphoid tissue</p> <p>Fibrous tissue, enclosing C-shaped rings of hyaline cartilage and secreting glands. Thin longitudinal and transverse muscles between ends of rings</p>
<p>3. Vitreous humor</p> <p>2. Crystalline lens</p> <p>1. Aqueous humor</p>	<p>3. Posterior vitreous layer</p> <p>2. Connective tissue and ciliary muscle</p> <p>1. Anterior epithelium</p> <p>Iris</p> <p>3. Stratified ciliated epithelium</p> <p>2. Basement membrane</p> <p>1. Areolar tissue, in which are blood vessels, nerves, lymphatics, masses of lymphoid tissue</p> <p>Fibrous tissue, enclosing C-shaped rings of hyaline cartilage and secreting glands. Thin longitudinal and transverse muscles between ends of rings</p>	<p>3. Stratified ciliated epithelium</p> <p>2. Basement membrane</p> <p>1. Areolar tissue, in which are blood vessels, nerves, lymphatics, masses of lymphoid tissue</p> <p>Fibrous tissue, enclosing C-shaped rings of hyaline cartilage and secreting glands. Thin longitudinal and transverse muscles between ends of rings</p>

Three-coated Tube

TABLE D, Continued

		Organs					
		Secreting Glands					
One Coat with Two Layers	Acini or Tubular Units of Structure	Lobules	Lobes	Secreting Glands	Secreting Glands of the Body		
a. Epithelium	{ Simple Polyserial, Polyserial, Columnar or Cubical }	Acini or tubular units of structure united by connective tissue containing blood vessels, nerves, and lymphatics	Lobules united by connective tissue containing blood vessels, nerves, and lymphatics	Lobes united by connective tissue containing blood vessels, nerves, and lymphatics	Thyroid, Parotid, Submaxillary, Sublingual, Glands in the subepithelial coats of organs, Compound tubular glands of stomach, Crypts of Lieberkühn, Liver, Pancreas, Sweat glands, Sebaceous, Mammary, Meibomian, Lacrymal, Prostate, Cowper's, Nishitshian, Bartholin		
b. Basement	{ Structureless Membrane }						
One Coat with Two Layers	Air Cells or Alveoli	Lang	Lang	Graafian Follicles	Ovary		
a. Epithelium	{ Simple Pavement, Epithelium of two Varieties— Clear and Granular }	Air cells or alveoli united by connective tissue containing blood vessels, nerves, and lymphatics		3. <i>Ovum</i> 2. <i>Dicous</i> <i>ovus</i> 1. <i>Membrana</i> <i>Granulosa</i>	Graafian follicles united by connective tissue containing blood vessels, lymphatics, nerves, and surrounded by germinal cells		
b. Basement	{ Interstitial, Fibrous and Elastic tissue }			Theca Folliculi— a wall derived from the strona			

One-coated Tube (Continued)

TABLE D, Continued

One Coat with two Layers	Small Ducts	Hair Follicle	Organs	Skin
a. Epithelial	Low Columnar or Cubical Epithelium	Int. root sheath Ext. root sheath Hyaline layer	Stratified pavement epithelium as— <i>Stratum corneum</i> <i>Stratum lucidum</i> <i>Stratum granulosum</i> <i>Stratum mucosum</i>	Epidermis
b. Basement	Structureless membrane	One or two layers of connective tissue	Fibrous and elastic tissues with blood vessels, lymphatics, nerves, nerve terminations, and <i>secreting glands</i>	Dermis
One-coated Tube (Continued)				
Middle Ear				
Tympanum				
Eustachian Tubes				
Internal Ear				
Vestibule-Utriculus-Sacculus				
Macula utriculi				
Remaining part				
Dense connective tissue				

TABLE D, Continued

		Organs	
		Internal Ear	
		Semicircular Canals	Cochlea
One Coat of Two Layers	a. Epithelial	{ Crista of ampulla Remaining part	{ Hair cells Sustentacular cells Simple Pavement epithelium
	b. Basement	Connective tissue	{ Scala vestibuli Scala media Scala tympani Connective tissue
One-coated Tube (Continued)	a. Epithelial	{ 2. Respiratory part 1. Olfactory part	{ 3. Stratified ciliated epithelium 2. Goblet cells 1. Racemose glands 2. Olfactory cells 1. Sustentacular cells
	b. Basement	Connective tissue	{ Serous Membranes Endothelium between cells of which are found Stigmata and Stomata
One-layer Tube	{ Characterized by a single layer of epithelial cells joined together by cement	Systems	One Layer
		Capillaries	Capillaries
		Small vascular and lymph	a. Epithelial
			Simple, Pavement, or Endothelium
		Connective tissue rich in lymph spaces, lymph capillaries, and lymph vessels	

EXPLANATION OF PLATES

The plates are, to a certain extent, diagrammatic, for the sake of clearness in demonstration. It is not the purpose of this system to exhibit accuracy of structural details; but to present a constructive plan of visceral formation.

Plates IX-XIII inclusive, represent different tissues arranged in the form of layers drawn as far as possible from a general formula, with which the organs of the animal body may be constructed. The sole object is to make especially prominent the *plan* of structure. Plate XIV shows the five tube classes built up according to this system. The system is devised as a teaching method for beginners in histology.

Plate IX

- Fig. 1. Epithelium of straight tubes of kidney.
- Fig. 2. Internal longitudinal layer of smooth muscle.
- Fig. 3. Internal oblique layer of smooth muscle.
- Fig. 4. Circular smooth muscle.
- Fig. 5. Subepithelial layer with Peyer's patches.
- Fig. 6. Subepithelial layer—general.
- Fig. 7. Basement membrane, structureless.
- Fig. 8. Internal circular smooth muscle layer.
- Fig. 9. Muscularis mucosae.
- Fig. 10. Epithelial layer of pyloric stomach.
- Fig. 11. External longitudinal cross section of smooth muscle.
- Fig. 12. Internal circular striped (voluntary) muscle.
- Fig. 13. External longitudinal striped (voluntary) muscle, cross section.
- Fig. 14. Connective tissue.

Plate X

- Fig. 15. Connective tissue enclosing C-shaped rings of hyaline cartilage and secreting glands.
- Fig. 16. Connective tissue enclosing plates of hyaline cartilage and secreting glands.
- Fig. 17. Epithelial and lymphoid layer of the vermiform appendix.
- Fig. 18. Villi.
- Fig. 19. Crypts of Lieberkühn.
- Fig. 20. Epithelial layer of cardiac stomach.
- Fig. 21. Stratified pavement epithelium of oesophagus.
- Fig. 22. Subepithelial layer of duodenum.
- Fig. 23. Subepithelial layer of oesophagus.
- Fig. 24. Middle circular, vascular layer of smooth muscle.

PLATE IX

26

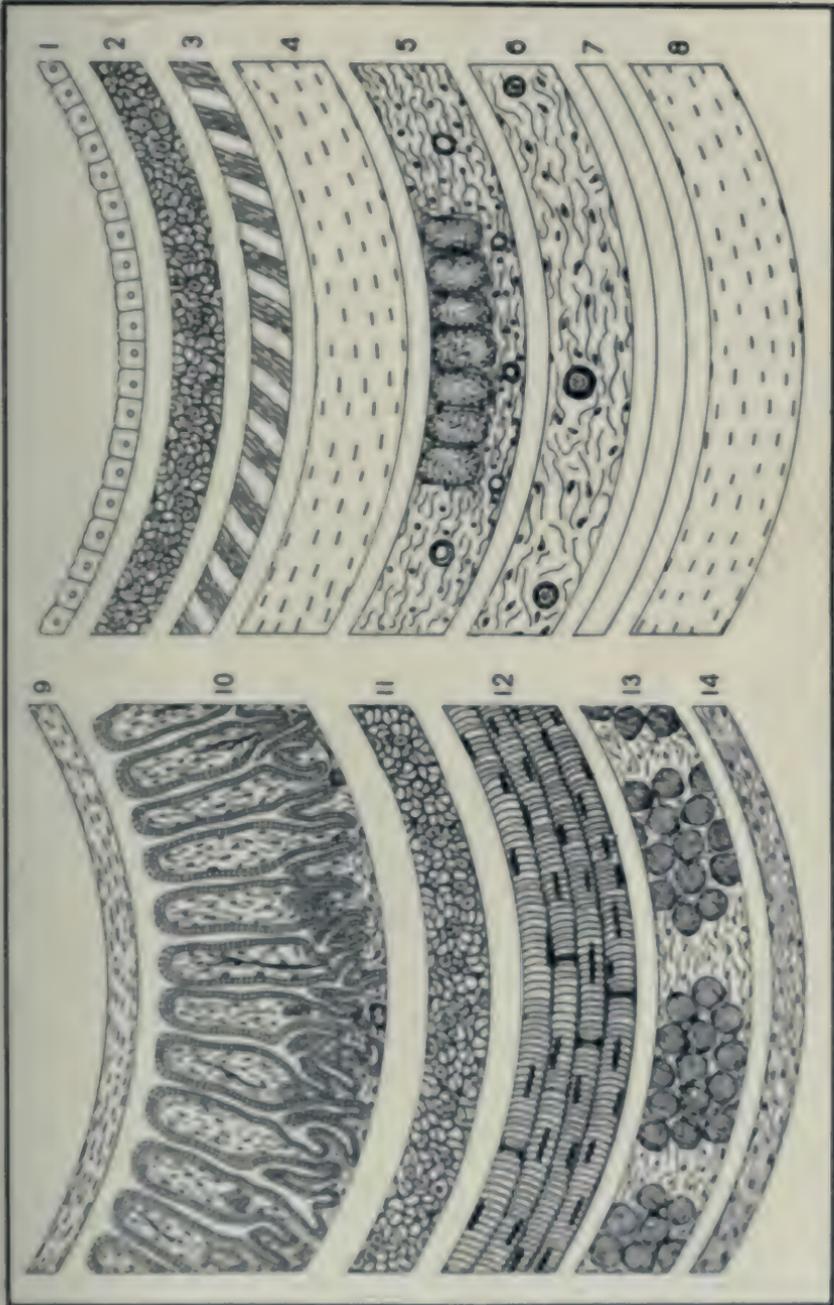


PLATE X

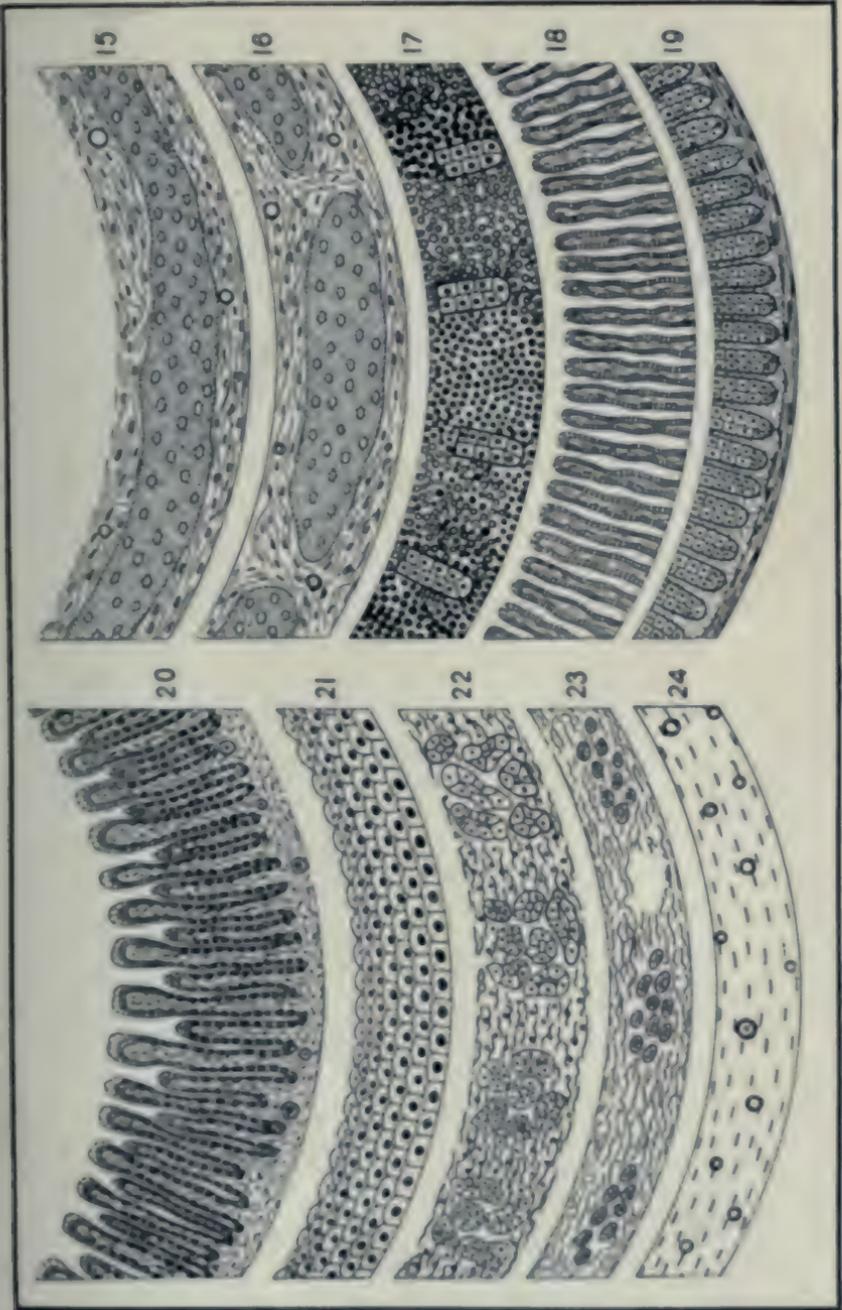


PLATE XI

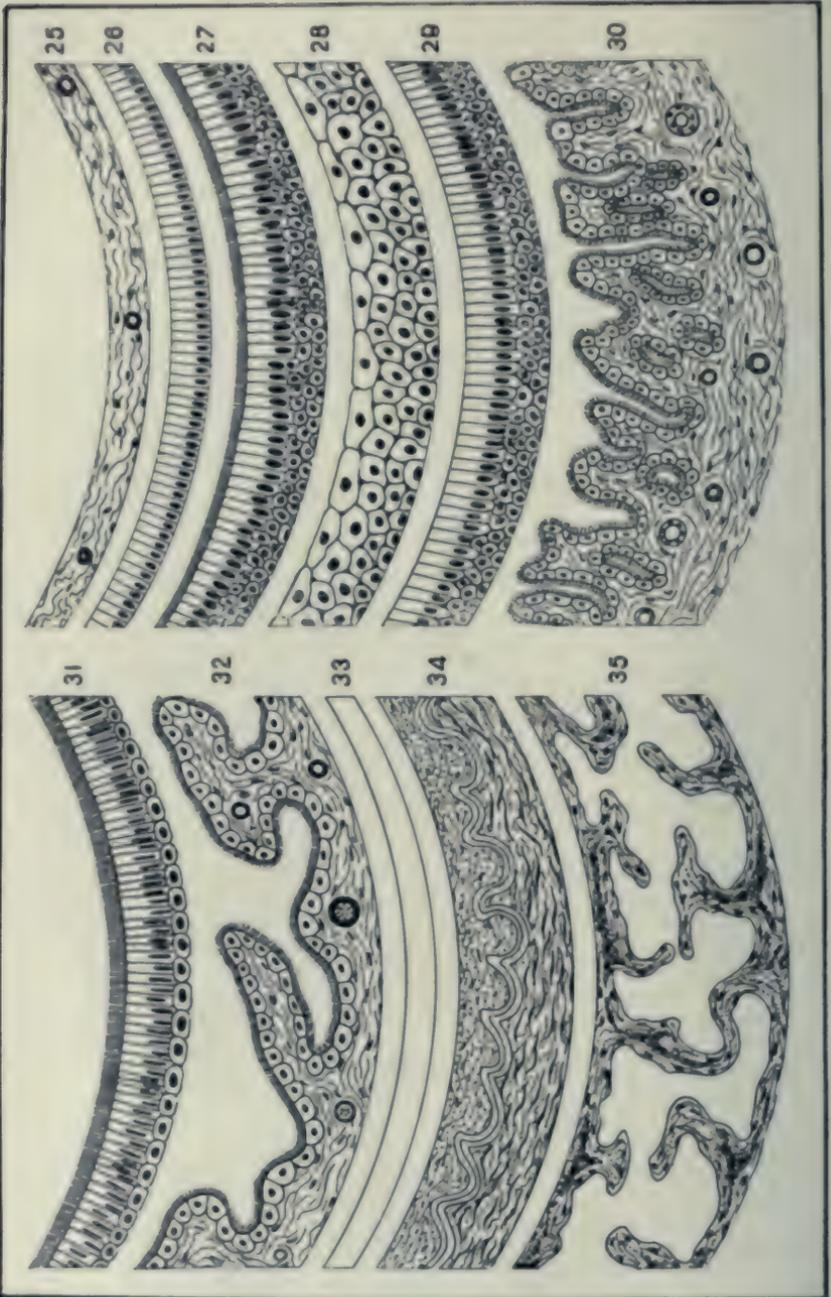
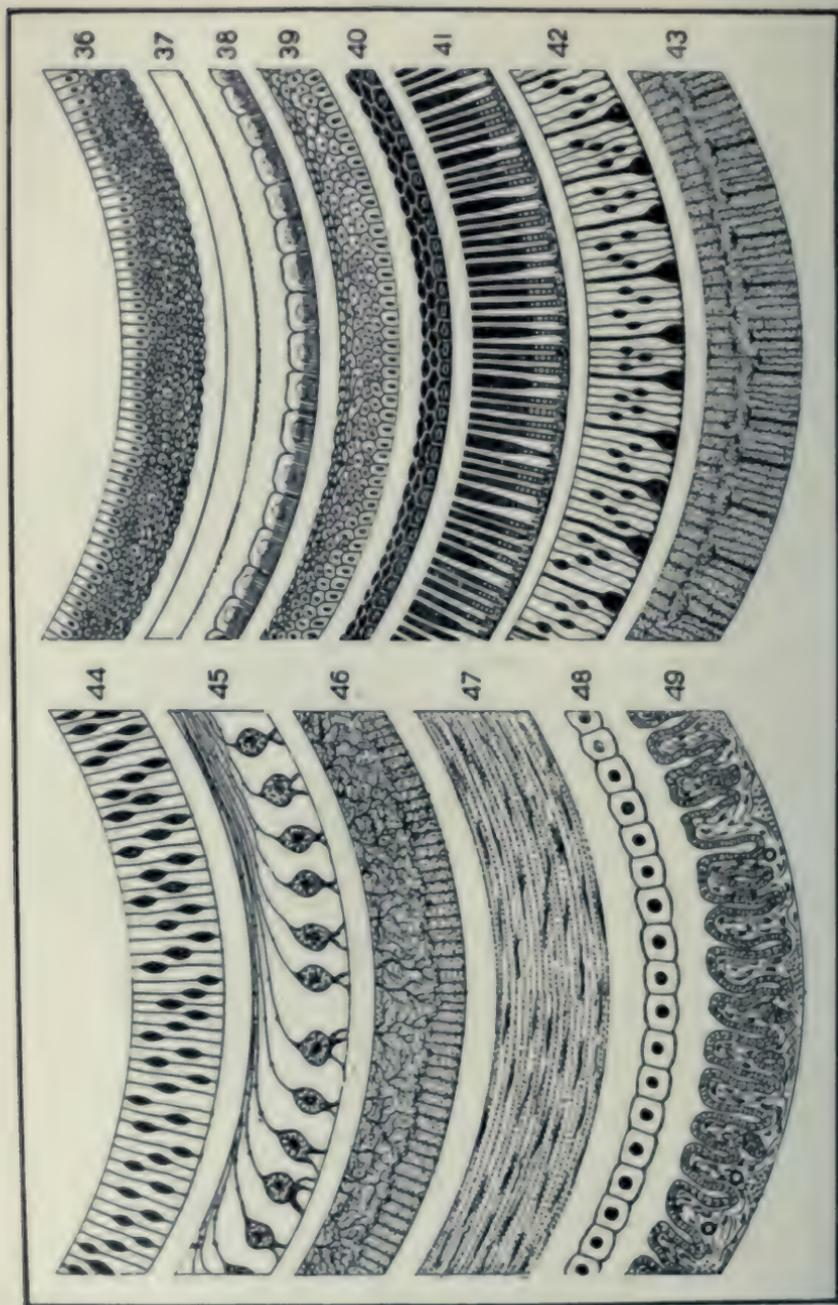


PLATE XII



25

PLATE XIII

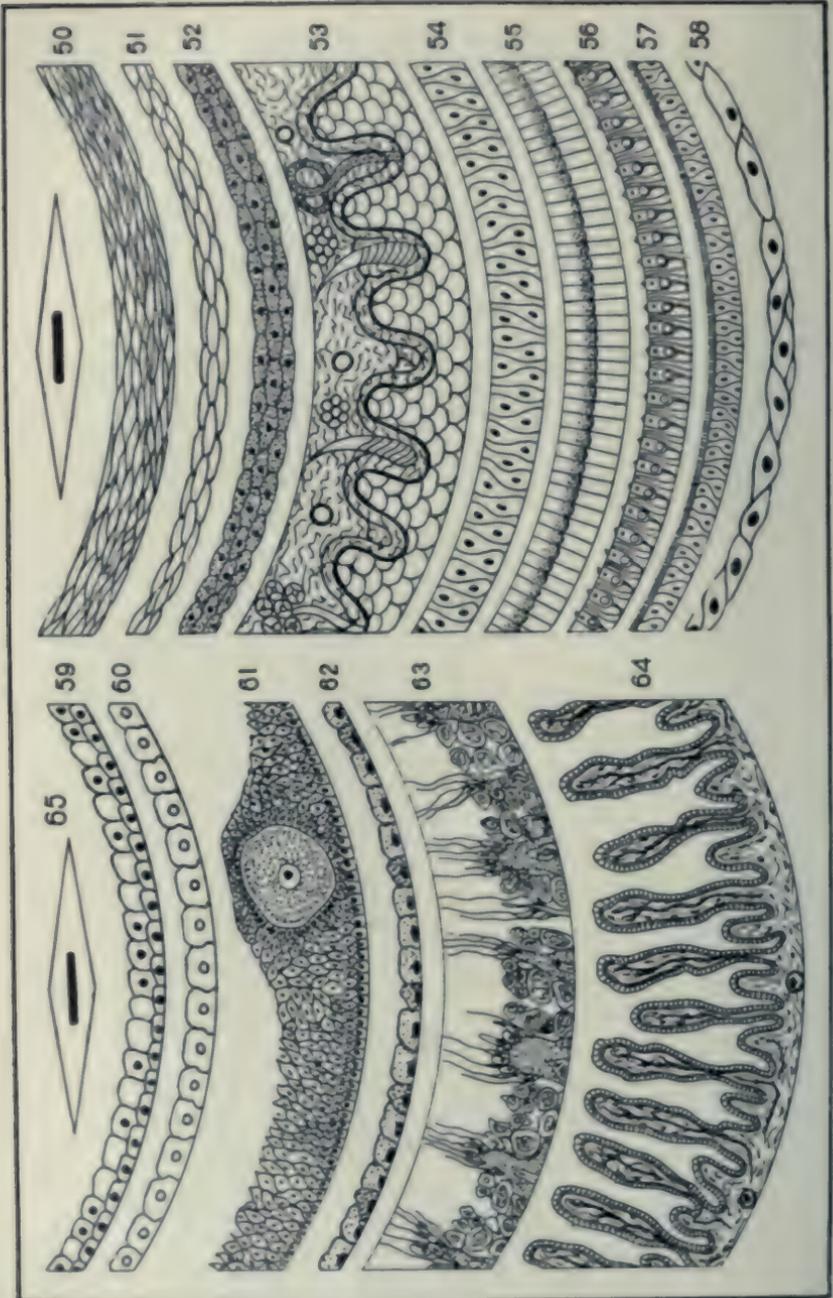


PLATE XIV

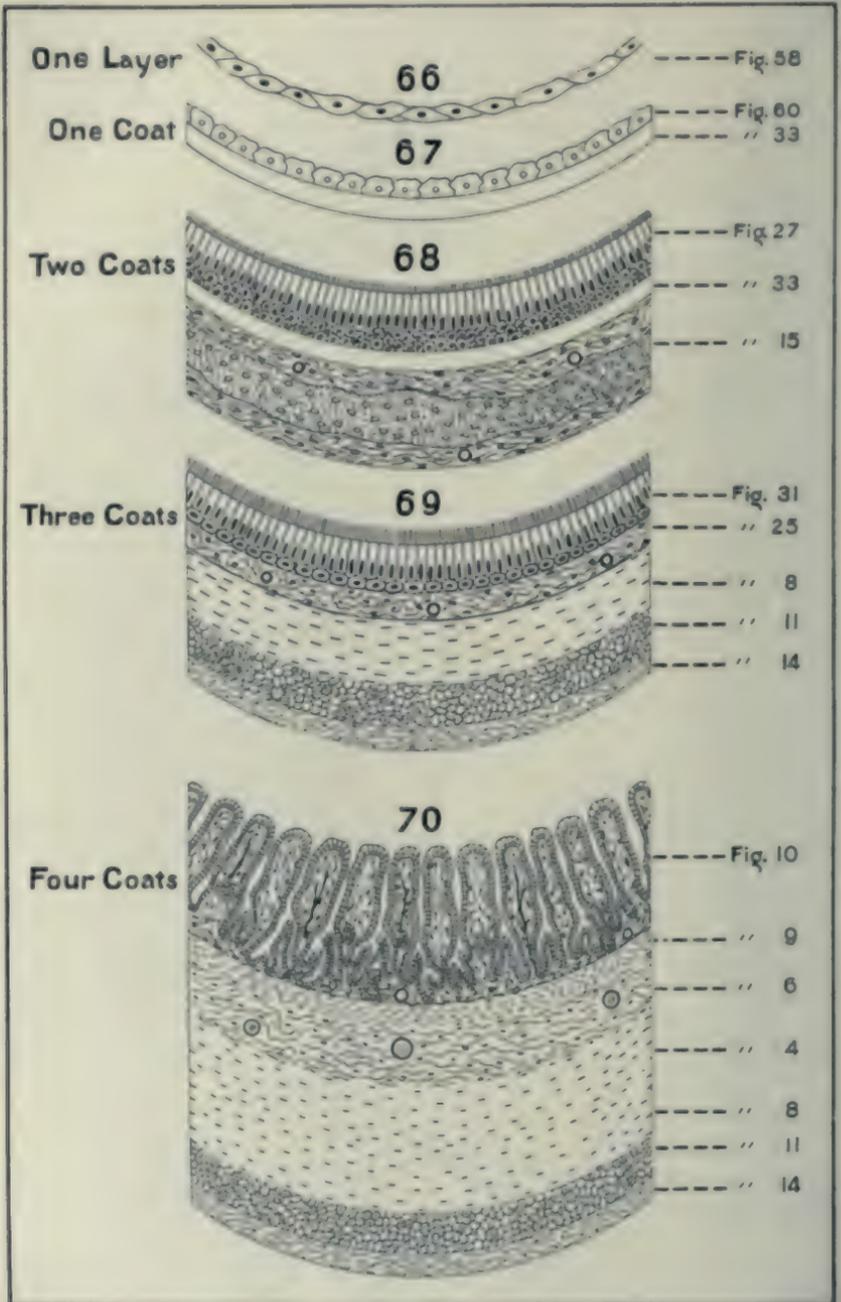


Plate XI

- Fig. 25. Connective tissue.
 Fig. 26. Simple columnar epithelium.
 Fig. 27. Stratified ciliated epithelium.
 Fig. 28. Transitional epithelium.
 Fig. 29. Stratified columnar epithelium.
 Fig. 30. Epithelial coat of uterus.
 Fig. 31. Stratified ciliated epithelium.
 Fig. 32. Epithelial coat of Fallopian tube.
 Fig. 33. Basement membrane.
 Fig. 34. Circular smooth muscle of artery, fenestrated membrane.
 Fig. 35. Erectile tissue.

Plate XII

- Fig. 36. Stratified pavement epithelium.
 Fig. 37. Elastic lamina.
 Fig. 38. Rodded epithelium of kidney.
 Fig. 39. Stratified pavement epithelium.
 Fig. 40. Pigment layer of retina.
 Fig. 41. Rods and cones of retina.
 Fig. 42. Outer nuclear layer of retina.
 Fig. 43. Outer molecular layer of retina.
 Fig. 44. Inner nuclear layer of retina.
 Fig. 45. Layer of nerve cells and fibers of retina.
 Fig. 46. Inner molecular layer of retina.
 Fig. 47. Tunica propria of cornea.
 Fig. 48. Simple cubical epithelium.
 Fig. 49. Epithelial coat of large intestine.

Plate XIII

- Fig. 50. Stratum corneum.
 Fig. 51. Stratum lucidum.
 Fig. 52. Stratum granulosum.
 Fig. 53. Dermis and epidermis.
 Fig. 54. Pseudo-stratified ciliated epithelium.
 Fig. 55. Pillar cells of ear.
 Fig. 56. Hair cells of ear.
 Fig. 57. Simple pseudo-stratified ciliated epithelium.
 Fig. 58. Endothelium—capillary.
 Fig. 59. Internal root sheath of hair follicle.
 Fig. 60. Simple polygonal glandular epithelium.
 Fig. 61. Graafian follicle.
 Fig. 62. Respiratory epithelium.
 Fig. 63. Epithelial layer of tubuli seminiferi.
 Fig. 64. Epithelial layer of small intestine.
 Fig. 65. Smooth muscle cells.

Plate XIV

The five classes of tubes are built up with the layers represented in plates IX-XIII.

THE CLASSIFICATION OF PROTOPHYTA

INCLUDING A REVISION OF THE FAMILIES, AND A REARRANGEMENT
OF THE NORTH AMERICAN GENERA

BY CHARLES E. BESSEY

Recent studies of the structure of the cell of the protophytes by Professor Kohl of Marburg¹ have given additional interest to this group of primitive plants. He has shown that instead of being composed of non-nucleated cells, they possess primitive nuclei, which develop simple karyokinetic figures during division. The nucleus is not surrounded by a nuclear membrane, and is thus not sharply set off from the surrounding cytoplasm. In the living cell its periphery is extended into many pseudopod-like protrusions which penetrate the cytoplasm, even reaching the cell wall at times. Kohl finds genuine chloroplasts imbedded in the usually bluish or brownish cytoplasm.

For many years I have been giving such attention to the general classification of the protophytes as the time at my disposal would allow, and about six years ago put my conclusions into manuscript. The recent revival of interest in the blue-green algae has suggested to me that it might be helpful to other students of these simple plants to have these results before them. The manuscript is now printed in essentially its original form. In it I have attempted to make such an arrangement of the families and genera as would conform to my ideas of their probable evolution.

I regard the group as consisting of autonomous plants, and while there may be a few which are merely forms or stages of other plants, I am convinced that the number of such is small, and further that in all such cases *they are still protophytes*. The protophyte cell is quite too characteristic to be mistaken for anything else, and we may rest assured that none of these plants are earlier stages of any of the Chlorophyceae, with their distinctly nucleated cells.

¹ Ueber die Organisation und Physiologie der Cyanophyceenzelle und die mitotische Teilung ihres Kernes, von Dr. F. G. Kohl, Professor der Botanik an der Universität Marburg. Mit 10 lithographischen Tafeln. Verlag von Gustav Fischer in Jena. 1903.

It will be observed that in the arrangement of the protophytic genera I have not separated the colorless ones from those which possess chlorophyll. In other words the "bacteria" are here regarded as merely degraded (and therefore colorless) forms of the protophyte type. In the Family *Chroococcaceae* there is one genus of such colorless plants ("bacteria"), *vis.*: *Sarcina*, whose relationship to *Merismopedia* is evident. In the *Oscillariaceae* no less than ten of the twenty-two genera are composed of colorless plants.

BRANCH I—PROTOPHYTA

Protophytes; Water Slimes

Single cells or threads of cells; reproducing by fission and endospores. Plants minute, aquatic and normally blue-green, brownish green or fuliginous, and generally surrounded by gelatinous matter. Each cell contains a primitive nucleus not surrounded by a nuclear membrane, so that it is not well defined.

CLASS I. SCHIZOPHYCEAE

Fission Algae

With the characters of the branch. About 1,000 species are known.

KEY TO THE ORDERS.

Plants strictly one-celled,

1. *Cystiphorae*.

Plants few- to many-celled, forming threads,

2. *Nematogeneae*.

Order 1. CYSTIPHORAE

One-celled Protophytes

Plants one-celled, single or associated in loose groups in a gelatinous matrix. There is but one family.

Family 1. CHROOCOCCACEAE

Blue-green Slimes

Microscopic plants with the characters of the order.

KEY TO THE GENERA.

- A. Cells globose (except in 7) dividing irregularly in three planes,
 I. Walls thin, 1. *Chroococcus*.
 II. Walls thick, lamellated, 2. *Gloeocapsa*.
 III. Walls confluent in colonies,
 a. Colonies forming a stratum, 3. *Aphanocapsa*.
 b. Colonies globular, solid,
 1. Single, envelope thin, 4. *Microcystis*.
 2. Aggregated, envelope thin, 5. *Polycystis*.
 3. Single, envelope thick, 6. *Anacystis*.
 4. Cells cuneate, 7. *Gomphosphaeria*.
 c. Colonies globular, hollow, 8. *Coelosphaerium*.
 d. Colonies irregular, latticed, 9. *Clathrocystis*.
- B. Cells globose, dividing regularly in two or three planes,
 I. Plants green, 10. *Merismopedia*.
 II. Plants colorless (bacteria), 11. *Carcina*.
- C. Cells cylindrical, dividing in one plane only,
 I. Walls thin, 12. *Synechococcus*.
 II. Walls thick, lamellated, 13. *Gloeothece*.
 III. Walls confluent in colonies, 14. *Aphanothece*.

A. CELL DIVISION IRREGULARLY IN THREE PLANES.

1. *Chroococcus* Naegeli. Cells globose, with thin walls, solitary or in small groups, blue-green, yellow, or reddish.—On damp rocks, walls and earth, and in ponds and springs. Diameter of cells 3 to 25 μ .

2. *Gloeocapsa* Kuetzing. Cells globose, with thick and lamellated walls, solitary or in small colonies surrounded by the walls of the mother-cells, blue-green, lead-colored, yellowish, or reddish.—On wet rocks, walls, and earth. Diameter of cells, cytoplasm 2.5 to 6 μ —including walls, 3 to 10 or 15 μ or more.

3. *Aphanocapsa* Naegeli. Cells globose, with thick, soft, colorless walls confluent into a gelatinous stratum in which are imbedded the blue-green cytoplasm.—On wet rocks, walls, and earth, and in ponds and streams. Diameter of cells, cytoplasm 2 to 8 μ , usually 3–5 μ .

4. *Microcystis* Kuetzing. Cells globose, minute with thin walls, densely aggregated into solid spherical colonies, each enclosed in a close thin envelope, blue-green, yellow, or orange.—On moist surfaces of wood, bark, earth, etc. Diameter of cells 1.5 to 4 μ ; colonies 20 to 60 μ .

5. *Polycystis* Kuetzing. Cells globose, minute, with thin walls, densely aggregated into solid spherical colonies (as in *Microcystis*) of which several are enclosed in a thin envelope, blue-green, yellow,

or orange.—On moist surfaces and in pools. Diameter of cells 2 to 3 μ ; colonies 50 to 100 μ .

6. *Anacystis* Meneghini. Cells globose, minute, with thin walls, densely aggregated into solid spherical colonies, each enclosed in a thickish envelope, pale blue-green, or brownish.—In springs and ponds. Diameter of cells 1 to 4 μ ; colonies from 4 to 10 μ , to 150 to 300 μ .

7. *Gomphosphaeria* Kuetzing. Cells cuneate, in small colonies which are aggregated into solid spherical compound colonies with thickish envelopes, blue-green, yellow, or orange.—In pools and ditches. Diameter of cells about 4 μ ; colonies 10 to 25 μ , or even 50 to 75 μ .

8. *Coelosphaerium* Naegeli. Cells globose, in small colonies, which are aggregated into compound globular, hollow colonies, the walls of the small colonies soon confluent and disappearing, blue-green and granulose.—In ponds. Diameter of cells 2 to 5 μ ; of colonies 40 to 100 μ .

9. *Clathrocystis* Henfrey. Cells globose, aggregated into minute, gelatinous, irregular saccate or latticed colonies, blue-green.—Floating on ponds and pools. Diameter of cells about 3 μ ; colonies 25 to 120 μ .

B. CELL DIVISION REGULARLY IN TWO OR THREE PLANES.

10. *Merismopedia* Meyer. Cells globose with thickish confluent walls, aggregated in flat, quadrate colonies of 4, 8, 16, 32, 64, etc., blue-green.—Floating in ponds. Diameter of cells 3 to 4.5 μ .

11. *Sarcina* Goodsir. Cells globose or at first angled, with thin walls, confluent in flat (or cubical) colonies of 4, 8, 16, 32, 64, etc.; colorless.—In intestinal or other animal fluids, and in stagnant pools. Diameter of cells 1 to 2, rarely 3 to 4 μ .

C. CELL DIVISION IN ONE PLANE ONLY.

11. *Synechococcus* Naegeli. Cells cylindrical, or oblong, with thin walls, solitary or in small groups, blue-green, or sometimes yellowish or orange.—On wet rocks and in pools. Diameter of cells 7 to 16 μ .

12. *Gloeothece* Naegeli. Cells cylindrical or oblong, with thick colorless lamellated walls, often forming colonies enclosed within a common wall, blue-green, lead colored, yellowish, or reddish.—On wet rocks, earth and in pools. Diameter of cells 1.5 to 2.5 μ in our species, much larger or smaller in others.

13. *Aphanothera* Naegeli. Cells cylindrical, with the walls gelatinous, and confluent into a continuous roundish mass in which the blue-green, yellowish, reddish (or even green) cytoplasm are imbedded.—On wet ground. Diameter of cells 1.5 to 12 μ , commonly 3 to 8 μ .

Order 2. NEMATOGENEAE

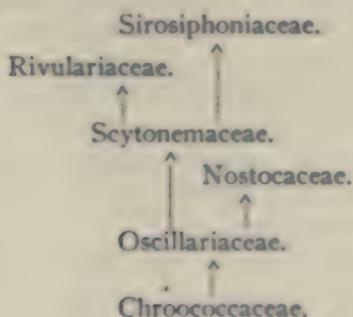
Filamentous Protophytes

Plants several- to many-celled, by division mainly in one plane, forming simple or branched threads, cell-walls often thickish and separating an outer continuous layer as a sheath which encloses the threads.

KEY TO THE FAMILIES.

- A. Cells of the threads all alike, no heterocysts,
 Threads cylindrical, motile, 2. *Oscillariaceae*.
- B. Cells differentiated, heterocysts present,
- I. Division of cells in one plane only,
- a. Threads moniliform, unbranched, 3. *Nostocaceae*.
- b. Threads cylindrical, sometimes spuriously branched, 4. *Scytonemaceae*.
- c. Threads tapering, sometimes spuriously branched, 5. *Rivulariaceae*.
- II. Division of cells ultimately in three planes,
 Threads with true branches, 6. *Sirosiphoniaceae*.

The following scheme illustrates the relationship of the families:



Family 2. OSCILLARIACEAE

Plants consisting of blue-green (exceptionally colorless) cylindrical, unbranched threads, which are usually composed entirely of disk-shaped cells separated by very thin transverse walls; longitudinal walls partly transformed into mucilage, forming a gelatinous investing sheath, or by fusing, a structureless jelly-mass in which

threads are imbedded (zoogloea). Reproduction by hormogones, *i. e.*, by the separation of few-celled sections of the threads, which afterwards increase in length by fission of their cells. Under favorable conditions the threads are motile, moving alternately forward and backward, at the same time curving and rotating.

KEY TO THE GENERA.

A. Tribe *Microcoleae*. Cells colored, green or greenish: usually two or more threads in each sheath.

I. Threads not very numerous in each sheath,

a. Sheaths firm, lamellose; threads not capitate,

1. Sheaths hyaline or colored, containing two or more threads,

1. *Schizothrix*.

2. Sheaths purple or salmon colored, containing one thread,

2. *Porphyrosiphon*.

b. Sheaths soft and more or less diffluent,

1. Sheaths hyaline, containing several capitate threads, cells short,

3. *Hydrocoleum*.

2. Sheaths hyaline or dark yellowish, containing few, remote, not capitate threads; cells longer than broad,

4. *Dasygloea*.

II. Threads many, crowded in each hyaline sheath,

Sheaths not lamellose, more or less mucose,

5. *Microcoleus*.

B. Tribe *Lyngbyae*. Cells colored, green or greenish; threads solitary in the sheaths, or sheathless,

I. Threads spuriously branched, or simple, apex always straight, sheaths firm,

a. Threads spuriously branched,

1. Threads free, branches often in pairs,

6. *Plectonema*.

2. Threads in fascicles, branches single,

7. *Symploca*.

b. Threads unbranched, free,

8. *Lyngbya*.

II. Threads simple, apex sometimes curved, sheaths thin, mucose, hyaline, or apparently wanting,

a. Sheaths diffluent, threads straight,

9. *Phormidium*.

b. Sheaths apparently wanting in most cases,

1. Threads straight or slightly curved,

10. *Oscillaria*.

2. Threads spirally curved,

a. Cells evident,

11. *Arthrospira*.

b. Cells not evident,

12. *Spirulina*.

C. Tribe *Leptotrichiae*. Cells colorless. Threads without sheaths or nearly so,

I. Normally filamentous,

a. Threads with sheaths,

13. *Leptotrichia*.

b. Threads without sheaths,

14. *Beggiatoa*.

II. Normally in short rods, sheathless and free (not aggregated as in III),

a. Spores internal (endosporous),

1. Cells straight or slightly curved,

a. Spores smaller than the diameter of ordinary cells,

i. Spores forming in ordinary cells,

- (a) Cells with uniform protoplasm, 15. *Bacillus*.
- (b) Cells with polar-diblastic protoplasm,
 - 16. *Pasteurella*.
 - ii. Spores formed in special, swollen cells, 17. *Clostridium*.
- b. Spores larger than the diameter of ordinary cells,
 - i. Spores in normal cells swollen in the middle, 18. *Cornelia*.
 - ii. Spores in special clavate cells,
 - 19. *Vibrio*.
 - 20. *Spirillum*.
- a. Cells spirally bent,
 - 21. *Pacinia*.
- b. Spores formed by the fission of cells (arthrosporous),
 - 1. Cells cylindrical, straight, or curved, 22. *Bacterium*.
 - 2. Cells ellipsoid, straight,
- III. Rods aggregated in plasmodium-like bodies,
 - a. Rods straight,
 - 1. Forming external cysts, 23. *Chondromyces*.
 - 2. Forming internal cysts, 24. *Polyangium*.
 - b. Rods curved, 25. *Myxococcus*.

Tribe I. MICROCOLEAE. Cells colored, green or greenish; usually two or more threads in each sheath.

1. *Schizothrix* Kuetzing. Sheaths firm, lamellose, hyaline, dark yellowish, or purplish, occasionally pale blue, containing a few loosely aggregated threads; cells often longer than broad, never much shorter, end cell straight, often attenuated, neither thick-walled nor capitate.—In water or moist places. Threads small, 1 to 3 μ , rarely more than 5 μ in diameter.

2. *Porphyrosiphon* Kuetzing. Sheaths firm, lamellose, purple or salmon colored, containing but one thread; cells as long as or shorter than broad, end cell obtuse, neither thick-walled nor capitate.—On moist earth. Threads rather large, 10 μ or more in diameter.

3. *Hydrocoleum* Kuetzing. Sheaths more or less mucose, or sub-amorphous, in age diffluent, sub-lamellose, hyaline, containing several threads; cells shorter than broad, end cell straight, more or less attenuated, capitate, its terminal wall thickened.—Aquatic, mostly marine plants. Threads rather large, usually more than 10 μ in diameter.

4. *Dasygloea* Thwaites. Sheaths mucose, diffluent, very much enlarged, hyaline or dark yellowish, containing a few remote threads, cells as long as or longer than broad, end cells straight, truncate, conical, neither thick-walled nor capitate.—In marshes. Threads rather small, 4 to 6 μ in diameter.

5. *Microcoleus* Demazieres. Sheaths more or less mucose, in some species eventually diffluent, not lamellose, hyaline, crowded

with many threads; cells not much longer than broad, end cell usually straight and attenuated (in one species capitate).—In water or on moist earth. Threads usually 4 to 10 μ in diameter, in some species less.

Tribe II. LYNGBYAE. Cells colored, green or greenish; threads solitary in the sheaths, or sheathless.

6. *Plectonema* Thuret. Sheaths firm, hyaline, rarely golden yellow; threads spuriously branched, singly or in pairs; cells mostly shorter than broad, end cell straight, rarely attenuated, not capitate.—Plants consisting of free threads growing on sticks and stones in ponds and streams. Threads in different species from 1 or 2 μ to nearly 50 μ in diameter.

7. *Symploca* Kuetzing. Sheaths firm or sub-mucose, thin, threads spuriously branched, singly; cells as long as, or longer than broad (in one species shorter), end cell straight, often somewhat attenuated, and sometimes with its walls slightly thickened.—Aquatic or terrestrial plants whose threads are usually collected in ascending fascicles. Threads small, mostly less than 3 or 4 μ in diameter (one species 6 to 14 μ).

8. *Lynngbya* C. Agardh. Sheaths firm, thin or later thick and lamellose, hyaline, rarely dark yellowish; threads unbranched; end cells straight, slightly if at all attenuated, sometimes with a thicker terminal wall (capitate).—Growing in salt, fresh, or thermal waters, or on the moist earth or the surfaces of other plants. Threads commonly 5 to 8 μ or even 20 to 30 μ in diameter (in a few species less than 2 μ).

9. *Phormidium* Kuetzing. Sheaths thin, mucose agglutinated, partly or entirely diffuent, hyaline; threads unbranched, sometimes moniliform; cells usually shorter than broad, end cell straight or curved, usually attenuated, sometimes capitate.—Aquatic or terrestrial plants. Threads usually about 3 μ or less in diameter, a few 10 to 11 μ .

10. *Oscillaria* Vaucher. Sheaths very thin, or apparently wanting in most cases; threads unbranched, cylindrical or moniliform, straight or slightly curved; end cell usually attenuated, straight or curved, terminal wall often thickened.—Growing in water or in wet places, forming dark green patches. Threads from very small (2 to 3 μ in diameter) to very large (50 to 60 μ).

11. *Arthrospira* Stizenberger. Sheaths apparently wanting;

threads unbranched coiled into a loose spiral; cells evident, end cells rounded, not capitate.—Aquatic. Threads in our species 5 to 8 μ in diameter (a Brazilian species 2 to 3 μ).

12. *Spirulina* Turpin. Sheaths apparently wanting; threads unbranched, coiled into a close spiral; cells not evident.—Aquatic. Threads very small (1 to 2 μ in diameter or less), moving actively with a spiral motion.

Tribe III. LEPTOTRICHIAE. Cells colorless, threads without sheaths, or nearly so. ("Bacteria.") *

13. *Leptotrichia* Trevisan. Threads long, slender, indistinctly septate, each enclosed in a thin sheath; usually not oscillating; not containing sulphur granules; base and apex usually unlike.—Saprophytes and parasites (on plants) in marine and fresh waters. Diameter of cells 0.4 to 3 μ .

14. *Beggiatoa* Trevisan. Threads long, indistinctly septate, not sheathed; usually oscillating freely; containing numerous sulphur granules; ends similar.—Saprophytes and parasites (on plants) in marine and fresh waters, common in warm sulphur springs. Diameter of cells 1 to 4 μ or even 16 to 20 μ .

15. *Bacillus* Cohn. Rods cylindrical or nearly so, straight or slightly curved, ends equal, rounded or truncate; cell protoplasm uniform; spores small; formed in ordinary cells.—Saprophytes in water and decaying organic matter, and parasites in the cells and fluids of many plants and animals. Rods 0.3 to 1 μ in diameter, and three or four times as long.

16. *Pasteurella* Trevisan. Rods usually cylindrical or ovoid, straight or slightly curved, ends equal, rounded or truncate; cell protoplasm polar-diblastic (i. e., apparently denser at the poles); spores small, formed in ordinary cells.—Mostly parasites in the cells and fluids of animals, a few saprophytes in water and decaying organic matter. Rods 0.5 to 0.7 μ in diameter, and two to four times as long.

* The Myxobacteriaceae, which have been carefully studied by Dr. Roland Thaxter (Botanical Gazette, 17: 389. 1892; 23: 395. 1897; 37: 405. 1904) probably belong here. Their "rods" are evidently the same as the "rods" in the organisms described under the Leptotrichiae. They form plasmodium-like aggregations, on which rise aerial "pseudofrustrifications." The Myxobacteriaceae appear to be an aerial modification of the usual aquatic bacterial type. It may be suggested that they are xerophytic Leptotrichiae, while ordinary bacteria are hydrophytic. They may be regarded as a sub-tribe, with the characters given by Dr. Thaxter as in the text.

17. *Clostridium* Prazmowski. Vegetative rods cylindrical or ovoid, straight, or slightly curved, ends equal, rounded; cell protoplasm uniform; spores small, formed in special, swollen cells.—Mostly saprophytes in decaying organic matter, a few parasites in the fluids of animals. Rods 0.5 to 1 μ in diameter, and three to four times as long.

18. *Cornilia* Trevisan. Rods cylindrical, straight, ends equal, rounded or pointed; cell protoplasm uniform; spores large, formed in ordinary cells which then become swollen centrally or apically.—Mostly saprophytes in decaying organic matter, a few parasites in the fluids of animals. Rods 0.3 to 1 μ in diameter.

19. *Vibrio* Zopf. Vegetative rods cylindrical, sometimes joined into long threads slightly curved, or undulate-flexed, ends rounded, sometimes flagellate; spores large, formed in special, clavate-swollen cells.—Parasites in the fluids of animals, and saprophytes in decaying organic matter. Rods 0.5 to 0.8 μ in diameter, and from three to ten times as long.

20. *Spirillum* Ehrenberg. Rods cylindrical, spirally curved, ends sometimes flagellate; cell protoplasm uniform; spores small, formed in ordinary cells.—Saprophytes in decaying organic matter, and parasites in the cells and fluids of animals. Rods 0.5 to 3 μ in diameter, and of variable length, 5 to 10 μ , even to 100 or 200 μ .

21. *Pacinia* Trevisan. Rods cylindrical, straight or slightly curved, often forming straight, curved, or undulate threads; cell protoplasm uniform; spores formed by abstriction (arthrosporous).—Mostly parasites in the cells and tissues of animals, a few saprophytes in decaying organic matter. Rods 0.3 to 1 μ in diameter, and three to ten times as long.

22. *Bacterium* Ehrenberg. Rods short, ellipsoid, rarely cylindrical, straight, ends obtuse; cell protoplasm uniform; spores formed by abstriction (arthrosporous).—Saprophytes in decaying organic substances, rarely parasitic. Rods 0.5 to 2.5 μ in diameter, and three to four times as long.

Sub-tribe MYXOBACTERIACEAE. "Motile, rod-like organism, multiplying by fission, secreting a gelatinous base, and forming pseudoplasmodium-like aggregations before passing into a more or less highly developed cyst-producing resting state, in which the rods may become encysted in groups without modification or may be converted into spore masses."—They are mostly saprophytes.

The three genera at present recognized are characterized as follows:

23. *Chondromyces* Berkeley and Curtis. "Rods forming free cysts, in which they remain unmodified. Cysts various, sessile or borne on a more or less highly developed cystophore."—Eleven species have been described as growing on rotten wood, dung, and other organic matter.

24. *Polyangium* Link. "Rods forming large rounded cysts, one or more free within a gelatinous matrix raised above the substratum."—Six species, on wet wood, dung, etc.

25. *Myrococcus* Thaxter. "Rods slender, curved, swarming together after a vegetative period to form definite, more or less encysted sessile masses of coccus-like spores."—Seven or eight species, on decaying substances, dung, etc.

Family 3. NOSTOCACEAE

Plants consisting of amber- or blue-green, more or less moniliform, unbranched threads, composed of globose or sub-globose cells, spores, and heterocysts; cell walls more or less transformed into mucilage forming a gelatinous investing sheath, or by fusing, a structureless jelly-mass in which the threads are imbedded. Reproduction in two ways, (1) by free-swimming hormogones of a few cells (4 to 12) which develop directly into new plants, or form rows of spores; (2) by spores formed in ordinary threads as well as in hormogones, which divide internally into minute chains of cells which are set free by the rupture of the old cell wall. The heterocysts are rounded, usually enlarged cells without granular contents, whose function is unknown.

KEY TO THE GENERA.

A. Heterocysts intercalated,

1. Threads moniliform (*i. e.*, composed of rounded bead-like cells) globose or irregular,

a. Flexuously curved, normally in gelatinous masses,

1. Colored (sometimes very slightly),

1. *Nostoc*.

2. Colorless (bacteria),

a. Threads evident,

2. *Leuconostoc*.

b. Cells in botryoid masses,

3. *Staphylococcus*.

c. Cells solitary or in zoogloecae,

4. *Micrococcus*.

b. Nearly straight,

1. Colored,

- | | |
|--|---|
| <p>a. Threads parallel, in a closed tube,
 b. Threads free, or in gelatinous masses,
 2. Colorless (bacteria),
 II. Threads cylindrical, nearly straight,
 a. Agglutinated in fascicles,
 b. Each in a sheath,
 B. Heterocysts terminal,</p> | <p>5. <i>Wolleea</i>.
 6. <i>Anabaena</i>.
 7. <i>Sireptococcus</i>.

 8. <i>Aphanisomenon</i>.
 9. <i>Nodularia</i>.
 10. <i>Cylindrospermum</i>.</p> |
|--|---|

1. *Nostoc* Vaucher. Threads mostly moniliform, flexuously curved, with or without a distinct sheath; cells globose, cask-shaped, or cylindrical; heterocysts intercalary (rarely terminal); spores intercalary, spherical or oblong.—Forming globose, nodulose, or irregular, amber- or pale-green gelatinous masses 1 mm. to 50 mm. or 100 mm. in diameter, in water or on moist ground. Threads small, 2 to 9 μ in diameter.

2. *Leuconostoc* Van Tieghem. Threads moniliform, curved, composed of globose, colorless cells.—Forming globose, nodulose, or irregular, white, gelatinous masses on beet-root sugar and the vessels used in its manufacture (also on leaves of plants, where they appear to grow in the sweetish exudate). Cells 0.8 to 1.2 μ in diameter.

3. *Staphylococcus* Ogston. Globose cells single, in pairs, short threads, or botryoid masses, colorless.—Parasites in the cells and fluids of animals, and saprophytes in decaying organic matter. Cells 0.3 to 2 μ in diameter.

4. *Micrococcus* Cohn. Globose or ovoid cells single, in short threads, or in irregular gelatinous masses (zoogloae), colorless.—Parasites in the cells and fluids of animals, and saprophytes in decaying organic matter. Cells 0.15 to 1 μ , rarely 2 to 4 μ in diameter.

5. *Wolleea* Bornet and Flahault. Threads blue-green, moniliform, nearly straight, sheaths confluent; cells oblong; heterocysts intercalary; spores intercalary, oblong.—Forming erect or floating cylindrical gelatinous masses enclosing many parallel agglutinated threads, in ponds. Threads small, 4 to 5 μ in diameter.

6. *Anabaena* Bory. Threads blue-green, moniliform, nearly straight, without a sheath, or but a vestige of one; cells globose or sub-globose; heterocysts intercalary; spores intercalary, globose, or elongated.—Floating free in ponds, or forming gelatinous masses on moist surfaces. Threads mostly small, 4 to 6 μ in diameter (one species 14 μ).

7. *Streptococcus* Bills. Threads moniliform, nearly straight, without a sheath; cells globose, colorless.—Parasites in the cells and

fluids of animals, and in decaying organic matter. Cells 0.2 to 2 μ in diameter.

8. *Aphanizomenon* Morren. Threads blue-green, cylindrical, nearly straight, without a sheath; cells cylindrical; heterocysts intercalary, large, sub-cylindrical; spores intercalary, large, cylindrical-elongated.—Threads 5 to 6 μ broad, agglutinated into small fascicles, floating free in ponds.

9. *Nodularia* Martens. Threads blue-green, cylindrical, nearly straight, each usually enclosed in a sheath; cells disk-shaped; heterocysts intercalary, compressed; spores intercalary, globose.—Threads 4 to 18 μ in diameter, floating free in ponds or forming an indefinite stratum on other aquatic plants.

10. *Cylindrospermum* Kuetzing. Threads blue-green, cylindrical, nearly straight, without a sheath; cells cylindrical; heterocysts terminal, globose or sub-globose; spores contiguous to the heterocysts, oblong or cylindrical.—Forming an indefinite stratum in ditches, on wet rocks, and on the ground. Threads small, 3 to 5 μ in diameter.

Family 4. SCYTONEMACEAE

Plants consisting of cylindrical, green or brown, usually branched threads which are composed of more or less disk-shaped cells; end cells thin walled, dividing repeatedly in one plane, and thus increasing the length of the thread; longitudinal walls partly transformed into mucilage, forming a gelatinous investing sheath. Reproduction by hormogones and spores, as in *Nostocaceae*. Heterocysts intercalary and basal.

KEY TO THE GENERA.

A. Threads solitary in each sheath,

I. Unbranched,

II. With spurious branches usually in pairs,

III. With spurious branches single,

a. Threads fragile, plants terrestrial,

b. Threads flexible, plants aquatic,

B. Threads generally 2 to 6 in each sheath,

1. *Microchaete*.

2. *Scytonema*.

3. *Hassallia*.

4. *Tolythrix*.

5. *Desmonema*.

1. *Microchaete* Thuret. Threads unbranched, solitary in each sheath; heterocysts basal and intercalary.—Minute plants of salt and fresh waters, growing in clusters or tufts about 1 mm. long, each thread 5 to 9 μ in diameter.

2. *Scytonema* Agardh. Threads solitary in each sheath, spuriously branched by the rupture of the sheath and the protrusion of one or commonly two branches.—Aquatic or terrestrial plants composed of usually large threads, often several millimeters long forming interwoven mats; threads from 7 to 45 μ broad, commonly 12 to 20 μ .

3. *Hassallia* Berkeley. Threads minute, fragile, solitary in each sheath, spuriously branched by the rupture of the sheath and the protrusion of a single branch; sheath thin, not mucilaginous.—Forming a green stratum on moist ground or stones. Threads 1 mm. or less long, 5 to 10 μ (or even 15) broad.

4. *Tolythrix* Kuetzing. Threads larger, flexible, solitary in each sheath, spuriously branched by the rupture of the sheath and the protrusion of a single branch; sheath thin.—Forming tufts 10 to 30 mm. high on plants and stones, or floating freely, in fresh waters. Threads 8 to 10 μ or even 15 to 18 μ broad.

5. *Desmonema* Berkeley and Thwaites. Threads usually 2 to 6 in each sheath, sub-dichotomously branched, a heterocyst at the base of each spurious branch; sheath thin.—Forming small, green tufts 5 to 6 mm. high on stones, etc., in streams and other fresh waters. Threads 9 to 10 μ or more in diameter.

Family 5. RIVULARIACEAE

Plants consisting of tapering, green or reddish, simple or spuriously branched threads, composed of nearly cylindrical (slightly tapering) cells; lower cells much larger and greener than the upper which form a slender, hyaline hair; longitudinal walls partly transformed into mucilage, forming a gelatinous investing sheath. Reproduction by hormogones and spores formed in the thicker portion of the thread. Heterocysts usually at the base of the threads.

KEY TO THE GENERA.

- A. Threads free, simple or spuriously dichotomo-corymbosely branched,
- I. Threads simple, or spuriously branched, the branches distinct and free.
 1. *Calothrix*.
 - II. Threads spuriously branched,
 - a. Branches several (2 to 6) in each sheath,
 2. *Dichothrix*.
 - b. Branches very many (even to 100) in each sheath.
 3. *Polythrix*.
- B. Threads grown into crustaceous, hemispherical or globose masses,

I. Heterocysts basal.

a. Threads simple, crowded parallel in crustaceous masses, 4. *Isactis*.

b. Threads spuriously branched, crowded and radiating, forming a globose or hemispherical mass,

1. No spores known,

3. *Rivularia*.

2. Spores large, solitary,

6. *Gloeotrichia*.

II. Heterocysts intercalary,

7. *Brachytrichia*.

1. *Calothrix* Agardh. Threads simple or spuriously branched, the branches distinct and free; sheaths cylindrical, enclosing a single thread; heterocysts intercalary or basal, sometimes none.—Forming minute tufts or cushions a millimeter or so high on stones and other objects in fresh and salt waters, and on moist earth. Threads from 3 to 5 μ to 25 to 40 μ broad.

2. *Dichothrix* Zanardini. Threads spuriously dichotomous, 2 to 6 included in a common sheath; heterocysts basal or intercalary.—Forming minute tufts or cushions 1 to 20 mm. high on stones and other objects in fresh and salt waters. Threads usually 10 to 12 μ broad, sometimes 25 to 30 μ .

3. *Polythrix* Zanardini. Threads spuriously dichotomous, very many (even to 100) enclosed in a common sheath; heterocysts basal and intercalary.—Forming tufts and cushions 10 to 30 mm. high on stones in salt waters (Key West). Threads 5 to 6 μ broad.

4. *Isactis* Thuret. Threads simple or rarely spuriously branched, erect and parallel; sheaths hyaline or yellowish; heterocysts basal; spores unknown.—Marine plants whose crowded, parallel threads form small, flattish, crustaceous masses. Threads 7 to 9 μ broad.

5. *Rivularia* Roth. Threads spuriously branched, crowded and radiating; sheaths narrow to broad, hyaline or colored; heterocysts basal; spores unknown.—Forming small, globular or hemispherical masses a millimeter or so in diameter, in salt or fresh waters. Threads 2 to 14 μ broad.

6. *Gloeotrichia* J. Agardh. Threads spuriously branched, crowded and radiating; sheath enclosing the base of the thread, dissolving above, hyaline or colored; heterocysts basal; spores present, above the heterocysts; hormogones serial and numerous.—Forming globose or hemispherical masses, a millimeter or so in diameter (or 20 to 100 nun.), in fresh or brackish waters. Threads 4 to 9 μ broad.

7. *Brachytrichia* Zanardini. Threads spuriously much branched, parallel, flexuously curved; sheaths at first distinct, finally deliquescent; heterocysts intercalary.—Forming solid, or eventually

hollow, gelatinous masses, 6 to 60 mm. in extent, in which the threads are enclosed. Threads 5 to 6 μ broad.

Family 6. SIROSIPHONIACEAE

Plants consisting of cylindrical or irregular, greenish, brown, or blackish, sheathed and usually branched threads, at first consisting of a single row, but later mostly of several rows of cells; end cells usually dividing at first repeatedly in one plane only, and later in more than one plane, some of the latter again dividing repeatedly in one plane (parallel to the axis of the thread) thus originating branches; all walls of the cells more or less transformed into mucilage, the outer forming a gelatinous sheath for the thread, the inner separating the protoplasts; heterocysts intercalary (rarely terminal also). Reproduction by hormogones and spores, the latter formed by the change of disk-like cells toward the end of a thread into roundish resting spores, which germinate after a period of rest.

KEY TO THE GENERA.

- A. Threads consisting of one row of cells, rarely of two rows, 1. *Haplosiphon*.
 B. Threads commonly consisting of two or more rows of cells, 2. *Stigonema*.

1. *Haplosiphon* Naegeli. Threads creeping, consisting of one row of cells, rarely of two rows; branches erect, parallel.—Aquatic, cespitose-floccose, slender plants, forming green, blue-green, or at length brown tufts which are floating or attached. Threads 6 to 24 μ broad.

2. *Stigonema* Agardh. Threads commonly consisting of two or more rows of cells; branches irregular, spreading.—Terrestrial or aquatic, dark brown plants, forming expanded, slimy strata. Threads 7 to 10 μ , or even 45 to 90 μ broad.

RIVER POLLUTION AND PURIFICATION

A STUDY OF THE EFFECT OF CHICAGO SEWAGE UPON THE WATER
SUPPLY OF ST. LOUIS

By T. J. BURRILL

WITH THREE PLATES

The Chicago River discharges into Lake Michigan through one main channel made navigable for the largest lake vessels, and has two branches which run nearly north and south respectively through the city. This stream, which ordinarily has otherwise a comparatively small flow of water, receives the sewage of about 1,600,000 people—four-fifths of the inhabitants of the great city—beside an enormous amount of wastes from manufactories. The river has almost no fall. Originally the current was always sluggish and when by reason of the wind the level of the lake was temporarily raised there was none at all, or the direction of the flow was inland. Under these conditions the stream—we can hardly say water—consisted of a dark and seething mass of corruption, foul beyond the power of words to describe.

The sewage of about 400,000 people has been and still is sent directly into the lake through pipes bearing no relation to the river. The city water supply is from the lake and notwithstanding the intakes were pushed four miles from the shore the contaminations too often reach this distance. To prevent this and to purify the river has long been a problem of the utmost importance to the city and it has received the earnest attention of the authorities and the best studies of experts.

The Illinois and Michigan canal completed in 1848 connects with the south branch of the river at a point within the city called Bridgeport, and at this place a lock and pumping works were established to supply the canal when the water was otherwise too low for the boats. The canal discharged in part at Lockport, 29 miles away, and

further at Joliet, 4 miles beyond, at both places into the Desplaines River. At the latter point the canal crosses the river by means of a dam and pool, so that the waters are well mixed, and continues onward to LaSalle, where it opens into the Illinois River 95 miles from Bridgeport.

At first the pumping at Bridgeport from the Chicago River was only to supply the needs of navigation but as early as 1865 the city arranged with the canal commissioners to utilize the pumps for cleansing the river. From time to time other means have been adopted for this purpose, but most reliance has been placed, especially of late, upon these pumps, by which the waters of the lake were caused to flow in a slow current, at least part of the time, through the river course into the canal and thus at length into the Illinois River. This operation, gradually increasing in proportions, continued from the date mentioned onward through the remaining years of the century, and at its close there was thus poured into the canal about 35,000 cubic feet per minute of the river water and sewage, of which the latter contributed an estimated amount of 26,000 cubic feet.¹ This sewage, including wastes from the stock yards, carried, according to the same authority, the equivalent of 150 tons of dry organic matter and ammoniacal salts daily into the canal. Still the river was not cleansed and something more effectual became imperative. The increase of pollution with little dilution made the effluent stream more and more noxious to the inhabitants along its course especially in its upper reaches and more and more contaminated the city water supply. There was therefore a double reason for some heroic action.

After wide examination of systems of sewage disposal in use, and with much expert consultation, a bill was introduced in the state legislature, which became in 1899 an Act creating the Chicago Sanitary District and authorizing a sanitary canal through which by gravity might pass 600,000 cubic feet per minute of water from Lake Michigan into the Desplaines and hence onward down the Illinois River. This canal begun in 1892 was completed sufficiently to turn in the water on January 17, 1900, after an expenditure of over \$30,000,000. It connects with the south branch of the Chicago River and discharges into the Desplaines at Lockport over a controllable dam. It is 29 miles in length and runs somewhat parallel to the

¹ Long, *Sanitary Investigations*, Springfield, Ill., 1900, p. 37.

Illinois and Michigan canal, which remains as before. The flow maintained during the first year (1900) varied from about 150 to 220 cubic feet per minute with some lower and some higher quantities. This is to be compared with 35,000 cubic feet previously pumped. The reversed flow of the river through the city was made in the interests of shipping not to exceed 3 miles an hour, but the effect was speedily to change the black, maladorous cesspool into a stream of blue water from the lake. The sanitary canal is an immense relief to Chicago. What is its effect upon the valley of the Illinois River and below?

To make this more intelligible some description of the water course onward is required. The Illinois River is formed by the junction of the Desplaines and Kankakee about 16 miles below Lockport (12 miles southwest of Joliet). The Desplaines varies above Lockport from nothing during dry seasons to more than 300,000 cubic feet per minute at flood times, while the more stable Kankakee ranges commonly from 30,000 to above 300,000. Further down stream the main tributaries are the Fox, about two-thirds the size of the Kankakee; the Vermilion, more like the Desplaines, sometimes practically dry but subject to floods; Spoon River, most of the year a small stream, usually not above 5,000 to 10,000 cubic feet flow; and the Sangamon, as large as the Kankakee. Besides these there are a large number of smaller tributaries.

At Kampsville, 30 miles above the mouth of the Illinois where it joins the Mississippi, the government maintains a dam and keeps a record of the water. At one time in September, 1899, there was a flow of only 10,000, but in June, 1902, there passed the station about 9,300,000 cubic feet per minute. These are extremes. Prior to the opening of the sanitary canal there was commonly a flow here from March to June inclusive of about 1,000,000 to 3,000,000, and from August to October, of about 250,000 to 500,000 cubic feet per minute, the latter not being more than the proposed flow of the sanitary canal. Since the latter was opened the stream throughout has been very noticeably greater than it was before during its lowest stages, but it commonly is a large river at all times. Its length from the junction of its head waters to Grafton at its mouth is 263 miles.

All the main tributary streams are strongly sewage-polluted and there is a very extensive wash from a great area of highly fertile and well-populated regions, though with the exception to be noted

the amount of organic matter entering from any one point received from other sources is small compared with that from Chicago. The exception is in the case of Peoria and Pekin. Here, as is well known, exist the largest distilleries and glucose factories in the country and great numbers of cattle are kept and fed upon the slops. The direct wastes from the manufactories and all the offal from the cattle sheds go directly into the river. This added to the sewage of some 70,000 people makes the contamination of the stream at this point only short of that from Chicago. Sometimes masses of filth collect in the river to such an extent that in times of low water dynamite has been used to break up the stranded islands composed of it. We shall see below results of this pollution in the prodigious multiplication of the number of bacteria in the water.

As related above, the sanitary canal was opened in January, 1900. Anticipating this event the trustees of the Chicago drainage district, acting upon the advice and cooperation of Arthur R. Reynolds, M.D., Commissioner of Health of the City of Chicago, arranged in 1899 for an exhaustive chemical and bacteriological study of the stream from Bridgeport to St. Louis. In order that this work might have all possible weight and that the results might be abundantly conclusive, Commissioner Reynolds was given authority to secure under his own general direction prolonged series of independent examinations and analyses by several well-accredited experts. In the fulfilment of this task the Commissioner arranged for the work by the Municipal Laboratory of Chicago, by the laboratory of the University of Chicago, and by that of the University of Illinois. He endeavored also to secure the cooperation of Washington University or of the City Laboratory of St. Louis, but in this was not successful. The work as undertaken was put in charge of Dr. Adolph Gehrman of the laboratory first named, of Professor E. O. Jordan of the second, of Professors A. W. Palmer and T. J. Burrill of the third. In the latter case the bacteriological examinations were conducted by the present writer and his results alone are herein given, except that other general conclusions are mentioned.

The work was commenced in May, 1899, and continued uninterruptedly until October, 1900. Further examinations, made during the latter part of the year 1901, did not significantly modify the earlier conclusions. Collections, usually one each week at each place, were made from 38 carefully located stations on the course

of the stream and tributaries, including the canals above named, the Desplaines, Kankakee, Fox, Big Vermilion, Sangamon, Illinois, and Mississippi rivers and from Chicago and St. Louis tap waters. Comparative tests were also made of the Missouri River several miles above its mouth. During the period mentioned there were received by the writer and his assistants 2,800 samples, from which an aggregate of about 30,000 bacterial cultures were made. In all this two primary ends were sought: (1) To determine for each sample the number of bacteria in a cubic centimeter which could be made to develop colonies on a culture plate, and (2) to test the presence or absence in each sample of *Bacillus coli-communis*. In work of such magnitude, and upon waters generally so polluted, further refinements of analysis were impracticable or less important. The first was expected to indicate quantitative and the second to give the best obtainable knowledge of qualitative contamination, that is, whether or not such pathogenic species as *Bacillus typhosus* were present in the samples examined. In work of this kind it is impossible directly to identify the latter, but since the two species just named gain access to such water from intestinal evacuations the presence of one of them must give a comparative indication of that of the other.

There is no room for doubt as to the polluted character of the head waters of this stream. What becomes of the highly putrescible and often pathogenic germ-laden matter equal to 150 tons of dry matter daily from Chicago and as much more from other sources that is persistently poured into the water?

The question has been much discussed and opinions have been exceedingly diverse upon what has been called the self-purification of running water. Somewhat misquoting an expression in a report of a British commission, it has recently been asserted before the American Medical Association that "biologists have about come to the conclusion that no river is long enough to purify itself." In a recent book on sanitation it is argued that the apparent purification in a river course is principally due to the dilution by pure water and not to any destruction of the organic matter with which the stream is originally polluted. "The theory of self-purification is now abandoned, or rather accepted only after so much modification that it is practically new."¹

Because of contentions of this kind and otherwise the authorities of St. Louis, Missouri, became alarmed lest the Chicago contamina-

¹ Sedgwick: Principles of Sanitary Science and the Public Health, p. 120.

tions should reach the intake in the Mississippi River, from which the city receives its water supply. An injunction has therefore been sought from the United States Supreme Court against the use of the sanitary canal, and the discharge into the Illinois River of Chicago sewage. This suit is now in progress. Let us see what bearings the investigations as summarized below have upon the problem.

It is not possible to give in detail the figures for all the results of the cultures upon which this account is based. Neither does it seem feasible within the limits of permissible space to describe methods of procedure. It should be said, however, that the greatest possible pains were taken to have the collections properly made and shipped. The samples, taken in sterilized glass-stoppered bottles, securely sealed and tagged, were packed in ice and commonly reached the laboratory within eight to twenty-four hours after taking from the stream. After collectors and expressmen became accustomed to handling the packages, undue delay very seldom occurred and only in rare cases was the packing ice completely melted when the samples were received. Analyses were not made, or the results were not included in the case of any samples not received in good order. The collecting stations, so far as this account goes, are named in the table, with the distance in each case from Chicago.

For the colony count standard plating agar was used at 1% acid above the phenolphthalein neutral point and the plates were counted after a uniform development period of 10 days at 20° C. For the identification of *Bacillus coli-communis* carbolized lactose-litmus broth with 1 cc. of water was first incubated at 38° C. for 48 hours, and cultures indicating the presence of the bacillus were further continued for indol tests, glucose-fermentation tests, and milk coagulation tests. No animals were inoculated.

NUMERICAL VARIATIONS IN DIFFERENT PARTS OF THE STREAM

A very casual inspection of the table will show the wide variations in the monthly average number of bacteria in a cubic centimeter of the waters examined—from a few hundred to several millions. At first sight there may not appear to be any law in these differences, but further study will show that the numbers are always very large at Joliet and that there is generally, and usually very decidedly, a decrease to Averyville (North Peoria), then there is a very great increase at Pekin, followed again by a gradual decrease

to Grafton (mouth of the Illinois River). For the sake of brevity the collections above Joliet are not given, but both in the Illinois and Michigan and in the sanitary canals the numbers of bacteria found were always represented by at least six and very often by seven places of figures, the latter more commonly than the other for the first-named canal. The largest average number for any one month during the whole work was from samples taken at Lockport, from the Illinois and Michigan canal in July, 1899, and reached 5,323,750, and the smallest from the stream anywhere from Bridgeport to St. Louis was from samples taken from the Illinois River at Grafton in October, 1899, namely 743. These, let it be noted, are each the averages of at least eight culture plates from four samples—weekly collections, duplicate plates. The largest count from a single sample, during the whole course of the work, was made from the water at Lockport, April 17, 1900, and showed 11,200,000. The largest monthly average from samples taken at Averyville (North Peoria), 159 miles from Chicago, was 129,500 for February, 1900, while the smallest was for June of the same year, *viz.*, 1,637; but the preceding November there were practically the same number, 1,640. At Grafton, 318 miles from Chicago and 143 from Peoria, the largest average was 191,500 from the Illinois for February, 1900, and 227,750 from the Mississippi river (above mouth of Illinois) March, 1900. The smallest monthly average at this place from the Illinois was, as above stated, 743 for October, 1899, and from the Mississippi 915 for July, 1899.

A very similar showing, subject naturally to wider variations in numbers, can be made by comparing the results of cultures from single samples taken on the same day (or at most not more than 24 hours apart) from each of any two stations differently located in regard to the principal source of pollution. In this way we may compare the colony counts in cultures from Bridgeport and Averyville, 159 miles apart, not by selecting maximum at one and minimum at the other, but just as they occur through given months. Here they are for November, 1899, and April, 1900.

	Nov. 7	Nov. 15	Nov. 21	Nov. 27
Bridgeport	4,790,000	1,960,000	3,920,000	4,315,000
Averyville	550	1,100	1,200	2,800
	April 9	April 16	April 17	April 23
Bridgeport	5,300,000	3,725,000	11,200,000	3,925,000
Averyville	28,000	17,000	5,500	1,850

This is scarcely a fair showing for a general difference in the two places, but it does illustrate excellently the marvellous decrease in the number of bacteria that takes place in the running stream during this distance of 159 miles. We shall see further along that there is only one way by which this decrease can be explained.

As before mentioned, the river receives immense quantities of polluting matter at Peoria and Pekin, and the number of bacteria very soon correspondingly increase. Havana is only 25 miles below Pekin and 37 miles below the main sewers of Peoria. There are no tributary streams of importance between these places except Mackinaw River, which carries a small volume of water drained from a very rich agricultural region and subject to much pollution. It enters a little distance south of Pekin. There is tabulated here the results of all the examinations made in July, 1899, and in September, 1900, from Pekin and Havana.

	July 7	July 13	July 20	July 26
Pekin	300,000	1,190,000	640,000	820,000
Havana	13,300	1,420	5,880	3,200
	Sept. 6	Sept. 14	Sept. 20	Sept. 27
Pekin	1,320,000	600,000	47,500	2,280,000
Havana	35,500	4,150	144,000	19,000

These results show as clearly as figures can show anything that there is some potent influence at work in cleansing the water. If these numbers were specially selected from the very great variations in the results as obtained, they would mean little or nothing, but an inspection of the whole counts as put down in the laboratory records shows that the lessons which may be drawn from such figures as the above are abundantly supported and any one may construct other comparisons from the monthly averages herewith presented, all teaching the same thing. The differences as shown for Joliet, Morris, and Ottawa are commended to the reader especially interested. There is practically no change in the volume of the water between Morris and Ottawa, 24 miles, but the difference in bacterial content is remarkable.

While with reference to particular counts there are many unexplained variations, the work in general very clearly and decidedly shows that the numbers of bacteria at the polluted headwaters of the stream are always very great, that these numbers more or less constantly decrease to Averyville, then decidedly increase below

Peoria and again decrease to Grafton, at which point the numbers are normal to the rivers in the region of the country under consideration. There are no more bacteria in the Illinois at its mouth than there are in the rivers tributary to the Illinois, nor than there are in the Mississippi above the mouth of the Illinois, or the Missouri above its junction with the Mississippi. Upon this point compare the monthly averages in the table. Here are a few of them:

	June, 1899	Oct., 1899	March, 1900	Aug., 1900
The Kankakee, Wilmington	22,837	11,075	72,250	1,975
The Fox, Ottawa	11,027	5,475	84,166	2,962
The Sangamon, Chandlersville	7,125	3,683	105,875	4,450
The Mississippi, Grafton	5,017	2,406	227,750	3,291
The Missouri, West Alton		16,325	179,750	12,450
The Illinois, Grafton	4,155	743	159,500	2,708

This gradual diminution of the numbers of bacteria down the stream from the place of pollution was equally evident before and after the opening of the Sanitary Canal. Any difference which the figures of the table reveal in regard to the results of 1899 and 1900 may easily be from other causes than the opening of the canal, except that the increased dilution by lake water decidedly reduced the number of bacteria in a cubic centimeter in the upper part of the stream, *i. e.*, above Ottawa.

SEASONAL VARIATIONS

So much for the variations in the bacterial content of the waters in the different parts of the stream. An examination of the figures will show that there is another marked difference according to seasons of the year. This is specially true in places distant from the points of principal contamination. Note for instance the figures at Averyville and Grafton. For easy comparison we may place together the average results for February and August, 1900, from a number of stations on the Illinois River as follows:

	Ottawa	Henry	Averyville	Beardstown	Grafton
February	228,000	160,500	120,500	420,500	101,500
August	18,830	1,850	8,000	15,000	2,700

The sewage contaminations are undoubtedly as great in the summer as in the winter. Are there other and added sources of bacteria in cold weather, or do the organisms sooner die in warm water? It

has often been argued that the increase is prominently due to the greater washing from the soil in times of floods and it cannot be otherwise than that enormous numbers of bacteria do thus find their way into the rivers with every cubic inch of fertile soil, but this does not explain our tables of figures, neither does it commonly sufficiently explain results obtained elsewhere by other bacteriological analysts. Our floods come in March or later in the spring and the soil washes most after it thaws out; the bacteria in waters like that of the Illinois are more numerous before the ground thaws out and before the great floods occur. The river is nearly always much higher in June and July than it is in December and January, but the numbers of bacteria are in the reverse order.

CAUSES OF PURIFICATION

This leads to the question so often asked and so variously answered: to what cause or causes must the "self-purification" of streams be attributed? The various answers include dilution, sedimentation, insolation, the effects of the plankton, etc. It is impossible here to enter the discussion of the subject, but it may be said at once that in the opinion of the writer the bacteria themselves constitute the chief agency. They are preeminently the purifying agents. When conditions are favorable they multiply with astonishing rapidity, so that the progeny of one may become millions in 24 hours. In such situations as have been herein described they are fermentation-workers. The organic wastes sent into the waters are rich food for these little creatures. In myriad numbers they attack it from all quarters. The solids are converted, in good part, into gaseous forms and come bubbling up through the filth-laden water. The supply rapidly decreases, the water becomes clearer, the bacteria die either as a prey to other organisms or by starvation. This, in a word, is the story. The more favorable the conditions, temperature among other things, the more rapid the process. In cold weather the fermentation is slower, the fermentable matter is carried further down stream; the bacteria live, not so fast but longer, and in the lower portions of the stream, distant from the place of pollution, are found in cold weather in greater numbers.

QUALITATIVE TESTS

It has seemed impossible to present the results reported above in briefer space, but there is little room to show those of the tests for

Bacillus coli-communis. This organism was found in all samples of the water taken at Joliet and above in 1899 and at Joliet in about 75% of the samples collected in 1900. Onward in the course of the stream the percentage of positive tests, showing the bacillus present, varied closely with the colony counts. The species, or species-group, was to some extent found in the waters from every station upon the river and its tributaries. Whenever and wherever the count showed 100,000 or more bacteria to the cubic centimeter this species was commonly among them though it seemed to be evident that in the "survival of the fittest" others longer existed and sometimes greatly multiplied. At Averyville the positive tests were found to be about 30% of the whole number, the lowest anywhere in the stream; below Peoria about 90% and at Grafton about 45%. At the station last named the waters of the Illinois and the Mississippi rivers proved to be as near alike in this respect as in the total numbers of bacteria. The collections from the Missouri River at West Alton always showed higher colony counts and a very considerably greater percentage of positive tests for *Bacillus coli-communis* than did those at any time for the Illinois River at its mouth or from the Mississippi River above the junction of the Missouri. Such results were also true from the samples collected taken from the mixed waters of the two rivers last mentioned. Five samples were weekly taken at different points across the stream in line with the St. Louis pumping works, called Mitchell in the list of stations in the table, and the greater counts showed very plainly and constantly the worse contaminations of the Missouri, the percentage of all tests for the bacillus named rose to about 80 of positive determinations. This seems bad indeed for a municipal water supply, but in the light of the foregoing the charge cannot lie against the Chicago sanitary canal.

There is however a side-light here to which attention should be drawn. The records show that typhoid fever is commonly much more prevalent in recent years in Chicago than in St. Louis, though it may be taken to be certain that *Bacillus typhosus* has very often found its way into the stream along with so great numbers of *Bacillus coli-communis*. The lesson is that the former soon dies out and this is supported not only from theoretical considerations but from all actual tests wherever reported from similar conditions. There is not the slightest evidence known to the writer to show that the typhoid bacillus, even for one germ, ever passed in the stream

from Chicago down to the mouth of the Illinois River. More probably the very many that have started in the current perished long before they reached the clearer water at Averyville.

On the other hand those which from the same source were poured directly into the lake water and sometimes as directly pumped back into the city mains, making the round perhaps in one or two days were vastly more likely to carry infection to many people. Chicago has suffered much and must continue to suffer in this respect until the sanitary system is completed. Four-fifths of the sewage has for many years gone into the river and with much greater dilution is now so disposed of. When the other fifth shall have been added the plague may cease and this without serious consequences elsewhere. It cannot be held, however, that the water from any open stream in a populated country is safe to drink. All cities must find other supplies or inaugurate purifying processes, now known to be feasible.

TABLE I—CHICAGO DRAINAGE WATER
 Monthly Averages of the Number of Bacteria from Weekly Collections of Water taken at the Stations
 named in the first column during 1899 and 1900

Station	Miles from Chicago	Year	January	February	March	April	May	June
Juliet	33	1899	973,000	1,448,333	2,000,000	1,655,000	485,000	1,445,000
"	"	1900						18,000
Wilmington		1899						22,817
"		1900	5,790	100,000	75,250	52,000	3,300	3,050
Morris	57	1899						999,875
"	"	1900	2,737,500	1,731,250	1,593,750	392,500	46,200	246,125
Ottawa	81	1899						205,560
"	"	1900	256,250	228,000	116,750	68,500	15,125	14,237
"	"	1899						11,027
"	"	1900	12,275		84,166	49,250	5,800	2,412
La Salle	95	1899						17,800
"	"	1900	192,400	278,750	367,666	96,125	13,050	12,275
"	"	1900						170,050
"	"	1899	193,300	169,625	212,000	157,750	25,300	31,062
"	"	1899						7,062
Henry	123	1900	13,750	45,912	103,125	33,000	22,270	8,550
"	"	1899						64,350
Averyville	159	1900	41,462	160,500	183,625	39,875	14,260	3,487
"	"	1899						8,700
Pekin	175	1900	27,570	139,500	93,375	13,087	15,920	1,637
"	"	1899						1,500,000
Havana	199	1900	128,100	84,000	125,125	27,250	106,500	150,625
"	"	1899						6,810
Chandlerville		1900	124,166	79,575	181,875	26,500	23,850	15,000
"	"	1899						7,125
Beardstown	231	1900	10,620	101,433	105,875	13,625	11,850	20,562
"	"	1899						4,000
"	"	1900	239,750	420,500	145,750	28,375	12,880	7,962
"	"	1899						5,110
Kamsville	285	1900	36,725	202,666	155,625	15,825	5,038	2,425

TABLE I—CHICAGO DRAINAGE WATER (Continued)
 Monthly Averages of the Number of Bacteria from Weekly Collections of Water taken at the Stations
 named in the first column during 1899 and 1900

Station	Miles from Chicago	Year	January	February	March	April	May	June
Grafton	318	1899	46,600	191,500	159,500	14,550	6,850	4,155
"		1900						6,875
"		1899						5,017
"		1900	13,750	69,625	227,750	66,750	10,580	3,650
Alton	333	1899	20,470	86,500	119,750	18,125	17,620	2,457
"		1900						13,125
"		1899						7,250
"		1900	18,620	104,100	144,875	85,500	24,080	5,875
Mitchell	348	1899	35,087	113,100	98,166	17,500	21,800	19,700
"		1900						14,875
"		1899						16,650
"		1900	64,925	50,300	143,333	57,500	64,125	25,375
West Alton		1899	84,960	40,066	179,750	77,000	66,200	63,375
"		1900						
Station	Miles from Chicago	Year	July	August	September	October	November	December
Joliet	33	1899	2,848,666	3,220,000	217,000	1,145,000	1,023,000	1,026,250
"		1900	170,000	134,750	203,330			25,300
Wilmington		1899	4,720	4,000	5,387	11,075	11,650	
"		1900	950	1,975	4,950			
Morris	57	1899	930,750	4,822,375	2,186,100	505,000	747,000	170,000
"		1900	42,375	76,000	624,750			
Ottawa	81	1899	9,298	7,512	40,100	33,050	18,070	261,766
"		1900	2,950	18,830	34,875			
"		1899	3,670	4,560	4,822	5,475	5,900	7,000
"		1900	3,266	2,962	9,375			
La Salle	95	1899	6,370	11,875	9,700	27,112	11,910	101,400
"		1900	3,500	13,000	17,412			

TABLE I—CHICAGO DRAINAGE WATER (Continued)
 Monthly Averages of the Number of Bacteria from Weekly Collections of Water taken at the Stations
 named in the first column during 1899 and 1900

Station	Miles from Chicago	Year	July	August	September	October	November	December
La Salle		1899	157,766	247,000	166,775	131,250	164,400	223,000
"		1900	38,375	17,200	73,775			
"		1899	4,570	1,480	3,200	3,087	14,050	12,787
"		1900	5,475	7,000	2,200			
Henry	123	1899	22,362	26,350	17,100	8,575	5,880	59,966
"		1900	40,433	1,850	136,700			
Averyville	159	1899	9,558	4,060	3,100	3,768	1,640	9,300
"		1900	4,233	8,060	3,100			
Pekin	175	1899	737,625	1,028,323	391,250	1,047,500	812,000	69,000
"		1900	313,375	286,500	1,061,875			
Havana	199	1899	5,925	5,725	6,737	12,433	159,040	301,333
"		1900	24,125	21,362	50,662			
Chandlerville		1899	9,900	19,783	20,300	3,683	7,100	10,266
"		1900	13,900	4,450	4,316			
Beardstown	231	1899	1,352	10,287	3,039	5,000	26,070	114,100
"		1900	4,275	15,090	5,550			
Kampsville	283	1899	3,101	6,225	3,280	1,717	5,065	28,850
"		1900	1,850	10,700	5,850			
Grafton	318	1899	2,628	1,866	793	743	7,210	40,344
"		1900	3,911	2,708	5,274			
"		1899	075	1,379	2,350	2,406	8,380	15,912
"		1900	3,027	3,291	3,934			
Alton	333	1899	1,222	3,319	3,612	2,775	9,600	23,750
"		1900	3,266	3,180	6,687			
"		1899	2,927	2,215	2,602	2,200	5,730	4,183
"		1900	3,862	7,610	4,433			
Mitchell	348	1899	5,737	11,700	5,225	3,075	5,937	9,816
"		1900	26,191	6,110	4,357			
"		1899	5,902	32,275	9,250	10,187	30,125	25,233
"		1900	29,275	10,256	12,927			
West Alton		1899	20,000	32,625	27,477	16,325	28,510	10,475
"		1900		12,450	25,187			

EXPLANATION OF PLATES

Plate XV

Map showing the drainage stream from Chicago to St. Louis and location of stations at which collections of samples of water were taken for examination.

Plate XVI

A graphic representation of the average number of bacteria in the water at the stations named for the months of July, 1899 and 1900, before and after the sanitary canal was opened. Some of the lines run more than once across the plate because of their great length. Note how short they are during the lower course of the stream.

Plate XVII

Graphic representation of the identification of *Bacillus coli-communis* by percentages of positive results of total tests. The stream seems freest from this species at Averyville. The greater numbers at Mitchell appear to be due to the contamination of the waters of the Missouri River received above this point.



PLATE XVI

120

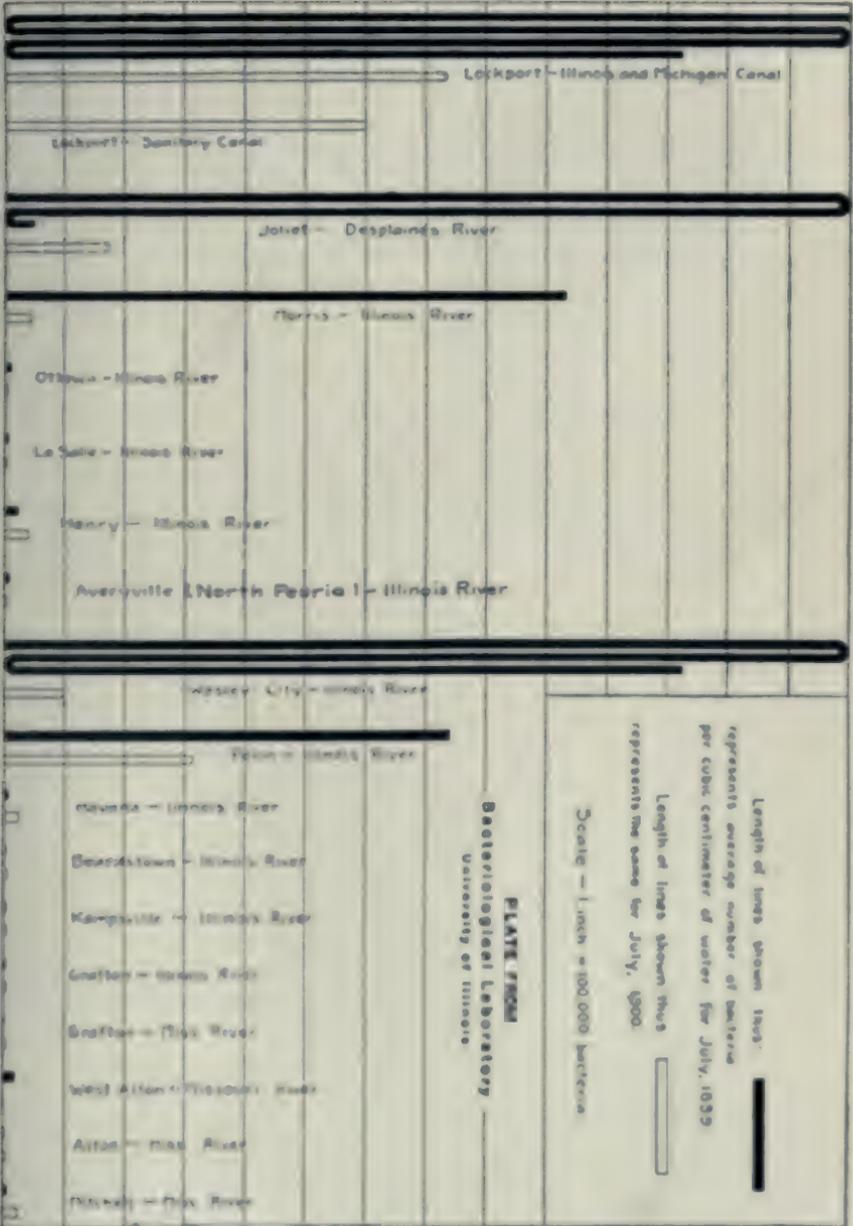
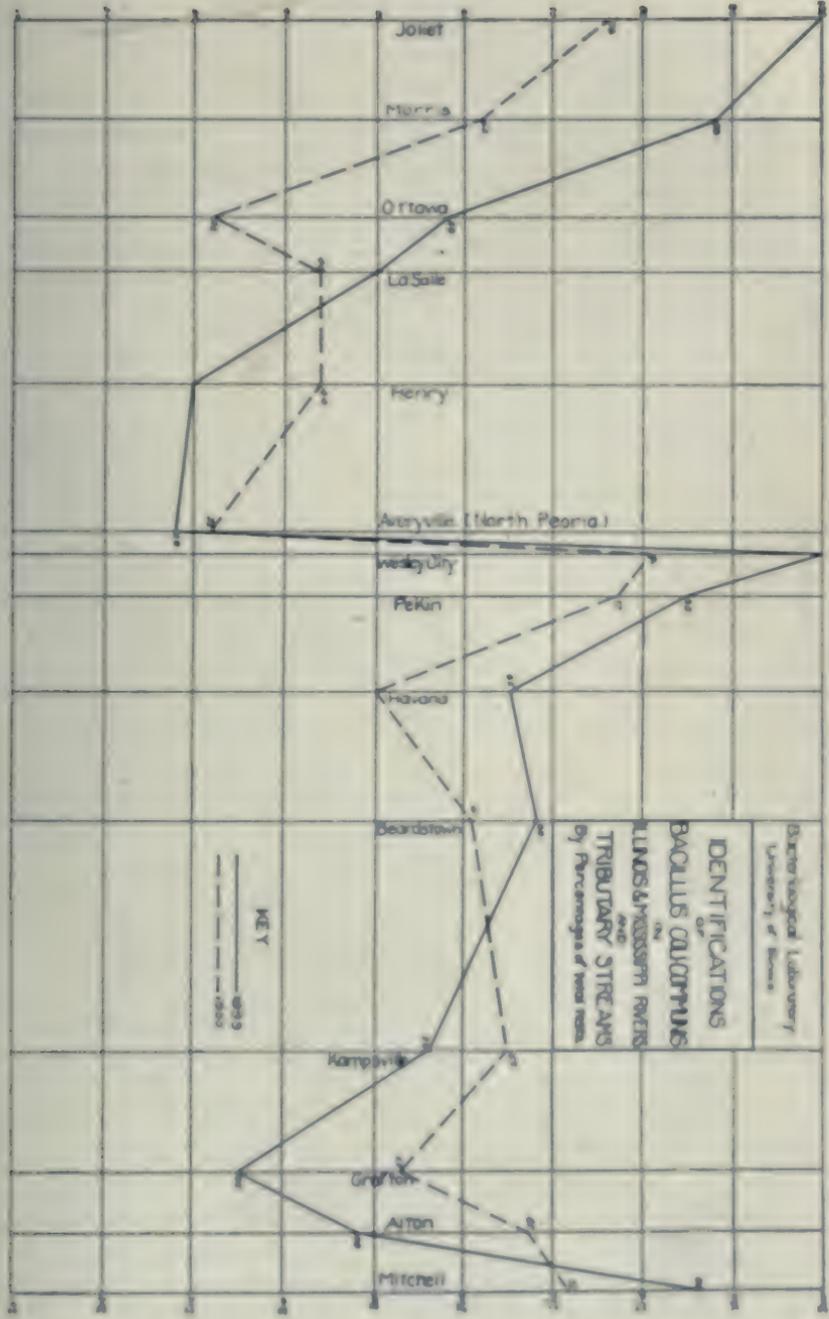


PLATE XVII



SYNCHAETA BICORNIS: A NEW ROTIFER FROM THE
BRACKISH WATERS OF LAKE PONTCHAR-
TRAIN, LOUISIANA

By J. C. SMITH

WITH PLATE

During the summer of 1902, while making some investigations on the microscopic life of Lake Pontchartrain, Louisiana, I took a large number of a species of rotifer which, on comparing with the known species of the genus *Synchaeta*, appeared to differ so much as to warrant it being placed as a new species. At that time, Mr. C. F. Rousselet had begun publishing his Monograph of the Genus *Synchaeta*¹ and had given notice that he would describe several new brackish-water species. In order to determine whether my take was one of his new species I sent him some preserved material. He recognized the rotifer as a distinctly new species and suggested "*bicornis*" as an appropriate specific name.

The body of this rotifer (fig. 1) is of the usual *Synchaeta* type, *i. e.*, cone-shaped; this shape, owing to the very elastic nature of the cuticula, is subject to considerable variation as to length and width. In its most extended form, it is sub-cylindrical, the dorsum being slightly convex and the ventral surface correspondingly concave. It diminishes gradually towards the foot which is short, bulky, and quite distinctly marked off from the body. This foot bears two small peg-shaped toes, which are usually well separated while the animal is in motion. The foot and toes can be retracted entirely within the body of the animal.

The head portion, or corona, is well extended as a convex curve, and on its summit and most ventral aspect has three small papillae, each bearing a tuft of cilia, above which are two pairs of tactile setae, the inner pair apparently connected with the ciliary wreath;

¹ Rousselet, C. F. The Genus *Synchaeta*: A Monographic Study, with descriptions of Five New Species. *Journal of the Royal Microsc. Society*, 1902.

the outer lateral pair arising from heavy triangular processes. The setae pierce the processes and are evidently connected with the brain mass.

The auricles are of medium size and stand out at a right angle to the body when they are extended.

On the dorsal surface, some distance below the extended auricles, originate two very prominent horns, which are tubular prolongations of the cuticula (fig. 1). These horns extend directly forward and sometimes reach almost to the limit of the protruded corona. Seen from above (fig. 1) they appear as cones, but when viewed from the side when the animal is turning slowly and the head part is retracted, they are seen to be true horns with their apices curved downwards (fig. 2). These horns are always more or less wrinkled transversely and can be extended and retracted to a considerable degree. While they often reach almost to the limit of the extended head parts, as noted above, it is not unusual to see very large forms with horns quite small and very small forms with very long horns, so that it may be concluded that the length of the horns does not bear any close relation to the size of the animal.

The dorsal antenna is inconspicuous and is in its usual position. The lateral antennae, if present, are very obscure, for the most careful examination of very many living and dead animals failed to disclose their presence.

The brain mass bears three distinct red eyes—one cervical connected with two frontal by two very obvious (in the living animal) streams of red granules. The cervical eye, as a rule, is composed of two segments which are not always of equal size, and together with the frontal eyes, is surrounded by red granules which seem to be a continuation of the granular streams. This peculiarity of three eyes and their granular connections is shared with another brackish-water species, *S. littoralis* Rousset and a marine species, *S. triophthalmus* Laut.

The large mastax corresponds in shape with that of most of the species, while the fulcrum rests on two distinctly striated V-shaped muscles. The muscles surrounding the trophi appear to be of a tougher consistency than the other muscles of the body, for it was with difficulty that these were sufficiently dissolved to get a fairly good view of the trophi.

Fig. 4 represents an outline camera drawing of the trophi, which

correspond closer to the *tremula* type, as figured by Weber,¹ than to any other.

The fulcrum is very long and knobbed at its free or lower end; each incus has five small teeth on its free edge. The manubria and their wing-like processes can be best understood by consulting fig. 4.

On the ventral side of the mastax were found what appeared to be a pair of densely nucleated salivary glands, which were seen only while manipulating the isolated mastax.

The non-ciliated oesophagus is long and narrow and originates well up on the dorsal surface of the mastax. The stomach, when not unduly distended by food, is longish and ends in an intestine which is quite distinct.

The stomach has the usual gastric glands attached. The ovary offers nothing characteristic of this species. The lateral or excretory canals extend upward to a short distance above the summit of the gastric glands, a peculiarity which seems to be characteristic of all the *Synchaetae*. Excepting a small portion above the glands, they are obscured by the ovary and distended stomach. The usual turnings seem to be absent. There are three or four flame cells on each canal, which are not indicated in the figure. The contractile vesicle is of medium size and normal in position. The two foot-glands are elongate and distinct.

Many of the muscles are distinctly striated and a few muscle-fibrils are to be seen extending longitudinally through the horns.

This little creature is very transparent, the only color seen being that of the stomach contents, which is usually yellow or golden. In this connection, it is probably worthy of mention that all the rotifers of this species taken in July, 1902, were ornamented in a peculiar manner. Purplish spots of irregular shapes and sizes were distributed over the muscles, brain, and all other internal organs, the cuticula being free from them. Even the foot-glands and muscle-fibrils of the horns were affected. The color of the eyes was modified by what appeared to be layers of this colored matter. Nothing in the water in which these rotifers were taken could be correlated with these spots.

It is an exceedingly graceful animal in its movements, swimming in a straight line, revolving on its long axis at the same time and

¹ Weber, E. F. Faune Rotatorienne du Bassin du Léman. Revue suisse de Zoologie, t. 8, 1898.

turning abruptly from side to side. It has a habit of stopping suddenly without any apparent cause, and retracting completely within the body its head, foot, and toes and extending and approximating its horns. It remains in this curious condition (fig. 3) for a second or two, when it again resumes its active state and starts off on its mad chase. Another habit, which was noticed only when the cover-glass was used, is that of "standing on its head"—*i. e.*, it fixes its head to the cover-glass or slip while its body stands out at a right angle.

These delicate animals, so accustomed to the rough water of the lake, seem to be very susceptible to change of conditions, as they perish soon after being transferred to quiet water, for four hours after being taken but a small proportion were found still alive and active, making it necessary to examine them soon after being captured. They vary much in size; measuring when alive and fully extended from 200 microns to 300 microns long and from 100 microns to 150 microns wide across the extended auricles.

The oval egg is carried for a long time on the foot of the animal.

Lake Pontchartrain is a large body of water in southern Louisiana and drains a considerable area. It is about 40 miles long with a maximum width of about 25 miles and its greatest depth is about 18 feet. It connects with Lake Borgne and this again opens into the Gulf of Mexico. It is the waters from the Gulf which make the waters of both these lakes constantly brackish. The specific gravity of the water of Lake Pontchartrain during these investigations varied from 1.006 to 1.010. The rotifers were taken from the upper strata in water varying in depth from three to eight feet and from one to two miles from shore and over a course of six miles. At no time were any found in less depth than three feet and never near shore or among algae or floating debris. They may therefore be classed as belonging to the limnetic fauna.

They were first taken in July, 1902, and were then very abundant. They continued to diminish in numbers until November, when they disappeared entirely. In 1903 they first made their appearance in May, were again found in abundance in July, when they again began to diminish and finally disappeared in November.

The one characteristic which distinguishes *S. bicornis* from all other species of the genus is the two dorsal horns.

Mr. C. F. Rousselet, in his Monograph of the Genus *Synchaeta*,

has described sixteen species, of which seven are fresh-water forms, two brackish-water, and seven marine forms. *S. bicornis* will increase the brackish-water forms to three and the whole number of the genus to seventeen.

The following rotifers were found sparingly in company with *S. bicornis*: *Polyarthra platyptera*, *Anuraea curvicornis*, *Colurus amblytelus*, *Schizocerca diversicornis*, *Brachionus urceolaris*, *Monostyla bulla*, *Monostyla lunaris*, *Distyla gissensis*, and *Notus quadricornis*.

Diatoms were represented by species of the following distinctly brackish and salt-water genera: *Coscinodiscus*, *Melosira*, *Biddulphia*, *Rhizosolenia*, *Chaetoceros*, *Terpsonia*, *Grammatophora*, *Suriella*, *Actinoptychus*, *Triceratium*, and others.

The Protozoa were represented by *Tintinnopsis beroidea* in great abundance, *Ceratium tripos*, and *C. furca*.

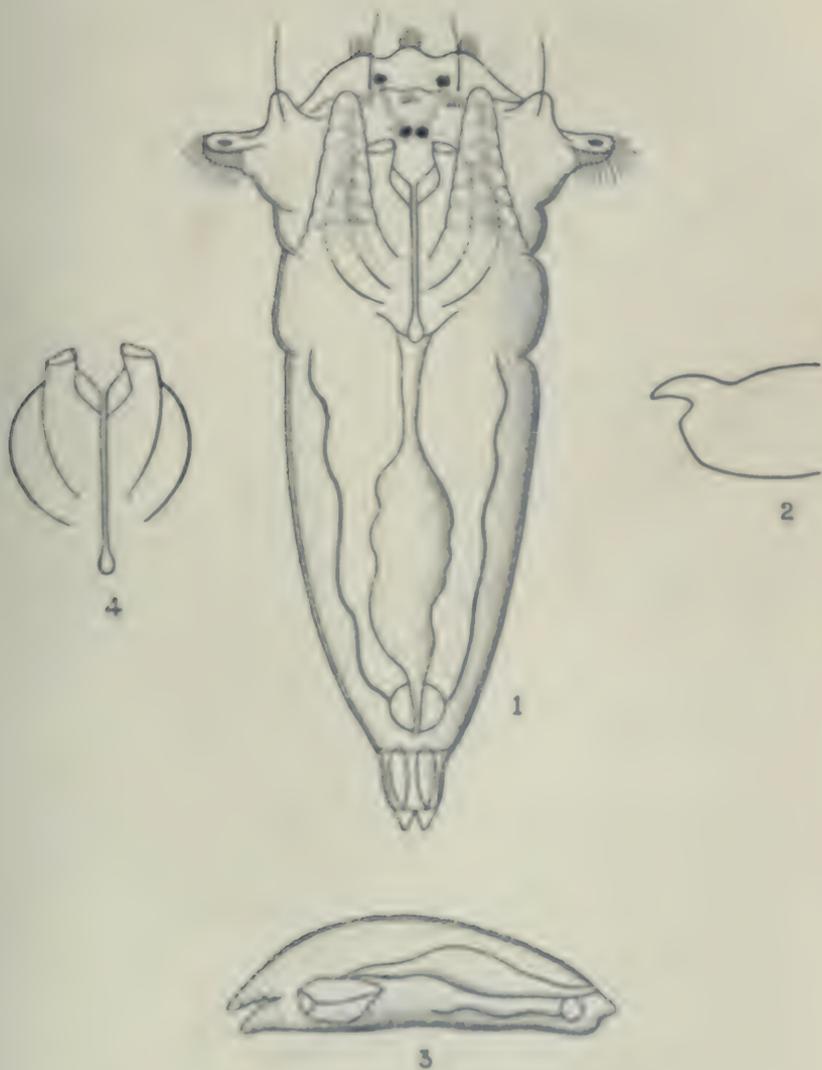
A copepod belonging to the genus *Acartia* was present in very large numbers.

EXPLANATION OF PLATE

Plate XVIII

- Fig. 1. *Synchaeta bicornis* n. sp.
Fig. 2. Horns, viewed from side.
Fig. 3. Animal, still and with head, foot, and toes retracted and horns extended.
Fig. 4. Outline drawing of trophi.

PLATE XVIII



A BIOLOGICAL RECONNOISSANCE OF SOME
ELEVATED LAKES IN THE SIERRAS
AND THE ROCKIES

By HENRY B. WARD

WITH REPORTS ON THE COPEPODA BY C. DWIGHT MARSH, AND ON
THE CLADOCERA BY E. A. BIRGE

WITH TWELVE PLATES

During the early summer of 1903, I had the privilege of spending a brief time at Glen Alpine Springs, California, and directly after leaving that point of making a short stay also in the Pike's Peak region, Colorado. Both locations afforded the opportunity of making observations on groups of elevated lakes which, though brief, disclosed certain features of interest. The period of study extended from June 25 to July 15, so that one could speak with some definiteness regarding comparative conditions in the two places at the same time of year.

The work aroused generous interest on the part of some enthusiastic students of nature whom I had the good fortune to meet, and it is their cooperation both before, during and after the time I spent in the field, that has made this report possible.

So far as the Sierra lakes are concerned, I am particularly indebted to Mr. R. S. Gray for his untiring efforts in many directions, especially in the endeavor to secure for me references to all publications bearing upon the Lake Tahoe region, and for his generosity in placing at my disposal collections made in the Glen Alpine lakes in September, 1902. Mr. W. W. Price and Miss Gilmore also afforded me valuable assistance in tracing out literature on this region. For the work on the lakes of the Pike's Peak region, Dr. F. E. Clements proved an indispensable guide and assistant; the fine illustrations of these lakes are made from his photographs, which were freely placed at my disposal. Professors E. A. Birge and C. Dwight

Marsh were kind enough to take up the exact determination of the Cladocera and Copepoda; and to Dr. R. H. Wolcott I am also indebted for many favors in connection with this study.

The fragmentary character of this work, which was carried out under serious limitations as to time, apparatus, and supplies, is apparent to all. My only excuse in presenting it lies in the desire that it may be an incentive to others to take up under more favorable circumstances the study of these elevated lakes so interesting in themselves, and so important in the problems associated with them. This examination of these lakes was simply a reconnoissance; this report of it is at most an outline of the work which is to be done.

Apart from the fragmentary notes jotted down in my field book at the time, the results of my examination of the lakes are contained in a series of thirty Birge net collections, made in the Sierra lakes about July 1, 1903, and in the Pike's Peak lakes about July 13, 1903. These collections were made with great care to secure representative material from the different bodies of water. They certainly do not represent the entire limnofauna of the lakes. But they probably give a fair general idea of the fauna at that time of year. Some reasons for expecting a change later in the summer are detailed elsewhere in this paper.

To the above was added a series of forty-five vials of material collected by Mr. R. S. Gray in September, 1902. This represents to some extent the autumnal life of the waters, although the collections were not made with the purpose of securing all types of life in the lakes.

No effort was made to examine the geology of the two regions; but of both it is well known and admirably represented in the Pyramid Peak and Pike's Peak folios of the U. S. Geological Survey, which include fully the regions studied. It was also impossible in the lack of time and suitable apparatus to make any observations on the physical characters of the lakes. Even the temperature had to be estimated rather than precisely measured. Although many plant organisms were collected from the lakes in both regions, no accurate work has been done in studying them, and only general statements can be made concerning the limnoflora.

The first point to be considered is the character of the lakes studied. Between the lakes in the Sierras and those near Pike's Peak

there are not inconsiderable differences which may be made clear by a description and discussion of the chief features in each group. The Sierra lakes will be considered first.

Muir (1900: 122) speaks of the "marvellous abundance of glacier lakes hidden in the fastnesses of California mountains. . . . They nestle in rocky nooks and hollows about all the high peaks and in the larger cañons, reflecting their stern and rugged beauty and giving charming animation to the bleakest and most forbidding landscapes. From the summit of Red Mountain, a day's journey to the east of Yosemite Valley, 42 may be seen within a radius of eight or ten miles. The whole number in the Sierra can hardly be less than 1,500, exclusive of the smaller gems which are innumerable. Perhaps two-thirds of them lie on the west flank of the range, and all are restricted to the alpine and subalpine regions, those which once brightened the lower regions having long since vanished by the filling in of their basins. Lake Tahoe is king of them all, not only in size, but in the surpassing beauty of its shores and waters. . . . With these comparatively unimportant exceptions, the lake itself and all its grandly sculptured, ice-scored, and moraine-streaked basins exist today in just about the condition they presented when first they came to light toward the close of the Glacial Period."

In a later publication (Muir, 1903: 98) the same author adds the following: "Though the eastern flank of the range is excessively steep, we find lakes pretty regularly distributed throughout even the most precipitous portions. They are mostly found in the upper branches of the cañons and in the glacial amphitheatres around the peaks."

The group of Sierra lakes which I studied lies on this precipitous eastern flank of the range at the southwestern corner of Lake Tahoe into which all of them ultimately drain (Plate XIX) through the medium of a smaller body of water, known as Fallen Leaf Lake. The latter is separated from Lake Tahoe by a low plain which was apparently an ancient moraine, and which is not quite two miles in width. While the lower northern end of Fallen Leaf Lake lies in the plain, the upper end is encompassed by mountains, especially on the west, where the steep flank of Mt. Tallac rises directly from the water's edge. The valley in which Glen Alpine Springs is located trends westward from this end. It is narrow, with cragged sides and little vegetation beyond that which is crowded together near the

stream. The floor ascends so rapidly that the channel of the brook is little more than a succession of rapids and falls, in some cases of considerable height, with occasional pockets of a swampy nature bearing an abundant plant growth. The lakes occur as a series of larger pockets, in some of which the filling in has progressed so far as to produce a shallow, marsh-edged basin with a distinct rapidly-flowing stream through the center. Others present themselves as deep basins with rocky, often precipitous shores, and little current apart from the immediate region of inlet and outlet. The shallower lakes are also the lower in the series. I have been unable to ascertain the exact altitude of these lakes, but this factor can be calculated sufficiently exactly from the topographic charts of the U. S. Geological Survey, from which I obtained the following list of elevations above sea level: Lily Lake, 2010 m.; Grass Lake, 2194 m.; Susie Lake, 2347 m.; Heather Lake, 2377 m.; Half Moon Lake, 2500 m.; Lake Aloha, 2470 m.; Gilmore Lake, 2530 m. The figures given are probably 5 to 15 m. below the true altitude.

Inflow and outflow are large in proportion to the volume of the lakes, especially in the spring and early summer, while the snow accumulated during the winter is melting rapidly. Later in the season the volume of the streams is said to decrease markedly. The fluctuations in the level of the lakes due to this factor are, however, inconsiderable, since the outflowing streams possess very little depth. At the time of my visit the upper lakes were fed directly from melted snow (Plate XXII), and at many points on sheltered slopes great masses of snow reached into the water, while miniature icebergs floated on the surface. The temperature was accordingly low and conditions were typically glacial.

By the time the water had reached the lower levels, however, it had become much warmer and all snow and ice had disappeared from the immediate environment of the basins. The color of the stream had also acquired a distinct brown tone leached out from the forest mould through which it had filtered. It was everywhere clear and transparent, carrying a very insignificant amount of debris of all kinds whatsoever.

Lily Lake, the lowest of the series, had been filled in considerably and was surrounded by swampy areas covered with plant growth and shallow flats on which at the time of my visit the first traces of a sub-aqueous vegetation were beginning to show themselves. It

was the smallest and clearly also the most decadent of all these water basins. Grass Lake was larger, much more open and of greater average depth. The upper end was apparently closed by a thicket of partly submerged alders, through which the water found its way without any proper channel that was visible. There were also banks of eel grass that covered parts of the bottom beyond the alders; but except at the upper end there was no approach to a swampy condition.

In the higher lakes the shallows, swampy areas, and water vegetation were either minimal or absent. The lakes were apparently much deeper on the average, and also larger. Furthermore, instead of possessing a single inlet, water was pouring down every rocky defile from the snow banks above and had worn only shallow channels in the debris of the mountain side, while the debouchment of these rivulets had often no trace of the formation of a delta. These lakes are young and the process of destruction had not yet begun.

The group of lakes in the Rocky Mountains which were made the object of my study, lie in the valley of Beaver Creek, about 7.5 km. (4.5 miles) south-southeast of the summit of Pike's Peak (Plate XXIII). They are known collectively as Seven Lakes and lie at an elevation of about 3,300 to 3,310 m. above sea level. The individual lakes are near together and all empty into Middle Beaver Creek. About 2 km. distant lies a small water basin near the saddle of a divide; it is without visible inlet and outlet and is called Dead Lake. Its altitude is approximately 3,340 m. above sea level. It is of small size and insignificant depth.

Among the Seven Lakes some are very shallow and surrounded by an extensive swamp margin, while others are of considerable depth. At the time of my visit the snow had entirely disappeared from the proximity of these lakes, and even from Mt. Garfield, which towers above them. The surface water was not noticeably cool to the hand and in the shallow lakes even apparently warm. Though much higher than the lakes of the Sierras, these water basins present nothing of the typical glacial conditions already described for the others.

In Dead Lake July 13, 1900, the surface temperature was $14^{\circ}.4$ C., the bottom 13° C. At Ribbon Lake the temperature was $14^{\circ}.2$ C. alike at surface and bottom. The temperature of the air varied during the day from $13^{\circ}.6$ to 18° C.

The amount of inflow and outflow was small comparatively and the normal fluctuations in level slight. One can see that within comparatively recent times several of these lakes have had a greater extent than at present. Within a year, however, they have been connected with the city water supply of Colorado Springs and the level in one of the largest, Mirror Lake, has been reduced so much as to lay bare the entire lake shelf. This result appears clearly in a comparison of the two illustrations (Plates XXVII and XXVIII). The changes contemplated are certain to effect notable alterations in these lakes and also in their fauna.

Viewed as a whole these lakes are old, and some of them are just about to disappear, if natural conditions persist. Very little, if any, of the rocky sides of the mountain enter into their boundaries; the shore is made of broken fragments and detritus, which have also filled the basins in great part. The lakes lie exposed to the sun and wind, not shut in by high banks, nor protected immediately by heavy forest growth. The surrounding territory has a large amount of soil and supports a vigorous growth of mountain vegetation. In most respects then these lakes stand in sharp contrast to those in the Sierras already described.

Zschokke gives (1900:40) as the picture of a typical alpine lake the following: Water basins of more than 1,500 m. (5,000 ft.) altitude, of variable, but mostly insignificant area and very different depth. The bottom and shore show in their character manifold local differences, and the general external features vary equally. Drought and avalanches may threaten the existence of the basin. The Characeae, algae, and mosses play the chief part in the flora and the littoral plant world generally disappears rapidly with increase in altitude. The inflow is poor in nutriment, and often carries cold water exclusively or in predominant amounts, while periodic increase or decrease of the inflow often produces very important oscillations in the niveau of the lake. The inflow or outflow is often subterranean. The quiet of the surface is almost undisturbed. The water temperature, even in midsummer, is low, wintry. Little difference exists between surface and deep temperatures, between summer maxima and winter minima. The ice covering lasts long. The chemical composition of the water is very variable. In Alpine lakes the most important and most constant conditions which present themselves to the fauna are northerly, glacial. Low temperature of the medium

inhabited, long continued winter with heavy covering of ice, sparse development of the flora. Copious inflow of snow water or cold water, poor in food and often unsated with oxygen, and with large amount of mineral matter in suspension. Other conditions are as in water basins of the plain. Glacial conditions control the composition of the fauna of alpine lakes and the animals of elevated lakes are still in the midst of the glacial epoch.

The general limit assumed by Zschokke (1900:2) which confines his work to lakes having an altitude of more than 1,500 m. is recognized as more or less arbitrary, and yet it corresponds well in the region he studied to the other limitations of strictly alpine lakes. This is not only the case in Switzerland where Zschokke worked, but also in the Tatra lakes, according to Wierzejski and von Daday, in the elevated lakes of the Pyrenees, according to de Guerne and Richard, and in the French Alps and the Pyrenees, according to Delebecques.

The same conditions do not obtain on this continent. There are lakes in Colorado above the 1,500 m. line (about 5,000 ft.) which, located on elevated plateaus, have all the characteristics of flat land lakes. One must usually go higher than this limit to find water basins to which the term "alpine" may properly be applied. Apparently no such limit, even of an approximate character, can be used in this country since conditions at the same elevation evidently vary in different regions. That the limit of alpine lakes does vary my own observations in the White Mountains (New Hampshire) the Rockies (Colorado) and the Sierras (California) show me unmistakably; what may be the extent of this variation and what the approximate altitude of characteristic alpine lakes in different regions can only be determined by much more extensive observations than I have made as yet.

That latitude as well as altitude is an important factor in the comparison of elevated lakes has been recognized by Forbes. In contrasting the two largest lakes in the regions he studied he says (1893:236): "Flathead Lake is over 200 miles [320 km.] farther northward than Yellowstone, but the latter is 4,775 feet [— 1,455 m.] the higher above the level of the sea." Among others, "These differences tend largely to neutralize each other."

The Sierra Lakes visited were much more clearly glacial in their environment than those near Pike's Peak and yet they lie about 1,000

m. lower than the latter, while in latitude they are almost identical, as the line marking $38^{\circ}50'$ N. Lat. crosses both regions (Plates XIX and XXIII). It is clear, however, that conditions are not so constant as in the Alps and questionable whether the same relative conditions persist between the lakes of the Sierras and Rockies throughout the year. In the course of the summer the snow in the Sierras disappears (Plate XXIII), the inflow becomes scantier in amount and probably somewhat higher in temperature, while the lakes themselves, no longer under the influx of a large amount of cold water, must rise in temperature noticeably towards late summer. In the Pike's Peak region these conditions had already come, and the change towards fall would bring even higher temperature. In the Alps the persistent snow masses and ice fields keep down the temperature of the inflow.

Another noteworthy difference between the elevated lakes of this country and of Europe is found in the greater area of our own. Lake Tahoe, lying at an elevation of nearly 2,000 m. (6,225 ft.) has an area of over 50,000 ha. (193 sq. mi.), Shoshone Lake, studied by Forbes (1893) has an elevation of 2,360 m. (7,740 ft.) and an area of about 3,100 ha. (12 sq. mi.), Lewis Lake and Heart Lake, of nearly the same altitude, have from 780 to 1,300 ha. (3 to 5 sq. mi.) of area (Forbes, 1893), while Yellowstone Lake, also at an altitude of about 2,360 m. (7,740 ft.), measures 36,260 ha. (140 sq. mi.). These are by no means isolated cases, as a glance at the contour map of the U. S. Geological Survey will show. The 1,500 m. (5,000 ft.) contour line encloses many water basins of considerable area; some of these are saline, a few, as Mono and Owens lakes, California, excessively so, but others contains water of extreme freshness and purity. Mingled with these large lakes are myriads of smaller. As Russell says (1895:63): "These lakes are of all sizes, from mere tarns across which one might spring with the aid of an alpenstock, to broad plains of blue, many square miles in area, and worthy of comparison with the most beautiful mountain lakes of other lands." The Sierras are peculiarly rich in such water basins. With Lake Tahoe,¹ "the gem of the Sierras," at one extreme of size, and with the tiny rock pool, or swamp-filled basin at the other, the series embraces every variety of contour and environment. Among the

¹ For a splendid description of this incomparably beautiful sheet see Russell (1895:63).

Rockies, however, such lakes are far less numerous, and like the Pike's Peak group already described, are for the most part well on the way to final disappearance.

The lakes in the Sierras are about of the same altitude as those studied by Zschokke in Switzerland, and at the time of this study presented the same typically glacial features. In other respects also they are in general agreement with his descriptions, save, as already noted, that the disappearance from the mountains of the snow and ice in late summer is undoubtedly accompanied by a rise in temperature and a consequent greater thermal range than is found in the lakes of the Alps.

The lakes in the Pike's Peak region of the Rockies are 800 m. higher than any in the Sierra group studied; the conditions are, however, much less distinctly glacial. In Dead Lake, the shallow water had already attained a moderate temperature ($14^{\circ}.2$ C.) and after two months of summer sunshine would be decidedly higher in spite of the cool nights and cold rains of that elevation. Such lakes will furnish, accordingly, only transiently glacial or northern conditions during the spring and fall. And these periods will be interrupted by an interval in which the temperature conditions are nearer those of the lakes in the flat land. The summer interval will be especially marked in those water basins which are very shallow like Dead Lake, which is also dependent upon seepage for inflow and outflow, and least so in the deeper ones such as Mirror Lake. Locally the latter is said to be "bottomless"; it is certainly more than 10 to 15 m. deep at the maximum. Ribbon Lake measures about 8 m. at the deepest point, while none of the others much exceed one meter in depth and over the greater part of their area the water has a depth of only one-third that figure.

In one further particular both series of lakes studied differ notably from the lakes of the Alps: they all lie below timber line, as an examination of the plates will show distinctly. Two results of this position affect the biological character of the lakes: A considerable amount of plant debris is washed into the waters, which by its presence and gradual disintegration influences the food supply. In the second place, the living trees, as well as the dead fragments, attract additional members to the terrestrial fauna which sooner or later, and in one form or another, add to the water fauna or furnish food for the latter. The forms concerned are chiefly insects, of which a very

considerable number depend upon the timber for their presence in the region. The relative importance of insect larvae in the water fauna is discussed elsewhere in this paper.

The fauna of elevated lakes has been subjected to a careful study by Zschokke, whose results have appeared in a series of papers on special regions extending through a number of years and culminating in the splendid crowned memoir of the Swiss Naturalists' Society (Zschokke, 1900). The characteristics of elevated lakes are precisely stated therein in terms which also apply, as already noted, to the lakes of the Sierras and the Rockies that were the seat of my observations. Zschokke sums up these features as follows: (1900:377) "The truly characteristic external conditions of the alpine lakes are glacial: a low mean temperature, inflow from melting snow and ice, long continued ice covering, poverty in plant growth and fluctuations in level. The elevated water basins still stand in regard to physical and chemical relations in the midst of the glacial epoch. Hence their fauna bears a distinct glacial stamp in composition, origin, distribution, manner of life, and structure of its representatives." The description of the physical features applies to the lakes under discussion, as the description and views reproduced here will show; it remains accordingly to examine the character of the fauna.

At other places in Europe investigations have been made on the fauna of elevated lakes; they are, however, less intensive than the work of Zschokke just noted and need no special mention here. Data concerning them may be found in the full bibliography given by Zschokke (1900:382).

The earliest study of the fauna of elevated lakes in this country was that of Forbes (1893). There are to be sure, earlier references to the fauna of our mountain lakes, but casual observations made in connection with various expeditions and surveys, or the description of a single species collected by some traveller cannot be considered a study of the lakes themselves. Isolated observations of this type are referred to both in the paper of Forbes (1893) and in those by Beardsley (1902, 1902a). Forbes investigated the lakes of the Yellowstone National Park in Wyoming and of the Flathead region of Montana, spending two seasons, 1890 and 1891, in the field. The lakes examined were many of considerably size and depth; the highest elevation from which material was collected was Mary

Lake at about 2,500 m. (8,200 ft.). The extensive collections included a number of new forms apparently characteristic of elevated lakes. Unfortunately these collections have never been described in detail. This paper contains many points of great interest and will be referred to in detail under later paragraphs.

While the records of Forbes (1893) concern the Rocky Mountain chain, they were made much further to the north than those from the Pike's Peak region. Recorded studies on forms from Colorado are rare and I have traced out but a single recent author. Beardsley (1902, 1902a) has recorded a considerable number of species from Colorado, both of Entomostraca and of Protozoa. Doubtless some of these came from lakes which are strictly alpine. All of them were taken above 1,200 m. and yet very few are in any way characteristic of elevated regions. The significance of this will be pointed out later. He also gives complete references to previous papers on these forms which contain records of their occurrence in Colorado.

So far as the group of Sierra Lakes is concerned almost the only data on the natural history of this region are given by Price (1902), in a pamphlet which embodies the results of several years personal studies by the author, and his students, on the higher animals and plants found in this territory. The birds and mammals are well treated in concise form, the fish and reptiles somewhat more briefly, and the discussion of the plants is confined to trees and shrubs. While the pamphlet does not include any immediate reference to the aquatic plants or animals, it contains much of great interest in the consideration of the general environment of the lakes.

In a brief paper (Ward, 1903) I have related some of the observations made in the series of lakes near Glen Alpine, and have pointed out the relation in which these observations stand to the planting of trout in these waters.

Some collections of Entomostraca, made in the lakes of the Sierras, by G. Eisen, were studied by Lilljeborg and reported by de Guerne and Richard (1889). The localities are given in general terms, except for *Epischura nevadensis*, which was collected in Lake Tahoe and Echo Lake; these water basins lie very near the lakes under consideration (see Plate XIX).

The fauna of the Sierra lakes was noticeably scanty in amount in all regions; neither in shore nor in open water was one able to find either plant or animal forms in considerable numbers of individuals

or in variety of species. Only once in a very shallow pool by the side of the trail did I find a moderately populous water basin and even here conditions were far behind what would have been met with under similar conditions at a lower level.

The same scantiness of animal and plant life was observed in the deeper lakes in the Pike's Peak region. In the shallow water basins here, however, the fauna was distinctly richer both in species and in individuals. From bottom hauls came a rich flora of unicellular algae and a more numerous fauna than was elsewhere obtained.

The records from the lakes of the Pike's Peak region represent the greatest altitude from which the limnofauna has been reported in this country, and they also surpass any from European countries. As already pointed out mere altitude cannot be considered as determinative in comparing two elevated lakes. The most important factor here, as in the distribution of marine life, is temperature, and this is related in part to altitude, but also to other factors, the most general of which is latitude. A striking instance of this is drawn from my collection. *Holopedium gibberum* was found in the Sierras at Susie Lake, at an elevation of about 2350 m. above sea level. The greatest altitude at which it had been collected previously was Lewis Lake (Forbes, 1893), at almost exactly the same level, but in the Rocky Mountains. The same species occurs in Gotthard Lake, Switzerland (Zschokke, 1900), at 2,100 m. altitude, and in lakes of the Hohe Tatra, Bohemia, up to 1,795 m. It also occurs in mountain lakes of Norway at altitudes of less than 1,000 m., in Iceland in a shallow pond on an elevated plateau, which in any event is not very high above sea level, and finally in lakes at sea level in Greenland. More accurate and detailed consideration of the various points of occurrence from among which these instances have been taken would probably show them to be uniform in temperature conditions. The species is one which evidently prefers clear, cool water, finding this at different altitudes (or times of year?) in different latitudes.

It is not easy to find examples so distinct in their indications as the one just cited. Usually the evidence is partial; but it may be found in one form or other in the observations of many investigators of mountain lakes. I shall refer only to two instances taken from the same source. Zschokke furnishes many points illustrating this feature. One of the most striking is his statement (1900: 349) that the lakes of the Bohemian forest, investigated by Frič and Vávra,

contain a typical alpine fauna, although they lie at an altitude of scarcely 1,000 m. above sea level. Zschokke also gives (1900: 350) an extensive table of the maximum altitude reached by some sixty species in the lake of the Rhätikon, St. Gotthard, St. Bernard, and Upper Engadine regions of the Alps. This furnishes unmistakable evidence of the presence of a species at greater altitudes in the region of more favorable temperature conditions. Zschokke emphasizes the important feature that the fauna varies greatly from point to point both quantitatively and qualitatively by virtue of the general variation in external conditions. But all in all when both European and American lakes are compared, latitude and temperature, which go hand in hand, constitute that factor, the effect of which is most evident.

Certain notes regarding particular groups or individual species of the lake fauna call for special record here. The material could not be examined on the spot; consequently little definite information was obtained regarding the Protozoa and Rotifera which were present.

The paucity of records concerning Branchipoda from alpine lakes has been commented upon by Zschokke (1900: 188) who could find in all hardly half a dozen notices of their occurrence in such water basins of all lands. Their presence and relative abundance in the waters of Colorado are already well known through the work of Packard (1883). Beardsley (1902) has added five species to the faunal list of the state. The largest organism I found in Dead Lake was a branchipod which was present in considerable numbers. This form was *Branchinecta coloradensis* Packard which was originally collected at about 3,800 m. altitude near Grays Peak, Colorado. It is closely related to *B. paludosa* (Muller) which occurs in northern Scandinavia and Greenland. Packard (1883: 339), says of this form, "They thus live under almost exactly the same meteorological conditions as *B. paludosa* in northern Labrador and Greenland, the temperature near the snow line on Colorado in August being about the same as that of northern Labrador and Greenland in August." Dead Lake is the lowest point in Colorado at which the species has been taken.

The twenty species of Cladocera I obtained extend the range of the species into a territory from which the group has not been reported hitherto. The vertical distribution of these forms has also been greatly increased. This is of course true of the American

species heretofore known only from the flat land of the eastern or central states, but is equally the case with the cosmopolitan species like *Chydorus sphaericus*, collected in the Rockies about 700 m. above any previous record. European species of an alpine character, such as *Daphnia longispina* occurred here at an altitude equally greater than heretofore recorded. Such occurrences conform to the differences in the character of the American and European regions, which have been discussed in full in the earlier part of the paper. More striking is the presence of some forms, *Bosmina longirostris*, *Eurycercus lamellatus*, *Polyphemus pediculus*, in the Sierras at altitudes from 500 to 700 m. higher than Zschokke (1900: 156) has found them in the Alps, although conditions in the two regions, as already noted, are closely similar.

In the distribution of species in the two groups of lakes it was noteworthy that the new form described by Professor Birge, *Macrothrix montana*, occurred both in the Sierras and in the Rockies, and that *Diaphanosoma leuchtenbergianum*, heretofore known only from a single elevated lake, Lewis Lake in the Yellowstone region of the Rockies (Forbes, 1893), was collected from an almost identical altitude in the Sierras. This form has not been reported in Europe from any elevated water basin.

The Copepoda were present in almost every collection I made, although the number of species is small in comparison with the Cladocera. *Diaptomus signicauda* is a small form, viewed as one of the most peculiar of American species and reported hitherto only once from collections made in the Sierra Nevada mountains, California, at an elevation of 2,400 to 3,000 m. (8,000 to 10,000 ft.) above sea level. Its occurrence in the Sierra collections is natural, although the localities represented here lie on the eastern flank of the range, while it was probably collected before on the western slope. It was taken here at a slightly lower elevation than previously reported. Exceedingly interesting is the closely allied new species described by Professor Marsh (p. 147) which occurred only in the Rocky Mountain lakes.

Diaptomus shoshone "has never been found outside of Yellowstone Park" (Forbes, E. B.). The abundant occurrence of this conspicuous species in the lakes of the Pike's Peak region extends its range considerably along the chain of the Rockies; and also its vertical distribution which now includes 2,300 m. (Yellowstone

Park) to 3,300 m. (Pike's Peak region). Extended observations are necessary to determine how much of this may be due to the factor of latitude discussed above. This form may be regarded as a characteristic alpine species in the Rocky Mountains.

Epischura lacustris, a common species in the deeper, clearer lakes of the northern United States, was noted by Forbes specifically as wanting in collections from Yellowstone Park, while in the Flathead River system, Montana, it was apparently replaced by another member of the same genus, *E. nevadensis*. Forbes was inclined to attribute the absence of the common *E. lacustris* to the altitude; and yet the observations made in the Sierras show that this can hardly be the correct view, for this species occurred in collections made in September, 1902, from at least four of the lakes. Furthermore, these included Lake Gilmore, the most elevated of the entire series (2,530 m.). This record extends notably the vertical range of this species, and also of the entire genus. Regarding the latter point, Forbes says (1893: 254), "The absence of all representatives of this genus from the lakes of Yellowstone Park evidently adapted to them, hints strongly at a limit of altitude to their distribution. The highest locality from which any species has been reported is Lake Tahoe, said to be 6,250 feet above the sea; while the lowest lake of suitable size in Yellowstone Park from which our collections were made, was 1,200 feet higher than this." This topographical difference does not measure the biological difference, however, as the lower location is also more than five degrees south of the Yellowstone lakes. As the elevation of Lake Gilmore, the highest record of this species, made in this study, is nearly two hundred meters above the Yellowstone lakes, it is evident that the question of altitude merely is not decisive. The query raised in Forbes' concluding sentence falls under the problem of the influence of latitude upon the vertical distribution of the fauna, and serves to emphasize still further points already discussed in this paper.

The absence of *Epischura nevadensis* from these collections is especially noteworthy, since it was originally collected from Lake Tahoe and Echo Lake in the immediate vicinity and connected with the same water system as the lakes examined.

Among the Cyclopidae collected, *C. serrulatus* and *C. albidus* should be regarded, according to Forbes, as very common mountain forms, and are the only species reported from Crater Lake, Oregon (Forbes, E. B., 1897: 62); this lake is 1,902 m. above the sea.

One peculiar feature which was recorded several times in my field notes, seems to be definitely related to altitude. Says Zschokke (1900: 130), "an extremely striking characteristic of the diaptomids of alpine lakes lies in their brilliant red coloring." This brilliancy of coloring does occur among the diaptomids of lower elevations, and varies much in the same species from point to point; yet it is far more general and more striking among the alpine forms. The red color occurs in other groups, of which Zschokke names hydra, the Cyclopidae, many Turbellaria, some Annelida, and at least one rotifer. Apparently the color is transmitted secondarily to the other forms along with the Copepoda used as food. This view is supported by the fact that hydræ when starved bleach out. Low temperature clearly favors the development of this coloring matter.

Forbes (1893) published the first records on the abundant occurrence in elevated lakes of several red species: *Diaptomus shoshone*, of which the adults of both sexes are blood red throughout except the egg sac of the female which was purple; *Diaptomus lintoni*, and a brick red hydra (p. 222). All of these finds were in the Snake river system, at an altitude of approximately 2,277 m. above sea level.

Such a red color has also been noted in alpine lake forms by Elrod and Ricker (1902). Hydra taken in Echo Lake, Montana, was conspicuous by reason of the bright coral red coloring and a reddish *Daphnia* is abundant in the same water. The authors fed such red hydræ five weeks on colorless entomostraca but in contrast with the results obtained by Zschokke, observed no noticeable dimming of the color. One of the most striking features noted in the Sierra collecting was the presence of similarly colored Entomostraca. The extreme case occurred in Gilmore Lake when apparently the entire haul was made up of a copepod¹ so deeply colored red as to stand out with great distinctness in the water. The latter was at the time ice cold and although the surface was free from ice, the snow banks lay near the margin on all sides. Lake Gilmore is the most elevated of all those visited, being about 2,530 m. above the sea.

In an earlier paper Elrod (1901: 76-78) reported *Diaptomus ashlandi* in McDonald Lake as "conspicuous on account of its red

¹ This form does not appear in the list by Professor Marsh. It was recorded in my field notes as a large brilliant red copepod and I recall its appearance distinctly, but the vial of specimens has disappeared.

color." *Daphnia pulex* from Daphnia Pond (elevation 914 m.) was "so abundant that the water appeared of a dirty red color."

The majority of my collections from both regions contained Ostracoda, but the species were not determined. Zschokke did not find the members of this group in water basins higher than 2,500 m.; in the Pike Peak region they are present 840 m. higher than that level. In algae from the Seven Lakes *Macrobiotus* sp. was also found.

The worms were poorly represented in the collections. A few Oligochaeta were taken both in the Sierras from a temporary pool near Susie Lake, and from Lake of the Rocks and Dead Lake in the Rockies. Numbers of an immature *Planaria* were also present in a bottom haul from the latter place.

The number of hydrachnids collected was not large but rather widely distributed. One form of *Notaspis* was collected from a small pond near Susie Lake at Glen Alpine and from Lake of Rocks near Pike's Peak. From the former young of *Atax crassipes* were also taken and from the latter an *Acercus*; *Limnesia* and *Curvipes* occur in the September, 1902, collections from the lakes of the Sierras, and one specimen of *Lebertia* was found in the collection I made from Dead Lake at Pike's Peak. The records of these forms from lakes in the Rockies conform to the records of the other groups in being the highest (3,300 m.) yet made for these species, and probably represent the greatest altitude at which water-mites have ever been collected. Undoubtedly more extensive collecting would have added to this element of the fauna.

Thysanura and *Thrips* were observed in both localities, though no more precise determination of the forms was attempted.

Among mollusks *Pleurocera* and *Pisidium* were observed in the Pike's Peak lakes, while *Sphaerium* was obtained in Susie Lake, Glen Alpine Springs.

Insect larvae were relatively abundant in all the collections and in fact appeared to form the predominating element in the fauna. There were larvae of several Hemiptera, Diptera (*Culex*, *Simulium*?) and Coleoptera, in the collections from the shallower of the Seven Lakes and also from the temporary pools in the Sierra region. From the deeper lakes in the Sierras I collected only Chironomid larvae which were present in nine hauls out of ten, being the most conspicuous organism taken. These were also present in about half the hauls made in the Rockies.

Not only were insect larvae abundant in the pools of the Sierra region, but adult forms were seen in the air and on the vegetation about the water. The air was relatively much warmer than the water so that terrestrial and aerial forms had developed in advance of the limnofauna. It seemed as if the mature insects had pushed their way up from lower altitudes into this region by the aerial route and were taking advantage of the first appearance of suitable water basins which afforded a place to deposit their eggs. Thus the insect fauna was developing in advance of the other elements. Of the larger aquatic forms we saw nothing beyond the insect larvae save that in a single haul were two large Amphipoda.

Two observations contributed evidence in favor of the view just stated. I had the opportunity of examining the stomach contents of a female mallard duck which was shot on one of the lakes, and preserved for the U. S. National Museum. The duck was well nourished and the stomach well filled with food; but there were none of the various small crustacea which usually constitute a very large part of the food of these birds. Not a single part was found which even doubtfully could be referred to such forms; almost the entire mass of stomach contents was composed of mature insects, among which were a few insect larvae. Substantially the same was true of the stomach contents of the trout which were caught during the same time.

I was unable to ascertain what was the original condition of these lakes in the Sierras as to fish fauna. The precipitous character of the outlets, and the limited volume of the outflow, together with the landlocked character of the system which does not reach the ocean, but terminates in saline lakes on the desert, all make it probable that they were entirely without fish in the early days. The impassable character of these outlets in some instances at least may be judged from the photograph of Grass Lake (Plate XXI) where in the midbackground appears the outlet of one of the higher lakes spreading like a film of gauze over the face of a precipitous cliff.

Within recent years, however, numerous plants of trout fry have been made in the lakes with varying degrees of success. The trout caught in different lakes varied much in robustness; from some they were plump and well nourished, from others they were evidently starved, presenting a gaunt, cadaverous appearance, which the fishermen described as "all head and tail." Evidently such had obtained

scant nourishment through the winter and had had no opportunity to improve their condition as yet since they came from the highest lakes which were indeed only partly free of their ice covering. The fish which came from the lower lakes were taking the fly eagerly and were voracious after larvae and mature insects, as evinced by the contents of the stomach. If their winter fare had been as limited as that of the others, they had recouped their fortunes on a spring diet of insects which, commensurate with the earlier opening of their basins, came much in advanced of the disappearance of ice from the higher lakes.

In view of these facts one may ask whether the normal winter fauna of these lakes is not scanty for the support of fish life, so poor in fact as to set a distinct limit to the number of fish which may be planted under present circumstances. The limitation will be more apparent in the higher lakes, both on account of the poorer fauna and of the longer closed period, than in the lower basins.

It is also suggested from the foregoing data that the question of food supply for the trout in this region is largely an entomological one, at least at the period in which these observations were made. Of course more extended study is necessary before these conclusions are finally accepted, but the uniform testimony of all data obtained cannot but be suggestive. There has certainly been some modification of the aquatic fauna due to the introduction of the trout, and it may yet be possible to determine this in a broad way by the examination of virgin waters in the vicinity. Such exist and their study would yield data of great value on the question connected with the future of the fish. But these problems as well as those which concern the adaptation of the trout to a new environment that compels some modification of the usual habits of the species, lie really beyond the scope of this paper and must be passed by here.

The biological problems which suggest themselves in the Rockies are of a very different type. Trout have been seen in Mirror Lake and salamanders occur in both Mirror and Ribbon lakes. But on the whole the lakes are unfitted to support a fish population. Their relation to the city water system of Colorado Springs indicates not only irregular changes in level which may be extreme at certain times, but also modifications of shore and immediate environment which will have a pronounced effect on the water fauna. Frič and Vávra (1897) have called attention to the entire destruction of one

element in the fauna of a mountain lake by a considerable change in level alone.

The immediate surroundings are sure to be modified also. Within recent years the quality of the water supply has suffered greatly from the caterpillars on the aspen trees along the banks of the mountain streams. These larvae became at times so abundant and dropped into the water in such numbers that the destruction of the aspen trees near the bank was ordered and has been carried out in great part. In connection with the use of the basins for water storage the shores will be cleaned up, and the shore fauna largely annihilated. The bottom will also be freed of all debris and ultimately the process will leave only that part of the original fauna which was not dependent upon either shore or bottom, namely, the true limnetic forms.

REPORT ON THE COPEPODA BY C. DWIGHT MARSH

Species of Copepoda Found

- Diaptomus signicauda* Lilljeborg.
Diaptomus shoshone Forbes.
Diaptomus nudus sp. nov.
Epischura lacustris Forbes.
Cyclops viridis var. *americanus* Marsh.
Cyclops albidus Jurine.
Cyclops serrulatus Fischer.

In regard to the occurrence of the species of *Cyclops* there is nothing of any especial interest. The species are of world-wide distribution, and would be found anywhere under similar circumstances. I have listed *Cyclops americanus* as a variety of *viridis*. This is not yet proven but I think it is a fact which the recent paper of Miss Lehmann (Lehmann, '03) goes far to prove. The variety *americanus* seems to be the common form in these collections rather than *brevispinosus*.

Epischura lacustris was found in four of the lakes, viz., Lake of the Woods, Strawberry Lake, Grass Lake, and Gilmore Lake.

Diaptomus signicauda occurred in four of the localities, Lake of the Woods, Susie Lake, and in a pond in Glen Alpine.

Diaptomus shoshone and *D. nudus* occurred only in the lakes on Pike's Peak. *D. nudus* appeared in Lake of Rocks, Mirror

Lake, Dead Lake, and Lake Michigan. *D. shoshone* was in the same list with the exception of Lake Michigan.

D. nudus is closely allied to *D. signicauda* which was first reported from California, and probably is widely distributed over the mountain regions of the western part of the United States.

DIAPTOMUS SHOSHONE Forbes. (Plate XXX, fig. 3; Plate XXXI, figs. 1-3.)

This beautiful species is very striking because of its size and color. It is the largest described American species except *D. stagnalis* Forbes. It is highly colored in blues and reds. The cephalothorax is of a deep blue while the antennae, maxillipeds, and abdomen are red. The species was described by Forbes from material found in Shoshone Lake, and it also occurred in other lakes and ponds in the vicinity of Yellowstone Park. In the Ward collection it appeared in the material from Dead Lake, Mirror Lake, and Lake of Rocks, all being in the Pike's Peak region.

As this species was figured only in connection with Forbes's original description and the later description of Schacht from Forbes's material, it has seemed wise to add diagnostic figures to this report. The description of Forbes was very complete and it seems necessary here only to add some things of minor importance. I did not find the female abdomen asymmetrical, and in this my observations agree with those of Schacht. The branches of the furca are setose on both the inner and outer margins and the furcal setae are unusually long. In my specimens the endopodite of the female fifth foot is indistinctly divided into two segments. I also find the endopodite of the left fifth foot of the male two-segmented. In size the specimens agree very closely with the figures given by Forbes.

DIAPTOMUS NUDUS sp. nov. (Plate XXIX, Figs. 1, 2, 4 and 5.)

This species is of moderate size. The first cephalothoracic segment is nearly equal in length to the rest of the cephalothorax. The last cephalothoracic segment is armed laterally with two minute spines. The first abdominal segment of the female is somewhat longer than the rest of the abdomen. It is dilated laterally and armed upon each side with a sharp spine. These spines are at about the termination of the first third of the segment. The distal margin of the segment is extended on the right side in a conical process which extends beyond the second segment. The second segment is very short, and

is nearly covered by the first. The third segment is about one-third the length of the first, and somewhat shorter than the furca.

The antennae reach slightly beyond the end of the furca. The right antennae of the male is swollen anterior to the geniculating joint. The antepenultimate segment bears upon its distal extremity a hook-like process which is rather less than half the length of the penultimate segment. In the female fifth foot, the spine of the first basal segment is very pronounced. The second basal segment is armed with the customary delicate hair. The first segment of the exopodite is stout. The second segment is of the usual form, and with the usual armature of the inner margin. The third segment is not distinct, and is represented by two short spines. The endopodite equals in length the first segment of the exopodite, and is armed at the tip with two spines and with short hairs.

In the male fifth foot, the spines of the first basal segment are very pronounced. The second basal segment of the exopodite is trapezoidal in form, and its length exceeds its average width by about one-half. The lateral hair is at about one-fourth its length from the distal end. The first segment of the exopodite is about as broad as long, and has its distal external angle somewhat produced. The second segment of the exopodite is elongate, being more than three times the length of the first. The lateral spine is situated at about one-third the distance from the proximal end, is hook-shaped, and is inserted at an angle with the plane of the segment, that is, it does not lie in the same plane with the flat surface of the segment. The terminal hook is elongate, falciform, with a regular curvature. The endopodite is short, rather shorter than the first segment of the exopodite, and is somewhat triangular in form. The second basal segment of the left foot is similar in form to the corresponding segment of the right foot and is about one-half as long. The lateral hair is situated well towards the distal end. The first segment of the exopodite about equals the basal segment in length, but is more slender. The second segment is short, armed with a terminal pad, a pad on its inner face, and with two blunt spines near its distal end. The pads are armed with short stiff hairs. The endopodite is very slender and very nearly equals in length the two segments of the exopodite.

Average length of the male, 1.115 mm. Average length of the female, 1.132 mm. Locality, Dead Lake, Pike's Peak, associated with *D. magnus*; also Lake Michigan, Lake of Rocks, and Mirror

Lake. It was especially abundant in the collections from Lake Michigan.

This species resembles *D. signicauda* in the process on the posterior border of the first abdominal segment of the female. It differs in so many points, however, that there seems to be no question of its specific difference. The fifth foot of the female and the antennal appendage of the male are as in *signicauda*. The proportions of the female abdomen are quite different. The second abdominal segment in *nudus* is nearly covered while in *signicauda* it is nearly as long as broad. The general proportions of the fifth foot of the male are the same in both species. The first segment of the right exopodite in *signicauda* bears a prominent hyaline lamella on its inner margin, which is entirely lacking in *nudus*. It is on account of this peculiarity that the name is proposed. The lateral spine of the second segment of the right exopodite is nearer the distal end in *signicauda*, while in *nudus* it is nearer the proximal end, is very strongly curved, and does not lie in the same plane with the segment.

REPORT ON THE CLADOCERA BY E. A. BIRGE

The Cladocera in this collection are comparatively few in number and almost all of the species are the common widespread forms, such as would be expected if any representatives of the group were secured. Not only are the species few in number but ordinarily there are but few individuals of each species. *Daphnia*, *Eurycerus*, and *Chydorus* are ordinarily abundant when present at all, but there are only scanty representatives of the other species. I have, therefore, given a list of the species only, together with the description of one form of *Macrothrix*, which apparently represents a new species. *Diaphanosoma leuchtenbergianum* S. Fischer.

In the name of this species I follow Lilljeborg, Cladocera Succiae. Glen Alpine, pond near Susie Lake.

Holopedium gibberum Zaddach.

Glen Alpine, Susie Lake.

Daphnia pulex (De Geer).

A large semi-transparent form of this species was found, in numbers, from Dead Lake, Pike's Peak.

Daphnia longispina O. F. Müller.

Some specimens of this species resembled the variety *caerifrons*; others were typical.

Glen Alpine, Lily Lake (male and female), pond near Susie Lake (July 1), Susie Lake (July 1); Pike's Peak, Ribbon Lake, Mirror Lake.

Scapholeberis mucronata (O. F. Müller).

Glen Alpine, Lily Lake.

Simocephalus serrulatus (Koch).

Glen Alpine, Lily Lake; Pike's Peak, Lake of Rocks.

Ceriodaphnia reticulata (Jurine).

Glen Alpine, Grass Lake, Lake of the Woods.

Ceriodaphnia pulchella G. O. Sars.

Glen Alpine, Susie Lake; Pike's Peak, Lake Michigan.

Bosmina longirostris (O. F. Müller) P. E. Müller.

A very few specimens were somewhat doubtfully referred to this species.

Pond near Grass Lake.

Macrothrix montana, sp. nov.

Length 0.45–0.55 mm.; height 0.23–0.27 mm. The general form is oval or round (Pl. XXV, fig. 2). The shell is thin and transparent. Its ventral edge and the post-abdomen are often much overgrown by algae and *Vorticella*. The dorsum of the head is evenly rounded to the junction of head and body, where there is a deep indentation. The shell of the head projects backward and overlies this depression in two or three collar-like folds. No trace of spine or tooth has been found on this ridge; thus differing from *M. odontocephala* Daday. No fornix was seen, but as all the specimens are somewhat swollen by the preservative, such a structure may be present. The carapace is nearly round. The arched dorsal margin meets the ventral edge in a sharply marked posterior angle. The usual spines are found on the ventral margin. The antero-ventral angle is produced into a rounded lobe. The surface of the carapace is marked by very faint hexagonal meshes.

The macula nigra is about one-half the diameter of the eye. It is situated near the point of the restrum and is nearly quadrangular in outline. The eye is of moderate size, not very deeply pigmented. The antennule is large and stout, with a sense hair near the base and about six rows of hairs on the anterior face and three posterior rows. The terminal sense hairs are of the regular *Macrothrix* type; two of them being much longer than the others. The antennule in this species, unlike that of *M. odontocephala*, shows no trace of being two-

jointed. The antenna shows no marked peculiarities or departure from the ordinary type. The stoutest seta has a length of over 0.3 mm.

The post-abdomen is bilobed (Pl. XXV, fig. 3). The terminal lobe bears several teeth of small size and scattered hairs. The terminal claws are very small, not much larger than the other spines in this part of the post-abdomen. The larger anterior lobe is semi-elliptical in outline and bears 15 to 18 rows of fine hairs. The setae are about 0.35 mm. long, sparsely plumose. Very few specimens afford a good view of the structure of the post-abdomen, as it is usually much overgrown with algae, etc.

This species belongs to the group represented by the forms described by Daday as *M. odontocephala* and *M. bicornis*; being nearer to the former species. From this it differs in the absence of the spine, which gives the name to the species, in the shape of the ventral margin of the head, and in the minute size of the terminal claws.

Susie Lake; Lake Michigan, and Lake of Rocks.

Eurycerus lamellatus (O. F. Müller).

Glen Alpine, Grass Lake, Susie Lake, Small Lake (July 1).

Camptocercus rectirostris.

Grass Lake.

Acroperus harpae Baird.

Grass Lake, Lake of the Woods, Strawberry Lake.

Alona affinis Leydig.

Glen Alpine, Grass Lake, pond near Susie Lake (July 1); Pike's Peak, Lake Michigan, Mirror Lake.

Alona guttata (G. O. Sars).

Glen Alpine, Grass Lake, pond near Susie Lake.

Graptoleberis testudinaria (S. Fischer).

Grass Lake.

Alonella excisa (Fischer).

Lake of the Woods, Strawberry Lake.

Pleuroxus procurvatus Birge.

Pike's Peak, Lake Michigan.

Chydorus sphaericus (O. F. Müller).

Glen Alpine, Grass Lake, pond near Grass Lake, Lily Lake, Susie Lake, pond near Susie Lake (July 1), Small Lake (July 1), pond near Half Moon Lake (cast shells), Lake of the Woods, Strawberry Lake.

Polyphemus pediculus (Linné).

Glen Alpine, Susie Lake, pond near Susie Lake (July 1).

LITERATURE CITED

- BEARDSLEY, A. E.
 1902. Notes on Colorado Entomostraca. Trans. Amer. Mic. Soc., XXIII, 41-48.
 1902a. Notes on Colorado Protozoa. Trans. Amer. Mic. Soc., XXIII, 49-59, 1 pl.
- ELROB, M. J.
 1901. Limnological Investigations in Flathead Lake, Montana, and Vicinity, July, 1899. Trans. Amer. Mic. Soc., XXII, 63-80, 9 pl.
- ELROB, M. J. and RICKER, M.
 1902. A New Hydra. Trans. Amer. Mic. Soc., XXIII, 257-258.
- FORBES, E. B.
 1897. A Contribution to a Knowledge of North American Cyclopidae. Bull. Ill. State Lab. Nat. Hist., V, 27-82, 13 pl.
- FORBES, S. A.
 1893. A preliminary Report on the Aquatic Invertebrate Fauna of the Yellowstone National Park, Wyoming, and of the Flathead Region of Montana. Bull. U. S. Fish Comm. for 1891, 207-258, 6 pl.
- FRIC, A., und VÁVRA, V.
 1897. Untersuchungen über die Fauna der Gewässer Böhmens III. Untersuchung zweier Böhmerwaldseen, des Schwarzen und des Teufelsees. Arch. natw. Landesdurchf. Böhmens, X, 3, 74 pp.
- GUERNE, J. DE, et RICHARD, J.
 1889. Révision des Calanides d'eau douce. Mém. Soc. Zool. France, II, 53-181, 4 pl.
- LEHMAN, HARRIET.
 1903. Variations in Form and Size of *Cyclops brevispinosus* Herrick and *Cyclops americanus* Marsh. Trans. Wis. Acad., XIV, 279-298, 1 pl.
- MUIR, JOHN.
 1900. Lake Tahoe in Winter. (Reprint of a letter published in the San Francisco *Bulletin* in 1878). Sierra Club Bulletin, III, 119-126.
- MUIR, JOHN.
 1903. The Mountains of California. 381 pp. Many plates. The Century Co., New York.
- PACKARD, A. S.
 1883. A Monograph of the Phyllopod Crustacea of North America, with Remarks on the Order Phyllocanida. XII An. Rept. U. S. Geol. Surv. (Hayden) II, 295-592, 39 pl.
- PRICE, W. W.
 1902. A Guide to the Lake Tahoe Region. An account of the scenery, geology, natural history, the fishing, hunting and resorts. The information gathered by the members of Camp Agassiz. 30 pp.
- RUSSELL, I. C.
 1895. Lakes of North America. Boston. 125 pp., 23 pl.
- WARD, H. B.
 1903. Some Notes on Fish Food in the Lakes of the Sierras. Trans. Amer. Fish. Soc., XXXII, 218-220.

171

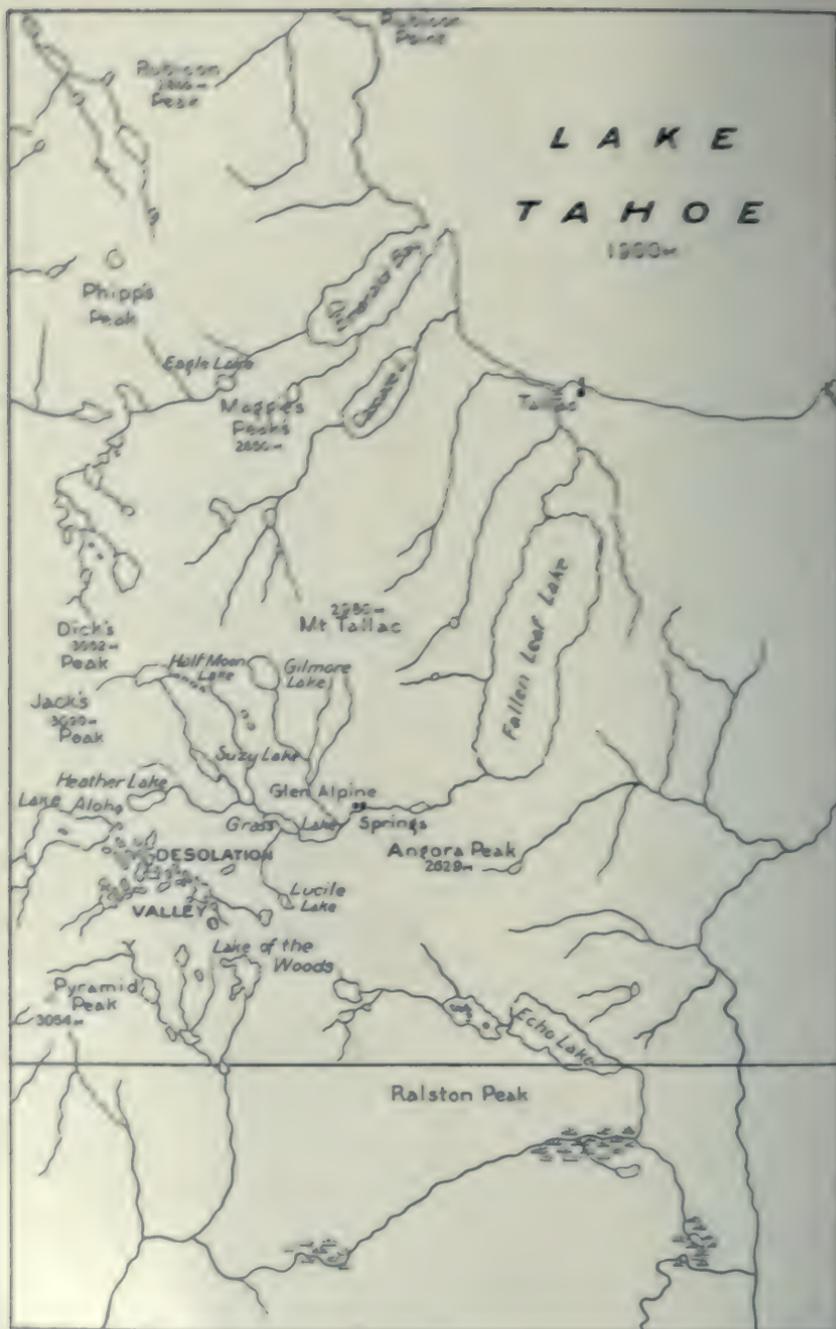


PLATE XX



PLATE XXI



PLATE XXII

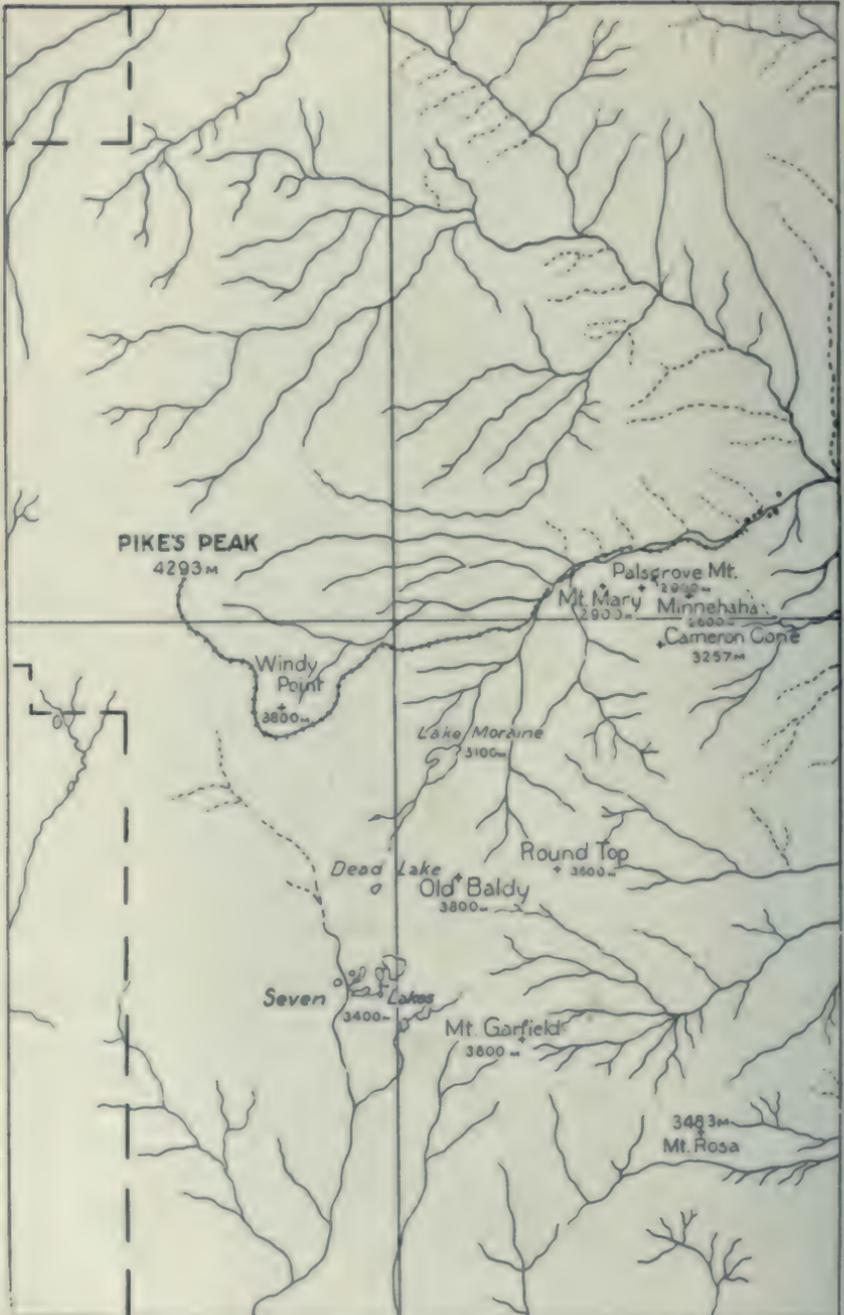


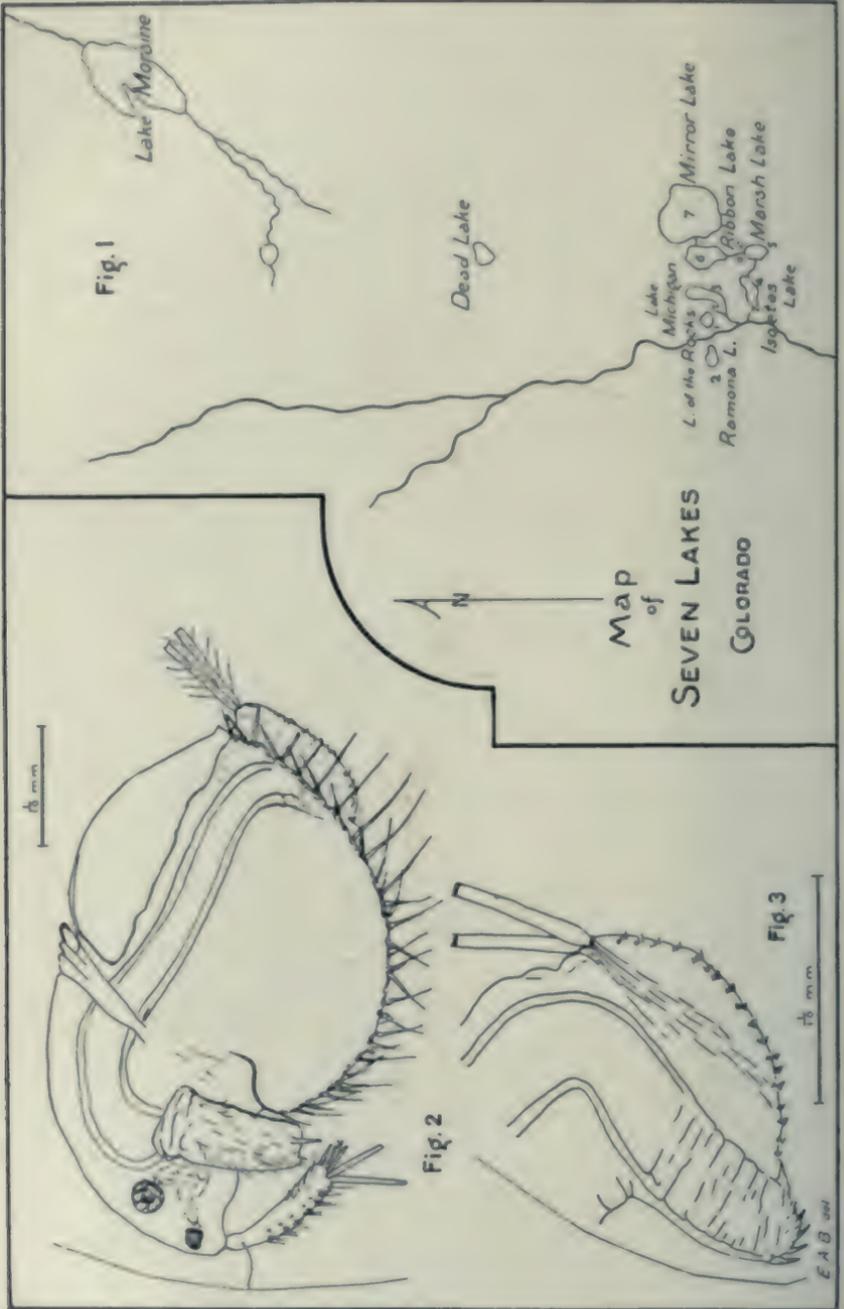
5
152

PLATE XXIII



PLATE XXIV.





EXPLANATION OF PLATES

Plate XIX

Sketch map of lakes near Glen Alpine Springs, California, after topographic map of the U. S. Geological Survey, Pyramid Peak sheet, with minor alterations after Mr. W. W. Price. The upper northeast corner of the map is exactly 39° N. Lat. and 120° W. Long. The map is just 10' of longitude wide, while the line crossing it near the bottom marks $38^{\circ} 50'$ N. L.

Plate XX

The upper view is Eagle Lake, the lower Cascade Lake. Both show the forest growth of the region, the precipitous lake shores and the well protected surface.

Plate XXI

Grass Lake and surroundings. The rocky shore, scanty soil and vegetation, and lack of beach appear at various points.

Plate XXII

Gilmore Lake in early summer. The snow was only a little less extensive on my visit to this lake July 1, 1903.

Plate XXIII

Susie Lake, in late summer. The snow on the mountains has almost disappeared.

Plate XXIV

Sketch map of Pike's Peak region, Colorado, after topographic maps of the U. S. Geological Survey, Pike's Peak and Colorado Springs sheets, with minor alterations after Dr. F. E. Clements. The lines which cross near the center of the map mark 105° W. Long. and $38^{\circ} 50'$ N. Lat.

Plate XXV

Fig. 1. Enlarged plat of territory immediately around Seven Lakes (Cf. Plate XXIII).

Fig. 2. *Macrothrix montana* n. sp. See page 150.

Fig. 3. *Macrothrix montana* n. sp., postabdomen.

Plate XXVI

Valley of Seven Lakes from Mt. Garfield. The view is NNW with Pike's Peak at extreme right. 1, Lake of Rocks; 2, Ramona Lake; 3, Lake Michigan; 4, Isoetes Lake; 5, Marsh Lake; 6, Ribbon Lake; 7, Mirror Lake. Photographed by Dr. F. E. Clements in 1899.

Plate XXVII

Ribbon and Mirror lakes from the north. Mt. Garfield in the background. Photographed by Dr. F. E. Clements in 1899.

Plate XXVIII

West shore of Mirror Lake with Garfield range in background, showing reduction in water level in a single year. Compare Plate XXVI. Photographed in 1903 by Dr. F. E. Clements.

Plate XXIX

Dead Lake from the north with Old Baldy in background. Photographed in 1899 by Dr. F. E. Clements.

Plate XXX

Fig. 1. *Diaptomus nudus*—abdomen of female $\times 165$.

Fig. 2. *Diaptomus nudus*—fifth feet of male $\times 165$.

Fig. 3. *Diaptomus shoshone*—terminal segments of right antenna of male $\times 165$.

Fig. 4. *Diaptomus nudus*—penultimate and antepenultimate segments of right antenna of male $\times 290$.

Fig. 5. *Diaptomus nudus*—fifth foot of female $\times 290$.

Plate XXXI

Fig. 1. *Diaptomus shoshone*—abdomen of female $\times 76$.

Fig. 2. *Diaptomus shoshone*—fifth foot of female $\times 165$.

Fig. 3. *Diaptomus shoshone*—fifth foot of male $\times 76$.



150



PLATE XXVIII



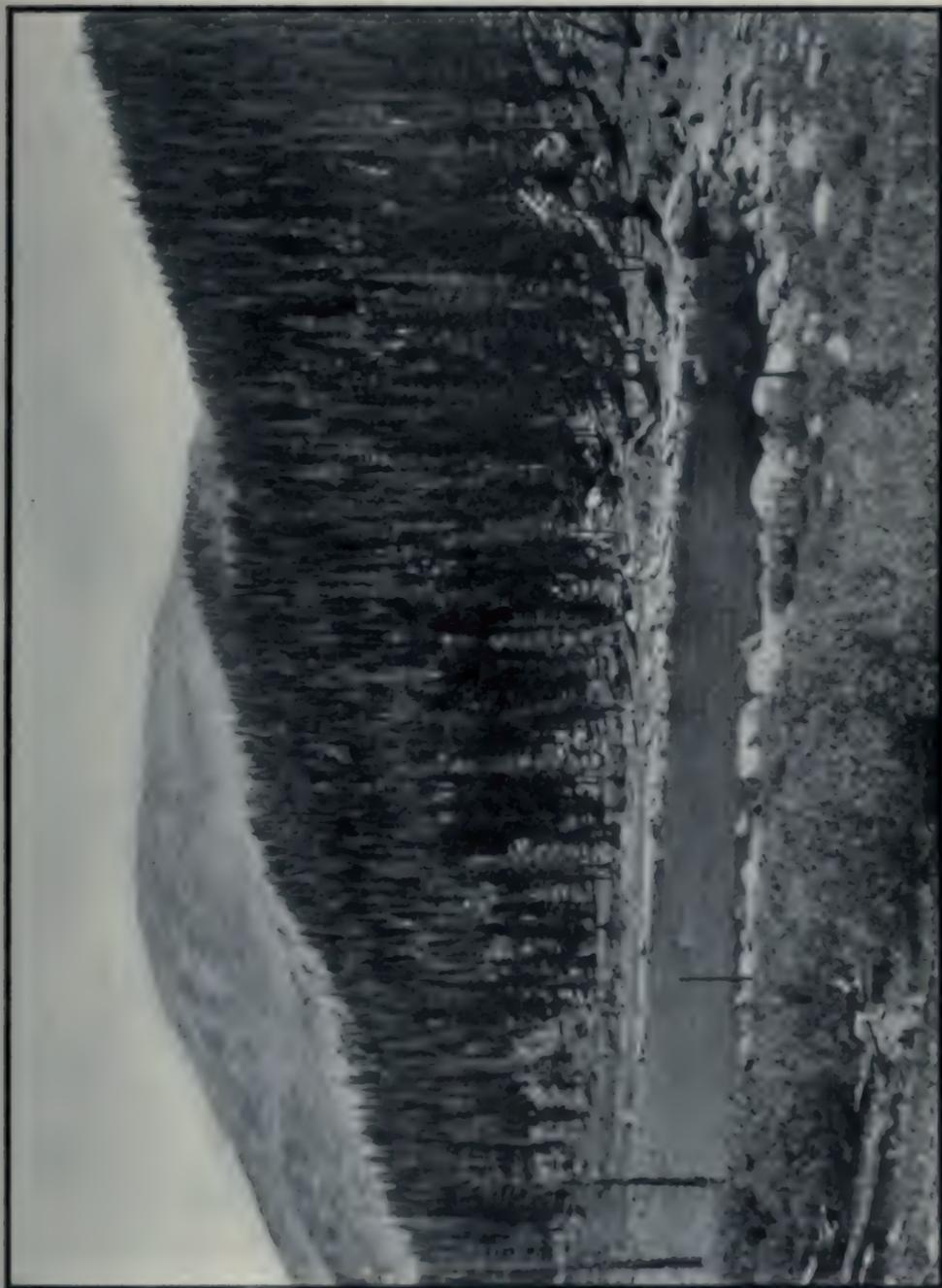


PLATE XXX

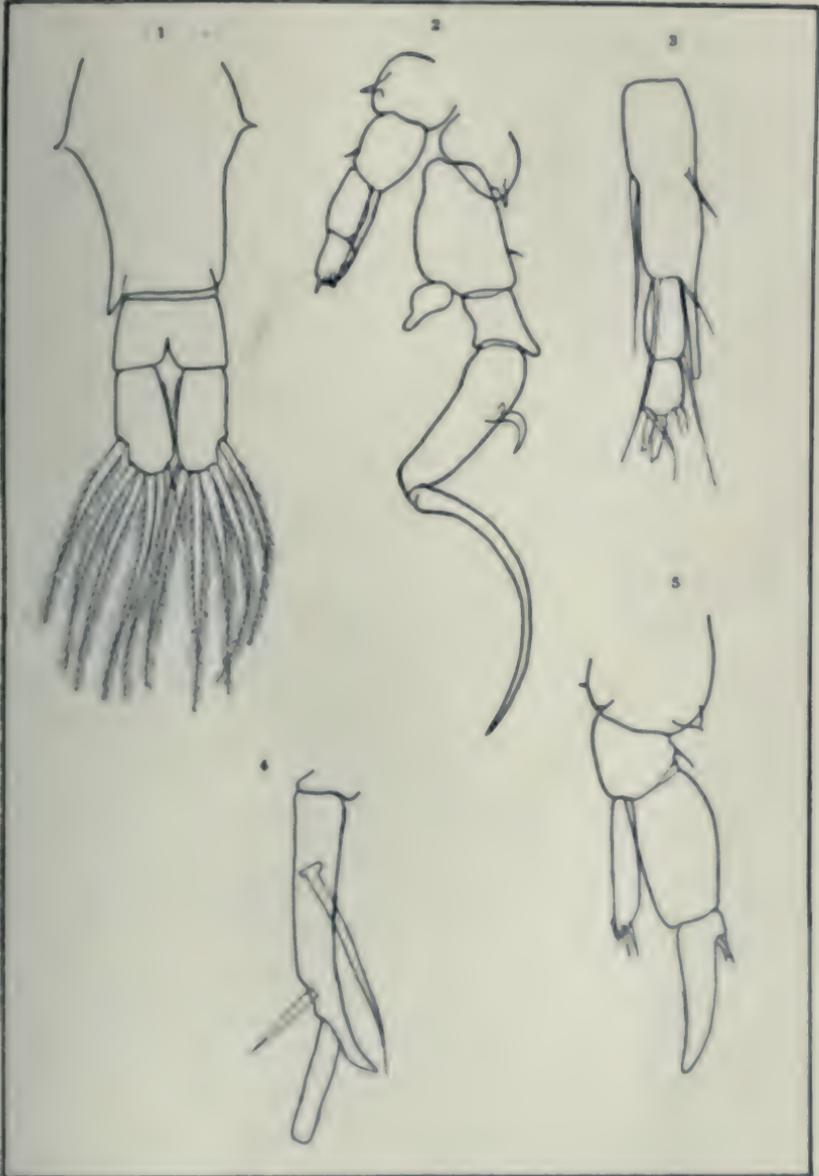
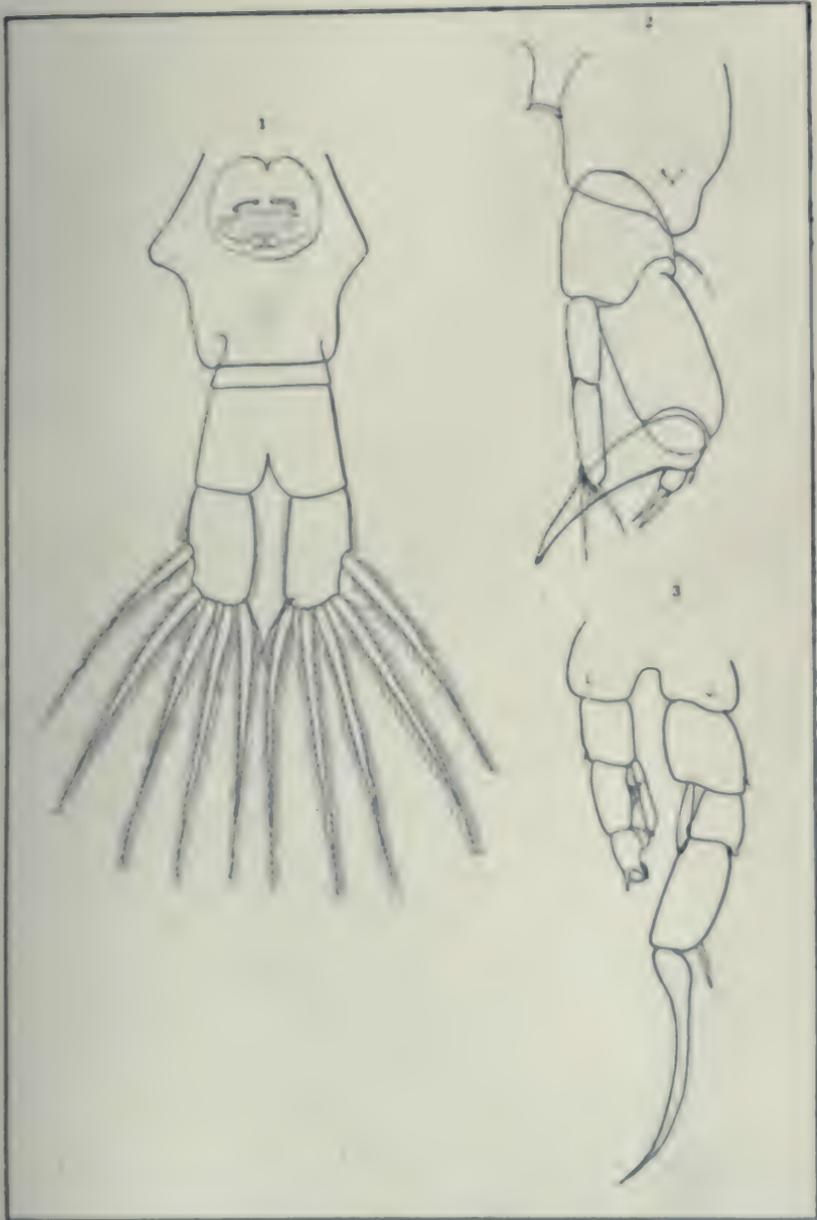


PLATE XXXI





Yours very truly
Alfred

NECROLOGY

RICHARD LEACH MADDOX

On Sunday, May 11, 1902, there passed away at Portswood, Southampton, England, Dr. Richard Leach Maddox, the pioneer of photomicrography, and an honorary member of our Society, and by his demise the scientific world is the poorer, losing as it does a steady hard worker and accurate observer, as well as a most genial and charming personality.

Richard Maddox was born at Bath in August, 1816. Of his early days, very few details are on record, beyond the fact that he was educated at a public school in Somersetshire. Then, having decided on entering the profession of medicine, he became a student at University College, London, in 1837. Always delicate, he had, even while a student, to suspend his work on account of the condition of his health, and in 1839 he left England for a voyage around the world. On his return in 1840 he resumed his studies, and obtained the diploma of the Royal College of Surgeons of England two years later. To this he added the license of the Society of Apothecaries in 1843. As might have been expected from a man with such a keen desire for work, and work for its own sake, we find him in 1844 pursuing his studies in Paris, which was then the centre of medical research, attending chiefly the practice of the *Hôtel de la Charité* and the lectures of the late Dr. Donne. Dr. Maddox also devoted a very large amount of his time to microscopy, and in this connection it may be mentioned that he translated Dr. Dujardin's "Manual" at about the time that Quekett's "Treatise on the Microscope" appeared, but as it was impossible to arrange for the use of the beautiful plates illustrating the work, the translation was never published. In 1847 he appears to have visited Smyrna, proceeding afterwards to Constantinople, where for a time he practised his profession, and where he met Amelia, daughter of Benjamin Winn Ford, Esq., of that city, whom he married in 1849. In 1850 he re-

turned to England, and the following year took the degree of M.D. of Aberdeen University. In 1852 he again settled in practice in Constantinople, and during the latter part of the Crimean War held the appointment of Civil Surgeon to the hospital at Scutari. His health again causing him some anxiety, Dr. Maddox came back to England, practising for a time at Islington, London, then at Ryde, Isle of Wight, and finally settling at Woolston, near Southampton, in 1859, where he remained for fourteen years. In 1874 he left Woolston to become resident physician to the late Duke of Montrose, from whom he went to Sir William Watkins-Wynn, and then to Lady Katherine Bannerman. His wife having died in 1871, Dr. Maddox married in 1875, Agnes, daughter of George Sharp, Esq., of Newport, Isle of Wight (who survives him), and the same year he again went abroad, first to Ajaccio, and afterwards to Bordighera and Cornigliano, practising his profession amongst the English residents. Returning to England finally in 1879, he lived for some years at Gunnersbury, but from 1886 onwards resided at Greenbank, Portswood, Southampton, England, living in a most retired manner, but keeping up his interest in everything relating to scientific work, and constantly writing for various journals and papers in England, France, and the United States; indeed, within a few days of his death he contributed a letter to the papers, dealing with the controversy anent the discovery of the "Holy Shroud" at Turin. On the 10th of May, 1902, his old-standing complaint, aortic aneurysm, suddenly became worse, and on the following day he breathed his last at the advanced age of eighty-five years. Dr. Maddox was interred in the Southampton cemetery on May 15. A son and a daughter by his first wife, and a son by his second wife, survive him.

From this brief outline of a busy, restless life it is not easy to see where, and when, Dr. Maddox secured the necessary time and opportunity for the more strictly scientific research work which has made his name famous, and it speaks volumes for his powers of adaptability and of steady application that he was able to accomplish so much under such unfavorable circumstances. As early as 1853, he took up the study of photography, and in a contribution to "Photography," February 11, 1892, he refers to this in the following words; "My first lens was bought about 1846, but active professional duties prevented its being used until 1852; from that date

onwards, as an amateur, I have been interested in photography." Then, too, he was undoubtedly the pioneer in the application of photography to microscopical work, just as he was one of the very first to grasp its potentialities for the reproduction of pictures of microscopical preparations. In spite of his early failures in this direction he was sanguine of ultimate success and subsequently referring to the subject he wrote: "Still, I felt and trusted its day would come, and be of much assistance to the busy microscopist." His disheartening efforts in photomicrography only spurred him on to further endeavors, and there is not the least doubt that the substitution of gelatine for collodion in the preparation of photographic plates, resulting in the manufacture of dry plates, is the direct outcome of his early photomicrographic failures. The first public recognition of his work in the portrayal of microscopical objects took the form of a medal from the then "Photographic Society of London" in 1853. This was followed after a long interval by a medal from the Council of the International Exhibition of Dublin (1865) for a series of his photomicrographs, published by the late James Howe. In 1865 a reproduction of some of Dr. Maddox's photographs formed the frontispiece of Lionel Beale's "How to work with the Microscope"—probably the first attempt in England to employ photomicrographs as book-illustrations.

The periodical attacks of ill-health to which he was subject, and which so frequently drove him from England in search of more genial climes, were often due to over-work; at these times, over-work in a vitiated atmosphere, charged with ether vapor from the collodion emulsions of the "wet" photographic plate of that period, made its effects painfully apparent, and, combined with the desire to obtain a less cumbersome and troublesome method of securing his photograms of microscopical objects, caused Dr. Maddox to somewhat restrict the scope of his research work. The result of his experiments became apparent in 1871, when he published in the "British Journal of Photography" an account of the compounding of a practicable gelatino-bromide emulsion, and its employment as a "dry" photographic plate. The Royal Microscopical Society of England immediately recognized the value of his work by electing him an honorary Fellow in 1871. Later on, he became a student of the then infant science of bacteriology, and among other researches upon which he was subsequently engaged, was one upon the micro-organ-

isms present in the air, in which he used a piece of apparatus of his own invention, the "aeroconiscope," practically a multiple funnel set up as a vane. The wind passing through this apparatus deposited its contained organisms upon a thin coverglass prepared for its reception by being coated with a layer of gelatine; the organisms were then cultivated and the results accompanied by many careful figures, published in the current monthly *Microscopical Journal*. He gave up much time also to microscopical drawing, and examples of his skill may be found in the work of the late Dr. Parkes on "Hygiene," and also in Dr. Nayler's "Skin Diseases." Many of his colored drawings, however, of Diatomaceae, when subjected to the action of various reagents, and figures of the various yeasts in beer deposits, have not been published.

General public recognition of the value of Dr. Maddox's work was, as is too often the case in the world of science, delayed till late in life. In 1885 he received the gold medal of the Inventions Exhibition, at which he exhibited the earliest specimens of gelatine-bromide negatives made, in 1871, and after this many honors reached him. The Scott Legacy medal and premium from the Franklin Institute in Philadelphia, U. S. A., was awarded him in 1889, whilst in the autumn of 1891, as it was reported that he had lost heavily through a defaulting trustee, a sum of between £500 and £600 was raised for him in contributions from photographers in England, France, Germany, and America, in recognition of the value of his work. A gold medal from Antwerp, numerous diplomas, and finally the Progress Medal of the Royal Photographic Society of England (1901), were in turn conferred upon him.

Although Dr. Maddox's experiments in emulsifying silver in gelatine do not entitle him, as many erroneously claim, to the credit of having *invented* the gelatine dry-plate, there is not the least doubt that he pointed the way for other workers. This is not the time to go into the acrimonious discussions that have raged around this distinguished worker's name—discussions which were rendered acrimonious by the claims and counter-claims of others, for Dr. Maddox himself seems to have troubled very little about the dispute. Indeed, on his part there was throughout a conspicuous absence of assertiveness of virulence; he was one of that very high type of investigator who works for the love of his subject and for the sake of truth, without any ulterior motive, and certainly with no thought of

pecuniary reward. Perhaps the most pleasant trait of his character was his readiness to help to the fullest of his capabilities everyone who sought his advice on photographic or photomicrographic work, holding as he did, that the claims of science for her advance were, "If freely ye have received, freely give."

J. W. H. E.

BUSHROD WASHINGTON JAMES, A.M., M.D., LL.D.

For several successive generations the James family, from which Dr. James was descended, has resided in America. His paternal great-great-great-grandfather, David James, came from Wales, accompanying William Penn, and located in Radnor Township, Montgomery Co., Pa. He purchased an extensive tract of land where Bryn Mawr and Rosemont are now located. Dr. James' grandfather, Dr. Isaac James, was a physician, who lived to the advanced age of ninety-seven. One of his uncles, Dr. Thomas P. James, of Cambridge, Mass., was an eminent botanist and bryologist and a great authority on mosses. The Doctor's father was David James, M.D., a graduate of Jefferson Medical College, who was one of the pioneers of homoeopathy in Philadelphia.

Dr. Bushrod Washington James was born in the city of Philadelphia, August 25, 1836. His father gave him a careful and liberal education. In 1857 he graduated from the Homoeopathic Medical College of Pennsylvania, receiving therefrom the degree of M.D. and H.M.D. The faculty on his graduation placed him in charge of the large dispensary connected with the college. Subsequently he originated a surgical infirmary and mainly supported it for years by his own efforts and energy and that of two of his friends. He located at the northeast corner of 19th and Wallace streets in Philadelphia and has ever since resided in that section of the city. His connections with various societies, medical, scientific, and literary, have been and still are numerous, and he has also been connected with various medical institutions, serving in one as professor. For seven years he was attending physician to the Northern Home for Friendless Children. He here obtained a very valuable experience in diseases of the eye, having treated several hundred cases of contagious ophthalmia without loss of vision in any case. He has been for seventeen years eye clinician at the Children's Homoeopathic Hospital.

In 1867, Dr. James visited Paris as a national delegate from the American Institute of Homoeopathy to the French Homoeopathic Medical Congress, to which he presented a medical essay. In 1881 he



B. W. JAMES

attended the International Homoeopathic Medical Convention, held in London, before which he read a paper on iritis. He also attended the World's Medical Congress, London, held the same year. During the Centennial year, 1876, he was a member of, read a paper before, and took other active part in the proceedings of the first International Homoeopathic Convention, which was held in Philadelphia. In 1873 he was President of the Pennsylvania State Homoeopathic Medical Society, and in 1883, at Niagara, he was President of the National Society of the American Institute of Homoeopathy. For seventeen years he was Surgical Editor and Sanitary Science Editor of the then *American Observer* of Detroit. For several years he was President of the American Literary Union and also of the Hahnemann Club of Philadelphia. He was for years President of the Children's Homoeopathic Hospital of Philadelphia, and was previously President of its Medical Board. He was one of the consulting physicians in the Hahnemann Hospital of Philadelphia, a member of the advisory board of the Hahnemann Medical College, and for twenty-five years also one of the trustees of the Spring Garden Institute. At one time he filled for several years the chair of physiology, sanitary science and climatology in the New York Medical College for Women of the University of New York. Professor James was a member of the American Public Health Association, of the American Association for the Advancement of Science, of the American Microscopical Society and of the Senate of Seniors of the American Institute of Homoeopathy, and Vice-President of the Pennsylvania Fish and Game Protective Association, and a member of the American Fisheries Association for the care of the food-fishing interests in the United States.

During the Civil War he was a member of the Christian Commission, and was a volunteer surgeon on the battle-fields of Antietam and Gettysburg, and a surgeon in one of the army hospitals of Philadelphia. In 1878 he was one of the Commission of Eleven appointed by the American Institute of Homoeopathy to investigate the yellow fever epidemic of that year and collect statistics of its treatment and mortality. He also belongs to several bodies of a general character, including the Masonic fraternity, Knights Templar, Masonic Veterans, the Union League, the Horticultural Society, the Franklin Institute, Pennsylvania Historical Society, Sons of the Revolution, the Academy of Natural Sciences and the Authors' Guild of America.

As a writer he achieved some distinction. From 1880 to 1888 he was business manager of the *Hahnemannian Monthly* and did much to raise the literary and general character and increase the circulation and value of that periodical. Dr. James was the author of "Alaskana, or Legends of Alaska," now in its third edition. This is written in the Finnish style of Longfellow's *Hiawatha*. It is a beautiful literary production and has many graphic descriptions of the life of people of Alaska and the sublime scenery of that region. He has also written several books and pamphlets on that region, being an ardent believer in its great future. Dr. James visited Alaska and all sections of the United States and British America, and Newfoundland. He was a great traveller, visiting many foreign places, especially in Mexico, Europe, Asia, and Africa. Another of his productions, entitled "American Resorts and Climates," is a scientific description of the resorts of this country. The "Dawn of a New Era in America," touches upon some of the live political issues of the day. As an author, he combined the accurate conceptions of science with the charms of poetry and philosophy. As a physician, his rare attainments, long years of experience and connection with the principal medical societies of the age made him justly prominent in his profession.

He was stricken with pneumonia a year ago and recovered sufficiently to return home, but never regained his strength, and after a long illness he died January 7, 1903, in the sixty-seventh year of his age. He was never married. In him this society has lost an active and efficient member and the state a valuable and much honored citizen.



OSCAR C. FOX

OSCAR C. FOX

Major Oscar C. Fox was born in Pitcher, N. Y., of English and Scotch ancestry, August 23, 1830, his parents being Daniel Fox and Harriet Amanda, born Chapman. His grandfather, Hubbard Fox, served in the First Connecticut line during the Revolutionary War, and the boy Oscar began working in his father's flour and saw mills. He was educated in Pitcher Springs Academy, Chenango County, and McGrawville or Central College, Cortland County.

Like many prominent and successful men he taught school in early life, and from 1856 to 1860 was principal of Nelson Academy in Ohio. In 1861 he raised a company of soldiers in his native county of Chenango and entered the 76th New York Vols. with the rank of Captain. They were immediately sent to the front and after taking part in several battles, on August 28, 1862, he was dangerously wounded at the battle of Gainesville, Va., receiving a shot through the lungs, the ball remaining in his body during the rest of his life. While slowly recovering he was discharged from active service on account of disability December 22, 1862, with the rank of brevet Major. Three years after he received this wound, and at the exact hour of Lincoln's assassination, in a paroxysm of coughing, he threw out a quantity of cotton the bullet had carried into his body from the lining of his vest, and from that time on his health gradually and steadily returned.

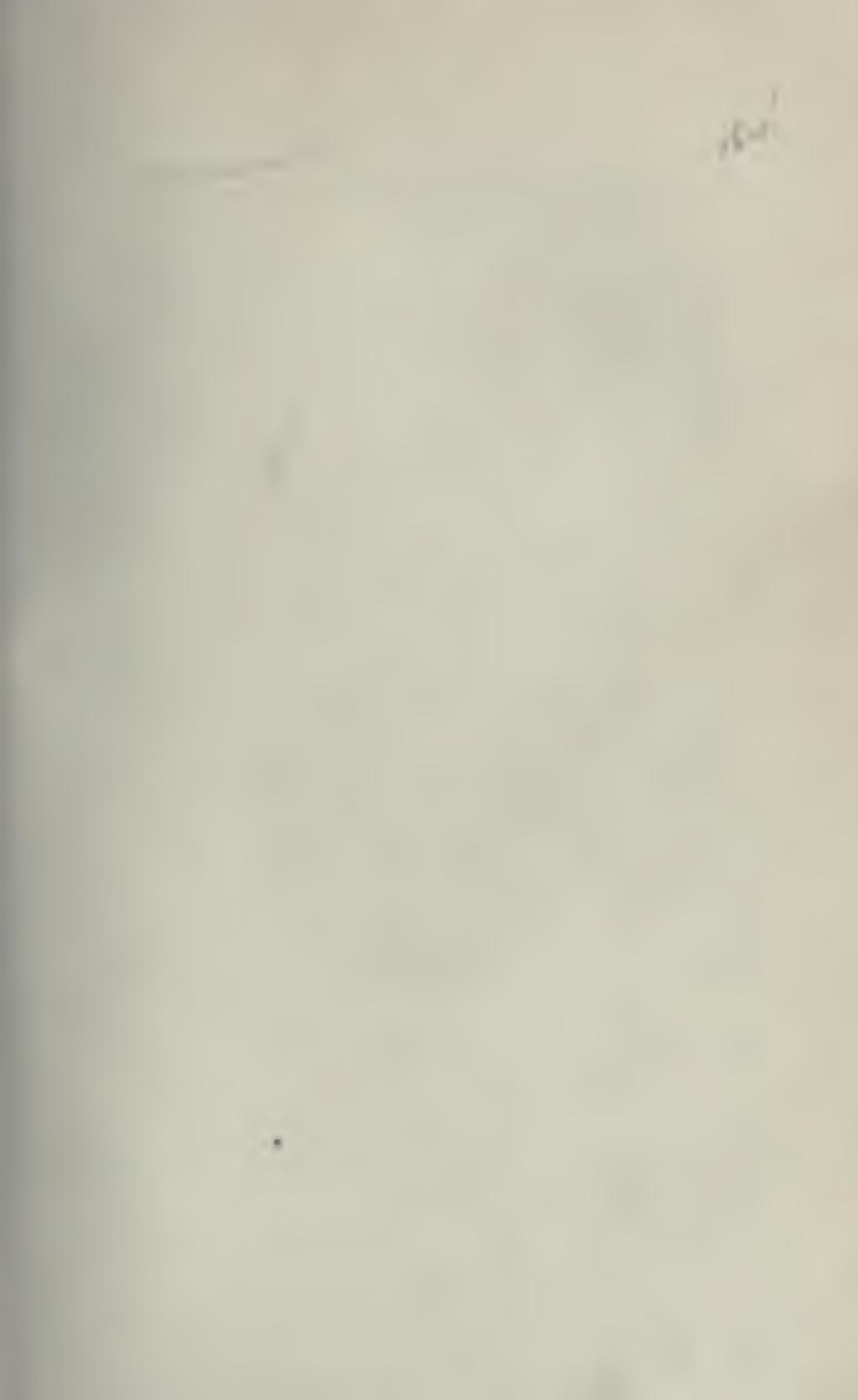
From 1864 to 1870 Mr. Fox served as a clerk in the office of the Commissary General of Subsistence at Washington, a position he resigned to enter the Patent Office, in which he obtained as the result of competitive examination, in July, 1873, the position of Principal Examiner. He was placed in charge of one division, which includes agricultural machinery and tools chiefly, and occupied this position until his death, which took place June 6, 1902.

Major Fox had a strong natural inclination for scientific work, and while living at Linden, in the suburbs of Washington, constructed a small reflecting telescope, polishing the mirror himself. He planned a much larger one, and partially made it, but change of location and failing health prevented its completion. In May, 1876,

he conceived the idea of introducing compressed air into the hermetically sealed tube of a telescope to prevent flexure of the objective by gravity. He also contrived a novel uniform motion mechanism for rotary fluid parabolic reflectors of any possible aperture for zenith observations. Besides these inventions he made several improvements in other lines of mechanics, his mind being constantly active and interested in scientific work. He was a member of the G. A. R., of the Union Veteran Legion, of the American Association for the Advancement of Science, of the Washington Microscopical Society and of the American Microscopical Society, having joined the latter in 1892.

In person he was tall and large-framed, with a gentle manner that seemed almost a contrast to a somewhat imposing personality. He was married on September 11, 1866, to Abbie Galt, of Delaware County, N. Y., who, with one daughter, survives him.

WM. H. SEAMAN





J. C. MILLES

J. C. MILLEN

Dr. J. C. Millen was born in Philadelphia, Penn., July 5, 1865. He was educated in the Philadelphia High School and at the age of fifteen entered the Baldwin Locomotive Works as draughtsman. He advanced so rapidly that at the age of eighteen he was one of its chief draughtsmen and was placed in charge of a number of men. At an early age he was deeply interested in medicine and spent every available minute in its study. To enable him to continue his studies in this line he started, in 1885, to manufacture a roll blue print paper for commercial purposes. All blue print paper on the market at this time was hand-coated and very imperfect. He introduced specially designed machinery of his own invention whereby he was able to produce paper perfectly coated and one which had great keeping qualities, a point heretofore unattainable in this process. He started originally with an output of about one hundred yards of prepared paper per day, and by 1890 was coating and shipping about five miles of paper per day. About 1890 he conceived the idea of producing a high grade of photographic paper suitable for the amateur photographer, the paper which he manufactured for architects and engineers being of too coarse a texture to render the fine detail and half-tones necessary for the photographic process. With this idea in view he introduced "French Satin, Jr.," which has since become the standard photographic blue print paper. At first his output amounted to about one hundred packages per week and it was considered a very small side issue of his business. Today, the demand for this kind of photographic blue print paper has grown to such an extent that practically his entire plant is devoted to its manufacture, and the production represents practically all of the photographic blue print paper used in America.

In the meantime, he had entered the Hahnemann Homeopathic Medical College in Philadelphia and graduated from this institution in 1887. He was able to adjust his business so that it required only a small portion of his attention each day and immediately began the practice of medicine in Philadelphia, establishing a large and lucrative practice in a few years. He was a deep student of chemistry

and also a fine microscopist. He was connected with the Homeopathic Hospital as well as the Children's Homeopathic Hospital and was noted for his untiring energy. He was a man of great magnetism and his skill and ready sympathy made him a favorite with his patients as well as his associates. Being an enthusiastic amateur photographer, he made photographs of all his interesting cases before and during the different stages of treatment and his collection is large and interesting.

In 1897, owing to overwork, his health failed, and he was advised by his physicians to give up medicine and remove to Colorado. He took up his residence in Denver, and immediately removed his manufacturing plant to that city. He devoted his entire time to adding new photographic specialties to his already well-established business, and today his developers, combined toning and fixing powder, chromium fixing salt, and library paste are without peer.

In 1900, thinking that he had fully recovered from his former illness, he again resumed medicine in Denver, and was rapidly establishing a good practice, when again his health failed, and from this attack he did not recover. His death occurred April 26, 1901. He was a member of the American Microscopical Society, the Homeopathic Medical Society of Philadelphia, and the A. R. Thomas Club.

PROCEEDINGS
OF
The American Microscopical Society

MINUTES OF THE ANNUAL MEETING
HELD AT
WINONA LAKE, INDIANA, JULY 27, 28 AND 29, 1903

The twenty-sixth annual meeting was called to order at The Inn, Lake Winona Assembly Grounds, Warsaw, Indiana, at 10:40 A.M., Wednesday, July 27, 1903. President Birge presided.

The Secretary presented a brief, informal report on the printing of the annual volume, the condition of the membership, and on the addition of life members, with conditions attached thereto.

The report of the Treasurer was formally postponed till the close of the fiscal year, which was fixed for October 3, and Messrs. F. W. Kuehne and Rudolph Siemon were appointed auditors.

The report of the Custodian was read and Drs. J. S. Foote and B. E. Bush were appointed an auditing committee.

The Secretary reported for the Executive Committee that an invitation had been received from Professor Eigenmann to visit the laboratory of the University of Indiana Biological Station, and recommending its acceptance. On motion of Mr. J. C. Smith the same was accepted and the Society adjourned.

SECOND SESSION

The Society was called to order in the laboratory of the Biological Station, at 2 P.M., for the purpose of listening to the reading of papers, as follows:

Dr. V. A. Latham: Structure of the Dental Pulp, with Photographic Demonstrations; discussed by Dr. J. S. Foote.

Dr. J. S. Foote: The Tube Plan of Structure of the Animal Body; discussed by Dr. H. B. Ward and Professor E. A. Birge.

Dr. C. H. Eigenmann: Ontogenetic Degeneration of the Optical Organs of the Cuban Blind Fishes; discussed by several members briefly and informally, after which the Society adjourned.

THIRD SESSION

The Society convened in the auditorium at The Inn at 7 P.M., and listened first to an address of welcome by Dr. S. C. Dickey, President of the Winona Association, which was responded to by the President of the Society, Professor E. A. Birge. The latter then delivered his annual address on The Biological Significance of the Thermocline.

After a general discussion of the topic presented, the Society again adjourned, on invitation of the Winona Assembly board of managers to attend a lecture by Mr. Ernest Thompson Seton.

FOURTH SESSION

The Society was called to order at 10:30 A.M., Thursday, July 28, in the Biological Station laboratory, and the following papers were read:

Professor T. J. Burrill: River Pollution and Purification; discussed by Professors Birge, Caldwell, and others.

Mr. J. C. Smith: The Parasite of Yellow Fever; discussed by Professors E. A. Birge, H. B. Ward, and T. J. Burrill, and Dr. V. A. Latham.

Professor B. L. Seawell: Some Observations on the Plankton of a Small Lake under Storm-flood Conditions; discussed by Professors E. A. Birge, O. W. Caldwell, Charles Fordyce, and H. B. Ward.

A nominating committee, consisting of Professor T. J. Burrill, Dr. V. A. Latham, Professor H. B. Ward, Dr. J. S. Foote, and Mr. J. C. Smith, was unanimously elected. The Secretary reported the loss by death of Drs. M. L. Holbrook, B. W. James, J. C. Millen, O. C. Fox, regular members, and Dr. R. L. Maddox, honorary member, and was instructed to secure biographical sketches for the next volume. The Society adjourned at noon.

FIFTH SESSION

The members came together once more at 2:15 P.M., and the following papers were considered:

Professor R. H. Wolcott: Studies on the Lakes of the Sandhill Region of Nebraska; discussed by Professors Charles Fordyce, E. A. Birge, C. H. Eigenmann, and others.

Professor H. B. Ward: A Biological Reconnaissance of Some Elevated Lakes in the Sierras; discussed by many members, informally, during the examination of numerous photographs used to illustrate the paper.

Professors R. H. Wolcott and B. L. Seawell exhibited apparatus for collecting aquatic micro-organisms and the explanation of methods of handling the same, which led to a general discussion of the methods suggested, and of others used in collecting such material.

A report from the Executive Committee was read recommending that St. Louis be made the place of the mid-winter meeting, and on motion of Mr. J. C. Smith the report was adopted.

A further recommendation of the Executive Committee that Dr. F. E. Clements and Mrs. Clements be granted the sum of \$25 from the income of the Spencer-Tolles Fund to carry on certain investigations on the microscopical structure of xerophytic plants, was also adopted.

The following papers were read by title:

Mr. J. C. Smith: *Synchaeta bicornis*, a new Rotifer.

Professor M. J. Elrod: The Ricker Pump in Limnological Investigations.

Dr. D. C. Hilton: Preliminary Report on a Specimen of *Bothriocephalus latus*.

The Society then adjourned.

In the evening, Professor and Mrs. C. H. Eigenmann tendered a reception to the members at their summer home, which was beautifully decorated in honor of the Society. The occasion was most enjoyable and the guests lingered until a late hour in discussion. The presence of the staff from the Biological Station added to the enjoyment of the evening.

SIXTH SESSION

Friday, July 29, the entire day was occupied by an excursion to Turkey Lake, under the leadership of Professor Eigenmann. This afforded opportunities of examining other lakes *en route*, of collecting in them, and of enjoying a trip about Turkey Lake itself in a general survey of the biological conditions. On board the steamer, which was chartered by Professor Eigenmann for the exclusive use of the Society, a business session was held, during which the amendments to the Constitution, printed on pages 175 and 176 of Volume XXIV, were considered and adopted.

On recommendation of the nominating committee the following persons were unanimously elected to serve as officers for the ensuing year:

President, Professor T. J. Burrill, Urbana, Ill.

First Vice-President, Professor H. A. Weber, Columbus, O.

Second Vice-President, Dr. F. W. Kühne, Fort Wayne, Ind.

Assistant Secretary, Dr. R. H. Wolcott, University of Nebraska, Lincoln, Neb.

Elective members of Executive Committee: Mr. Chas. F. Cox, New York City; Mr. L. B. Elliott, Rochester, N. Y.; Professor J. M. Stedman, Columbia, Mo.

The thanks of the Society were voted to the retiring President, Professor Birge, to the directors of the Winona Assembly and of the Indiana University Biological Station, for many courtesies and privileges extended to the Society, and also to both Professor and Mrs. Eigenmann for their generous hospitality to those in attendance. The Society then adjourned subject to the call of the Executive Committee.

HENRY B. WARD,
Secretary.

MID-WINTER MEETING, ST. LOUIS, MO., DECEMBER
28 AND 29, 1903

Pursuant to the call of the Executive Committee the Society convened in Room 109 of the Central High School, St. Louis, Mo., Tuesday, December 28, 1903, at 9 A.M. By the courtesy of the Local Committee an adjoining room was also set aside and furnished for social purposes while a supply of microscopes and a projection lantern was provided for demonstrations.

Owing to the number of other meetings in progress at the same time, and to the small number of members who went to St. Louis, the sessions were very informal and somewhat irregular. The following papers were presented and discussed by members in general in connection with the microscopical demonstrations appertaining thereto. The work was of peculiar interest and importance and deserved a much larger audience than was assembled.

Dr. H. M. Whelpley: North American Flint Implements of Microscopical Interest (with demonstrations).

Professor F. L. Landacre: Fresh-water Protozoa of Ohio, with Bibliography.

Dr. G. C. Crandall: Plasmodium malariae (with demonstrations).

Dr. J. H. Stebbins: Haematozoa of the Turtle.

Dr. Henry B. Ward: Some Notes on the Morphology of Trypanosomes (with demonstrations).

Dr. Carl Fisch: *Amoeba dysenteriae* (with demonstrations).

Dr. H. M. Whelpley: A Compound Microscope of 1750, and an Objective of Peculiar Construction.

Dr. H. M. Whelpley: Notes on Technic in Mounting and Demonstrating Microscopic Objects.

Dr. C. A. Snodgras (by invitation): A Municipal Microscopical Laboratory.

Miss G. A. Gillmore: Some Points in the Minute Structure of Heart Muscle.

Dr. H. M. Whelpley: Radium as an Element of Microscopical Interest Compared with the Fumes of Phosphorus, examined with a microscope by Leeuwenhoek in 1693 (with demonstration of radium under the microscope).

Dr. Charles E. Bessey: The Structure and Classification of the Protophyta with a Revision of the Families and a Rearrangement of the North American Genera.

Dr. T. J. Burrill: Aerial Disinfection.

At the business meeting Wednesday it was voted that until further action be taken the President and Secretary shall represent this Society on the Council of the American Association for the Advancement of Science. A cordial invitation, presented from the Buffalo Society of Natural Sciences, urging that the Society hold its regular meeting in Buffalo in August, 1904, was received and referred to the Executive Committee. The Secretary was instructed to express to the Buffalo Society the appreciation of this Society for the courtesy.

A vote of thanks was unanimously adopted for the courtesies received in St. Louis, especially from the general Local Committee for all affiliated societies, from the committee of the St. Louis Microscopical Society, and from the directors and boards of managers of the Missouri Botanic Garden and of the Louisiana Purchase Exposition.

Wednesday noon a luncheon was tendered to members of the Society and their wives by the St. Louis Microscopical Society, under the direction of a committee consisting of its President, Dr. G. C. Crandall, and Dr. H. M. Whelpley. The tables were beautifully decorated and all details were admirably carried out, so that the occasion was thoroughly enjoyed by all present. The Society recorded an appropriate vote of thanks to the gentlemen and to the St. Louis Microscopical Society for the generous hospitality.

HENRY B. WARD,
Secretary.

CUSTODIAN'S REPORT FOR YEAR ENDING JULY 23, 1903

SPENCER-TOLLES FUND

Reported at Pittsburgh Meeting.....	\$1419 24
Dividends received.....	110 63
Sale of Proceedings.....	53 04
Contributions	66 96
Life Membership	50 00
Invested	1699 87
Cash on hand.....	3 92
Total	\$1703 79
Increase during the year.....	284 55

Year	ANNUAL GROWTH	Increase	Total
1885			\$ 60 20
1886		\$ 25 00	85 20
1887		10 00	95 20
1888		52 66	147 86
1889		76 00	223 86
1890		30 00	253 86
1891		39 02	292 88
1892		19 12	312 00
1893		18 06	330 06
1894		19 32	349 38
1895		22 89	372 27
1896		50 77	423 04
1897		45 99	469 03
1898		86 43	555 46
1899		97 90	653 36
1900		102 65	756 01
1901		388 11	1144 12
1902		275 12	1419 24
1903		284 55	1703 79

CONTRIBUTORS TO SPENCER-TOLLES FUND GIVING \$50 OR OVER (CONSTITUTION, ARTICLE VII)

John Aspinwall

Troy Scientific Association

Robert Brown

MAGNUS PFLAUM, *Custodian.*

WINONA LAKE, IND.

We, the undersigned, hereby certify that we have carefully examined the accounts of the Custodian as given in the foregoing report, compared the same with vouchers, and found the same to correspond and to be correct.

J. S. FOOTE,

B. E. BUSH,

Auditing Committee.

TREASURER'S REPORT

FROM NOVEMBER 24, 1902, TO FEBRUARY 30, 1904

DR.	
To Membership dues, 1901.....	\$ 5 00
To Membership dues, 1902.....	22 00
To Membership dues, 1903.....	318 00
To Membership dues, 1904.....	50 00
To Membership dues, 1905.....	4 00
To Membership dues, 1906.....	2 00
To Membership dues, 1907.....	2 00
	\$403 00
To Admission fees.....	57 00
To Subscribers, Vol. XXIII.....	\$ 4 00
To Subscribers, Vol. XXIV.....	48 00
	52 00
To Advertisers, Vol. XXIII.....	\$ 16 00
To Advertisers, Vol. XXIV.....	84 00
	100 00
To Volumes sold.....	28 15
	\$640 15

CR.	
By Postage, Secretary.....	\$ 25 10
By Postage, Treasurer.....	13 50
	\$ 38 60
By Expressage, Secretary.....	42 98
By Stationery and Printing, Secretary.....	\$ 39 45
By Stationery and Printing, Treasurer.....	2 75
	42 20
By Typewriting, Secretary.....	24 70
By Sundries, Secretary.....	6 60
By Bank charges, Treasurer.....	1 95
By Balance on Vol. XXIII.....	17 00
By Plates for Vol. XXIV.....	25 67
By Printing Vol. XXIV.....	302 24
By Cash returned to Treasurer.....	88 09
By Balance on hand.....	50 12
	\$640 15

FT. WAYNE, IND., April 15, 1904.

We do hereby certify that we have examined the foregoing account and the vouchers submitted therewith, and have found the same true and correct.

F. W. KEHNE,

FRED. SIEMON,

Auditing Committee.

CONSTITUTION

ARTICLE I

This Association shall be called the AMERICAN MICROSCOPICAL SOCIETY. Its object shall be the encouragement of microscopical research.

ARTICLE II

Any person interested in microscopical science may become a member of the Society upon written application and recommendation by two members and election by the Executive Committee. Honorary members may also be elected by the Society on nomination by the Executive Committee.

ARTICLE III

The officers of this Society shall consist of a President and two Vice-Presidents, who shall hold their office for one year, and shall be ineligible for re-election for two years after the expiration of their terms of office, together with a Secretary, a Treasurer, and a Custodian, who shall each be elected for three years, be eligible for re-election and whose terms of office shall not be coterminous.

ARTICLE IV

The duties of the officers shall be the same as are usual in similar organizations; in addition to which it shall be the duty of the President to deliver an address during the meeting at which he presides; of the Custodian to receive and manage the property and permanent funds of the Society under the direction of the Executive Committee and in conjunction with a permanent committee to be called the Spencer-Tolles Fund Committee, and to make a full and specific annual report of the condition of all the property, funds, and effects in his charge; and of the Secretary to edit and publish the *Transactions* of the Society.

ARTICLE V

There shall be an Executive Committee, consisting of the officers of the Society, three members elected by the Society, and the past Presidents of the Society and of the American Society of Microscopists who still retain membership in this Society.

ARTICLE VI

It shall be the duty of the Executive Committee to fix the time and place of meeting and manage the general affairs of the Society.

ARTICLE VII

The initiation fee shall be \$3, and the dues shall be \$2 annually, payable in advance. But any person duly elected may upon payment of \$50 at one time, or in instalments within the same year, become a life member entitled to all the privileges of membership, but exempt from further dues and fees. All life membership fees shall become part of the Spencer-Tolles Fund, but during the life of such member his dues shall be paid out of the income of said fund. A list of all life-members and of all persons or bodies who have made donations to the Spencer-Tolles Fund in sums of \$50 or over, shall be printed in every issue of the *Transactions*. The income of said fund shall be used exclusively for the encouragement and support of original investigations within the scope and purpose of this Society. The principal of the fund shall be kept inviolate.

ARTICLE VIII

The election of officers shall be by ballot.

ARTICLE IX

Amendments to the Constitution may be made by a two-thirds vote of all members present at any annual meeting, after having been proposed at the preceding annual meeting.

BY-LAWS

ARTICLE I

The Executive Committee shall, before the close of the annual meeting for which they are elected, examine the papers presented and decide upon their publication or otherwise dispose of them.

All papers accepted for publication must be completed by the authors and placed in the hands of the Secretary by October 1st succeeding the meeting.

ARTICLE II

The Secretary shall edit and publish the papers accepted, with the necessary illustrations.

ARTICLE III

The number of copies of *Transactions* of any meeting shall be decided at that meeting. But if not decided, the Secretary shall, unless otherwise ordered by the Executive Committee, print the same number as for the preceding year.

ARTICLE IV

No applicant shall be considered a member until he has paid his dues. Any member failing to pay his dues for two consecutive years, and after two written notifications from the Treasurer, shall be dropped from the roll, with the privilege of reinstatement at any time on payment of all arrears. The *Transactions* shall not be sent to any member whose dues are unpaid.

ARTICLE V

The election of officers shall be held on the morning of the last day of the annual meeting. Their term of office shall commence at the close of the meeting at which they are elected, and shall continue until their successors are elected and qualified.

ARTICLE VI

Candidates for office shall be nominated by a committee of five members of the Society. This committee shall be elected by a plurality vote, by ballot, after free nomination, on the second day of the annual meeting.

ARTICLE VII

All motions or resolutions relating to the business of the Society shall be referred for consideration to the Executive Committee before discussion and final action by the Society.

ARTICLE VIII

Members of this Society shall have the privilege of enrolling members of their families (except men over twenty-one years of age) for any meeting upon payment of one-half the annual subscription (\$1).

ARTICLE IX

There shall be a standing committee known as the Spencer-Tolles Fund Committee to take general charge of the fund and to recom-

mend annually what part of the income shall be expended for the encouragement of research, but the apportionment of the sum thus set apart shall be made by the Executive Committee.

The Spencer-Tolles Fund Committee shall also have general charge of the expenditure of such money as may be apportioned, under the conditions laid down by the Society for its use.

The Custodian shall be an *ex-officio* member of this committee.

ARTICLE X

The Executive Committee shall have the power annually to appoint two members to represent the Society on the Council of the American Association for the Advancement of Science, in accordance with the regulations of the latter organization.

Revised by the Society, July, 1903.

LIST OF MEMBERS

LIFE MEMBER

BROWN, ROBERT.....Observatory Place, New Haven, Conn.

HONORARY MEMBERS

CRISP, FRANK, LL.B., B.A., F.R.M.S.,
5 Lansdowne Road, Notting Hill, London, England
DALLINGER, REV. W. H., F.R.S., F.R.M.S.,
Ingleside, Lee, S. E., London, England
HUDSON, C. T., A.M., LL.D., F.R.M.S. (died October 24, 1903),
Hillside, Clarence Road, Shanklin, Isle of Wight, England
SMITH, HAMILTON L., LL.D.....606 W. 115th St., New York City
WARD, R. HALSTED, A.M., M.D., F.R.M.S.....53 Fourth St., Troy, N. Y.

MEMBERS

The figures denote the year of the member's election, except '78, which marks an original member. THE TRANSACTIONS are not sent to members in arrears, and two years' arrearage forfeits membership. (See Article IV of By-laws.)

MEMBERS ELECTED DURING THE YEAR 1903

For addresses see regular list.

BARKER, FRANKLIN D., A. M.	HODGE, E. M.
BELL, ALBERT T., A.M.	LANDACE, F. L., B.A.
CALDWELL, OTIS W., Ph.D.	LINE, J. EDWARD, D.D.S.
CLEMENTS, MRS. EDITH SCHWARTZ, Ph.D.	MYERS, PERRY C.
CRANDALL, GEO. C., M.D.	OTT, HARVEY N., A.M.
DUNCANSON, HENRY B., A.M.	PRINCE, S. FRED.
FISCH, CARL, M.D., Ph.D.	SMITH, THEODORE W.
FISCHER, CHAS. E. M.	STURDEVANT, L. B., A.B., B.S.
GILLMORE, GERTRUDE A., B.A.	WATSON, WM. F., A.M.
HANKINSON, T. L.	

ALLEGER, WALTER W., M.D., '94.....143 U St., N. W., Washington, D. C.
ASPINWALL, JOHN, M.A., '00.....Newburg, N. Y.
ATWOOD, E. S., '79.....Highlands P. O., Monmouth Co., N. J.
ATWOOD, H. F., '78.....16 Seneca Parkway, Rochester, N. Y.

BARKER, ALBERT S., '97.....Twenty-fourth and Locust Sts., Philadelphia, Pa.
BARKER, FRANKLIN D., A.M., '03.....University of Nebraska, Lincoln, Neb.

- BARNSFATHER, JAMES, M.D., '91.....Sixth Ave. and Walnut St., Dayton, Ky.
- BARTLETT, CHARLES JOSEPH, M.D., '96..96 Sherman Ave., New Haven, Conn.
- BAUSCH, EDWARD, '86.....179 N. St. Paul St., Rochester, N. Y.
- BAUSCH, HENRY, '86.....Rochester, N. Y.
- BAUSCH, WILLIAM, '88.....St. Paul St., Rochester, N. Y.
- BEAL, PROF. JAMES HARTLEY, '96.....Scio College, Scio, Ohio
- BEARDSLEY, PROF. A. E., '97.....1412 Tenth St., Greeley, Colo.
- BELL, ALBERT T., B.S., A.M., '03,
Nebraska Wesleyan University, University Place, Neb.
- BELL, CLARK, ESQ., LL.D., '92.....39 Broadway, New York City
- BENNETT, HENRY C., '93.....Fourth Flat, 1692 Broadway, New York City
- BERING, J. EDWARD, '99.....421 W. William St., Decatur, Ill.
- BESSEY, PROF. CHARLES EDWIN, Ph.D., LL.D., '98.....Lincoln, Neb.
- BEYER, PROF. GEO. E., '99.....Tulane University, New Orleans, La.
- BIRGE, PROF. E. A., S.D., LL.D., '99.....Univ. of Wisconsin, Madison, Wis.
- BISCOE, PROF. THOMAS D., '91.....404 Front St., Marietta, Ohio
- BLEILE, A. M., M.D., '81.....Ohio State University, Columbus, Ohio
- BODINE, PROF. DONALDSON, '96.....303 W. Main St., Crawfordsville, Ind.
- BOOTH, MARY A., F.R.M.S., '82.....60 Dartmouth St., Springfield, Mass.
- BOYER, C. S., A.M., '92.....3223 Clifford St., Philadelphia, Pa.
- BREDIN, GEO. S., '96.....Sistersville, W. Va.
- BROMLEY, ROBERT INNIS, M.D., '93.....Washington St., Sonora, Cal.
- BROWN, N. HOWLAND, '91.....33 S. Tenth St., Philadelphia, Pa.
- BRUNDAGE, A. H., M.D., '94.....1073 Bushwick Ave., Brooklyn, N. Y.
- BULL, JAMES EDGAR, ESQ., '92.....141 Broadway, New York City
- BURRILL, PROF. T. J., Ph.D., '78.....Urbana, Ill.
- BURT, PROF. EDWARD A., Ph.D., '91.....Middlebury College, Middlebury, Vt.
- BUSH, MISS BERTHA E., M.D., '95.....808 Morse Ave., Chicago, Ill.
- BYLES, D. E., '02.....114 W. Second St., Oil City, Pa.
- CALDWELL, OTIS W., Ph.D., '03.....State Normal, Charleston, Ill.
- CARPENTER, THOS. B., M.D., '99.....533 Franklin St., Buffalo, N. Y.
- CARTER, JOHN E., '86..Knox and Coulter Sts., Germantown, Philadelphia, Pa.
- CLARK, GAYLORD P., M.D., '96.....619 W. Genesee St., Syracuse, N. Y.
- CLARK, GEORGE EDW., M.D., '96.....Skaneateles, Onondaga Co., N. Y.
- CLEMENTS, FREDERIC E., A.M., Ph.D., '98...Univ. of Nebraska, Lincoln, Neb.
- CLEMENTS, MRS. EDITH SCHWARTZ, A.M., Ph.D., '03,
Univ. of Nebraska, Lincoln, Neb.
- COATS, A. J., '02.....University of Nebraska, Lincoln, Neb.
- COCKS, PROF. REGINALD S., '99....McDonogh High School, New Orleans, La.
- COFFIN, ROBERT, '00.....Bedford City, Bedford Co., Va.
- COUCH, FRANCIS G., '86,
Kalish Pharmacy, 100 E. Twenty-third St., New York City
- COX, CHAS. F., F.R.S.M., '85.....Grand Central Station, New York City
- CRAIG, THOMAS, '93.....1013 Sherbrooke St., Montreal, Canada
- CRANDALL, GEO. C., B.S., M.D., '03.....4287 Olive St., St. Louis, Mo.

- DAVIS, F. L., M.D., '99.....209 Locust St., Evansville, Ind.
 DIBROW, WILLIAM S., M.D., Ph.G., '01.....151 Orchard St., Newark, N. J.
 DOHR, S. HOBART, Ph.G., '95.....907 Seventh St., Buffalo, N. Y.
 DRESCHER, W. E., '87.....Box 1033, Rochester, N. Y.
 DUNCANSON, HENRY B., B.S., A.M., '03.....State Normal, Peru, Neb.

 ECHEVERRIA, EMILIO, M.D., '02.....San José, Costa Rica
 EIGENMANN, PROF. C. H., '95.....630 Atwater St., Bloomington, Ind.
 ELLIOTT, PROF. ARTHUR H., '91.....4 Irving Place, New York City
 ELLIOTT, LUTHER B., '98.....17 Birr St., Rochester, N. Y.
 ELROD, PROF. MORTON J., M.A., M.S., '98,
 University of Montana, Missoula, Mont.
 ELSNER, JOHN, M.D., '83.....1014 Fourteenth St., Denver, Colo.
 ELWELL, A. T., '89.....16 Pearl St., Council Bluffs, Iowa
 ELWELL, MARSHALL D., M.D., LL.D., '85.....59 Clark St., Chicago, Ill.
 EYRE, JOHN W. H., M.D., M.S., F.R.M.S., '99,
 Guy's Hospital, London, E. C., England

 FEHL, ADOLPH, M.D., '81.....520 E. Main St., Columbus, Ohio
 FEEL, GED. E., M.D., F.R.M.S., '78.....30 Woodland Ave., Buffalo, N. Y.
 FELLOWS, CHAS. S., F.R.M.S., '83,
 912 Chamber of Commerce, Minneapolis, Minn.
 FERGUSON, MEADE, M.S., Ph.D., '02.....Blacksburg, Va.
 FERRIS, PROF. HARRY B., M.D., '96.....118 York St., New Haven, Conn.
 FINDER, WM., JR., M.D., '98.....2 Union Place, Troy, N. Y.
 FISCH, CARL, M.D., Ph.D., '03.....3212 Pine St., St. Louis, Mo.
 FISCHER, ALF., '02.....646 Broadway, Milwaukee, Wis.
 FISCHER, CHAS. E. M., '03.....250 S. Clinton St., Chicago, Ill.
 FISCHER, MAX, '93.....Zeiss Optical Works, Jena, Germany
 FISHER, REV. STOKELY S., '99.....Pleasantville, Ohio
 FLINT, JAMES M., M.D., '91....."The Portland," Washington, D. C.
 FOOE, J. S., M.D., '01.....202 S. Thirty-first Ave., Omaha, Neb.
 FORDYCE, CHARLES, B.S., A.M., Ph.D., '98,
 Nebraska Wesleyan University, University Place, Neb.
 FOSTER, EDWARD, '99.....P. O. Box 405, New Orleans, La.
 FRAKER, H. C., M.D., '99.....342 Ohio Ave., Columbus, Ohio
 FULLER, CHAS. G., M.D., F.R.M.S., '81.....Reliance Bldg., Chicago, Ill.

 GAGE, PROF. SIMON H., B.S., '82.....Cornell University, Ithaca, N. Y.
 GAGE, MRS. SUSANNA PHELPS, '87.....4 South Ave., Ithaca, N. Y.
 GALLOWAY, PROF. T. W., '01.....McMillen University, Decatur, Ill.
 GATES, ELMER, '96.....Chevy Chase, Md.
 GILLET, JOHN, M.D., '02.....Sparta, Kent Co., Mich.
 GILLMORE, MISS GERTRUDE A., B.A., '03.....27 Charlotte Ave., Detroit, Mich.
 GRAY, R. S., '02.....1520 Eighth Ave., East, Oakland, Cal.
 GRAYBILL, H. W., B.Sc., '01.....High School, Clinton, Iowa
 GROSSKOPF, ERNEST C., M.D., '99.....Wauwatosa, Wis.

- HAAG, D. E., M.D., '86.....Liberty Center, Ohio
 HALL, VICTOR S., '01.....1911 Webster St., San Francisco, Cal.
 HANAMAN, C. E., F.R.M.S., '79.....State and Second Sts., Troy, N. Y.
 HANKINSON, T. L., '03.....State Normal, Charleston, Ill.
 HATFIELD, JOHN J. B., '82.....333 N. Arsenal Ave., Indianapolis, Ind.
 HERTZLER, ARTHUR A., M.D., '06.....508 Altman Bldg., Kansas City, Mo.
 HERTZOG, MAXIMILIAN, M.D., '01.....174 E. Chicago Ave., Chicago, Ill.
 HIGGINS, F. W., M.D., '98.....20 Court St., Cortland, N. Y.
 HILL, HERBERT M., Ph.D., '87.....24 High St., Buffalo, N. Y.
 HILTON, DAVID CLARK, A.M., M.D., '01.....1116 O St., Lincoln, Neb.
 HODGE, E. M., '03.....Jefferson City, Mo.
 HOFFMAN, JOS. H., M.D., '96.....111 Steuben St., Pittsburg, Pa.
 HOLLIS, FREDERICK S., Ph.D., '99...Yale Medical School, New Haven, Conn.
 HOLMES, A. M., M.D., '98.....205 Jackson Block, Denver, Colo.
 HOSKINS, WM., '79.....Room 54, 81 S. Clark St., Chicago, Ill.
 HOWE, W. T. H., Ph.D., '00.....Evansville Ind.
 HOWLAND, HENRY R., A.M., '98.....367 Seventh St., Buffalo, N. Y.
 HUMPHREY, PROF. O. D., Ph.D., '95...State Normal School, Jamaica, N. Y.
 HYATT, J. D., '78.....69 Burling Lane, New Rochelle, N. Y.

 IVES, FREDERIC E., '02.....550 W. Twenty-fifth St., New York City

 JACKSON, DANIEL DANA, B.S., '99.....941 President St., Brooklyn, N. Y.
 JAMES, FRANK L., Ph.D., M.D., '82.....514 Century Bldg., St. Louis, Mo.
 JAMES, GEO. W., '92.....108 Lake St., Chicago, Ill.
 JOHNSON, FRANK S., M.D., F.R.M.S., '93.....2521 Prairie Ave., Chicago, Ill.
 JOHNSON, WM. D., M.D., '98.....Batavia, N. Y.
 JONES, MRS. MARY A. DIXON, M.D., F.R.M.S., '98,
 249 E. Eighty-sixth St., New York City
 JUDAY, CHANCEY, '00.....1060 Twelfth St., Boulder, Cal.

 KELLOGG, J. H., M.D., '78.....Battle Creek, Mich.
 KERR, ABRAM TUCKER, JR., M.D., '95.....61 Waite Ave., Ithaca, N. Y.
 KINGSBURY, BENJ. F., A.B., M.S., '98.....125 Dryden Road, Ithaca, N. Y.
 KINLEY, JOS. B., M.D., '01.....1405 Welton St., Denver, Colo.
 KIRKPATRICK, T. J., '93.....701 E. High St., Springfield, Ohio
 KOFOID, CHARLES A., Ph.D., '99.....University of California, Berkeley, Cal.
 KOTZ, A. L., M.D., '91.....32 S. Fourth St., Easton, Pa.
 KRAFFT, WILLIAM, '95.....411 W. Fifty-ninth St., New York City
 KRAUSS, WM. C., B.S., M.D., '90.....479 Delaware Ave., Buffalo, N. Y.
 KUEHNE, F. W., '79.....723 Court St., Fort Wayne, Ind.

 LAMB, J. MELVIN, M.D., '91.....910 T St., N. W., Washington, D. C.
 LANDAGRE, F. L., B.A., '03.....Ohio State University, Columbus, Ohio
 LATHAM, MISS V. A., M.D., D.D.S., F.R.M.S., '88,
 808 Morse Ave., Rogers Park, Chicago, Ill.
 LAWTON, EDWARD P., '88.....3 Linden Ave., Troy, N. Y.

- LEIPPE, J. HARRY, '96.....336 Pine St., Reading, Pa.
 LEWIS, MRS. KATHARINE B., '89.. "Elmstone," 656 Seventh St., Buffalo, N. Y.
 LEWIS, IRA W., '87.....408 S. Galena St., Dixon, Ill.
 LINE, J. EDWARD, D.D.S., '03.....39 State St., Rochester, N. Y.
 LOCKE, JOHN D., '93.....P. O. Box 129, Haverhill, N. H.
 LOMB, ARSLPH, '92.....48 Clinton Place, Rochester, N. Y.
 LOMB, HENRY, '84.....48 Clinton Place, Rochester, N. Y.
 LOOMIS, CHANDLER H., '87.....316 Seneca St., Manlius, N. Y.
 LOVE, PROF. E. G., '91.....80 E. Fifty-fifth St., New York City
 LYMAS, R. A., A.M., M.D., '01.....1200 Pacific St., Omaha, Neb.
 LYON, HOWARD N., M.D., '84.....828 Wheaton Ave., Wheaton, Ill.
- MARSH, J. P., M.D., '01.....1828 Fifth Ave., Troy, N. Y.
 MARSHALL, COLLINS, M.D., '96.....2507 Penn. Ave., Washington, D. C.
 MARSHALL, WM., JR., '92.....Coudersport, Pa.
 MASTERMAN, ELMER E., '97... Rural Mail Delivery No. 2, New London, Ohio
 MATHER, E. M.D., Ph.D., '02.....80 Park Place, East, Detroit, Mich.
 MAYWALD, FREDERICK J., '02.....1028 Seventy-second St., Brooklyn, N. Y.
 McCALLA, ALBERT, Ph.D., '80,
 414 Monadnock, Dearborn and Jackson Sts., Chicago, Ill.
 McKAY, JOSEPH, '84.....259 Eighth St., Troy, N. Y.
 McKIM, REV. HASLETT, '85.....9 W. Forty-eighth St., New York City
 McMILLAN, R. M., M.D., '00.....35 Twentieth St., Wheeling, W. Va.
 MEADER, LEE DOUGLAS, M.D., '96.....2651 Gilbert Ave., Cincinnati, Ohio
 MELLOR, CHAS. C., '85.....319 Fifth Ave., Pittsburg, Pa.
 MERCER, A. CLIFFORD, M.D., F.R.M.S., '82,
 324 Montgomery St., Syracuse, N. Y.
 MERCER, FREDERICK W., M.D., F.R.M.S., '83..2540 Prairie Ave., Chicago, Ill.
 MERCER, W. F., Ph.D., '99,
 Biological Laboratory, Ohio University, Athens, Ohio
 METCALF, HAVEN, A.M., Ph.D., '02.....Clemson College, S. C.
 MICHENOR, AVA, M.D., '02.....State Training School for Girls, Geneva, Ill.
 MILES, MRS. C. S., '01.....1544 Franklin St., Denver, Colo.
 MILLER, JOHN A., Ph.D., F.R.M.S., '89.....44 Lewis Block, Buffalo, N. Y.
 MOCKETT, J. H., SR., '01.....Burr Block, Lincoln, Neb.
 MOODY, ROBERT O., M.D., '91.....Hearst Anatomical Laboratory,
 University of California, San Francisco, Cal.
 MYERS, PERRY C., '03.....Woodlawn Ave., Winona, Minn.
- NUNN, RICHARD J., M.D., '83.....5 York St., Savannah, Ga.
- OERTEL, T. E., M.D., '92.....Med. Dept., Univ. of Ga., Augusta, Ga.
 OHLER, W. H., '91.....18 Locust St., Portland, Me.
 OTT, HARVEY N., A.M., '03.....Spencer Lens Co., Buffalo, N. Y.
- PARK, ROSWELL, A.M., M.D., '94.....510 Delaware Ave., Buffalo, N. Y.
 PARKER, HORATIO N., '99.....Bloomfield Ave., Montclair, N. J.

PATRICK, FRANK, Ph.D., '91.....601 Kansas Ave., Topeka, Kan.
 PEARSE, ARTHUR S., B.Sc., M.A., '02..Harvard University, Cambridge, Mass.
 PEASE, FRED N., '87.....1307 Third Ave., Altoona, Pa.
 PENNOCK, ED., '79.....3609 Woodland Ave., Philadelphia, Pa.
 PFLAUM, MAGNUS, ESQ., '91.....440 Diamond St., Pittsburg, Pa.
 PIWONKA, THOS., ESQ., '97.....243 Superior St., Cleveland, Ohio
 POUND, ROSCOE, A.M., Ph.D., '98.....Lincoln, Neb.
 POWERS, JAS. H., A.B., Ph.D., '02.....Doane College, Crete, Neb.
 PRINCE, S. FRED, '03.....University of Nebraska, Lincoln, Neb.
 PYBURN, GEORGE, M.D., '86.....1011 H St., Sacramento, Cal.

RANSOM, BRAYTON H., '99.....1362 B St., S. W., Washington, D. C.
 REED, RAYMOND C., Ph.B., D.V.M., '79....120 W. Hudson St., Elmira, N. Y.
 REVBURN, ROBERT, M.D., '90.....2129 F St., N. W., Washington, D. C.
 RICHARDS, ELIAS, '99.....1722 Calhoun St., New Orleans, La.

SARCAR, HEM CHUNDR, M.B., '01,

Listerpet, Rajamundry, District Godawari, India

SCHONEY, L., M.D., '98.....23 W. 135th St., New York City
 SEAMAN, WM. H., M.D., '86....1424 Eleventh St., N. W., Washington, D. C.
 SEAWELL, BENJ. LEE, B.S. (Edin.) '01..308 E. Market St., Warrensburg, Mo.
 SHANKS, S. G., M.D., '00.....547 Clinton Ave., Albany, N. Y.
 SHEARER, J. B., '88.....809 Adams St., Bay City, Mich.
 SHULTZ, CHAS. S., '82.....Seventh St. Docks, Hoboken, N. J.
 SIBLEY, E. R.....902 Pine St., Philadelphia, Pa.
 SIEMON, RUDOLPH, '91.....1215 Calhoun St., Fort Wayne, Ind.
 SLOCUM, CHAS. E., Ph.D., M.D., '78.....Defiance, Ohio
 SMITH, J. C., '96.....131 Carondelet St., New Orleans, La.
 SMITH, THEODORE W., '03.....171 La Salle St., Chicago, Ill.
 STAUFFER, REV. T. F., '01.....200 Eleventh St., Sioux City, Iowa
 STEBBINS, J. H., JR., Ph.D., M.D., '01.....351 Fourth Ave., New York City.
 STEDMAN, PROF. J. M., '95.....Mo. Experiment Station, Columbia, Mo.
 STONEY, ROBERT J., JR., '96.....424 Fifth Ave., Pittsburg, Pa.
 STURDEVANT, LAZELLE B., A.B., B.S., '03....Univ. of Nebraska, Lincoln, Neb.
 SUMMERS, PROF. H. E., '86.....Ames, Iowa

TAYLOR, GEO. C., LL.D., '99.....437 W. Fourteenth St., Oklahoma City, Okl.
 THOMAS, ARTHUR H., '99.....Twelfth and Walnut Sts., Philadelphia, Pa.
 THOMAS, PROF. MASON B., '90.....College Campus, Crawfordsville, Ind.
 TIMMINS, GEORGE, '96.....1410 E. Genesee St., Syracuse, N. Y.
 TWINING, FREDERICK E., '96.....29 Patterson Block, Fresno, Cal.

ULRICH, CARL J., B.S., '01.....Central High School, Duluth, Minn.

VANDERPOEL, FRANK, M.E., Ph.D., '87.....153 Center St., Orange, N. J.
 VEEDER, M. A., M.D., '85.....Broad and Queen Sts., Lyons, N. Y.
 VREDENBURGH, E. H., '84.....60 Plymouth Ave., Rochester, N. Y.

- WARD, HENRY B., A.M., Ph.D., '87.....University of Nebraska, Lincoln, Neb.
- WATSON, WM. F., A.M., '03.....Furman University, Greenville, S. C.
- WEBER, PROF. HENRY A., Ph.D., '86.....1342 Forsyth Ave., Columbus, Ohio
- WEIGHTMAN, CHAS. H., '86.....5859 Michigan Ave., Chicago, Ill.
- WELCH, GEO. O., M.D., '91.....Box 416, Fergus Falls, Minn.
- WENDE, ERNEST, M.D., F.R.M.S., '91.....471 Delaware Ave., Buffalo, N. Y.
- WHEELER, E. J., Ph.D., '00.....79 Chapel St., Albany, N. Y.
- WHELPLEY, H. M., M.D., Ph.G., F.R.M.S., '90,
2342 Albion Place, St. Louis, Mo.
- WHIPPLE, G. C., '90.....220 Broadway, New York City
- WHITE, CHAS. H., M.D., '02.....Center Sandwich, N. H.
- WHITLEY, JAMES D., M.D., F.R.M.S., '85.....405 S. Main St., Petersburg, Ill.
- WIARD, MARTIN S., '86.....21 Walnut St., New Britain, Conn.
- WOLCOTT, ROBERT HENRY, A.M., M.D., '98,
University of Nebraska, Lincoln, Neb.
- YOUNG, L., '00.....High School, Evansville, Ind.
- ZENTMAYER, FRANK, '91.....228 S. Fifteenth St., Philadelphia, Pa.

SUBSCRIBERS

PUBLIC LIBRARY.....	Detroit, Mich.
FIELD COLUMBIAN MUSEUM.....	Chicago, Ill.
COLUMBIA UNIVERSITY LIBRARY.....	New York City
NEW YORK PUBLIC LIBRARY.....	New York City
DULAU & Co.....	37 Soho Square, London, England
CARNEGIE LIBRARY.....	Pittsburg, Pa.
SYRACUSE CENTRAL LIBRARY.....	Syracuse, N. Y.
ACADEMY OF NATURAL SCIENCES.....	Logan Square, Philadelphia, Pa.
NEW YORK ACADEMY OF MEDICINE, 17 W. Forty-third St., New York City	
THE MISSOURI BOTANICAL GARDEN.....	St. Louis, Mo.
SCIENTIFIC LIBRARY.....	U. S. Patent Office, Washington, D. C.
N. Y. STATE VETERINARY COLLEGE.....	Cornell University, Ithaca, N. Y.
U. S. MEDICAL MUSEUM AND LIBRARY, Surgeon General's Office, Washington, D. C.	
NEW YORK STATE LIBRARY.....	Serial Section, Albany, N. Y.
BOSTON SOCIETY OF NATURAL HISTORY.....	Berkeley St., Boston, Mass.
HYGIENIC LABORATORY.....	Burlington, Vt.
LIBRARY OF THE OHIO STATE UNIVERSITY.....	Columbus, Ohio
LABORATORY OF HISTOLOGY AND EMBRYOLOGY, University of Minnesota, Minneapolis, Minn.	
LIBRARY OF THE UNIVERSITY OF NEBRASKA.....	Lincoln, Neb.
JOHN CRERAR LIBRARY.....	Chicago, Ill.
LIBRARY OF THE ILLINOIS STATE LABORATORY OF NATURAL HISTORY, Urbana, Ill.	
NEW HAMPSHIRE STATE LIBRARY.....	Concord, N. H.
MEDICAL LIBRARY.....	McGill University, Montreal, Canada
S. C. FULLER.....	Westboro Insane Hospital, Westboro, Mass.
LIBRARY OF THE COLORADO STATE NORMAL.....	Greeley, Colo.
LIBRARY OF THE UNIVERSITY OF MONTANA.....	Missoula, Mont.
PUBLIC LIBRARY.....	Plainfield, N. J.
SAN FRANCISCO MICROSCOPICAL SOCIETY.....	San Francisco, Cal.
LIBRARY OF THE UNIVERSITY OF WISCONSIN.....	Madison, Wis.
LIBRARY OF THE STATE NORMAL.....	Warrensburg, Mo.
BUREAU OF GOVERNMENT LABORATORIES.....	Manila, P. I.
LIBRARY OF CHICAGO UNIVERSITY.....	Chicago, Ill.

INDEX TO VOLUMES I TO XXV

- Acanthocephala*, Structure of, XXIII: 191.
- Acan, Destruction of, by a Fungus, III: 49.
- Accessories, New Microscopical, XVI: 124.
- Account of a Morbid Growth in a Pig's Stomach, An—W. H. Birchmore, V: 125.
- Acetylene Gas as the Illuminant in Photomicrography—W. H. Waïmsley, XVIII: 136.
- Acid, Chronic, Effect of, upon Red Blood Corpuscles, XV: 129; Chronic, for Rapid Preparation of Tissues, XII: 120; Citric, Production of, by Fermentation, XV: 90; Pieric, for Rapid Preparation of Tissues, XII: 120.
- Actinic and Visual Focus in Micro-photography with High Powers, The—Jacob D. Cox, VII: 29.
- Actinospharium *Eichhornii*, Development and Reproduction of, X: 107.
- Action of Strong Currents of Electricity upon Nerve Cells, The—Pierre A. Fish, XVII: 179.
- Addition to the Parasites of the Human Ear, An—Roscoe Pound, XXII: 81.
- Additional Notes on Certain Species of Rotifera—D. S. Kellicott, IX: 181.
- Additional Notes on *Gomphogaster*—C. M. Vorce, XII: 174.
- Additional Notes on the Cladocera of Nebraska—Chas. Fordyce, XXV: 45.
- Adulterations, of Butter, VIII: 103, 116; of Lard, V: 97.
- Aeration of Organs and Tissues in *Mikania* and other Phanerogams—W. W. Rowlee, XV: 143.
- Agar-agar—W. W. Alleger, XX: 91.
- Air-sacs, of Birds, XX: 29.
- Algae, Influence of, on Deep Sea Life, II: 17; Mounting of, XV: 248.
- Alleger, W. W. Agar-agar, XX: 91; Formalin, XV: 192; Formalin—Adenda, XV: 219; Some Remarks on the Limitation of Tuberculosis, Illustrating the Value of the Microscope in Preventive Medicine, XVI: 101.
- Altitude, Effect of, on Blood Counts, XX: 177.
- Amblystoma*, Albino Eggs of, XX: 69.
- American and European Microscopes—H. J. Detmers, X: 149.
- American Work on Cestodes in 1893—Henry B. Ward, XV: 183.
- Amoeba villosa*, Leidy, Sporular Development of, XIX: 69.
- Amia calva*, Structure of Stomach of, XII: 165.
- Ammoniacal Fermentation of Urine, The—Veranus A. Moore, XII: 97.
- Amount of Oxygen and Carbonic Acid Dissolved in Natural Waters, On the, and the Effect of these Cases upon the Occurrence of Microscopic Organisms—Geo. C. Whipple and Horatio N. Parker, XXIII: 103.
- Amphibia, Lateral Line System of, XVII: 115; Phagocytic Action of Leukocytes in, XIX: 93; Peritoneal Epithelium of, XVIII: 76.
- Amphipleura pellucida*, Resolution of, by Central Light, XII: 170.

- Amphistomum Fabaceum Diesing, Anatomy of, XI: 85.
 Amplifier, Use of, IX: 263.
 Amplifying Power of Objectives and Oculars in the Compound Microscope, On the—Geo. E. Blackham, XI: 22.
 Angiosperms, Fecundation of Ovules in, VI: 93.
 Anilin Dyes, Reaction of Diabetic Blood to, XXI: 31.
 Animal Body, Tube Plan of Structure of, XXV: 63.
 Animals, Domestic, Size of Blood Corpuscles of, IX: 216.
 Aperture, Angle of, in Air, Water and Balsam, in Relation to Numerical Angle, VII: 199; as a factor in Microscopic Vision, XVIII: 321; Numerical, XIV: 44; Numerical, in Relation to Angle of Aperture in Air, Water and Balsam, VII: 199; Relation of, to Amplification, V: 33.
 Apparatus, Discussion of, III: 85; New and Improved, VII: 112.
 Apparatus for Holding Cover-glasses, An—Veranus A. Moore, XIII: 51.
 Apparatus for Illustrating the Circulation of the Lymph—G. S. Hopkins, XVII: 336.
 Apparatus for the Exhibition of Microscopic Objects—James M. Flint, XIII: 54.
 Apparent Structure of the Scales of *Siera buskii* in Relation to the Scales of *Lepidocyrtus curvicollis*, On the—R. L. Maddox, XVIII: 194.
 Aqueous Solution of Hematoxylin which does not readily Deteriorate, An—Simon H. Gage, XIV: 125.
 Argulus catostomi, VIII: 144.
 Arrangement of the Muscular Layers of the Intestine of the Cat in the Region of the Juncture of the Large and Small Intestines, The—Robert O. Moody, XIII: 120.
 Arteries, Diseased Cerebral, Trauma in Relation to, XXI: 1.
 Arthropods, Cleavage among, XIX: 74.
 Aspinwall, John. Methods of Producing Enlargements and Lantern Slides of Microscopic Objects for Class Demonstrations, XXII: 41.
 Astronomical Photography with Photomicrographic Apparatus—A. Clifford Mercer, XVIII: 132.
 Atax (Fabr.) Bruz., North American Species of, XX: 193.
 Attacus Cecropia, Structure of, XI: 135.
 Atwood, H. F. A New Apparatus for Photo-micrography, VI: 176.
 Bacillus, of Cholera, Feeding Insects with, XX: 75; Comma, an Etiological Factor in Asiatic Cholera, VIII: 84; Comma, Feeding Insects with, XX: 75; of Diphtheria, XX: 81; of Foot-rot in Sheep, IX: 209; of Leprosy, X: 119.
 Bacillus of Foot-rot in Sheep—Mark Francis, IX: 209.
 Bacteria, and Disease, VIII: 5; Cultivation of, VII: 142; Dahlia as Stain for, XIX: 182; in Ice, XI: 70; in Milk Ducts of Udder, XX: 57; Motile, Flagella of, XVII: 239; Motile, Standing Flagella on, XIII: 85; on the Normal Eye, XI: 120; Pathogenic, V: 87; Preparing and Mounting, V: 79; the Cause of Disease, IX: 193.
 Bacteria and Disease: President's Address—Thomas J. Burrill, VIII: 5.
 Bacteria in Ice, especially in their Relation to Typhoid Fever—Chevalier Q. Jackson, XI: 70.

- Bacterial Research, Popular Fallacies of, IX: 254.
- Barker, Arthur M., M.D., Memoir of, X: 165.
- Bartlett, C. J. Memoir of Moses Clark White, A.M., M.D., XXII: 202.
- Bastin, Edson S. A New Section Instrument for Vegetable Materials, XVI: 121.
- Bat, Ending and Relation of Muscle Fibres in, IX: 207.
- Bausch, Edward. The Universal Screw for Microscope Objectives, VI: 153; Two New Combined Inverted and Vertical Microscopes, VIII: 148; The Full Utilization of the Capacity of the Microscope and Means for Obtaining the Same, XII: 43; New American Microscopes, made by Bausch & Lomb Optical Co., Rochester, N. Y., XIII: 116.
- Beardsley, Arthur E. Notes on Colorado Entomostraca, XXIII: 41; Notes on Colorado Protozoa with Description of New Species (1 Plate), XXIII: 49.
- Beef, Poisonous Dried, VII: 54.
- Belfield, William T. The Microscope in the Detection of Lard Adulterations, (1 Plate), V: 97.
- Bell, Clark. Blood and Blood Stains in Medical Jurisprudence, (4 Plates), XIV: 91.
- Bennett, A. W. Fungi found in Sewage-effluents, VI: 90.
- Bermuda, Chirodota of, IV: 139.
- Berry, John M. A Comparison of the Phagocytic Action of Leukocytes in Amphibia and Mammalia, (5 Plates), XIX: 93.
- Bessey, Chas. E. The Modern Conception of the Structure and Classification of Diatoms, with a Revision of the Tribes and a Rearrangement of the North American Genera, (1 Plate), XXI: 61; The Modern Conception of the Structure and Classification of Desmids, with a Revision of the Tribes, and a Rearrangement of the North American Genera, (1 Plate), XXII: 89; The Structure and Classification of the Conjugatae, with a Revision of the Families and a Rearrangement of the North American Genera, XXIII: 145; President's Address: Evolution in Microscopic Plants, XXIV: 5; The Structure and Classification of the Phycomycetes, with a Revision of the Families and a Rearrangement of the North American Genera, (1 Plate), XXIV: 27; The Classification of Protophyta, Including a Revision of the Families, and a Rearrangement of the North American Genera, XXV: 89.
- Best Technique for High-power Photo-micrography. On the—George W. Rafter, XI: 112.
- Bidens cernua*, Intercellular Spaces in Embryos of, XVII: 174.
- Binocular Microscope and Stereoscopic Vision, The—Geo. E. Fell, III: 69.
- Binocular Microscope of the Seventeenth Century, The—Charles E. West, XII: 57.
- Binocular, Wenham, XIV: 57.
- Biological Reconnoissance of some Elevated Lakes in the Sierras and the Rockies, A—Henry B. Ward, XXV: 127.
- Birchmore, W. H. An Account of a Morbid Growth in a Pig's Stomach, V: 125.
- Birds, Air-sacs of, XX: 39.

- Birge, E. A. President's Address: The Thermocline and its Biological Significance, (2 Plates), XXV: 5; Cladocera of some Elevated Lakes in the Sierras and the Rockies, XXV: 149.
- Biscoe, Thomas D. The Wenham Binocular—Can it be made Adjustable to a Variable Tube Length? XIV: 57.
- Blackham, Geo. E. On the Systematic Examination of Objectives for the Microscope, with a Convenient Form for Recording Results, I: 62; Should Homogeneous-immersion Objectives be made Adjustable or Non-adjustable? III: 62; President's Address: The Evolution of the Modern Microscope, IV: 25; The Relation of Aperture to Amplification in the Selection of a Series of Objectives, V: 33; Memoir of Robert B. Tolles, VI: 41; Memoir of Thad S. Up de Graff, M.D., F.R.M.S., VII: 216; On the Amplifying Power of Objectives and Oculars in the Compound Microscope, XI: 22.
- Bleile, A. M. Some Notes on the Innervation of the Lungs, (1 Plate), III: 35; Memoir of David Simons Kellicott, B.Sc., B.Ph., Ph.D., XX: 21; President's Address: The Detection and Recognition of Blood, XXII: 1.
- Bleile, A. M., and Feiel, A. The Effects of Division of the Vagi on the Heart, IV: 91, 261; The Effects of a Division of the Vagi on the Muscles of the Heart, V: 47.
- Blood, and Blood Stains, XIV: 91; Corpuscular Elements of, XIV: 63; Detection and Recognition of, XXII: 1; Diabetic, Reaction of, to Anilin Dyes, XXI: 31; Drawing for Microscopic Examination, XIX: 186; Effect of Altitude on, XX: 177; Histology of, XVIII: 49; Methods of Determining Percentage of Haemoglobin in, XVII: 165; Micro-Organisms in, in Tetanus, IV: 157; of Frog, Haemosporidia in, XXV: 55; of Necturus and Cryptobranchus, XV: 39; Preparing in Bulk, XX: 49; Rheumatic, Morphology of, VI: 194; Study of, III: 39.
- Blood and Blood Stains in Medical Jurisprudence—Clark Bell, XIV: 91.
- Blood Corpuscles, Comparative Size of in Man and Domestic Animals, IX: 216; of Lamprey, X: 77; of Necturus, VII: 126; Red, Effect of Dilute Solutions of Chromic Acid and Acid Urine upon, XV: 129; Red, Human, Micrometry of, XX: 41; Red, in Legal Medicine, XVIII: 201; White, Diapedesis of, XVI: 165.
- Blood of Necturus and Cryptobranchus, The—Edith J. Claypole, XV: 39.
- Blood Platelets, XVI: 181.
- Blood Stains, *Sarcina ventriculi* in Medico-legal Investigation of, XV: 136.
- Botany, Collodion Method in, XII: 123.
- Brain, Comparative Morphology of, XVII: 185; Human, Physiology and Pathology of, V: 141.
- Brain Cavities, Epithelium of, XII: 140.
- Brain Sections, Preparation and Mounting, IV: 275.
- Branchial Cleft, Growth of the First, I: 57.
- Bray, Thomas J. Photomicrography, XVIII: 107.
- Brayton, Forest W., M.D., Memoir of, XIII: 171.
- Brief Account of the Microscopical Anatomy in a case of Chrome Lead Poisoning, A—Vida A. Latham, XIII: 110.
- Britcher, Horace W. An Occurrence of Albino Eggs of the Spotted Salamander, *Amblystoma punctatum* L., (1 Plate), XXI: 69.

- Brief Study of a Case of Elephantiasis and its Histology, A—V. A. Latham, XIV: 133.
- Brooklyn Water Works, Mt. Prospect Laboratory—XXII: 25.
- Brownell, J. T. Brownell Turn-table, VI: 173; Original Method of Staining and Mounting Pollens, VI: 212; How to make Wax Cells, neat, permanent and free from "Sweating," VI: 214; Memoir of, VIII: 202.
- Brownian Movement, Prevention of, XXIV: 22.
- Bryophyllum calycinum, Salisb., Buds in Leaf of, XIV: 80.
- Buffalo Water Supply, Microscopic Organisms in, IV: 165, 281.
- Bulloch, Walter H. The Magnifying Power of Microscope Objectives and Lenses, VI: 183.
- Burrill, T. J. Preparing and Mounting Bacteria, V: 79; The Uredineæ of Illinois—A List of the Species, VII: 93; President's Address: Bacteria and Disease, VIII: 5; Disease Germs. Another Illustration of the Fact that Bacteria Cause Disease, IX: 193; The Erysipheæ of Illinois, (1 Plate), IX: 301; The Ustilagineæ, or Smuts; with a List of Illinois Species, X: 45; A Microscope Stand, XI: 53; Report of Working Session, XI: 143; Microscopic Objectives, XII: 35; River Pollution, and Purification, (3 Plates), XXV: 105.
- Burrill, T. J. and Stratton, S. W. A Heliostat for Photo-micrography, VII: 103.
- Busch, F. C. and Kerr, A. T., Jr. Comparison of the Fleischl, the Gowers, and the Specific Gravity Methods of Determining the Percentage of Haemoglobin in the Blood for Clinical Purposes, XVII: 165.
- Busy Man's Amateur Microscopic Laboratory, A—Martin S. Wiard, XI: 126.
- Butter, Crystallography of, IX: 315; distinguishing of by Means of Microscope, VII: 128; Examination of and Its Adulterations, VIII: 103, 116.
- Butter and Fats. To Distinguish one Fat from Another by Means of the Microscope—Thomas Taylor, VII: 128.
- Camera, Handy Photomicrographic, XII, 69; in Detection of Forgery, XII: 86; New Photo-Micro, IX: 263.
- Cameras, Photo-micrographic, XVII: 340.
- Cancer, Curability of, XXI: 17; Discoveries in relation to, XX: 165.
- Carbonic Acid, Dissolved in Natural Waters, Effect of on Microscopic Organisms, XXIII: 103.
- Carcinoma, Cellular Pathology of, XVIII: 248; on Floor of Pelvis, XX: 165.
- Carcinoma on the Floor of the Pelvis. Two Discoveries in Cancerous Disease—Mary A. Dixon Jones, XX: 165.
- Cardiac Muscle Cells in Man and Certain Other Mammals—B. L. Oviatt, IX: 283.
- Carmine, Picro- and Alum-, as Counter Stains, XX: 337.
- Cartilage, Development of, in Embryo of Chick and Man, VII: 76; Sectioning Fresh, VIII: 142.
- Caryophyllales, Histogenesis of XX: 97.
- Cataloguing, Labeling and Storing Microscopical Preparations—Simon H. Gage, V: 169.

- Cat, Comparison of Ear with Human, XII: 146; Meibomian Glands in, VIII: 143; Muscular Layers of Intestine of, XIII: 120; Soft Palate of, X: 58.
- Cells, Wax, How to make, VI: 214; Use in Connection with White Zinc Cement for Fluid Mounts, II: 63.
- Centering Block, XVII: 373.
- Centimeter Scale A, Comparison with Centimeter Scale Fasoldt II, IX: 299; Comparison with Standard Centimeter Ruled on Glass, VIII: 83; Further Study of, VIII: 75; Report on, V: 181; Securing Copies of, XI: 109; Study of, V: 184; Study of Subdivisions, XI: 64.
- Centimeters, Standard, Glass and Speculum Metal, XIII: 71; Manufactured in Pursuance of the Resolution of A. S. M. adopted in 1889, Description of, XII: 84; Report on, XIII: 207.
- Cephalic Extremity and Movements of the Human Spermatozoon, The—George E. Fell, V: 121.
- Certain Crustacea Parasitic on Fishes from the Great Lakes, On—D. S. Kellicott, I: 53.
- Certain Crustaceous Parasites of Fresh-water Fishes, On—D. S. Kellicott, IV: 75.
- Cestode, New Avian, XXI: 213.
- Cestodes, American Work on, in 1893, XV: 183.
- Chara Coronata, Chlorophyll Bodies of, XVII: 155.
- Character of the Flagella, The—Veranus A. Moore, XVI: 217.
- Chataqua Lake, A New species of Copepoda and List of Entomostraca found at, IX: 246.
- Cheap and Efficient Life-box, A—Jas. E. Whitney, VI: 215.
- Cheap Punches for Sheet Wax—Jas. E. Whitney, VI: 215.
- Chester, Albert H. A New Method of Dry Mounting, V: 143.
- Chick, Development of Cartilage in Embryo of, VII: 76; Development of Muscle in Embryo of, VII: 71.
- Chick Embryos, for Microscopical Examination, VII: 66; Preparation and Imbedding, XII: 128.
- Chirodota, Spicula of, IV: 139.
- Chlamydomonas, XXI: 97; in Connecticut, XXIV: 13.
- Chlamydomonas and Its Effect on Water Supplies—Geo. C. Whipple, XXI: 97.
- Chlorophyll Bodies of Chara Coronata, The—W. W. Rowlee, XVII: 155.
- Cholera, Asiatic, Comma Bacillus an Etiological Factor in, VIII: 84.
- Cholera Bacillus, VII: 142.
- Chrome Lead Poisoning, Microscopical Anatomy in, XIII: 110.
- Cicada septendecim, Ovipositor and Mouth Parts of, XVII: 111.
- Circulation, Extra-vascular, VI: 81.
- Cittotaenia, XXIII: 173.
- Cladocera of Nebraska, The—Chas. Fordyce, XXII: 119.
- Cladocera, of Elevated Lakes in the Sierras and the Rockies, XXV: 149; of Nebraska, Additional Notes on, XXV: 45.
- Classification of Protozoa, The, Including a Revision of the Families, and a Rearrangement of the North American Genera—Chas. E. Bessey, XXV: 89.

- Claypole, Agnes M. A New Method for Securing Paraffin Sections to the Slide or Cover-glass, XVI: 65; The Enteron of the Cayuga Lake Lamprey, (to Plates), XVI: 125; Some Points on Cleavage among Arthropods, (1 Plate), XIX: 74.
- Claypole, Edith J. The Blood of *Necturus* and *Cryptobranchus*, (6 Plates), XV: 30; Notes on Comparative Histology of Blood and Muscle, (5 Plates), XVIII: 49; The Comparative Histology of the Digestive Tract, (1 Plate), XIX: 83.
- Claypole, E. W. On the Value of Cheap Microscopes for Educational Purposes, XIV: 60; Structure of the Bone of *Dinichthys*, XV: 189; On the Structure of the Teeth of Devonian Cladodont Sharks, XVI: 191; On the Teeth of *Mazodus*, (1 Col. Plate), XVIII: 146; On the Structure of Some Paleozoic Spines from Ohio, (1 Col. Plate), XVIII: 151; President's Address: Microscopical Light in Geological Darkness, XIX: 3; Memoir of, (Portrait p. 268), XXIII: 269.
- Cleaning and Arranging Diatoms—F. S. Newcomer, VIII: 128.
- Clearer, for Collodionized Objects, XV: 86.
- Cleavage, among Arthropods, XIX: 74.
- Clements, Frederic E. Contributions to the Histogenesis of the Caryophyllales, (18 Plates), XX: 97.
- Clevenger, S. V. Physiology and Pathology of the Human Brain, V: 141.
- Clinical Advantages of Ozone and its effects on the Micro-Organisms of Infusions—George E. Fell, V: 69.
- Cocaine in the Study of Pond-life—H. N. Conser, XVII: 310.
- College Microscope, A—William H. Seaman, XII: 67.
- College Microscopical Societies—Sarah F. Whiting, V: 27.
- Collodion Embedding, XVII: 312.
- Collodion Method, in Blood Examinations, XIII: 79; in Botany, XII: 123.
- Collodion, Oil-sectioning with, XVII: 361.
- Collodion Method in Botany—Mason B. Thomas, XII: 123.
- Colorado, Entomostraca of, XXIII: 41; Protozoa of, XXIII: 49.
- Combined Focusing and Safety Stage for Use in Micrometry with High Powers, A—C. M. Vorce, VII: 115.
- Comma Bacillus, an Etiological Factor in Asiatic Cholera, VIII: 84.
- Comma Bacillus of Asiatic Cholera, The. A Reply to Arguments Denying that it is an Etiological Factor in that Disease—George W. Lewis, VIII: 84.
- Committee of the American Society of Microscopists on Uniformity of Tubelength, Report of, XII: 250.
- Committee on Eye-Pieces, Report of, V: 175.
- Committee on Micrometry, Report of, VIII: 197; Report of, X: 163; National, History of, V: 178.
- Committee on Oculars, Report of, VI: 228.
- Committee on the Spencer-Tolles Fund, Report of, XXIII: 265.
- Committee on Standard Micrometer, Report of, VI: 220; Report of, VII: 212.
- Committee on Universal Microscope Screw, Report of, VIII: 199.
- Comparative Histology of the Digestive Tract, The—Edith J. Claypole, XIX: 83.

- Comparative Morphology of the Brain of the Soft-shelled Turtle (*Amyda mutica*) and the English Sparrow (*Passer domestica*)—Susanna Phelps Gage, XVII: 185.
- Comparative Size of Blood Corpuscles of Man and Domestic Animals—Freda Detmers, IX: 216.
- Comparative Study in Methods of Plankton Measurement, A—Henry B. Ward, H. W. Graybill, and others, XXI: 227.
- Comparative Study of Hair for the Medico-legal Expert, A—Wm. Geo. Reynolds, XIX: 117.
- Comparative Study of the Soft Palate—Wm. Fairfield Mercer, XXI: 41.
- Comparison of a Standard Centimeter Ruled on Glass by Chas. Fasoldt, with Centimeter Scale A—Marshall D. Ewell, VIII: 83.
- Comparison of Centimeter Scale, "Fasoldt II," with "Centimeter Scale A."—Marshall D. Ewell, IX: 299.
- Comparison of the External and Middle Ear of Man and the Cat, A—Thomas B. Spence, XII: 146.
- Comparison of the Fleischl, the Gowers, and the Specific Gravity Methods of Determining the Percentage of Haemoglobin in the Blood for Clinical Purposes—F. C. Busch and A. T. Kerr, Jr., XVII: 165.
- Comparison of the Phagocytic Action of Leukocytes in Amphibia and Mammalia, A—John M. Berry, XIX: 93.
- Concave Mirror, The—Marshall D. Ewell, XIV: 43.
- Conditions of Success in the Construction and the Comparison of Standards of Length, On the—William A. Rogers, IV: 231; V: 240.
- Conjugatae, Structure and Classification of, XXIII: 145.
- Connecticut, *Chlamydomonas* in, XXIV: 13.
- Connective-tissue corpuscles, of *Necturus* (*Menobranchus*), IV: 109.
- Conser, H. N. Cocaine in the Study of Pond-life, XVII: 310; Paraffin and Collodion Embedding, XVII: 312.
- Constitution and By-Laws, II: 79; III: 95; VI: 283; VIII: 224; X: 166; XI: 171; XII: 253; XIV: 39; XVI: 251; XVII: 377; XVIII: 401; XIX: 190; XX: 355; XXI: 265; XXII: 211; XXIII: 283; XXIV: 181; XXV: 175.
- Consumption, Curability of, XXI: 17.
- Contribution to the Life History of the Diatomaceae, A—H. L. Smith, VIII: 30.
- Contribution to the Life History of the Diatomaceae—Part II—H. L. Smith, IX: 126.
- Contribution to the Study of Malignant Growths in the Lower Animals, A—Eva H. Field, XVI: 223.
- Contribution to the Study of the Myelin Degeneration of the Pulmonary Alveolar Epithelium, A—Veranus A. Moore, XV: 77.
- Contribution to the Subterranean Fauna of Texas, A—Carl J. Ulrich, XXIII: 83.
- Contribution to the Histogenesis of the Caryophyllales—Frederic E. Clements, XX: 97.
- Contributions to the Life-history of *Symplocarpus foetidus*—W. W. Rowlee and Mary A. Nichols, XVII: 157.

- Coons, Henry C., *Memoir of*, XX: 28.
- Copepoda, A New Species of, IX: 246; of Elevated Lakes in the Sierras and in the Rockies, XXV: 146.
- Coscinodisceae, *Criteria of Genera and Species of*, XII: 184.
- Coscinodisceae, *The—Notes on some unreliable Criteria of Genera and Species—*Jacob D. Cox, XII: 184.
- Cuthurnia lata, N. S.—D. S. Kellicott, V: 113.
- Cover-Glass Cleaner—Frank L. James, VI: 181.
- Cover-glass Support for Solid Mounts, A—Howard N. Lyon, XII: 75.
- Cover-glasses, An Apparatus for Holding, XIII: 51; Thickness of for which Unadjustable Objectives are Corrected, IX: 168.
- Cox, Jacob D. A New Form of Microscope Stand with Concentric Movements, V: 147; President's Address: Robert B. Tolles and the Angular Aperture Question, VI: 5; Photography with High Powers by Lamplight: Illustrating Structure of Diatoms, VI: 99; Memoir of Lewis R. Sexton, VI: 251; Memoir of Joseph Janvier Woodward, M.D., VI: 253; The Actinic and Visual Focus in Micro-Photography with High Powers, (1 Plate), VII: 29; Some Diatom Hoops. The Question of Their Mode of Growth (*Aulacodiscus Kittoni*), VII: 33; Deformed Diatoms, (1 Plate), XII: 178; The Coscinodisceae—Notes on some unreliable Criteria of Genera and Species, (2 Col. Plates), XII: 184; President's Address: A Plea for Systematic Instruction in the Technique of the Microscope at the University, XV: 1; Memoir of, (Portrait, p. 196), XXII: 197.
- Craig, Charles F. A Study of the Microscopic Phenomena of Inflammation, with Special Reference to the Diapedesis of the White Blood Corpuscle, (3 Plates), XVI: 165; Diphtheria—Its Bacteriology, XVIII: 271.
- Cray-Fish, Infusoria on, V: 105; Parasites of, V: 115.
- Crenothrix manganifera*, XXIII: 31.
- Critical Study of the Action of a Diamond in Ruling Lines upon Glass, A—W. A. Rogers, V: 147.
- Croup, Vegetable Nature of, IV: 101.
- Crustacea, Parasitic on Fishes from the Great Lakes, I: 53; Parasitic on Fresh-water Fishes, IV: 75.
- Crustaceous Parasite of the "Miller's Thumb" (*Cottus*)—D. S. Kellicott, XIV: 76.
- Cryptobranchus*, Blood of, XV: 39.
- Crystallography of Butter and Other Fats, *The*—Thomas Taylor, (6 Plates), IX: 315.
- Cultivation of Bacteria, and the Cholera Bacillus, *The*—Lester Curtis, VII: 142.
- Cultural Studies of a Nematode associated with Plant Decay—Haven Metcalf, XXIV: 89.
- Current Microscopical Notes—J. M. Lamb, XVI: 242.
- Curtis, Lester. A Study of Blood, (1 Plate), III: 39; Micro-Organisms in the Blood of a case of Tetanus, IV: 157; The Cultivation of Bacteria, and the cholera Bacillus, VII: 142.
- Curvipes*, North American, XXIII: 201.

- Custodian, Report of, VI: 282; VII: 213; VIII: 198; IX: 324; XXII: 210; XXIII: 282; XXIV: 179; XXV: 172.
- Cutter, Ephraim. Micrographical Contribution.—The Vegetable Nature of Croup, IV: 101; Morphology of Rheumatic Blood, VI: 194.
- Cutting Sections, Hints on, VI: 209.
- Cymatogaster, Sex-Cells of, XVII: 172.
- Dahlia as a Stain for Bacteria in Sections cut by the Collodion Method—Raymond C. Reed, XIX: 182.
- Daphnella, A New, XII: 172.
- Data for the Determination of Human Entozoa—Henry B. Ward, XXIV: 103.
- Davies, John Eugene, Memoir of, XXI: 249.
- Davis, Ellery W. Memoir of John Eugene Davies, XXI: 249.
- Davis, Myron C., Memoir of, IX: 333.
- Davis, N. S. Memoir of Hosmer Allen Johnson, M.D., XIII: 172.
- Dayton, Robert. Modification of the Wenham half-disc illuminator, with an improved mounting, IV: 161.
- Debt of American Microscopy to Spencer and Tolles, The—Wm. C. Krauss, XXIII: 19.
- Decalcification, Methods of, XIV: 121.
- Deck, Lyman. Note on Resolution of *Amphipleura pellucida* by Central Light, XII: 170; A New Heliostat, (1 Plate), XIII: 49.
- Deecke, Theodore, Preparation and Mounting of Brain Section, IV: 275.
- Deep Sea Soundings, II: 17.
- Defective Development and Disease, with Special Reference to the Curability of Consumption and Cancer—M. A. Veeder, XXI: 17.
- Defendorf, Allen Ross. Yeasts and their Relation to Malignant Tumors, XVIII: 119.
- Deformed Diatoms—Jacob D. Cox, XII: 178.
- Degeneration, Myelin, of the Pulmonary Alveolar Epithelium, XV: 77.
- Demodex Folliculorum in Diseased Conditions of the Human Face—George E. Fell, VIII: 120.
- Deposition of Silver on Glass and other Non-metallic Surfaces, The—Frank L. James, VI: 71.
- Deposit-glass, Simple and Efficient, XI: 139.
- Description of a New Cave Salamander, *Spelerpes stejnegeri*, from the Caves of Southwestern Missouri—Carl H. Eigenmann, XXII: 189.
- Description of a New Genus of North American Water Mites, with Observations on the Classification of the Group—Robt. H. Wolcott, XXII: 105.
- Description of a New Portable Microscope—E. H. Griffith, II: 66.
- Description of *Ergasilus chautauquaensis*, A. A New Species of Copepoda, and a List of Other Entomostraca found at Lake Chautauqua, in August, 1886—Charles S. Fellows, IX: 246.
- Description of Rotary Section Cutter—J. J. B. Hatfield, VI: 171.
- Description of the Standard Centimeters Manufactured in Pursuance of the Resolution of A. S. M. adopted in 1889—M. D. Ewell, XII: 84.
- Descriptions of Certain Worms—T. S. Up de Graff, V: 117.

- Descriptions of the Griffith Turn Tables—E. H. Griffith, VI: 165.
- Desmidia, of the United States, V: 137; Structure and Classification of, XXII: 89.
- Detection and Recognition of Blood, The. President's Address—A. M. Bleile, XXII: 1.
- Determination of the Absolute Length of Eight Rowland Gratings at 62° Fahr.—William A. Rogers, VII: 151.
- Determination of the Number of Trichinae or Other Animal Parasites in a Given Quantity of Meat—Simon H. Gage, IX: 191.
- Detmers, Freda. The Comparative Size of Blood Corpuscles of Man and Domestic Animals, (12 Plates), IX: 216; Remarks on Pathogenic Bacteria, V: 87.
- Detmers, H. J. Poisonous Dried Beef, (1 Plate), VII: 54; The Numerical Aperture of an Objective in Relation to its Angle of Aperture in Air, Water and Balsam, VII: 199; Photographing with High Powers by Lamp-light, X: 143; American and European Microscopes, X: 149.
- Development, Defective, and Disease, XXI: 17.
- Development and a Supposed New Method of Reproduction in the Sun-Animalcule—Actinospharium Eichhornii, On the—John M. Stedman, X: 107.
- Development of Methods in Microscopical Technique—Henry B. Ward, XIX: 175.
- Device, for Enabling Two Observers to View Objects Simultaneously, VII: 120.
- Device for Testing Refractive Index of Immersion Fluids—H. L. Smith, VII: 83.
- Diabetes, Reaction of blood in, to Anilin Dyes, XXI: 31.
- Diagnosis, Differential, Use of Stains in, XIII: 94; Microscope in, XI: 67.
- Diagnosis of Tumors—William C. Krauss, XIV: 71.
- Diamond, Action of, in Ruling Lines upon Glass, V: 149.
- Diapedesis, of White Blood Corpuscle, XVI: 165.
- Diatomaceae, Life History of, VIII: 30; Life History of,—Part II., IX: 126.
- Diatoms, Cleaning and Arranging, VIII: 128; Deformed, XII: 178; Mode of Growth of Hoops, VI: 33; Sporadic Growth of, and Relation to Impurities in Water, IV: 197; Structure and Classification of, XXI: 61; Structure of, VI: 99; Structure of the Valve, VI: 105.
- Digestive Tract, Histology of, XIX: 83.
- Dinichthys, Structure of Bone of, XV: 189.
- Diphtheria, Bacillus of, XX: 81; Bacteriology of, XVIII: 271.
- Diphtheria—Its Bacteriology—Charles F. Craig, XVIII: 271.
- Dipnoans, Lateral Line System of, XVII: 115.
- Discussion of Papers, IV: 253; V: 220.
- Disease, and Bacteria, VIII: 5; and Defective Development, XXI: 17; Nerve Elements in, XVI: 234; The Natural in, XX: 3.
- Disease Germs. Another Illustration of the Fact that Bacteria Cause Disease—T. J. Burrill, IX: 193.

- Distribution of Growths in Surface Water Supplies, On the, and on the Method of Collecting Samples for Examination—Fred'k S. Hollis, XXII: 49.
- Division of Labor among Microscopists—J. M. Mansfield, V: 43.
- Dog, Structure of Heart Muscle of, XXV: 35.
- Doubleday, Henry H., Memoir of, XXI: 250.
- Drescher, W. A. E. A New Form of Microscope, Made by Bausch & Lomb Optical Co., Rochester, XI: 131; Memoir of Maitland L. Mallory, M.D., XVI: 248.
- Drying Oven, XIV: 152.
- Duffield, Geo. A Few Hints on Hardening, Imbedding, Cutting, Staining and Mounting Specimens, VI: 209.
- Durkee, R. P. H. The Structure of the Diatom Valve, (3 Col. Plates), VI: 105.
- Ear, Human, Parasite of, XXII: 81; of Man and Cat; XII: 146.
- Early American Microscope, An—Wm. H. Seaman, XIV: 156.
- Early Morphogenesis and Histogenesis of the Liver in *Sus scrofa domesticus*, The, including Notes on the Morphogenesis of the Ventral Pancreas—David C. Hilton, XXIV: 55.
- Eastman, Lewis M. Egg-like Bodies in the Liver of the Rabbit, V: 167; Some Remarks on Fat-infiltration of the Liver, (1 Plate), VII: 60.
- Eel Question, Solution of, XXIII: 5.
- Effect of Curvature of the Cover-glass upon Micrometry, The—M. D. Ewell, XII: 79.
- Effect of Dilute Solutions of Chromic Acid and Acid Urine upon the Red Blood Corpuscles of Man, The—M. L. Holbrook, XV: 129.
- Effect of High Altitude on Blood Counts—A. Mansfield Holmes, XX: 177.
- Effects of a Division of the Vagi on the Muscles of the Heart, The—A. M. Bleile and Adolph Feiel, V: 47.
- Effects of Division of the Vagi on the Heart, The—A. M. Bleile and A. Feiel, IV: 91, 261.
- Egg-like Bodies in the Liver of the Rabbit—Lewis M. Eastman, V: 167.
- Eigenmann, C. H. The History of the Sex-Cells from the Time of Segregation to Sexual Differentiation in *Cymatogaster*, XVII: 172; The Eyes of the Blind Vertebrates of North America, II. The Eyes of *Typhlomolge rathbuni* Stejneger, (2 Plates), XXI: 49; Description of a New Cave Salamander, *Spelerpes stejnegeri*, from the Caves of Southwestern Missouri, (2 Plates), XXII: 189; President's Address: The Solution of the Eel Question, (4 Plates), XXIII: 5.
- Electricity, Action of, upon Nerve Cells, XVII: 179; Influence of, on Protoplasm, XII: 1.
- Elephantiasis, XIV: 133.
- Ellis, Sylvanus A., Notice of Death, XVIII: 397.
- Elrod, Morton J. Limnological Investigations at Flathead Lake, Montana, and Vicinity, July 1899, (9 Plates), XXII: 63.
- Elrod, M. J. and Ricker, Maurice. A New Hydra, XXIII: 257.
- Embedding, XVII: 312.

- Embryos, of Chick, for Microscopical Examination, VII: 66; of Chick, Preparation and Imbedding, XII: 128; of Chick and Man, Development of Cartilage in, VII: 76; of Chick and Man, First Development of Muscle in, VII: 71.
- Embryologic and Histologic Laboratory, Modification of Some Standard Apparatus to Facilitate the Work of—Simon Henry Gage, XXIII: 259.
- Embryology, Laboratory, Apparatus in, XXIII: 259.
- Ending and Relation of the Muscular Fibres in the Muscles of Minute Animals (Mouse, Mole, Bat and English Sparrow). (Abstract.)—Susanna Phelps Gage, IX: 207.
- Endothelium, Stigmata and Stomata occurring in, XXIII: 63.
- Enteron, of *Necturus maculatus*, Histological Structure of, XVI: 19.
- Enteron of the Cayuga Lake Lamprey, The—Agnes Mary Claypole, XVI: 125.
- Entrekin, F. W. Memoir of Forest W. Brayton, M. D., XIII: 171.
- Entomostraca, of Colorado, XXIII: 41; of Lake Chautauqua, IX: 246.
- Entozoa, Human, Determination of, XXIV: 103.
- Epiphegus Virginiana, Parasitism of, XV: 91.
- Epithelium, Intestinal, Regeneration of, XX: 45; of Brain Cavities, XII: 140; Peritoneal, of Amphibia, XVIII: 76; Pulmonary Alveola, Myelin Degeneration of, XV: 77.
- Epithelium of the Brain Cavities—Pierre A. Fish, XII: 140.
- Erechthites hieracifolia, Intercellular Spaces in Embryos of, XVII: 174.
- Ergasilus Chautauquaensis, Description of, IX: 246.
- Erysipheae of Illinois, The—T. J. Burrill, IX: 301.
- Evolution in Microscopic Plants. President's Address—Chas. Edwin Bessey, XXIV: 5.
- Evolution of the Modern Microscope, The. President's Address—George E. Blackham, IV: 25.
- Ewell, Marshall D. A Further Study of Centimeter Scale "A," VIII: 75; Comparison of a Standard Centimeter Ruled on Glass by Chas. Fasoldt, with Centimeter Scale A, VIII: 83; Comparison of Centimeter Scale, "Fasoldt II," with "Centimeter Scale A," IX: 299; A Further Study of the Subdivisions of the First Millimeter of "Centimeter A," XI: 64; Two New Forms of Stage Micrometers, XII: 76; The Effect of Curvature of the Cover-glass upon Micrometry, XII: 79; Description of the Standard Centimeters Manufactured in pursuance of the Resolution of A. S. M. adopted in 1889, XII: 84; The Microscope and Camera in the Detection of Forgery—Exemplified by Lantern Slides and Photographs of Signatures in the Jerome will case, (1 Plate), XII: 86; A New Form of Graphological Stand, XIII: 699; Standard Glass and Speculum Metal Centimeters, XIII: 71; President's Address: The Relation of the Microscope to the Administration of Justice, XIV: 1; The Concave Mirror, XIV: 43.
- Examination of Agreement, Exhibit "B"—The People vs. Colby—Geo. E. Fell, VI: 47.
- Examination of Legal Documents with the Microscope—Qualifications of Examiner—Geo. E. Fell, XI: 102.
- Exhibitions, of Microscopic Objects, XIII: 54; Microscopical, IX: 311.

- Expedient for Use in Difficult Resolution, An—R. H. Ward, XXI: 111.
- Experimental Study of Aperture as a Factor in Microscopic Vision, An. President's Address—A. Clifford Mercer, XVIII: 321.
- Experiments in Feeding some Insects with Cultures of Comma or Cholera Bacilli—R. L. Maddox, XX: 75.
- Expert Testimony, Hints on, XIII: 64.
- Extra-vascular Circulation, The—J. Redding, VI: 81.
- Eye, An Imperfection of, VII: 91; Bacteria on, XI: 120.
- Eye-piece, Use of, in Photo-micrography, XII: 50.
- Eye-Pieces, Report of Committee on, V: 175.
- Eyes of the Blind Vertebrates of North America, The, II. The Eyes of Typhlomolge rathbuni Stejneger—Carl H. Eigenmann, XXI: 49.
- Face, Human, Demodex Folliculorum in Diseased Conditions of, VIII: 120.
- Fallacies of Popular Bacterial Research, The—George W. Lewis, IX: 254.
- Fasoldt Stage Micrometer, On the—T. C. Mendenhall, IV: 201.
- Fasoldt Test-plate, IX: 318.
- Fat Cells, of Necturus (Menobranchus), IV: 109.
- Fats, Crystallography of, IX: 315; distinguishing of by Means of Microscope, VII: 128.
- On the Fecundation of Ovules in Angiosperms—John Kruttschnitt, VI: 93.
- Feil, A., and Bleile, A. M. The Effects of Division of the Vagi on the Heart, IV: 91, 261; The Effects of a Division of the Vagi on the Muscles of the Heart, V: 47.
- Fell, Geo. E. Treasurer's Report, II: 80; The Binocular Microscope and Stereoscopic Vision, III: 69; Treasurer's Report, III: 97; Treasurer's Report, IV: 286; Clinical Advantages of Ozone and its Effects on the Micro-Organisms of Infusions, V: 69; The Cephalic Extremity and Movements of the Human Spermatozoon, V: 121; Report of Treasurer, V: 219; Examination of Agreement, Exhibit "B"—The People vs. Colby, VI: 47; Report of Treasurer and Custodian, VI: 282; Memoir of Jas. N. Scatcherd, VII: 222; Demodex Folliculorum in Diseased Conditions of the Human Face, VIII: 120; Report of Committee on Micrometry, X: 163; The Microscope in Diagnosis, XI: 67; Examination of Legal Documents with the Microscope—Qualifications of Examiner, XI: 102; Microscopical Examination of and Experiments with Glandular Secretions according to Method of Dr. Brown Squard, XI: 115; A Simple and Efficient Deposit-glass, XI: 139; President's Address: The Influence of Electricity on Protoplasm, (2 Col. Plates), XII: 1.
- Fellows, Charles S. A Description of Ergasilus Chautauquaensis. A New Species of Copepoda, and a List of Other Entomostraca found at Lake Chautauqua in August, 1886, IX: 246.
- Fermentation, Ammoniacal, of Urine, XII: 97; Production of Citric Acid by, XV: 90.
- Ferns and their Development—John Kruttschnitt, V: 135.
- Ferris, Charles R. Notice of death, V: 245.
- Ferris, H. B. Memoir of Albert E. Loveland, M.A., M.D., XXI: 251.

- Fertilization, in Salamanders and Newts, XVII: 261.
- Few Hints on Hardening, Imbedding, Cutting, Staining and Mounting Specimens, A—Geo. Duffield, VI: 209.
- Fibrin, XIII: 79.
- Field, Eva H. A Contribution to the Study of Malignant Growths in the Lower Animals, XVI: 223.
- Fine Adjustment, New, X: 161.
- Finer Structure of the Heart Muscle of the Dog, The—Gertrude A. Gillmore, XXV: 35.
- First Development of Muscle in the Embryo of the Chick and Man—M. L. Holbrook, VII: 71.
- Fish, Parasites of, XXII: 175; XV: 173.
- Fish, Pierre A. The Epithelium of the Brain Cavities, (1 Plate), XII: 140; A New Clearer for Collothonized Objects, XV: 86; The Action of Strong Currents of Electricity upon Nerve Cells, (1 Plate), XVII: 179; The Use of Formalin in Neurology, XVII: 319; Zoophily versus Homophily, XVIII: 142; Notes on Technique, XVIII: 287.
- Fisher, J. H. Notes on the Structure, Development, and Position, of an undescribed Flagellate Infusorian, (2 Col. Plates), II: 44.
- Fishes, Crustaceous Parasites of, IV: 75; Parasites of, XV: 173.
- Flagella, Character of, XVI: 217; of Motile Bacteria, XVII: 239; on Motile Bacteria, Staining, XIII: 85.
- Flagella of Motile Bacteria, On the—Veranus A. Moore, XVII: 239.
- Flagellate Infusoria, Structure, Development, and Position, of an undescribed species of, II: 44.
- Flathead Lake, Montana, Limnological Investigations at, XXII: 63.
- Flint, James M. Apparatus for the Exhibition of Microscopic Objects, XIII: 54.
- Floresule, A New, VII: 48.
- Fluids, Colored, Photo-spectrography of, XXII: 99; Immersion, Testing Refractive Index of, VII: 83.
- Food Supply of the Great Lakes, The; and Some Experiments on its Amount and Distribution—Henry B. Ward, XVII: 242.
- Foster, J. S. Outline of the Tube Plan of Structure of the Animal Body, (6 Plates), XXV: 63.
- Foot-rot, Bacillus of, in Sheep, IX: 209.
- Foraminifera, Preparation and Mounting of, V: 65.
- Forceps, Cover-slip, XVI: 123.
- Fordyce, Chas. The Cladocera of Nebraska, (4 Plates), XXII: 119; Additional Notes on the Cladocera of Nebraska, (1 Plate), XXV: 45.
- Forensic Microscopy; or, the Microscope in its Legal Relations. President's Address—William J. Lewis, XI: 5.
- Forgery, Microscope and Camera in Detection of, XII: 86.
- Form and Size of the Red Blood Corpuscles of the Adult and Larval Lamprey Eels of Cayuga Lake—Simon Henry Gage, X: 77.
- Formalin, Notes on, XVI: 238; Use of, in Neurology, XVII: 319.
- Formalin—W. W. Alleger, XV: 192.

- Formalin—Addenda—W. W. Alleger, XV: 219.
- Formalin as a Hardening Agent for Nerve Tissues—William C. Krauss, XVII: 315.
- Formalin in the Zoological and Histological Laboratory—D. S. Kellicott, XVII: 331.
- Forms observed in Water of Lake Erie—C. M. Vorce, III: 51.
- Forms of Bacteria on the Normal Eye—Lucien Howe, XI: 120.
- Forty Years' Acquaintance with the Microscope and Microscopists—Charles E. West, VIII: 161.
- Fowl, Internal Parasites of, V: 131.
- Fox, Oscar C., Memoir of, XXV: 163.
- Francis, Mark. The Bacillus of Foot-rot in Sheep, IX: 209.
- Freshwater Investigations during the last Five Years—Henry B. Ward, XX: 261.
- Fresh-Water Sponge—Henry Mills, IV: 209, 253.
- Frog, Haemosporidia in blood of, XXV: 55.
- Fruit, Structure of, in Ranunculaceae, XVI: 69.
- Full Utilization of the Capacity of the Microscope and Means for Obtaining the Same, The—Edward Bausch, XII: 43.
- Fuller, Henry Weld, Memoir of, XIV: 160.
- Fungi found in Sewage-effluents—A. W. Bennett, VI: 90.
- Further Study of Centimeter Scale "A," A—Marshall D. Ewell, VIII: 75.
- Further Study of the Subdivisions of the First Millimeter of Centimeter "A," A—Marshall D. Ewell, XI: 64.
- Gage, Simon H. Observations on the fat cells and connective-tissue corpuscles of *Necturus* (*Menobranchus*), (1 Plate), IV: 109; Cataloguing, Labeling and Storing of Microscopical Preparations, V: 169; Serial Sections, VI: 202; Notes on the Epithelium Lining the Mouth of *Necturus* and *Menopoma*, and Notes on the Blood-corpuscles of *Necturus*, VII: 126; Microscopical Tube-length, and the Parts Included in it by the Various Opticians of the World. The Thickness of Cover-glass for which Unadjustable Objectives are Corrected, IX: 168; Determination of the Number of Trichinae or Other Animal Parasites in a Given Quantity of Meat, IX: 191; Form and Size of the Red Blood Corpuscles of the Adult and Larval Lamprey Eels of Cayuga Lake, X: 77; Picric and Chromic Acid for the Rapid Preparation of Tissues for Classes in Histology, XII: 120; Notes on Fibrin, Oxyhaemoglobin Crystals, and the Collodion Method, XIII: 79; Methods of Decalcification in which the Structural Elements are Preserved, XIV: 121; An Aqueous Solution of Hematoxylin which does not readily deteriorate, XIV: 125; A Marker for Indicating the Position of Objects or Parts of Objects in Microscopical Preparations, XVI: 112; President's Address: The Processes of Life Revealed by the Microscope; a Plea for Physiological Histology, XVII: 3; Improvements in Oil-sectioning with Collodion, XVII: 361; Histology and Methods of Instruction, XVIII: 299; Notes on the Isolation of the Tissue Elements, XIX: 179; Memoir of Wm. A. Rogers, A.M., Ph.D., LL.D., XX: 25; Memoir of Henry C. Coons, A.M.,

- M.D., Ph.D., XX: 28; Some Laboratory Apparatus, XXI: 107; Modification of Some Standard Apparatus to Facilitate the Work of the Histologic and Embryologic Laboratory, (1 Plate), XXIII: 259; Laboratory Photographic Apparatus, (2 Plates), XXIII: 263; Prevention of the Pedetic or Brownian Movement in Milk or other Liquids with Minute Objects in Suspension, XXIV: 22.
- Gage, Simon Henry and Gage, Susanna Phelps. Staining and Permanent Preservation of Histological Elements Isolated by Means of Caustic Potash (KOH) or Nitric Acid (HNO₃), XI: 34.
- Gage, Simon H. and Hopkins, Grant S. Preparation and Imbedding the Embryo Chick, XII: 128.
- Gage, Susanna Phelps. Ending and Relation of the Muscular Fibres in the Muscles of Minute Animals. (Mouse, Mole, Bat and English Sparrow.) Abstract, IX: 207; The Intramuscular Endings of Fibers in the Skeletal Muscles of the Domestic and Laboratory Animals, (1 Plate), XII: 132; A Reference Model, XIV: 154; Comparative Morphology of the Brain of the Soft-shelled Turtle (*Amyda mutica*) and the English Sparrow (*Passer domestica*), (5 Plates), XVII: 185.
- Gaseous Matter, Examination of, III: 65.
- Gases, Dissolved in Natural Waters, Effect of on Microscopic Organisms, XXIII: 103.
- Gaylord, H. R. A New Cover-slip Forceps, XVI: 123.
- Geology, Microscope in, XIX: 3.
- Gillmore, Gertrude A. The Finer Structure of the Heart Muscle of the Dog, (3 Plates), XXV: 35.
- Glandular Secretions, Microscopical Examination of and Experiments with, XI: 115.
- Glands, Meibomian, in Cat, VIII: 143.
- Gamphogaster Areolatus, IX: 250; Notes on, XII: 174.
- Graphological Stand, A New, XIII: 69.
- Gratings, Rowland, Absolute Length of, VII: 151.
- Graybill, H. W. Some Points in the Structure of the Acanthocephala, (1 Plate), XXIII: 191.
- Graybill, H. W., Ward, Henry B., and others. A Comparative Study in Methods of Plankton Measurement, (3 Plates), XXI: 227.
- Green, Isabella M. The Peritoneal Epithelium of Some Ithaca Amphibia, XVIII: 76.
- Gregarina, in the American Lobster, III: 47.
- Griffith, E. H. Description of a New Portable Microscope, II: 66; The Improved Griffith Club Microscope, IV: 149; Descriptions of the Griffith Turntables, VI: 165; Griffith Microscopist's Working Cabinet, VI: 168; Some New and Improved Apparatus, VII: 112; On Several New Microscopical Accessories, VIII: 150; A New Fine Adjustment, X: 161; Three New Accessories for the Microscope, XIII: 47; Memoir of, XV: 247.
- Growth of the First Branchial Cleft, On the—Lucien Howe, I: 57.
- Growths, Malignant, in Lower Animals, XVI: 223.

- Gundlach, Ernst. On Light and Illumination, IV: 79, 255; An Improvement in Objectives, VI: 148; On Immersion Objectives, VII: 51; Optical Errors and Human Mistakes, VIII: 157.
- Guttenberg, Gustave, Memoir of, (Portrait p. 399), XVIII: 399.
- Haematoblasts and Blood Platelets—M. L. Holbrook, XVI: 181.
- Haemoglobin, Methods of Determining, XVII: 165.
- Haemosporidia, in Blood of Frog, XXV: 55.
- Hair, Comparative Study of, XIX: 117.
- Hair: Microscopically Examined and Medico-legally Considered—William J. Lewis, VI: 59.
- Hamlin, F. M. The Wheel-like and other Spicula of the Chirodota of Bermuda, (1 Plate), IV: 139; The Microscopical Examination of Seminal Stains on Cloth, V: 21; The Preparation and Mounting of Foraminifera, with Description of a New Slide for Opaque Objects, V: 65; The Ideal Slide, VI: 179.
- Handy Photomicrographic Camera, A—W. H. Walmsley, XII: 69.
- Hardening, Hints on, VI: 209.
- Hatfield, J. J. B. Description of Rotary Section Cutter, VI: 171.
- Hawkshurst, D. C., Obituary Notice of, IV: 23.
- Health, Nerve Elements in, and in Disease, XVI: 234.
- Heart, Effects of Division of Vagi on, IV: 91; Effects of Division of Vagi on the Muscles of, V: 47; Muscle Cells of, IX: 283; Structure of Muscles of, of Dog, XXV: 35.
- Heliostat, A New, XIII: 49.
- Heliostat for Photo-micrography, A—S. W. Stratton and T. J. Burrill, VII: 103.
- Hematoxylin, An Aqueous Solution of, XIV: 125.
- Hemospast. A New and Convenient Instrument for Drawing Blood for Microscopic Examination—Veranus A. Moore, XIX: 187.
- Henrici, Jacob F. Note on a Microscope Presented by Linnæus to Bernard Jussieu in 1738, IX: 214.
- Henrici, J. F. and Mellor, C. C. An Old Microscope of the Culpeper Type, X: 140.
- Hertzler, Arthur E. The Morphogenesis of the Stigmata and Stomata occurring in Peritoneal and Vascular Endothelium, (2 Plates), XXIII: 63.
- Hilgard, J. E. Report on Centimeter Scale, A, 1882, V: 181.
- Hilton, David C. The Early Morphogenesis and Histogenesis of the Liver in *Sus scrofa domesticus*, including Notes on the Morphogenesis of the Ventral Pancreas, (4 Plates), XXIV: 55.
- Hints on Expert Testimony—Henry L. Tolman, XIII: 64.
- Histogenesis, of Caryophyllales, XX: 97.
- Histogenesis and Morphogenesis, Early, of the Liver in *Sus scrofa domesticus*, including Notes on the Morphogenesis of the Ventral Pancreas—David C. Hilton, XXIV: 55.
- Histological Conformation of the Medulla, The—William C. Krauss, XV: 167.

- Histological Specimens, Mounting Materials for, II: 60.
- Histological Structure of the Enteron of *Necturus maculatus*, The—Benjamin F. Kingsbury, XVI: 19.
- Histology, Apparatus for Laboratory, XXIII: 259; Physiological, Plea for, XVII: 3; of Animal Body, Tube Plan of, XXV: 63.
- Histology and Methods of Instruction—Simon H. Gage, XVIII: 299.
- History of the National Committee on Micrometry—R. H. Ward, V: 178.
- History of the Sex-Cells from the Time of Segregation to Sexual Differentiation in *Cymatogaster*, The—C. H. Eigenmann, XVII: 172.
- Hodges, E. F. Memoir of Frisby T. Newcomer, M.D., M.A., S.M., F.R.M.S., XII: 205.
- Hollbrook, M. L. The Termination of the Nerves in the Liver, IV: 95, 264; Structure of the Muscles of the Lobster, IV: 131; The Termination of the Nerves in the Kidney, V: 51; First Development of Muscle in the Embryo of the Chick and Man, VII: 71; Studies of the Development of Cartilage in the Embryo of the Chick and Man, VII: 76; Microscopical Researches on the Corpuscular Elements of Blood, XIV: 63; The Effect of Dilute Solutions of Chromic Acid and Acid Urine upon the Red Blood Corpuscles of Man, XV: 129; Haematoblasts and Blood Platelets, XVI: 181.
- Hollis, Fred'k S. On the Distribution of Growths in Surface Water Supplies and on the Method of Collecting Samples for Examination, (4 Plates), XXII: 49; Two Growths of *Chlamydomonas* in Connecticut, XXIV: 13.
- Holmes, A. Mansfield. Effect of High Altitude on Blood Counts, XX: 177. *Haemaphys*, versus *Zoophily*, XVIII: 142.
- Hopkins, Grant S. Structure of the Stomach of *Amia calva*, (1 Plate), XII: 175; Apparatus for Illustrating the Circulation of the Lymph, XVII: 336.
- Hopkins, Grant S. and Gage, Simon H. Preparation and Imbedding the Embryo Chick, XII: 128.
- How to make Wax Cells neat, permanent and free from "Sweating"—J. T. Brownell, VI: 214.
- Howe, Lucien. On the Growth of the First Branchial Cleft, I: 57; An Imperfection of the Eye, and Test Objects for the Microscope, VII: 91; Forms of Bacteria on the Normal Eye, XI: 120.
- Howland, Henry R. Memoir of Herbert R. Spencer, XXI: 252.
- Human Brain, Physiology and Pathology of, V: 141.
- Human Ear, Parasite of, XXII: 81.
- Human Entozoa, Determination of, XXIV: 103.
- Human Face, *Demodex folliculorum* in Diseased Conditions of, VIII: 120.
- Human Red Blood Corpuscle, Micrometry of, XX: 41.
- Human Spermatozoon, Cephalic Extremity and Movements of, V: 121.
- Hunt, Dr. J. Gibbons, Memoir of, XIV: 166.
- Hyatt, J. D. Sporadic Growth of Certain Diatoms and the Relation thereof to Impurities in the Water Supply of Cities, IV: 197; Some Peculiarities of the Mouth Parts and Ovipositor of *Cicada septendecim*, XVII: 111.
- Hydra, New, XXIII: 257.
- Hydrachnidae, Classification of, XXII: 105; New North American, XXI: 177; New Genus of, XXII: 105.

- Hymenolepis carioca (Magalhaes) and Hymenolepis megalops (Nitzsch),
On, with Remarks on the Classification of the Group—B. H. Ransom,
XXIII: 151.
- Ideal Slide, The—F. M. Hamlin, VI: 179.
- Illinois, Erysipheae of, IX: 301; Smuts of, X: 45; Uredineae of, VII: 93.
- Illumination, IV: 79, 255.
- Illuminator, Iris, VI: 160; Wenham half-disc, IV: 161.
- Imbedding, Sections, Hints on, VI: 209.
- Imbedding and Sectioning Mature Seeds—Willard W. Rowlee, XII: 113.
- Immersion Fluids, Testing Refractive Index of, VII: 83.
- Immersion Objectives, On—Ernst Gundlach, VII: 51.
- Imperfection of the Eye, and Test Objects for the Microscope, An—Lucien
Howe, VII: 91.
- Improved Griffith Club Microscope, The—E. H. Griffith, IV: 149.
- Improved Method of Constructing Slide Cabinets, An—Henry E. Summers,
VII: 108.
- Improved Slide for the Examination of Caseous Matter, An—E. L. Shurley,
III: 65.
- Improved Syracuse Solid Watch Glass, The—A. Clifford Mercer, XVII: 371.
- Improvement in Objectives, An—Ernest Gundlach, VI: 148.
- Improvements in Oil-sectioning with Collodion—Simon H. Gage, XVII: 361.
- Increasing Pollution of our Municipal Water-supplies, The—Frank J. Thorn-
bury, XVIII: 182.
- Incubator for Student Use, An—Veranus A. Moore, XXI: 103.
- Index to Current Literature of Microscopy, XV: 259; XVI: 265.
- Indiana, Plankton of Lake Maxinkuckee, XXIII: 61.
- Indices, IV: 293; VI: 294; VIII: 237; X: 166; XII: 265; XIV: 179; XVI:
261; XVIII: 417; XX: 365; XXII: 223; XXIV: 193; General Index to
vols. I-XXV, XXV: 187.
- Inflammation, Microscopic Phenomena of, XVI: 165.
- Influence of Electricity on Protoplasm, The. President's Address—George
E. Fell, XII: 1.
- Infusoria, Fresh-water, X: 97; Fresh-water, Observations and Descriptions
of New Species, VII: 38; from Louisiana, XIX: 55; from Louisiana,
XX: 51; from Louisiana, XXI: 87; New and Rare, IX: 187; Notes on,
VI: 126; Observations on, with Descriptions of New Species, VI: 110; on
the Cray-Fish, V: 105.
- Injections, Fine, Nitrite of Amyl for, VIII: 140.
- Insects, the Destructive Powers of, I: 68; Feeding, with Cultures of Bacilli,
XX: 75; Luminous Organs of, XIII: 133.
- Intestines, Muscular Tunic of, XVI: 197; of Cat, Muscular Layers of, XIII:
120.
- Intercellular Spaces in the Embryos of *Erechthites hieracifolia* and *Bidens
cernua*—Karl M. Wiegand, XVII: 174.
- Internal Parasites in the Common Fowl—Thomas Taylor, V: 131.
- Intramuscular Endings of Fibers in the Skeletal Muscles of the Domestic
and Laboratory Animals, The—Susanna Phelps Gage, XII: 132.

- Invertebrata, Killing of, XIII: 73.
 Iris Illuminator, The—R. H. Ward, VI: 160.
 Isolation, of Tissue Elements, XIX: 179.
 Ives, F. E. Stereoscopic Photomicrography with High Powers, (1 Plate), XXIV: 23.
 Jackson, Chevalier Q. The Bacillus of Leprosy. A Microscopical Study of its Morphological Characteristics, X: 119; Bacteria in Ice, especially in their Relation to Typhoid Fever, XI: 70.
 Jackson, D. D. A New Species of *Crenothrix* (*C. manganifera*), (1 Plate), XXIII: 31.
 James, Bushrod W., Memoir of, XXV: 160.
 James, Frank L. The Deposition of Silver on Glass and other Non-metallic Surfaces, VI: 71; Cover-glass Cleaner, VI: 181; Mounting, Finishing and Preserving Slides, VIII: 148; Shrinkage of Cement-cells the cause of Leakage and Creeping in Glycerin Mounts, IX: 173; President's Address, The Microscope in the Investigation of Burns and Scorches on Textile Fabrics, XIII: 1.
 Johnson, Hosmer Allen, Memoir of, XIII: 172.
 Jones, Mary A. Dixon. Carcinoma on the Floor of the Pelvis. Two Discoveries in Cancerous Disease, (1 Plate), XX: 165.
 Juday, Chancey. The Plankton of Lake Maxinkuckee, Indiana, XXIII: 61.
 Kellicott, D. S. On Certain Crustacea Parasitic on Fishes from the Great Lakes, (3 Plates), I: 53; Observations on *Lerneocera cruciata*, I: 64; *Lerneocera tortua*, n. s., (1 Plate), II: 41; On Certain Crustacean Parasites of Fresh-water Fishes, IV: 75; Polyzoa.—Observations on Species detected near Buffalo, N. Y., (1 Plate), IV: 217; On Some infusoria Found on the Cray-Fish, V: 105; *Cothurnia lata*, N. S., V: 113; Notes on Two Parasites of the Cray-Fish, V: 115; Observations on Infusoria, with Descriptions of New Species, (1 Plate), VI: 110; Notes: Infusoria, Rotatoria, etc., VI: 126; Observations on Some Fresh-water Infusoria. With descriptions of a Few Species Regarded as New, (1 Plate), VII: 38; A New Floscule, (1 Plate), VII: 48; A Note on *Argulus catostomi*, VIII: 144; Additional Notes on Certain Species of Rotifera, IX: 181; Some New and Rare Infusoria, IX: 187; Report upon the Collection of Slides, IX: 322; President's Address: The Nature of Protozoa and Lessons of these Simplest Animals, X: 6; Partial List of Rotifera of Shiawassee River at Corunna, Michigan, X: 84; Observations on Fresh-water Infusoria, X: 97; A New Rotiferon, XI: 32; Crustacean Parasite of the "Miller's Thumb" (*Cottus*), XIV: 76; Formalin in the Zoological and Histological Laboratory, XVII: 331; The Rotifera of Sandusky Bay, XVIII: 155; The Rotifera of Sandusky Bay, (Second paper), XIX: 43; Memoir of, XX: 21.
 Kellogg, Clifford Walcott. A Study of the Cellular Pathology of Carcinoma, (3 Col. Plates), XVIII: 248.
 Kenyon, Lorenzo M. Memoir of, X: 165.

- Kerr, Jr., A. T. and Busch, F. C. Comparison of the Fleischl, the Gowers, and the Specific Gravity Methods of Determining the Percentage of Haemoglobin in the Blood for Clinical Purposes, XVII: 165.
- Kidney, Termination of Nerves in, V: 51.
- Killing of Invertebrata in an Expanded and Natural Condition—J. M. Stedman, XIII: 73.
- Kingsbury, Benjamin F. The Histological Structure of the Enteron of *Necturus maculatus*, (8 Plates), XVI: 19; The Lateral Line System of Sense Organs in Some American Amphibia, and Comparison with the Dipnoans, (5 Plates), XVII: 115; Spermatheca and Methods of Fertilization in Some American Newts and Salamanders, (4 Plates), XVII: 261; The Regeneration of the Intestinal Epithelium in The Toad (*Bufo lentiginosus americanus*), during Transformation, XX: 45.
- Kinsman, D. N. Tumor of the Left Auricle, (3 Plates), III: 29.
- Kofoid, Chas. A. The Plankton of Echo River, Mammoth Cave, XXI: 113.
- Krauss, William C. Some Methods of Treating Nerve Tissues, XII: 116; The Microscope as a Factor in the Diagnosis, Prognosis, and Treatment of Morbid New Growths, XIII: 61; The Diagnosis of Tumors, XIV: 71; The Histological Conformation of the Medulla, (1 Plate), XV: 167; Simplification of Laboratory Methods, XVI: 119; The Nerve Elements in Health and Disease, (1 Plate), XVI: 234; Formalin as a Hardening Agent for Nerve Tissues, XVII: 315; A New Way of Marking Objectives, XVII: 359; The Requisites of a Pure Water Supply, XVIII: 165; President's Address: Some Medico-legal Aspects of Trauma in Relation to Diseased Cerebral Arteries, XXI: 1; The Debt of American Microscopy to Spencer and Tolles, (5 Plates), XXIII: 19.
- Krutchschnitt, John. Ferns and their Development, V: 135; On the Fecundation of Ovules in Angiosperms, VI: 93; Pollen-tubes Again, (1 Plate), VII: 62.
- Laboratory, Apparatus, XXI: 107; Embryologic, Apparatus of, XXIII: 259; Formalin in, XVII: 331; Histologic, Apparatus of, XXIII: 259; Mt. Prospect, XXII: 25; Laboratory, Microscopic, A Busy Man's Amateur, XI: 126; Simplification of Methods, XVI: 119.
- Laboratory Photographic Apparatus—Simon Henry Gage, XXIII: 263.
- Lake Erie, Forms observed in, III: 51; Microscopic Forms from, IV: 187.
- Lake Maxinkuckee, Indiana, Plankton of, XXIII: 61.
- Lakes, Elevated, Biological Reconnaissance in some, XXV: 127.
- Lamb, J. Melvin, The Microscope in the Government Work in Washington, (3 Plates), XIII: 13; Current Microscopical Notes, XVI: 242; Some Methods of Histologic Technique, XVIII: 291.
- Lamprey, Enteron of, XVI: 125.
- Lantern Slides, Enlarging, XXII: 41; of Photomicrographs and Photomicrographic Apparatus, XIV: 141.
- Lard Adulterations, Microscope in the Detection of, V: 97.
- Last, Louis, Notice of Death of, XVIII: 397.
- Lateral Line System of Sense Organs in Some American Amphibia, The, and Comparison with the Dipnoans—B. F. Kingsbury, XVII: 115.

- Latham, Vida A. The Use of Stains, especially with Reference to Their Value for Differential Diagnosis, XIII: 94; A Brief Account of the Microscopical Anatomy in a Case of Chrome Lead Poisoning, XIII: 110; A Brief Study of a Case of Elephantiasis and Its Histology, XIV: 133; A Plea for the Study of Re-agents in Micro Work, XV: 209; The Question of Correct Naming and Use of Micro-Reagents, XVII: 350; What is the Best Method of Teaching Microscopical Science in Medical Schools, XVIII: 311; The Reaction of Diabetic Blood to Some of the Anilin Dyes, XXI: 31.
- Lattimore, S. A. Memoir of Rev. J. T. Brownell, A.M., VIII: 202.
- Legal Documents, Examination of with the Microscope, XI: 102.
- Legal Medicine, Comparative Study of Hair, XIX: 117; Red Blood Corpuscle in, XVIII: 201; Trauma in Relation to Diseased Cerebral Arteries, XXI: 1.
- Length, Temperature in Comparison of Standards of, VIII: 67.
- Lens Holder, New, VI: 162.
- Lenses, Magnifying Power of, VI: 183.
- Lepidocyrtus curvicolis, Scales of, XVIII: 194.
- Leprosy, Bacillus of, X: 119.
- Lerneocera cruciata, Observations on, I: 64.
- Lerneocera tortua, n. s.—D. S. Kellicott, II: 41.
- Leukocytes, Phagocytic Action of, XIX: 93.
- Lewis, George W. The Coma Bacillus of Asiatic Cholera. A Reply to Arguments Denying that it is an Etiological Factor in that Disease, VIII: 84; The Fallacies of Popular Bacterial Research, IX: 254.
- Lewis, William J. Hair: Microscopically Examined and Medico-legally Considered, (2 Plates), VI: 59; President's Address: Forensic Microscopy; or, the Microscope in its Legal Relations, XI: 5.
- Library Experiments in Microscopy. Indexing, Cataloguing, Preparing and Arranging Literature and Slides—R. H. Ward, XXI: 127.
- Life, Processes of, Revealed by Microscope, XVII: 3.
- Life-box, Cheap and Efficient, VI: 215.
- Life-slide, New Form of, VII: 110.
- Light, Wave Length of, XVII: 305.
- Light and Illumination, On—Ernst Gundlach, IV: 79, 255.
- Line Light, Portable, XIII: 41.
- Limnesia, Species of, XXIV: 139.
- Linnobiology, Plea for, XXI: 201.
- Linnological Commission, Report of, XXII: 193.
- Linnological Investigations at Flathead Lake, Montana, and Vicinity, July, 1899—Morton J. Elrod, XXII: 63.
- Liver, Fat-infiltration of, VII: 60; in Fig. Morphogenesis and Histogenesis of, XXIV: 55; of Rabbit, Egg-like Bodies in, V: 167; Termination of the Nerves in, IV: 95, 264.
- Lobster, Structure of Muscles, IV: 131.
- Logan, James H. A New Form of Life-slide, VII: 110; Remarks on a Device for Enabling Two Observers to View Objects Simultaneously, VII: 120.

- Louisiana, Infusoria from, XIX: 55; XX: 51; XXI: 87; New Species of Rotifer from, XXV: 121.
- Loveland, A. E. A Study of the Organs of Taste, (3 Plates), XIX: 129; Memoir of, XXI: 251; On the Luminous Organs of Insects—William H. Seaman, XIII: 133.
- Lungs, Innervation of, III: 35.
- Lyman, Rufus Ashley. Studies on the Genus *Cittotaenia*, (2 Plates), XXIII: 173.
- Lymph, Illustrating Circulation of, XVII: 336.
- Lyon, H. N. Notes on the Structure of the Moth *Attacus Cecropia*, XI: 135; A Cover-glass Support for Solid Mounts, XII: 75.
- Maddox, R. L. On the Apparent Structure of the Scales of *Seira buskii* in Relation to the Scales of *Lepidocyrtus curvicollis*, (1 Plate), XVIII: 194; Experiments in Feeding some Insects with Cultures of Comma or Cholera Bacilli, (1 Plate), XX: 75; Memoir of, XXV: 155.
- Magnifying Power of Microscope Objectives and Lenses, The—Walter H. Bulloch, VI: 183.
- Mallory, Maitland L. Memoir of, XVI: 248.
- Mammalia, Phagocytic Action of Leukocytes in, XIX: 93; Cardiac Muscle Cells in, IX: 283.
- Mammoth Cave, Plankton of Echo River, XXI: 113.
- Man, Cardiac Muscle Cells in, IX: 283; Comparison of Ear with Cat's, XII: 146; Development of Cartilage in Embryo of, VII: 76; Effect of Dilute Solutions of Chromic Acid and Acid Urine upon Red Blood Corpuscles, XV: 129; First Development of Muscle in Embryo of, VII: 71; Muscular Tunic of Intestines of, XVI: 197; Size of Blood Corpuscles of, IX: 216.
- Mansfield, J. M. Division of Labor Among Microscopists, V: 43.
- Manton, W. P. On the Preparation of Chick Embryos for Microscopical Examination, VII: 66.
- Marker for Indicating the Position of Objects or Parts of Objects in Microscopical Preparations, A—Simon H. Gage, XVI: 112.
- Marsh, E. Dwight. Copepoda of some Elevated Lakes in the Sierras and the Rockies, (2 Plates), XXV: 146.
- Mazodus, Teeth of, XVIII: 146.
- McCalla, Albert. President's Address: The Verification of Microscopic Observation, V: 1.
- McIntosh, L. D. A Microscope Attachment, for Use with Solar or Artificial Light for Projecting, or Photographing, Microscopic Objects with Oblique Illumination, or Projecting Opaque Objects, X: 155; The Portable Lime Light, XIII: 41.
- Medical Jurisprudence, Blood and Blood Stains in, XIV: 91.
- Medical Microscopy—A. A. Young, XX: 87.
- Medico-legal, Study of Hair, XIX: 117.
- Medulla, Histological Conformation of, XV: 167.
- Meibomian Glands in the Cat, The. Note—E. H. Sargent, VIII: 143.

- Mellor, C. C. Report of Treasurer, XII: 252; Report of Treasurer, XIII: 209; Report of Treasurer, XV: 34.
- Mellor, C. C. and Henrici, J. F. An Old Microscope of the Culpeper Type, X: 140.
- Members, List of, I: 75; II: 81; III: 99; IV: 268; V: 269; VI: 266; VII: 251; VIII: 227; X: 166; XI: 174; XII: 256; XIII: 210; XIV: 168; XV: 249; XVI: 254; XVII: 381; XVIII: 405; XIX: 190; XX: 358; XXI: 268; XXII: 215; XXIII: 287; XXIV: 185; XXV: 179.
- Mendenhall, T. C. On the Fasoldt Stage Micrometer, (2 Plates), IV: 201.
- Menobranchnus, Fat cells and Connective-tissue Corpuscles of, IV: 109.
- Menopoma, Epithelium Lining the Mouth of, VII: 126.
- Mercer, A. Clifford. Stereoscopic Effects obtained by the High-power Binocular Arrangement of Powell & Lealand, IV: 127; Syracuse Solid Watch-glass, VI: 178; Photomicrograph versus Microphotograph, VIII: 131; On a Mooted Matter in the Use of an Eye-piece in Photo-micrography, XII: 50; A Series of Lantern Slides of Photomicrographs and Photomicrographic Apparatus, XIV: 141; The Improved Syracuse Solid Watch Glass, XVII: 371; Photomicrograph versus Microphotograph, XVIII: 131; Astronomical Photography with Photomicrographic Apparatus, (1 Plate), XVIII: 132; President's Address: An Experimental Study of Aperture as a Factor in Microscopic Vision, (4 Plates), XVIII: 321.
- Mercer, Wm. Fairfield. Comparative Study of the Soft Palate, (2 Plates), XXI: 41.
- Merriman, C. C. The Preparation and Mounting of Double Stainings, I: 71.
- Metal Centering Block for Mounting, A—M. Pflaum, XVII: 373.
- Metals, Radiation of Heat between, X: 33; The Microscope in the Study of their Behavior under Variations of Temperature, IX: 5.
- Metcalf, Haven. Cultural Studies of a Nematode associated with Plant Decay, (1 Plate), XXIV: 89.
- Meteoric Dust, Notes on Alleged, XVII: 95.
- Method of Preparing Nucleated Blood in Bulk for Class Demonstration—T. E. Oertel, XX: 49.
- Method of Sectioning Cartilage Fresh, by Partial Embedding—B. L. Oviatt, VIII: 142.
- Methods, Discussion of, III: 85; Improved, VII: 124.
- Methods of Dealing with the Question of Temperature in the Comparison of Standards of Length—William A. Rogers, VIII: 67.
- Methods of Decalcification in which the Structural Elements are Preserved—Simon Henry Gage, XIV: 121.
- Methods of Producing Enlargements and Lantern Slides of Microscopic Objects for Class Demonstrations—John Aspinwall, XXII: 41.
- Metrodinaesthes lucida, XXI: 213.
- Michels, Jahn. The Microscopical Examination of Pork by the United States Government, XIII: 59.
- Michigan, Rotifera of Shiawassee River, X: 84.
- Micrographical Contribution.—The Vegetable Nature of Group—Ephraim Cutter, IV: 101.

- Micrometer, Fasoldt Stage, IV: 201; Standard, Report of Committee on, VI: 220; Standard, Report of Committee on, VII: 212; Standard, Rules for the Control of, V: 200.
- Micrometers, Filar, XIV: 132; Stage, New Forms of, XII: 76.
- Micrometer Wires—R. H. Ward, VIII: 89.
- Micrometry, Combined Focussing and Safety Stage for Use in, with High Powers, VII: 115; Effect of Curvature of the Cover-glass upon, XII: 79; of Human Red Blood Corpuscle, XX: 41; Report of Committee on, VIII: 197; Report of Committee on, X: 163; Report of National Committee on, V: 181; Report on, XI: 140.
- Micrometry of Human Red Blood Corpuscle—Frank Judson Parker, XX: 41.
- Micro-organisms in the Blood of a case of Tetanus—Lester Curtis, IV: 157.
- Microphotograph, versus Photomicrograph, VIII: 131; XVIII: 131.
- Micro-photography, Actinic and Visual Focus in, VII: 29. (See Photomicrography.)
- Micro-photography with Dry-plates and Lamplight, and its application to making lantern positives—W. H. Walmsley, IV: 179, 273.
- Microscope, Accessories for, XIII: 47; An Early American, XIV: 156; An Old, X: 140; Binocular and Stereoscopic Vision, III: 69; Binocular, of the Seventeenth Century, XII: 57; Microscope, College, XII: 67; Evolution of, IV: 25; Microscope, Forty Years' Acquaintance with, VIII: 161; Full Utilization of Capacity of, XII: 43; Griffith, XIV: 53; Improved Griffith Club, IV: 149; in Detection of Forgery, XII: 86; in Diagnosis, Prognosis, and Treatment of Morbid New Growths, XIII: 61; in Examination of Legal Documents, XI: 102; in Government Work in Washington, XIII: 13; in the Workshop, XIV: 128; New Accessories, VIII: 150; New Form of, XI: 131; New Portable, II: 66; One Presented by Linnæus to Bernard Jussieu in 1738, IX: 214; Physician and, XVIII: 71; Plea for Instruction in Technique, XV: 1; Processes of Life Revealed by, XVII: 3; Relation of, to Administration of Justice, XIV: 1; Test Objects for, VII: 91; Tube-length, IX: 168; Value of, in Preventive Medicine, XVI: 101; Zentmayer's Dissecting, XIV: 51.
- Microscopes, American and European, X: 149; Cheap, XIV: 60; Combined Inverted and Vertical, VIII: 148; New American, XIII: 116.
- Microscope and Camera in the Detection of Forgery, The—exemplified by Lantern Slides and Photographs of Signatures in the Jerome will case—M. D. Ewell, XII: 86.
- Microscope as a Factor in a Study of the Behavior of Metals under Variations of Temperature, The. President's Address—William A. Rogers, IX: 5.
- Microscope as a Factor in the Diagnosis, Prognosis, and Treatment of Morbid New Growths, The—William C. Krauss, XIII: 61.
- Microscope Attachment, for Use with Solar or Artificial Light for Projecting, or Photographing, Microscopic Objects with Oblique Illumination, or Projecting Opaque Objects, A—L. D. McIntosh, X: 155.
- Microscope in Diagnosis, The—George E. Fell, XI: 67.

- Microscope in the Detection of Lard Adulterations, The—William T. Belfield, V: 97
- Microscope in the Government Work in Washington, The—J. Melvin Lamb, XIII: 13.
- Microscope in the Investigation of Burns and Scorches on Textile Fabrics, The. President's Address—Frank L. James, XIII: 1.
- Microscope in the Workshop, The—Wm. A. Rogers, XIV: 128.
- Microscope Objectives—T. J. Burrill, XII: 35.
- Microscope Screw, Universal, Report of Committee on, VIII: 199.
- Microscope Stand, A—T. J. Burrill, XI: 53.
- Microscope Stand, with Concentric Movements, V: 147.
- Microscopic Examination of Butter and Its Adulterations—H. A. Weber, VIII: 103.
- Microscopic Forms observed in Water of Lake Erie—C. M. Vorce, IV: 187.
- Microscopic Investigations Relating to Tea and its Adulterations—Thomas Taylor, XI: 46.
- Microscopic Observation, Verification of, V: 1.
- Microscopic Organism in the Buffalo Water Supply and in Niagara River—Henry Mills, IV: 165, 281.
- Microscopical Examination of and Experiments with Glandular Secretions according to Method of Dr. Brown Squard—George E. Fell, XI: 115.
- Microscopical Examination of Pork by the United States Government, The—John Michels, XIII: 59.
- Microscopical Examination of Seminal Stains on Cloth, The—F. M. Hamlin, V: 21.
- Microscopical Examination of Writing for the Detection of Forgery, Alteration, etc., The—C. M. Vorce, II: 50.
- Microscopical Exhibitions, IX: 311.
- Microscopical Light in Geological Darkness. President's Address—E. W. Claypole, XIX: 3.
- Microscopical Notes, Current, XVI: 242.
- Microscopical Preparations, Cataloguing, Labeling and Storing of, V: 169.
- Microscopical Researches of the Corpuscular Elements of Blood—M. L. Holbrook, XIV: 63.
- Microscopical Slide-catalogue, On a—R. H. Ward, IX: 233.
- Microscopical Societies, College, V: 27; Making them Successful, VIII: 94.
- Microscopical Tube-length, and the Parts Included in it by the Various Opticians of the World. The Thickness of Cover-glass for which Unadjustable Objectives are Corrected—Simon H. Gage, IX: 168.
- Microscopists, Division of Labor Among, V: 43; Forty Years' Acquaintance with, VIII: 161.
- Microscopy, Forensic, XI: 5; Library Experiments, XXI: 127; Medical, XX: 87.
- Micro-Structural Characteristics of Steel—Francis Scott Rice, XIX: 28.
- Microtome, Freezing, IV: 153.
- Microtomes, Simple, XIX: 189.
- Mikania, Aëration of Organs and Tissues in, XV: 143.

- Milk Ducts, of Udder, Bacteria in, XX: 57.
- Millen, J. C., Memoir of, XXV: 165.
- Mills, Henry. Microscopic Organisms in the Buffalo Water Supply and in Niagara River, IV: 165, 281; Fresh-Water Sponge, (1 Plate), IV: 209, 253; Thoughts on the Spongidae, VI: 131; Notes on the Fresh-water Sponges, VIII: 132; Memoir of, XI: 152.
- Minutes, I: 5; I: 17; II: 5; III: 5; IV: 3; V: 248; VI: 258; VII: 224; VIII: 204; IX: 334; X: 166; XI: 154; XII: 208; XIII: 176; XIV: 12; XV: 17; XVI: 1; XVII: 31; XVIII: 3; XIX: 190; XX: 347; XXI: 257; XXII: 205; XXIII: 275; XXIV: 171; XXV: 167.
- Mirror, Concave, XIV: 43.
- Missouri, Southwestern, Cave Salamander from, XXII: 189.
- Mix, C. M. A Rapid Staining Apparatus, XX: 341.
- Modern Conception of the Structure and Classification of Diatoms, The, with a Revision of the Tribes and a Rearrangement of the North American Genera—Chas. E. Bessey, XXI: 61.
- Modern Conception of the Structure and Classification of Desmids, The, with a Revision of the Tribes, and a Rearrangement of the North American Genera—Charles E. Bessey, (1 Plate), XXII: 89.
- Modification of Some Standard Apparatus to Facilitate the Work of the Histologic and Embryologic Laboratory—Simon Henry Gage, XXIII: 259.
- Modification of the Wenham half-disc illuminator, with an improved mounting—Robert Dayton, IV: 161.
- Mole, Ending and Relation of Muscle Fibres, IX: 207.
- Moody, Robert O. The Arrangement of the Muscular Layers of the Intestine of the Cat in the Region of the Juncture of the Large and Small Intestines, (8 Plates), XIII: 120; A Study of the Muscular Tunic of the Large and Small Intestines of Man in the Vicinity of the Caecum, (5 Plates), XVI: 197; Memoir of Edward Waller Claypole, B.A., D.S., XXIII: 269.
- Moore, Allen Y., Memoir of, IX: 327.
- Moore, Veranus A. The Ammoniacal Fermentation of Urine, (2 Plates), XII: 97; An Apparatus for Holding Cover-glasses, (1 Plate), XIII: 51; Observations on Staining the Flagella on Motile Bacteria, XIII: 85; A Contribution to the Study of the Myelin Degeneration of the Pulmonary Alveola Epithelium, (1 Plate), XV: 77; The Character of the Flagella, (1 Plate), XVI: 217; On the Flagella of Motile Bacteria, XVII: 239; The Hemospast. A New and Convenient Instrument for Drawing Blood for Microscopic Examinations, XIX: 186; President's Address: The Natural in Disease, XX: 3; An Incubator for Student Use, (1 Plate), XXI: 103.
- Mooted matter in the Use of an Eye-piece in Photo-micrography, On a—A. Clifford Mercer, XII: 50.
- Morphogenesis and Histogenesis, Early, of the Liver in *Sus scrofa domestica*, including Notes on the Morphogenesis of the Ventral Pancreas—David C. Hilton, (4 Plates), XXIV: 55.
- Morphogenesis of the Stigmata and Stomata Occurring in Peritoneal and Vascular Endothelium, The—Arthur E. Hertzler, XXIII: 63.
- Morphology of Rheumatic Blood—Ephraim Cutter, VI: 194.

- Mosgrove, S. M. Report of Treasurer, XI: 142.
 Mount Prospect Laboratory, Brooklyn, XXII: 25.
 Mounting Algae, XV: 248.
 Mounting, Centering Block for, XVII: 373; Dry, V: 143; Hints on, VI: 209.
 Mounting, Finishing and Preserving Slides—Frank L. James, VIII: 145.
 Mounting Media of High Refractive Index—Hamilton L. Smith, VII: 86.
 Mounting, Medium, New, VI: 186.
 Mounting Table, New, XIV: 150.
 Mounts, Glycerin, Leakage and Creeping in, IX: 173; Solid, Cover-glass Support for, XII: 75.
 Mouse, Ending and Relation of Muscle Fibres, IX: 207.
 Mouth Parts, of Cicada septendecim, XVII: 111.
 Mundorff, Edgar Alonzo, Memoir of, XV: 246.
 Muscle, First Development in Embryo of Chick and Man, VII: 71; Histology of, XVIII: 49.
 Muscle Cells, in Man and Certain other Mammals, IX: 283.
 Muscles of the Heart, Effects of Division of the Vagi on, V: 47; Finer Structure of, in Dog, XXV: 35; Structure of, in Lobster, IV: 131.
 Muscular Coats, of Intestine of Cat, XIII: 120; of Intestines of Man, XVI: 197; of the Oesophagus, X: 128.
 Muscle Fibres, Ending and Relation of, in Mouse, Mole, Bat and English Sparrow, IX: 207.
 Muscular Coats of the Oesophagus of the Domesticated Animals, The—Leonard Pearson, X: 128.
 Muscular Contractility—Jacob Redding, III: 17.
 Myelin Degeneration, of Pulmonary Alveola Epithelium, XV: 77.
 Myers, H. D. Picro-carminic and Alum-carminic as Counter Stains, XX: 337.
 Natural in Diseases, The. President's Address—Veranus A. Moore, XX: 3.
 Nature of Protozoa and Lesson of These Simplest Animals, The. President's Address—David S. Kellicott, X: 6.
 Nebraska, Cladocera of, XXII: 119; XXV: 45.
 Neurology. Charles A. Spencer, A.M.; Charles H. Sackrider, M.D.; D. C. Hawkshurst, M.D.; Edward B. Schickel, IV: 22; William B. Rezner, M.D., V: 242; Robert B. Tolles, VI: 41; Thad. S. Up de Graff, M.D., F.R.M.S.; Jas. N. Scatcherd, VII: 216; Rev. J. T. Brownell, A.M.; H. J. Rice, Sc.D., VIII: 202; Allen Y. Moore, M.D.; Myron C. Davis, IX: 327; Lorenzo M. Kenyon, M.D.; Arthur M. Barker, M.D., X: 165; Boardman Lambert Oviatt, B.S.; Henry Mills, XI: 151; Frisby T. Newcomer, M.D., M.A., S.M., F.R.M.S.; Eugene Pinckney, XII: 205; Forest W. Brayton, M.D.; Hosmer Allen Johnson, M.D., XIII: 171; Thomas Hill Urquhart, M.D.; Henry Weld Fuller; Joseph Zentmayer; Dr. J. Gibbons Hunt, XIV: 159; Rev. Francis Wölle; Dr. Edgar Alonzo Mundorff; Ezra Hollis Griffith, A.M., XV: 245; Maitland L. Mallory, M.D., XVI: 248; James Edmund Reeves, M.D.; Prof. Gustave Guttenberg, XVIII: 398; David Simons Kellicott, B.Sc., B.Ph., Ph.D.; Wm. A. Rogers, A.M., Ph.D., LL.D.; Henry C. Coons, A.M., M.D., Ph.D., XX: 21; John Eugene Davies; Henry

- H. Doubleday; Albert E. Loveland, M.A., M.D.; Herbert R. Spencer, XXI: 249; Jacob Dolson Cox; Moses Clark White, A.M., M.D., XXII: 197; Edward Waller Claypole, B.A., D.S., XXIII: 269; Chas. Marvin Vorce, XXIV: 163; Richard L. Maddox, M.D., F.R.M.S.; Bushrod W. James, A.M., M.D., LL.D.; Oscar C. Fox; J. C. Millen, M.D., XXV: 155.
- Necturus, Blood of, XV: 39; Epithelium Lining the Mouth of, and Blood-corpuses of, VII: 126; Fat cells and Connective-tissue Corpuses of, IV: 109; Histological Structure of Enteron of, XVI: 19.
- Nematode, Cultural Studies of, XXIV: 89.
- Nerve Cells, Action of Electricity upon, XVII: 179.
- Nerve Elements in Health and Disease, The—William C. Krauss, XVI: 234.
- Nerves, Intramuscular Endings of, in Skeletal Muscles, XII: 132; of the Kidney, V: 51; of Liver, IV: 95, 264; of the Lungs, III: 35.
- Nerve Tissues, Formalin as Hardening Agent for, XVII: 315; Formalin for, XVII: 319; Methods of Treating, XII: 116.
- Nervous System of the Fresh-water Sponge, The—J. M. Stedman, XIII: 77.
- Neurology, Formalin in, XVII: 319.
- New American Microscopes, made by Bausch & Lomb Optical Co., Rochester, N. Y.—Henry Bausch, XIII: 116.
- New Apparatus for Photo-micrography, A—H. F. Atwood, VI: 176.
- New Avian Cestode, *A. Metroliasthes lucida*—B. H. Ransom, XXI: 213.
- New Clearer for Collodionized Objects, A—Pierre A. Fish, XV: 86.
- Newcomer, F. S. Cleaning and Arranging Diatoms, VIII: 128.
- Newcomer, Frisby T., Memoir of, XII: 205.
- New Cover-slip Forceps, A—H. R. Gaylord, XVI: 123.
- New Daphnella, A—C. M. Vorce, XII: 172.
- New Fine Adjustment, A—E. H. Griffith, X: 161.
- New Floscule, A—D. S. Kellicott, VII: 48.
- New Freezing Microtome, A—Thomas Taylor, IV: 153.
- New Form of Graphological Stand, A—M. D. Ewell, XIII: 69.
- New Form of Life-slide, A—James H. Logan, VII: 110.
- New Form of Microscope, A; Made by Bausch & Lomb Optical Co., Rochester—W. A. E. Drescher, XI: 131.
- New Form of Microscope Stand with Concentric Movements, A—Jacob D. Cox, V: 147.
- New Form of Section Cutter, On a—William A. Rogers, VI: 191.
- New Genera and Species of North American Hydrachnidae—Robt. H. Wolcott, XXI: 177.
- New Heliostat, A—Lyman S. Deck, XIII: 49.
- New Hydra, A—M. J. Elrod and Maurice Ricker, XXIII: 257.
- New Lens Holder—R. H. Ward, VI: 162.
- New Method for the Quantitative Determination of Plankton Hauls, A—Henry B. Ward, XVII: 255.
- New Method for Securing Paraffin Sections to the Slide or Cover-glass, A—Agnes M. Claypole, XVI: 65.
- New Method of Dry Mounting, A—Albert H. Chester, V: 143.
- New Method of Making and Finishing Wax Cells, A—M. Pflaum, XVII: 374.

- New Microscopical Accessories, XVI: 124.
- New Mounting Medium, A—H. L. Smith, VI: 186.
- New Mounting Table, A—William N. Preston, XIV: 150.
- New Pocket Polaroscope, A—Oleomargariscope—Thomas Taylor, X: 150.
- New Rotiferon, A—D. S. Kellicott, XI: 32.
- New Section Instrument for Vegetable Materials, A—Edson S. Bastin, XVI: 121.
- New Species of *Crenothrix* (*C. manganifera*), A—D. D. Jackson, XXIII: 19.
- New Way of Marking Objectives, A—William C. Krauss, XVII: 359.
- Newts, Spermatheca and Fertilization in, XVII: 261.
- Niagara River, Microscopic Organisms in, IV: 161.
- Nichols, Mary A. and Rowlee, W. W. Contributions to the Life-history of *Symphlocarpus foetidus*, (2 Plates), XVII: 157.
- Nitrite of Amyl, for Fine Injections, VIII: 140.
- North American Species of *Curvipes*—Robt. H. Wolcott, XXIII: 201.
- North American Species of *Limnesia*—Robt. H. Wolcott, XXIV: 139.
- North American Species of the Genus *Atax* (Fabr.) Bruz., On the—Robert H. Wolcott, XX: 193.
- Note on a Microscope Presented by Linnæus to Bernard Jussieu in 1738—Jacob F. Henrici, IX: 214.
- Note on a New Rotifer.—*Gomphogaster Areolatus*—C. M. Vorce, IX: 250.
- Note on *Argulus catostomi*, A—D. S. Kellicott, VIII: 144.
- Note on Microscopical Exhibitions—R. H. Ward, IX: 311.
- Note on Resolution of *Amphipleura pellucida* by Central Light—Lyman Deck, XII: 170.
- Notes: Infusoria, Rotatoria, etc.—D. S. Kellicott, VI: 126.
- Notes on Colorado Entomostraca—Arthur E. Beardsley, XXIII: 41.
- Notes on Colorado Protozoa with Description of New Species—Arthur E. Beardsley, XXIII: 49.
- Notes on Comparative Histology of Blood and Muscle—Edith J. Claypole, XVIII: 49.
- Notes on Fibrin, Oxyhaemoglobin Crystals, and the Collodion Method—Simon H. Gage, XIII: 79.
- Notes on Technique—Pierre A. Fish, XVIII: 287.
- Notes on the Desmidiæ of the United States—Francis Wolle, V: 137.
- Notes on the Epithelium Lining the Mouth of *Necturus* and *Menopoma*, and Notes on the Blood-corpuseles of *Necturus*—Simon H. Gage, VII: 126.
- Notes on the Fresh-water Sponges—Henry Mills, VIII: 132.
- Notes on the Isolation of the Tissue Elements—Simon H. Gage, XIX: 179.
- Notes on the Parasites of the Lake Fish—Henry B. Ward, XXII: 175.
- Notes on the Structure, Development, and Position, of an undescribed Flagellate Infusorian—J. H. Fisher, II: 44.
- Notes on the Structure of the Moth *Attacus Cecropia*—H. N. Lyon, XI: 135.
- Notes on Two Parasites of the Cray Fish—D. S. Kellicott, V: 115.
- Notices of Some Undescribed Infusoria, from the Infusorial Fauna of Louisiana—J. C. Smith, XIX: 55.

- Notices of Some Undescribed Infusoria, from the Infusorial Fauna of Louisiana—J. C. Smith, XX: 51.
- Notices of Some Undescribed Infusoria, from the Infusorial Fauna of Louisiana—J. C. Smith, XXI: 87.
- Notogonia ehrenbergii Perty—J. C. Smith, (1 Plate), XXI: 95.
- Numerical Aperture—Marshall D. Ewell, XIV: 44.
- Numerical Aperture of an Objective in Relation to its Angle of Aperture in Air, Water and Balsam, The—H. J. Detmers, VII: 199.
- Obituary Notices. (See Necrology.)
- Objectives, XII: 35; Amplifying Power of, XI: 22; An Improvement in, VI: 148; Homogeneous-immersion, III: 62; Immersion, VII: 51; Magnifying Power of, VI: 183; Marking, XVII: 359; Penetration in, II: 70; Selection of a Series of, V: 33; Systematic Examination of, I: 62; Universal Screw for, VI: 153.
- Observations on Fresh-water Infusoria—D. S. Kellicott, X: 97.
- Observations on Infusoria, with Descriptions of New Species—D. S. Kellicott, VI: 110.
- Observations on *Lerneocera cruciata*—D. S. Kellicott, I: 64.
- Observations on Some Fresh-water Infusoria. With Descriptions of a Few Species Regarded as New—D. S. Kellicott, VII: 38.
- Observations on Staining the Flagella on Motile Bacteria—Veranus A. Moore, XIII: 85.
- Observations on the Fat cells and Connective-tissue Corpuscles of *Necturus* (*Menobranchus*)—Simon H. Gage, IV: 109.
- Occurrence of Albino Eggs of the Spotted Salamander, *Amblystoma punctatum* L., An—Horace W. Britcher, XX: 69.
- Occurrence of *Gregarina* in the American Lobster, On the—Albert H. Tuttle, III: 47.
- Occurrence of *Haemosporidia* in the Blood of *Rana catesbeiana*, Upon the, with an Account of their probable Life History—Jas. H. Stebbins, Jr., XXV: 55.
- Oculars, Amplifying Power of, XI: 22; Report of Committee on, VI: 228.
- Oertel, T. E. Method for Preparing Nucleated Blood in Bulk for Class Demonstration, XX: 49.
- Oesophagus, Muscle Coats of, X: 128.
- Oil-sectioning, with Collodion, XVII: 361.
- Old Microscope of the Culpeper Type, An—J. F. Henrici and C. C. Mellor, X: 140.
- Oleomargariscope, X: 159.
- Optical Errors and Human Mistakes—Ernst Gundlach, VIII: 157.
- Organs of Taste, XIX: 129.
- Original Method of Staining and Mounting Pollens—J. T. Brownell, VI: 212.
- Osmic Acid.—Its Uses and Advantages in Microscopical Investigations—Thomas B. Redding, IV: 183.
- Outline of the Tube Plan of Structure of the Animal Body—J. S. Foote, XXV: 63.

- Oviatt, B. L. Method of Sectioning Cartilage Fresh, By Partial Embedding, VIII: 142; Cardiac Muscle Cells in Man and Certain Other Mammals, IX: 283; Memoir of, XI: 151.
- Oviatt, B. L. and Sargent, E. H. Use of Nitrite of Amyl for Fine Injections, VIII: 140.
- Ovipositor, of Cicada septendecim, XVII: 111.
- Oxygen, Dissolved in Natural Waters, Effect of on Microscopic Organisms, XXIII: 103.
- Oxyhaemoglobin, Crystals, XIII: 79.
- Ozone, Clinical Advantages of, and Effects on Micro-Organisms of Infusions, V: 69.
- Palate, Soft, Comparative Study of, XXI: 41; of Cat, X: 58.
- Pancreas, Ventral, Morphogenesis of, in Pig, XXIV: 55.
- Paraffin and Collodion Embedding—H. N. Conser, XVII: 312.
- Paraffin Sections, Securing, XVI: 65.
- Parasite, Crustacean, of "Miller's Thumb" (Cottus), XIV: 76; of Human Ear, XXII: 81.
- Parasites, Animal, Determination of the Number of in Meat, IX: 191; Crustacean, on Fresh-water Fishes, IV: 75; of Common Fowl, V: 131; of the Cray-fish, V: 115; of Lake Fish, XV: 173; of Lake Fish, XXII: 175.
- Parasites of the Lake Fish, On the—Henry B. Ward, XV: 173.
- Parasitism of Epiphegus Virginiana—Hermann Schrenk, XV: 91.
- Parker, Frank J. Micrometry of Human Red Blood Corpuscles, XX: 41.
- Parker, Horatio N. Some Advantages of Field Work on Surface Water Supplies, XXII: 13.
- Parker, Horatio N. and Whipple, Geo. C. On the Amount of Oxygen and Carbonic Acid Dissolved in Natural Waters and the Effect of these Gases upon the Occurrence of Microscopic Organisms, (4 Plates), XXIII: 103.
- Partial List of Rotifera of Shiawassee River at Corunna, Michigan—D. S. Kellicott, X: 84.
- Pathology, of the Human Brain, V: 141.
- Patton, Amos W. Memoir of Eugene Pinckney, XII: 207.
- Pearson, Leonard. The Muscular Coats of the Oesophagus of the Domesticated Animals, X: 128.
- Pedetic Movement, Prevention of, XXIV: 22.
- Pelvis, Carcinoma on Floor of, XX: 165.
- Penetration in Objectives. Is it a Defect or an Advantage?—C. M. Vorce, II: 70.
- Pennock, Edward, Two Very Simple Microtomes, XIX: 189.
- Peple, G. A. Memoir of Dr. Wm. R. Weisiger, VI: 250.
- Peritoneal and Vascular Endothelium, The Morphogenesis of the Stigmata and Stomata occurring in—Arthur E. Hertzler, XXIII: 63.
- Peritoneal Epithelium of Some Ithaca Amphibia, The—Isabella M. Green, XVIII: 76.
- Perry, Stuart H. Rhizopods of Oakland Co., Mich., XII: 94.
- Persistence of Bacteria in the Milk Ducts of the Cow's Udder, The—Archibald R. Ward, XX: 57.

- Pflaum, Magnus. Report of the Treasurer, XVI: 18; Report of Treasurer, XVII: 94; Some Notes on Alleged Meteoric Dust, XVII: 95; A Metal Centering Block for Mounting, XVII: 373; A New Method of Making and Finishing Wax Cells, XVII: 374; Treasurer's Report, XVIII: 46; Treasurer's Report, XIX: 194; Memoir of Gustave Guttenberg, Ph.D., XVIII: 398; Treasurer's Report, XX: 353; Report of Custodian, XXV: 172.
- Phagocytic Action, in Amphibia and Mammalia, XIX: 93.
- Phanerogams, Aëration of Organs and Tissues in, XV: 143.
- Photographing with High Powers by Lamplight—H. J. Detmers, X: 143.
- Photographic Apparatus, Laboratory, XXIII: 263.
- Photography, Apparatus for use with Oblique Illumination, X: 155; as an Aid to Microscopical Investigations, I: 59; Astronomical, XVIII: 132; with High Powers by Lamplight, VI: 99; with High Powers by Lamplight, X: 143.
- Photography as an Aid to Microscopical Investigations—Carl Seiler, I: 59.
- Photography with High Powers by Lamplight: Illustrating Structure of Diatoms—Jacob D. Cox, VI: 99.
- Photomicrograph versus Microphotograph—A. Clifford Mercer, VIII: 131.
- Photomicrograph versus Microphotograph—A. Clifford Mercer, XVIII: 131.
- Photomicrographs by Gas-light—Geo. M. Sternberg, XIV: 85.
- Photo-micrography, XVII: 340; XVIII: 107; Acetylene Gas as Illuminant in, XVIII: 136; by Gas-light, XIV: 85; A Handy Camera, XII: 69; Heliostat for, VII: 103; High-power, Best Technique for, XI: 112; Lantern Slides and Apparatus, XIV: 141; New Apparatus for, VI: 176; New Camera for, IX: 263; Stereoscopic, with High Powers, XXIV: 23; Systematic, XVIII: 117; Theory and Practice of, IX: 263; Use of an Eye-piece in, XII: 50; Use of Apparatus in Astronomical Photography, XVIII: 132; with Dry-Plates and Lamp-Light, V: 59; with Opaque Objects, XX: 189.
- Photomicrography—Thomas J. Bray, XVIII: 107.
- Photomicrography with Opaque Objects—W. H. Walmsley, XX: 189.
- Photo-spectrography of Colored Fluids—Moses C. White, XXII: 99.
- Phycomycetes, Structure and Classification of, XXIV: 27.
- Physician and His Microscope, The—A. A. Young, XVIII: 71.
- Physiology, of the Human Brain, V: 141.
- Picric and Chromic Acid for the Rapid Preparation of Tissues for Classes in Histology—Simon H. Gage, XII: 120.
- Picro-Carmine and Alum-Carmine as Counter Stains—B. D. Myers, XX: 337.
- Pig. Morbid Growth in Stomach, V: 125; Morphogenesis and Histogenesis of Liver and Morphogenesis of Ventral Pancreas, XXIV: 55.
- Pinckney, Eugene, Memoir of, XII: 207.
- Plankton Hauls, Quantitative Determination of, XVII: 255.
- Plankton, Measurement of, XXI: 227.
- Plankton of Echo River, Mammoth Cave, The—Charles A. Kofoid, XXI: 113.
- Plankton of Lake Maxinkuckee, Indiana, The—Chancey Juday, XXIII: 61.
- Plant Decay, Nematode associated with, XXIV: 89.
- Plants, Microscopic, Evolution in, XXIV: 5.

- Plea for Systematic Instruction in the Technique of the Microscope at the University, A. President's Address—Jacob D. Cox, XV: 1.
- Plea for the Study of Limnobiology, A—Henry B. Ward, XXI: 201.
- Plea for the Study of Re-agents in Micro Work, A—Vida A. Latham, XV: 203.
- Poisoning, Chrome Lead, Microscopical Anatomy in, XIII: 110.
- Polariscope, Oleomargariscope, X: 159.
- Poisonous Dried Beef—H. J. Detmers, VII: 54.
- Pollens, Staining and Mounting, VI: 212.
- Pollen tubes Again—John Kruttschnitt, VII: 62.
- Pollution, of Rivers, and Purification, XXV: 105.
- Polyzoa—Observations on Species detected near Buffalo, N. Y.—D. S. Kellcott, IV: 217.
- Pork, Microscopical Examination of, XIII: 59.
- Portable Lime Light, The—L. D. McIntosh, XIII: 41.
- Pound, Roscoe. An Addition to the Parasites of the Human Ear, (1 Plate), XXII: 81.
- Powell & Lealand, High-power Binocular Arrangement of, IV: 127.
- Practical Drying Oven, A—William N. Preston, XIV: 152.
- Practical Method of Referring Units of Length to the Wave Length of Sodium Light, A—Wm. A. Rogers, XVII: 305.
- Practical Method of Securing Copies of the Standard Centimeter Designated "Scale A," A—William A. Rogers, XI: 109.
- Preparing and Mounting Bacteria—T. J. Burrill, V: 79.
- Preparation and Imbedding the Embryo Chick—Simon H. Gage and Grant S. Hopkins, XII: 128.
- Preparation and Mounting of Brain Sections—Theodore Deecke, IV: 275.
- Preparation and Mounting of Double Stainings—C. C. Merriman, I: 71.
- Preparation and Mounting of Foraminifera, with Description of a New Slide for Opaque Objects, The—F. M. Hamlin, V: 65.
- Preparation of Chick Embryos for Microscopical Examination, On the—W. P. Manton, VII: 66.
- Preparations, Microscopical, Marker for Indicating Position of Objects, XVI: 112.
- Preservation, of tissues Isolated by Means of Caustic Potash or Nitric Acid, XI: 34.
- President, Annual Address of—R. H. Ward, I: 35; Hamilton L. Smith, II: 17; George E. Blackham, IV: 25; Albert McCalla, V: 1; Jacob D. Cox, VI: 5; Hamilton L. Smith, VII: 5; Thomas J. Burrill, VIII: 5; William A. Rogers, IX: 5; David S. Kellcott, X: 6; William J. Lewis, XI: 5; George E. Fell, XII: 1; Frank L. James, XIII: 1; Marshall D. Ewell, XIV: 1; Jacob D. Cox, XV: 1; Simon H. Gage, XVII: 3; A. Clifford Mercer, XVIII: 321; E. W. Claypole, XIX: 3; Veranus A. Moore, XX: 3; Wm. C. Krauss, XXI: 1; A. M. Bleile, XXII: 1; Carl H. Eigenmann, XXIII: 5; Charles E. Bessey, XXIV: 5; E. A. Birge, XXV: 5.
- Preston, William N. A New Mounting Table, XIV: 150.
- Preston, William N. A Practical Drying Oven, XIV: 152.

- Prevention of the Pedetic or Brownian Movement in Milk or other Liquids with Minute Objects in Suspension—Simon H. Gage, XXIV: 22.
- Processes of Life Revealed by the Microscope, The; a Plea for Physiological Histology. President's Address—Simon H. Gage, XVII: 3.
- Production of Citric Acid by Fermentation, On the—Wm. H. Seaman, XV: 90.
- Projection apparatus, for Use with Oblique Illumination, or Opaque objects, X: 155.
- Protophyta, Classification of, XXV: 89.
- Protoplasm, Influence of Electricity on, XII: 1.
- Protozoa, Nature of, X: 6; of Colorado, XXIII: 49.
- Public Water Supply for Small Towns—M. A. Veeder, XVIII: 176.
- Punches, for Sheet Wax, VI: 215.
- Purification of polluted Rivers, XXV: 105.
- Purification of Water by the Alum Method, XV: 211.
- Question of Correct Naming and Use of Micro-reagents, The—V. A. Latham, XVII: 350.
- Questions in Regard to the Diphtheria Bacillus—M. A. Veeder, XX: 81.
- Rabbit, Egg-like Bodies in Liver of, V: 167.
- Radiation of Heat between Metals, with Numerical Results for Brass and for Steel, On the—W. A. Rogers, X: 33.
- Rafter, Geo. W. On the Use of the Amplifier, with Observations on the Theory and Practice of Photo-micrography, suggested by the Design of a New Photo-Micro-Camera, IX: 263; On the Best Technique for High-power Photo-micrography, XI: 112.
- Ransom, B. H. A New Avian Cestode—*Metroliasthes lucida*, (2 Plates), XXI: 213; On *Hymenolepis carioca* (Magalhaes) and *Hymenolepis megalops* (Nitasch) with Remarks on the Classification of the Group, (3 Plates), XXIII: 151.
- Ranunculaceae, Structure of Fruit of, XVI: 69.
- Rapid Section Cutting—James E. Whitney, VII: 122.
- Rapid Staining Apparatus, A—C. M. Mix, XX: 341.
- Reaction of Diabetic Blood to Some of the Anilin Dyes, The—V. A. Latham, XXI: 31.
- Reagents, Naming and Use of, XVII: 350; Plea for Study of, XV: 209.
- Red Blood Corpuscle in Legal Medicine—Moses C. White, XVIII: 201.
- Redding, Jacob. Muscular Contractility, (1 Col. Plate), III: 17; Osmic Acid.—Its Uses and Advantages in Microscopical Investigations, IV: 183.
- Redding, J. The Extra-vascular Circulation, VI: 81.
- Reed, Raymond C. *Dahlia* as a Stain for Bacteria in Sections cut by the Collodion Method, XIX: 182.
- Reeves, James Edmund, Memoir of, XVIII: 397.
- Reference Model, A—Susannah Phelps Gage, XIV: 154.
- Refractive Index, of Immersion Fluids, VII: 83.
- Regeneration of the Intestinal Epithelium in the Toad (*Bufo lentiginosus americanus*) during Transformation, The—B. F. Kingsbury, XX: 45.

- Relation of Aperture to Amplification in the Selection of a Series of Objectives, The—George E. Blackham, V: 33.
- Relation of the Microscope to the Administration of Justice, The. President's Address—Marshall D. Ewell, XIV: 1.
- Remarks on a Device for Enabling two Observers to View Objects Simultaneously—James H. Logan, VII: 120.
- Remarks on Improved Methods—R. N. Reynolds, VII: 124.
- Remarks on Mounting Materials for Histological Specimens, with Special Reference to Glycerine and Balsam—Carl Seiler, II: 60.
- Remarks on Pathogenic Bacteria—H. J. Detmers, V: 87.
- Remarks on *Stephanodiscus Niagarae*—C. M. Vorce, VII: 139.
- Remarks on the Fesoldt Test-plate—R. H. Ward, IX: 318.
- Remarks on the Methods of Making Microscopical Societies Successful—R. H. Ward, VIII: 94.
- Reply to Professor Weber—Thomas Taylor, VIII: 116.
- Report of the National Committee on Micrometry, V: 181.
- Report on Centimeter Scale A, 1882—J. E. Hilgard, V: 181.
- Report upon the Collection of Slides—D. S. Kellicott, IX: 322.
- Requisites of a Pure Water Supply, The—William C. Krauss, XVIII: 165.
- Researches on the Anatomy of *Amphistomum Fabaceum* Diesing—John Moore Stedman, XI: 85.
- Resolution, Difficult, XXI: 111.
- Resolution, of *Amphipleura pellucida* by Central Light, XII: 170.
- Respiration, Modifications of Stems and Roots for Purposes of, XVII: 98.
- Reynolds, R. N. Remarks on Improved Methods, VII: 124.
- Reynolds, Wm. Geo. A Comparative Study of Hair for the Medico-legal Expert. (2 Plates), XIX: 117.
- Rezner, William B., Memoir of, V: 242.
- Rheumatism, Morphology of Blood, VI: 194.
- Rhizopods of Oakland Co., Mich.—Stuart H. Perry, XII: 94.
- Rhizosolenia gracilis*, n. sp.—H. L. Smith, IV: 177.
- Rice, Francis Scott. Micro-Structural Characteristics of Steel. (3 plates), XIX: 28.
- Rice, H. J. Memoir of, VIII: 203.
- Ricker, Maurice and Elrod, M. J. A New Hydra, XXIII: 257.
- River Pollution and Purification—T. J. Burrill, XXV: 105.
- Robert B. Toiles and the Angular Aperture Question. President's Address—Jacob D. Cox, VI: 5.
- Rochester Academy of Sciences, Annual Soiree of the Society in Connection with, VI: 234.
- Rocky Mountains, Biological Reconnaissance of some elevated Lakes in, XXV: 127.
- Rogers, William A. On the Conditions of Success in the Construction and the Comparison of Standards of Length, IV: 231; V: 240; A Critical Study of the Action of a Diamond in Ruling Lines upon Glass, V: 149; A Study of the Centimeter, Marked "A," Prepared by the U. S. Bureau of Weights and Measures for the Committee on Micrometry, V: 184; On a New Form

- of Section Cutter, VI: 191; Determination of the Absolute Length of Eight Rowland Gratings at 62° Fahr., VII: 151; Methods of Dealing with the Question of Temperature in the Comparison of Standards of Length, VIII: 67; President's Address: The Microscope as a Factor in a Study of the Behavior of Metals under Variations of Temperature, IX: 5; On the Radiation of Heat between Metals, with Numerical Results for Brass and for Steel, X: 33; A Practical Method of Securing Copies of the Standard Centimeter Designated "Scale A," XI: 109; Report on Standard Centimeters, XIII: 207; The Microscope in the Workshop, XIV: 128; A Word Concerning Filar Micrometers, XIV: 132; A Practical Method of Referring Units of Length to the Wave Length of Sodium Light, (1 Plate), XVII: 305; Memoir of, XX: 25.
- Roots, Modifications of, XVII: 98.
- Ross, Mary J. Special Structural Features in the Air-sacs of Birds, (3 Plates), XX: 29.
- Rotifera, A New Species, XI: 32; a New Species, IX: 250; Certain Species of, IX: 181; Notes on, VI: 126; of Sandusky Bay, XVIII: 155; XIX: 43; of Shiawassee River, Michigan, X: 84; New Species from Louisiana, XXV: 121.
- Rotifera of Sandusky Bay—D. S. Kellicott, XVIII: 155.
- Rotifera of Sandusky Bay, The. (Second Paper)—D. S. Kellicott, XIX: 43.
- Rowlee, Willard W. Imbedding and Sectioning Mature Seeds, XII: 113; Structure and Development of Buds in the Leaf of *Bryophyllum calycinum*, Salisb., (2 Plates), XIV: 80; The Aeration of Organs and Tissues in *Mikania* and other Phanerogams, (6 Plates), XV: 143; The Chlorophyll Bodies of *Chara Coronata*, XVII: 155.
- Rowlee, W. W. and Nichols, Mary A. Contributions to the Life-history of *Symplocarpus Foetidus*, (2 Plates), XVII: 157.
- Rules for the Control of the Standard Micrometer, V: 200.
- Sackrider, Charles H., Obituary notice of, IV: 22.
- Salamander, New Cave, XXII: 189; Spotted, Albino Eggs of, XX: 69.
- Salamanders, Spermatheca and Fertilization in, XVII: 261.
- Sandusky Bay, Rotifera of, XVIII: 155; XIX: 43.
- Sarcina ventriculi* in Medico-legal Investigation of Blood Stains—W. N. Sherman, XV: 136.
- Sargent, E. H. The Meibomian Glands in the Cat.—Note, VIII: 143.
- Sargent, E. H. and Oviatt, B. L. Use of Nitrite of Amyl for Fine Injections, VIII: 140.
- Scales, of *Seira buskii* and *Lepidocyrtus curvicollis*, XVIII: 194.
- Scatcherd, James N., Obituary notice of, VII: 223.
- Schaufelberger, F. J. Memoir of Thomas Hill Urquhart, M.D., XIV: 159.
- Schickel, Edward B., Obituary notice of, IV: 23.
- Schrenk, Hermann. Parasitism of *Epiphegus Virginiana*, (10 Plates), XV: 91; Some Modifications of Stems and Roots for Purposes of Respiration, (3 Plates), XVII: 98.
- Science Studies, Influence of, VII: 5.

- Seaman, William H. A College Microscope, XII: 67; On the Luminous Organs of Insects, (5 Plates), XIII: 133; Victoria Regia, (1 Plate), XIII: 163; Report of Treasurer, XIV: 36; An Early American Microscope, XIV: 156; Memoir of Dr. J. Gibbons Hunt, XIV: 166; On the Production of Citric Acid by Fermentation, XV: 90; Some Notes on Formalin, XVI: 238; Memoir of James Edmund Reeves, M.D., XVIII: 397; Memoir of Henry H. Doubleday, XXI: 250; Memoir of Oscar C. Fox, XXV: 163.
- Section Cutter, New Form of, VI: 191.
- Section Cutter, Rotary, VI: 171.
- Section Cutting, Rapid, VII: 122.
- Sectioning, with Collodion and Oil, XVII: 361.
- Section Instrument, for Vegetable Materials, XVI: 121.
- Sections, Serial, VI: 202.
- Seeds, Nature, Imbedding and Sectioning, XII: 113.
- Seiler, Carl. Photography as an Aid to Microscopical Investigations, I: 59; Remarks on Mounting Materials for Histological Specimens, with Special Reference to Glycerine and Balsam, II: 60.
- Seira buskii, Scales of, XVIII: 194.
- Seminal Stains, Microscopical Examination of, on Cloth, V: 21.
- Sense Organs, Lateral Line System of, in Amphibia and Dipnoans, XVII: 115.
- Serial Sections—S. H. Gage, VI: 202.
- Series of Lantern Slides of Photomicrographs and Photomicrographic Apparatus, A—A. Clifford Mercer, XIV: 141.
- Several New Microscopical Accessories, On—E. H. Griffith, VIII: 150.
- Sewage, Fungi found in, VI: 90.
- Sexton, Lewis R., Memoir of, VI: 251.
- Sharks, Devonian Cladodont, Teeth of, XVI: 191.
- Shearer, James B. Systematic Photomicrography and Apparatus Pertaining Thereto, (5 Plates), XVIII: 117.
- Sheep, Bacillus of Foot-rot in, IX: 209.
- Sherman, W. N. Sarcina ventriculi in Medico-legal Investigation of Blood Stains, XV: 136.
- Should Homogenous-immersion Objectives be made adjustable or non-adjustable?—Geo. E. Blackham, III: 62.
- Shrinkage of Cement-cells the Cause of Leakage and Creeping in Glycerin Mounts—Frank L. James, IX: 173.
- Shurley, E. L. An Improved Slide for the Examination of Gaseous Matter, III: 65.
- Sierras, the, Biological Reconnaissance of some Elevated Lakes in, XXV: 127.
- Silver, Deposition of on Glass and other Non-metallic Surfaces, VI: 71.
- Simple and Efficient Deposit-glass, A—George E. Fell, XI: 130.
- Simplification of Laboratory Methods—William C. Krauss, XVI: 119.
- Slide, for Opaque Objects, V: 65; Ideal, VI: 179; Securing Paraffin Sections to, XVI: 65.
- Slides, Collection of, IX: 322; Indexing, Cataloguing, Preparing and Arranging, XXI: 127; List of, VII: 214; Mounting, Finishing and Preserving, VIII: 145.

- Slide Cabinets, Construction of, VII: 108.
- Slide-catalogue, Microscopical, IX: 233.
- Smith, Hamilton L. President's Address: Deep Sea Soundings and the Influence of Microscopical Algae on Deep Sea Life, with a few Remarks on Evolution, II: 17; Memoir of Charles A. Spencer, (Portrait p. 1), IV: 22; *Rhizosolenia gracilis*, n. sp., IV: 177; A New Mounting Medium, VI: 186; President's Address: The Unconscious Influence of Science Studies, VII: 5; Device for Testing Refractive Index of Immersion Fluids, VII: 83; Mounting Media of High Refractive Index, VII: 86; A Contribution to the Life History of the Diatomaceae, (5 Col. Plates), VIII: 30; Contribution to the Life History of the Diatomaceae,—Part II., (6 Col. Plates), IX: 126.
- Smith, J. C. Notices of Some Undescribed Infusoria, from the Infusorial Fauna of Louisiana, (2 Plates), XIX: 55; The Sporular Development of the *Amoeba villosa*, Leidy, XIX: 69; Notices of Some Undescribed Infusoria, from the Infusorial Fauna of Louisiana, (1 Plate), XX: 51; Notices of Some Undescribed Infusoria, from the Infusorial Fauna of Louisiana, (1 Plate), XXI: 87; *Notogonia ehrenbergii* Perty, (1 Plate), XXI: 95; Treasurer's Report, XXI: 263; Report of Treasurer, XXII: 209; Treasurer's Report, XXIII: 281; Treasurer's Report, XXIV: 178; *Synchaeta bicornis*: A New Rotifer from the Brackish Waters of Lake Pontchartrain, Louisiana, XXV: 121; Report of Treasurer, XXV: 173.
- Smuts, X: 45.
- Soft Palate in the Domestic Cat, The—T. B. Stowell, X: 58.
- Soiree, Annual, V: 201; in connection with the Rochester Academy of Sciences, VI: 234; XIV: 29.
- Solution of the Eel Question, The. President's Address—Carl H. Eigenmann, XXIII: 5.
- Some Advantages of Field Work on Surface Water Supplies—Horatio N. Parker, XXII: 13.
- Some Diatom Hoops. The Question of their Mode of Growth (*Aulacodiscus Kittoni*)—Jacob D. Cox, VII: 33.
- Some Infusoria Found on the Cray-Fish, On—D. S. Kellicott, V: 105.
- Some Laboratory Apparatus—Simon Henry Gage, XXI: 107.
- Some Medico-legal Aspects of Trauma in Relation to Diseased Cerebral Arteries. President's Address—Wm. C. Krauss, XXI: 1.
- Some Methods of Histologic Technique—J. Melvin Lamb, XVIII: 291.
- Some Methods of Treating Nerve Tissues—William C. Krauss, XII: 116.
- Some Modifications of Stems and Roots for Purposes of Respiration—Herman von Schrenk, XVII: 98.
- Some New and Improved Apparatus—E. H. Griffith, VII: 112.
- Some New and Rare Infusoria—D. S. Kellicott, IX: 187.
- Some New Points in Photo-micrography and Photo-micrographic Cameras—W. H. Walmsley, XVII: 340.
- Some Notes on Alleged Meteoric Dust—Magnus Pflaum, XVII: 95.
- Some Notes on Formalin—Wm. H. Seaman, XVI: 238.
- Some Notes on the Innervation of the Lungs—A. M. Bleile, III: 35.

- Some Observations upon the Destructive Powers of Certain Insects—C. M. Vorce, I: 68.
- Some Peculiarities of the Mouth Parts and Ovipositor of Cicada septendecim—J. D. Hyatt, XVII: 111.
- Some Points in the Structure of the Acanthocephala—H. W. Graybill, XXIII: 101.
- Some Points on Cleavage among Arthropods—Agnes M. Claypole, XIX: 74.
- Some Remarks on Fat-infiltration of the Liver—Louis M. Eastman, VII: 60.
- Some Remarks on the Limitation of Tuberculosis, Illustrating the Value of the Microscope in Preventive Medicine—W. W. Alleger, XVI: 101.
- Spaces, Intercellular, XVII: 174.
- Sparrow, English, Ending and Relation of Muscle Fibres, IX: 207; Brain of, XVII: 185.
- Special Structural Features in the Air-sacs of Birds—Mary J. Ross, XX: 29.
- Spelerpes stejnegeri*, XXII: 189.
- Spence, Thomas B. A Comparison of the External and Middle Ear of Man and the Cat, XII: 146.
- Spencer, Debt of American Microscopy to, XXIII: 19.
- Spencer, Charles A., Obituary notice of (with Portrait), IV: 22.
- Spencer, Herbert R., Memoir of, XXI: 252.
- Spencer-Tolles Fund, Report of, VII: 249; IX: 326; XII: 252; XIII: 209; XIV: 36; XV: 34; XVI: 18; XVII: 94; XVIII: 47; XIX: 195; XX: 354; XXI: 264; XXII: 210; Report of the Committee on, XXIII: 265; Report of, XXIII: 282; XXIV: 179; XXV: 172.
- Spermatheca and Methods of Fertilization in Some American Newts and Salamanders—B. F. Kingsbury, XVII: 261.
- Spermatozoon, Human, Cephalic Extremity and Movements of, V: 121.
- Spicula, of Chirodota, IV: 139.
- Spines, Paleozoic, XVIII: 151.
- Sponges, Fresh-Water, IV: 209, 253; Fresh-water, VIII: 132; Fresh-water, Nervous System of, XIII: 77.
- Spongidae, Thoughts on, VI: 131.
- Sporadic Growth of Certain Diatoms and the Relation thereof to impurities in the Water Supply of Cities—J. D. Hyatt, IV: 197.
- Sporular Development of the Amoeba villosa, Leidy, The—J. C. Smith, XIX: 69.
- Stain, Dahlia for Bacteria, XIX: 182.
- Staining, Apparatus, XX: 341; Hints on, VI: 209; of Tissues Isolated by Means of Caustic Potash or Nitric Acid, XI: 34.
- Staining and Permanent Preservation of Histological Elements Isolated by Means of Caustic Potash (KOH) or Nitric Acid (HNO₃)—Simon H. Gage and Susanna Phelps Gage, XI: 34.
- Stainings, Double, Preparation and Mounting of, I: 71.
- Stains, Counter, XX: 337; Use of, especially in Differential Diagnosis, XIII: 94.
- Stand, Zentmayer's American-continental, XIV: 48.
- Standard Glass and Speculum Metal Centimeters—M. D. Ewell, XIII: 71.

- Standards of Length, Construction and Comparison of, IV: 231; V: 240; Temperature in Comparison of, VIII: 67.
- Stebbins, Jas. H., Jr. Upon the Occurrence of Haemosporidia in the Blood of *Rana Catesbiana*, with an Account of their probable Life History, (2 Plates), XXV: 55.
- Stedman, J. M. The Tape Worm. Methods of Preparation for the Museum and the Microscope, IX: 243; On the Development and a Supposed New Method of Reproduction in the Sun-Animalcule—*Actinospharium Eichhornii*, (1 Plate), X: 107; Researches on the Anatomy of *Amphistomum Fabaceum* Diesing, (3 Col. Plates), XI: 85; Killing of Invertebrata in an Expanded and Natural Condition, XIII: 73; The Nervous System of the Fresh-water Sponge, XIII: 77.
- Steel, Micro-Structural Characteristics of, XIX: 28.
- Stems, Modifications of, XVII: 98.
- Stephanodiscus *Niagarae*, VII: 139.
- Stereoscopic Effects obtained by the High-power Binocular Arrangement of Powell & Lealand—A. Clifford Mercer, IV: 127.
- Stereoscopic Photomicrography with High Powers—F. E. Ives, XXIV: 23.
- Sternberg, Geo. M. Photomicrographs by Gas-light, (1 Plate), XIV: 85.
- Stigmata, of Endothelium, XXIII: 63.
- Stomach, of *Amia calva*, Structure of, XII: 165.
- Stomach, of Pig, Morbid Growth in, V: 125.
- Stomata, of Endothelium, XXIII: 63.
- Stowell, T. B. The Soft Palate in the Domestic Cat, X: 58.
- Stratton, S. W. and Burrill, T. J. A Heliostat for Photo-micrography, VII: 103.
- Structure and Classification of the Conjugatae, The, with a Revision of the Families and a Rearrangement of the North American Genera—Chas. E. Bessey, XXIII: 145.
- Structure and Classification of the Phycomycetes, The, with a Revision of the Families and a Rearrangement of the North American Genera—Chas. E. Bessey, XXIV: 27.
- Structure and Development of Buds in the Leaf of *Bryophyllum calycinum*, Salisb.—W. W. Rowlee, XIV: 80.
- Structure of Some Paleozoic Spines from Ohio, On the—E. W. Claypole, XVIII: 151.
- Structures of the Bone of *Dinichthys*—E. W. Claypole, XV: 189.
- Structure of the Diatom Valve, The—R. P. H. Durkee, VI: 105.
- Structure of the Fruit in the Order Ranunculaceae, The—Karl McKay Wiegand, XVI: 69.
- Structure of the Muscles of the Lobster—M. L. Holbrook, IV: 131.
- Structure of the Stomach of *Amia calva*—Grant S. Hopkins, XII: 165.
- Structure of the Teeth of the Devonian Cladodont Sharks, On the—E. W. Claypole, XVI: 191.
- Studies of the Development of Cartilage in the Embryo of the Chick and Man—M. L. Holbrook, VII: 76.
- Studies on the Genus *Cittotaenia*—Rufus Ashley Lyman, XXIII: 173.

- Study of Blood, A—Lester Curtis, III: 39.
- Study of the Cellular Pathology of Carcinoma, A—Clifford Walcott Kellogg, XVIII: 248.
- Study of the Centimeter, Marked "A," Prepared by the U. S. Bureau of Weights and Measures for the Committee on Micrometry, A—Wm. A. Rogers, V: 184.
- Study of the Microscopic Phenomena of Inflammation, A, with Special Reference to the Diapedesis of the White Blood Corpuscle—Charles F. Craig, XVI: 165.
- Study of the Muscular Tunic of the Large and Small Intestines of Man in the Vicinity of the Caecum, A—Robert Orton Moody, XVI: 197.
- Study of the Organs of Taste, A—A. E. Loveland, XIX: 129.
- Subterranean Fauna, of Texas, XXIII: 83.
- Summers, Henry E. An Improved Method of Constructing Slide Cabinets, VII: 108.
- Symplocarpus foetidus*, Life-history of, XVII: 157.
- Synchaeta bicornis*: A New Rotifer from the Brackish Waters of Lake Pontchartrain, Louisiana—J. C. Smith, XXV: 121.
- Syracuse Solid Watch-glass—A. Clifford Mercer, VI: 178.
- Systematic Examination of Objectives for the Microscope, with a Convenient Form for Recording Results, On the—Geo. E. Blackham, I: 62.
- Systematic Photomicrography and Apparatus Pertaining Thereto—James B. Shearer, XVIII: 117.
- Tape Worm, The. Methods of Preparation for the Museum and the Microscope—J. M. Stedman, IX: 243.
- Taste, Organs of, XIX: 129.
- Taylor, Thomas. A New Freezing Microtome, IV: 153; Internal Parasites in the Common Fowl, V: 131; Butter and Fats, To Distinguish One Fat from Another by Means of the Microscope, (1 Col. Plate), VII: 128; Reply to Professor Weber, (1 Plate), VIII: 116; The Crystallography of Butter and Other Fats, (6 Plates), IX: 315; A New Pocket Polariscopes—Oleomargariscopes, X: 159; Microscopic Investigations Relating to Tea and its Adulterations, (8 Plates), XI: 46.
- Tea, and its Adulterations, XI: 46.
- Teaching Microscopical Science in Medical Schools, XVIII: 311.
- Technique, Histologic, XVIII: 291; Methods in, XIX: 175; Notes on, XVIII: 287.
- Teeth of Devonian Cladodont Sharks, XVI: 191.
- Teeth of *Mazodus*, On the—E. W. Clappole, XVIII: 146.
- Temperature, in Comparison of Standards of Length, VIII: 67.
- Termination of the Nerves in the Kidney, The—M. L. Holbrook, V: 51.
- Termination of the Nerves in the Liver, The—M. L. Holbrook, IV: 95, 264.
- Tetanus, Micro-Organisms in Blood of a case of, IV: 157.
- Texas, Subterranean Fauna of, XXIII: 83.
- Textile Fabrics, Investigation of Burns and Scorches on, XIII: 1.
- Thermocline, The, and its Biological Significance—E. A. Birge, XXV: 5.

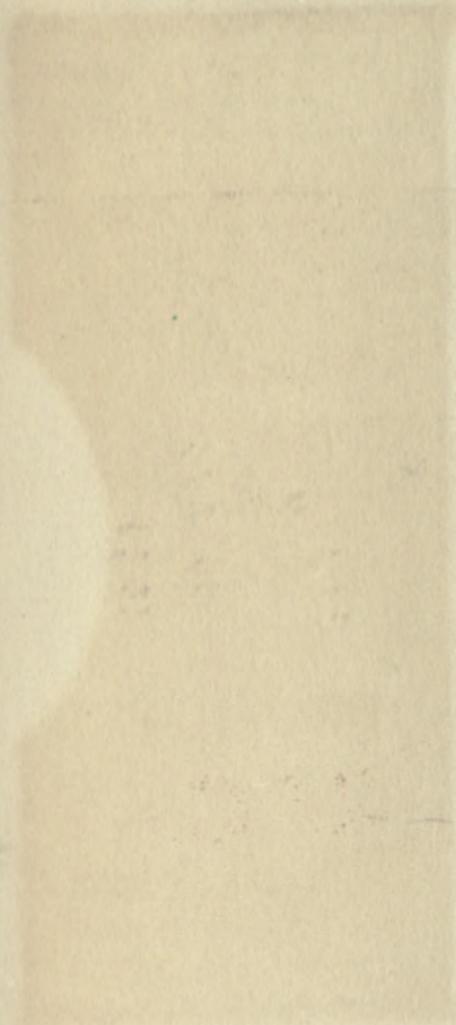
- Thomas, Mason B. Collodion Method in Botany, XII: 123.
- Thornbury, Frank J. The Increasing Pollution of our Municipal Water-supplies, XVIII: 182.
- Thoughts on the Spongidaë—Henry Mills, VI: 131.
- Three New Accessories for the Microscope—E. H. Griffith, XIII: 47.
- Tissue Elements, Isolation of, XIX: 179.
- Tissues, Isolated by Means of Caustic Potash or Nitric Acid, Staining and Permanent Preservation of, XI: 34; Rapid Preparation of, XII: 120.
- Toad, Regeneration of Intestinal Epithelium in, XX: 45.
- Tolles, Robert B. and the Angular Aperture Question, VI: 5; Debt of American Microscopy to, XXIII: 19; Elected an Honorary Member, VI: 253; Memoir of (with Portrait), VI: 41.
- Tolman, Henry L. Hints on Expert Testimony, XIII: 64.
- Treasurer's Report, II: 80; III: 97; IV: 286; V: 219; VI: 282; VII: 213; VIII: 198; IX: 324; XI: 142; XII: 252; XIII: 209; XIV: 36; XV: 34; XVI: 18; XVII: 94; XVIII: 46; XIX: 194; XX: 353; XXI: 263; XXII: 209; XXIII: 281; XXIV: 178; XXV: 173.
- Trichinaë, Determination of the Number of in Meat, IX: 191.
- Tube-length, Report of Committee of the American Society of Microscopists on Uniformity of, XII: 250.
- Tuberculosis, Limitation of, XVI: 101.
- Tumor of the Left Auricle—D. N. Kinsman, III: 29.
- Tumors, Diagnosis of, XIV: 71; Malignant, Relation of Yeasts to, XVIII: 119.
- Turn-table, Brownell, VI: 173.
- Turn-tables, Griffith's, VI: 165.
- Turtle, Soft-shelled, Brain of, XVII: 185.
- Tuttle, Albert H. On the Occurrence of Gregarina in the American Lobster, III: 47.
- Two Growths of Chlamydomonas in Connecticut—Fred'k S. Hollis, XXIV: 13.
- Two New Combined Inverted and Vertical Microscopes—Edward Bausch, VIII: 148.
- Two New Forms of Stage Micrometers—M. D. Ewell, XII: 76.
- Two Very Simple Microtomes—Edward Pennock, XIX: 189.
- Typhoid Fever, Bacteria in Ice, Relation to, XI: 70.
- Typhlomolge rathbuni Stejneger, Eyes of, XXI: 49.
- Udder, Bacteria in Milk Ducts of, XX: 57.
- Ulrich, Carl Jost. A Contribution to the Subterranean Fauna of Texas (5 Plates), XXIII: 83.
- Unconscious Influence of Science Studies, The. President's Address—Hamilton L. Smith, VII: 5.
- United States, Desmidiaë of, V: 137.
- Universal Screw for Microscope Objectives, The—Edward Bausch, VI: 153.
- Up de Graff, T. S. Descriptions of Certain Worms, V: 117; Memoir of, VII: 216.
- Uredineaë of Illinois, The—A List of the Species—T. J. Burrill, VII: 93.

- Urine, Acid, Effect of Dilute Solutions, upon Red Blood Corpuscles, XV: 129;
Ammoniacal Fermentation of, XII: 97.
- Urquhart, Thomas Hill. Memoir of, XIV: 159.
- Use of Formalin in Neurology, The—Pierre A. Fish, XVII: 319.
- Use of Nitrite of Amyl for Fine Injections—B. L. Oviatt and E. H. Sargent,
VIII: 140.
- Use of Stains, especially with Reference to Their Value for Differential
Diagnosis, The—Vida A. Latham, XIII: 94.
- Use of the Amplifier, with Observations on the Theory and Practice of
Photo-micrography, suggested by the Design of a New Photo-Micro-
Camera, On the—Geo. W. Rafter, IX: 263.
- Use of Wax Cells in Connection with White Zinc Cement for Fluid Mounts,
On the—W. H. Walmsley, II: 63.
- Ustilagineæ, or Smuts, The; with a List of Illinois Species—T. J. Burrill,
X: 45.
- Vagi, Effects of Division on the Heart, IV: 91; Effects of a Division of, on
the Muscles of the Heart, V: 47.
- Value of Cheap Microscopes for Educational Purposes, On the—E. W. Clay-
pole, XIV: 60.
- Veeder, M. A. Public Water Supply for Small Towns, XVIII: 176; Ques-
tion in Regard to the Diphtheria Bacillus, XX: 81; Defective Development
and Disease, with Special Reference to the Curability of Consumption and
Cancer, XXI: 17.
- Vegetable Materials, A New Section Instrument for, XVI: 121.
- Vegetable Nature of Croup, The—Micrographical Contribution—Ephraim
Cutter, IV: 101.
- Verification of Microscopic Observations, The. President's Address—Albert
McCalla, V: 1.
- Vertebrates, Blind, Eyes of, XXI: 49.
- Victoria Regia—William H. Seaman, XIII: 163.
- Vorce, C. M. Some Observations upon the Destructive Powers of Certain
Insects (2 Plates), I: 68; The Microscopical Examination of Writing for
the Detection of Forgery, Alteration, etc., II: 50; Penetration in Objec-
tives. Is it a Defect or an Advantage? II: 70; Forms observed in Water
of Lake Erie (1 Plate), III: 51; Wholesale Destruction of Acari by a
Fungus, III: 49; Microscopic Forms observed in Water of Lake Erie (1
Plate), IV: 187; A Memoir of William B. Reznor, V: 242; A Combined
Focusing and Safety Stage for Use in Micrometry with High Powers,
VII: 115; Remarks on *Stephanodiscus Niagare*, VII: 139; Note on a New
Rotifer.—*Gomphogaster Areolatus* (1 Plate), IX: 250; Memoir of Allen Y.
Moore, M.D., IX: 327; A New *Daphnella*, (1 Plate), XII: 172; Additional
Notes on *Gomphogaster*, XII: 174; Memoir of Jacob Dolson Cox, XXII:
197; Memoir of (Portrait, p. 162), XXIV: 163.
- Walmsley, W. H. On the Use of Wax Cells in Connection with White Zinc
Cement for Fluid Mounts, II: 63; Micro-photography with Dry-Plates and
Lamp-Light, and its application to making lantern positives, V: 59, 273;

- A Handy Photomicrographic Camera, XII: 69; Some New Points in Photo-micrography and Photo-micrographic Cameras, XVII: 340; Acetylene Gas as the Illuminant in Photo-micrography, XVIII: 136; Photo-micrography with Opaque Objects (1 Plate), XX: 189.
- Ward, Archibald R. The Persistence of Bacteria in the Milk Ducts of the Cow's Udder (1 Plate), XX: 57.
- Ward, Henry B. On the Parasites of the Lake Fish, (1 Plate), XV: 173; American Work on Cestodes in 1893, XV: 183; The Food Supply of the Great Lakes; and Some Experiments on Its Amount and Distribution, (2 Plates), XVII: 242; A New Method for the Quantitative Determination of Plankton Hauls, XVII: 255; Development of Methods in Microscopical Technique, XIX: 175; Freshwater Investigations during the last Five Years, XX: 261; A Plea for the Study of Limnobiology, XXI: 201; Notes on the Parasites of the Lake Fish, (1 Plate), XXII: 175; Data for the Determination of Human Entozoa, (4 Plates), XXIV: 103; Biological Reconnaissance of some Elevated Lakes in the Sierras and the Rockies, (12 Plates), XXV: 127.
- Ward, Henry B., Graybill, H. W., and others. A Comparative Study in Methods of Plankton Measurements, (3 Plates), XXI: 227.
- Ward, R. H. Annual Address of President, I: 35; History of the National Committee on Micrometry, V: 178; The Iris Illuminator, VI: 160; New Lens Holder, VI: 162; Micrometer Wires, VIII: 89; Remarks on the Methods of Making Microscopical Societies Successful, VIII: 94; On a Microscopical Slide—catalogue, IX: 233; Note on Microscopical Exhibitions, IX: 311; Remarks on the Fasoldt Test-plate, IX: 318; An Expedient for Use in Difficult Resolution, XXI: 111; Library Experiments in Microscopy. Indexing, Cataloguing, Preparing and Arranging Literature and Slides, XXI: 127; Memoir of Chas. Marvin Voree, (Portrait, p. 162), XXIV: 163.
- Watch-glass, Syracuse Solid, VI: 178; Improved Syracuse, XVII: 371.
- Water Mites, Classification of, XXII: 105; New Genera of, XXI: 177; XXII: 105.
- Water, Purification of, XV: 211.
- Water Supplies, Chlamydomonas and Effect on, XXI: 97; Surface, Advantages of Field Work on, XXII: 13; Surface, Growths in, XXII: 49; Surface, Collecting Samples for Examination, XXII: 49.
- Water Supply, of Cities, Growth of Certain Diatoms in and Relation thereof to Impurities, IV: 197; Pollution of, XVIII: 182; Public, for Small Towns, XVIII: 176; Pure, XVIII: 165.
- Water Works, Brooklyn, XXII: 25.
- Wax, Sheet, Punches for, VI: 215.
- Wax as a Cell Material—Jas. E. Whitney, VIII: 153.
- Wax Cells, How to Make, VI: 214; In Connection with White Zinc Cement for Fluid Mounts, II: 63; Making and Finishing, XVII: 374.
- Weber, H. A. Microscopic Examination of Butter and Its Adulterants, (1 Col. Plate), VIII: 103.
- Weisiger, Wm. R., Memoir of, VI: 250.

- Wenham Binocular, The. Can it be made Adjustable to a Variable Tube Length?—Thomas D. Biscoe, XIV: 57.
- West, Charles E. Forty Years' Acquaintance with the Microscope and Microscopists, VIII: 161; The Binocular Microscope of the Seventeenth Century. (1 Plate), XII: 57.
- What is the Best Method of Teaching Microscopical Science in Medical Schools?—Vida A. Latham, XVIII: 311.
- Wheel-like and other Spicula of the Chirodota of Bermuda, The—F. M. Hamlin, IV: 139.
- Whipple, Geo. C. Chlamydomonas and Its Effects on Water Supplies, (1 Plate), XXI: 97.
- Whipple, Geo. C. The Work of Mt. Prospect Laboratory of the Brooklyn Water Works, (4 Plates), XXII: 25.
- Whipple, Geo. C. and Parker, Horatio N. On the Amount of Oxygen and Carbonic Acid Dissolved in Natural Waters and the Effect of these Gases upon the Occurrence of Microscopic Organisms, (4 Plates), XXIII: 103.
- White, Moses C. The Red Blood Corpuscle in Legal Medicine, (12 Plates), XVIII: 201; Photo-spectrography of Colored Fluids, (1 Plate), XXII: 99; Memoir of, (Portrait, p. 203), XXII: 202.
- Whiting, Sarah F. College Microscopical Societies, V: 27.
- Whitney, Jas. E. Cheap Punches for Sheet Wax, VI: 215; A Cheap and Efficient Life-box, VI: 215; Rapid Section Cutting, VII: 122; Wax as a Cell Material, VIII: 153.
- Wholesale Destruction of Acari by a Fungus—C. M. Vorce, III: 49.
- Wiard, Martin S. A Busy Man's Amateur Microscopic Laboratory, XI: 126.
- Wiegand, Karl McKay. The Structure of the Fruit in the Order Ranunculaceæ, (8 Plates), XVI: 69; Intercellular Spaces in the Embryos of *Erechtithes hieracifolia* and *Bidens cernua*, (1 Plate), XVII: 174.
- Wolcott, Robert H. On the North American Species of the Genus *Atax* (Fabr.) Bruz., (5 Plates), XX: 193; New Genera and Species of North American Hydrachnidæ, (4 Plates), XXI: 177; Description of a New Genus of North American Water Mites, with Observations on the Classification of the Group, (1 Plate), XXII: 105; The North American Species of *Curvipes*, (5 Plates), XXIII: 201; The North American Species of *Limnesia*, (2 Plates), XXIV: 139.
- Wolle, Francis. Notes on the Desmidiæ of the United States, V: 137; Memoir of, (Portrait, p. 244), XV: 245.
- Woodward, Joseph Janvier, Memoir of, VI: 253.
- Word Concerning Filar Micrometers, A—Wm. A. Rogers, XIV: 132.
- Work of Mt. Prospect Laboratory of the Brooklyn Water Works, The—Geo. C. Whipple, XXII: 25.
- Working Cabinet, The Griffith Microscopist's, VI: 168.
- Working Session, VI: 199; VII: 203; VIII: 174; XI: 143.
- Worms, Descriptions of, V: 117.
- Writing, Microscopical Examination of, II: 50.

- Yeasts and their Relation to Malignant Tumors—Allen Ross Defendorf, XVIII: 119.
- Young, A. A. The Physician and His Microscope, XVIII: 71; Medical Microscopy, XX: 87.
- Zentmayer's American-continental Stand, XIV: 48.
- Zentmayer's Dissecting Microscope, XIV: 51.
- Zentmayer, Joseph, Memoir of, XIV: 161.
- Zoophily versus Homophily—Pierre A. Fish, XVIII: 142.



1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900

QH
201
A3

American Microscopical
Society
Transactions

<p>CALL NO:</p> <p>QH 201 A3</p>	<p>AUTHOR:</p> <p>American Microscopical Society</p>
<p>V. 24-5 1902-3 cop 2 BMS</p>	<p>TITLE:</p> <p>Transactions</p> <p>UNIVERSITY OF TORONTO LIBRARY</p> <p>VOL:</p>

STORAGE

