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CONTRIBUTIONS TO THE BIOLOGY OF THE GREAT LAKES.

A REPORT OF WORK ON THE PROTOZOA OF LAKE ERIE, WITH ESPECIAL REFERENCE TO THE LAWS OF THEIR MOVEMENTS.*

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The general plan of work outlined in the preceding paper for a study of the Rotatoria in their relations to the life conditions of the lake would apply equally, with some changes, to the Protozoa or to almost any other group of animals. In the study of the Protozoa it was decided to strike at once for the heart of the matter by beginning an investigation of the laws of their activities. A typical and very abundant Infusorian, *Paramecium caudatum*, was selected for special examination, and a study was made of the nature of its activities and the laws which govern them, in the hope that a full knowledge of such laws in the case of one Protozoan might furnish a key to an understanding of the activities of other members of the group, as well as, in time, to those of higher animals. The results of this work have already been published in detail elsewhere, so that a brief résumé is all that will be presented here.

The work was successful in determining the general mechanism of the reactions of Paramecium to changes in the external conditions, and in showing that the reactions are of the same essential nature in many other Protozoa. It was shown that the reactions of Paramecium are of extraordinary simplicity. As will be recalled by most biologists, Paramecium is a somewhat cigar-shaped animal, with one end narrow and blunt, the other broad but pointed. From the blunt end a groove passes obliquely along one side of the body to the middle, ending there in the mouth. The side on which the mouth and groove lie may be distinguished as the oral side; the opposite side (on which the contractile vacuoles lie) as the aboral side. The entire surface of the animal is covered with cilia, by means of which it moves. As it more usually moves in the direction of the narrower, blunter end, that may be called the anterior end, the other the posterior end.

In what might be called the normal condition of affairs all of the cilia strike backward, so that the animal moves forward; at the same time it revolves on its long axis. Now, when a change is produced in the environment of the Paramecium, such as by it striking against an obstruction or passing into water of different chemical content or different temperature, the normal activity is modified in one of two ways:

1. If the Paramecium comes in contact with a solid body of a loose fibrous texture, its activity is decreased; the cilia on the surface of the body cease their

* The papers in this series are based on investigations of the U. S. Fish Commission under direction of Prof. Jacob Reighard, of the University of Michigan. The following have already appeared:

The Mechanism of the Motor Reactions of Paramecium. <Am. Jour. Physiology, vol. II, pp. 311-341.

Laws of Chemotaxis in Paramecium. <Am. Jour. Physiology, vol. II, pp. 355-379.

movement, while those in the oral groove and the gullet continue active. As a consequence locomotion ceases; the animal comes to rest against the solid body, while the cilia of the oral groove continue to drive a stream of water to the mouth. This reaction to a solid body may be called thigmotaxis. If the loose solid body is a mass of bacterial zoogloea, the stream of water carries numbers of bacteria to the mouth, where they pass into the internal protoplasm of the animal and are digested; thus Paramecium gets its food. But the animal conducts itself in exactly the same way toward other loose fibrous bodies, such as bits of cloth, paper, sponge, or the like, the presence or absence of material that will serve as food having nothing to do with the production of the reaction. On the other hand, the substances held in solution in the water have a marked effect on the tendency of the Paramecia to react in the manner above described. If the water is faintly acid in reaction, the Paramecia are much more inclined to come to rest as just described. This is especially noticeable in water containing carbon dioxide. The presence in the water of an alkali in solution has, on the other hand, precisely the opposite effect, tending to inhibit the thigmotactic reaction.

2. Any other change in the conditions, of such a nature as to act as a stimulus, causes a definite change in the movements, which is of a stereotyped character, being of the same nature for almost every stimulus. When stimulated, Paramecium swims backward, turns toward its own aboral side, then swims forward again. The same reaction is produced by stimuli of the most varied kinds—by acids, alkalis, and neutral salts, by heat, by cold, by mechanical shock. The reaction is the same whether the stimulus first affects the anterior end, the posterior end, one side, or the entire surface of the animal at once. The direction in which the animal swims has thus no relation to the localization of the stimulus. If the stimulus comes from the anterior end, swimming backward of course carries the animal away from it; if the same stimulus comes from the posterior end, swimming backward carries the animal toward it. If an injurious chemical substance diffuses in such a way as to first come in contact with the posterior end of a resting Paramecium, the latter therefore swims backward directly into the substance and is killed. The turning is likewise without relation to the position of the stimulus. The animal always turns toward its own aboral side, so that the absolute direction in which it turns depends upon the chance position of the aboral side when the turning begins. As the animal continually revolves, both when swimming forward and when swimming backward, it is impossible to predict in which direction the aboral side will lie after the animal has swum backward a distance from its position when stimulation occurs; and observation shows that when Paramecium strikes on one side against an obstruction, it is fully as likely to turn toward the obstruction, after swimming backward, as to turn away. In the former case it of course strikes the obstruction again; the whole reaction is then repeated. Owing to the continual rotation on the long axis, the aboral side will probably be in a new position next time, so that the animal will turn in a new direction. If this repetition is continued, the Paramecium is certain finally, by the laws of chance, to avoid the obstacle.

The factors determining the direction of motion in Paramecium are thus internal; the direction of its movements has no relation to the position of external objects. This result is of fundamental significance for interpretation of the movements of these creatures, and throws a flood of light on many of the phenomena of their life. Study of some other Infusoria in the light of the result on Paramecium has shown that the same is true for these. *Spirostomum ambiguum* when stimulated contracts, swims backward, turns toward the aboral side, and swims forward. If touched with a spicule of glass at its anterior end it swims backward, *away* from the glass; if touched at the posterior end it likewise swims backward, therefore *toward* the glass. *Stentor polymorphus* when stimulated contracts, swims backward, turns to the right, then swims forward, the direction of motion having, as in the other cases, no relation to localization of the stimulus. Similar results, not yet published in detail, have been obtained with certain Flagellata, as well as with other Ciliata.*

Besides determining the general mechanism of the reactions of Paramecium, an extended study was made of the effects upon its activities of different chemicals. If into a preparation of Paramecia mounted upon the slide a drop of some chemical substance in solution is introduced, the Paramecia may either collect in the drop or leave it entirely empty. In the former case they show positive chemotaxis to the substance; in the latter case, negative chemotaxis. As to what might be called the mechanism of chemotaxis, the following was made out. The Paramecia are not attracted by the drop of substance into which they gather. They may graze the very edge of the drop without swerving a particle from their course so as to pass into it. But Paramecia when first brought upon the slide swim rapidly in every direction, so that many will quickly come by chance against the edge of such a drop. They do not react, but swim straight ahead—the substance in the drop not acting as a stimulus to produce the motor reaction above described. But on passing across the drop, the outer fluid does, after the Paramecia have been in the drop of the chemical, act as a stimulus to produce the motor reaction. The Paramecium therefore, on coming to the outer edge of the drop, swims backward, thus returning into the drop. It then turns toward the aboral side and swims forward (in accordance with the general scheme of reaction above described). It thus comes to the outer edge of the drop once more; reacts again, and this being kept up, is continually prevented from crossing the boundary of the drop into the surrounding water. The same process is repeated for many Paramecia, until in time the drop swarms with the Infusoria, so that they appear to have been attracted into it.

In case of a substance in which the Paramecia do not collect at all, observation shows that the motor reaction (swimming backward, turning, and swimming forward) is produced when the Paramecia come against the drop from the outside; hence they are prevented from entering and the drop remains empty.

It was found possible to classify chemical compounds thus into two classes. On the one hand may be placed together those which do not produce the reaction when the Paramecia enter them, but throw the animals into such a physiological condition that they do react when they pass out of a drop containing the substance in question. In these the Paramecia, therefore, gather and are said to be positively chemotactic toward them. On the other hand are substances which produce the motor reaction as soon as the Paramecia come in contact with them, so that the animals do not enter

* The reactions of a large number of Protozoa have been studied since the above was written. In all of these the direction of turning was found to be determined entirely by internal factors, and to have no relation to the position of the source of stimulus. The direction of motion along the body axis, on the other hand, was found in a number of cases, for mechanical stimuli, to be determined by the localization of the stimulus. *Loxodes rostrum*, for example, when touched with a glass rod at the anterior end swims backward; touched at the posterior end it swims forward. For chemical stimuli, however, the *absence* of any such dependence of the direction of movement on the localization of the stimulus was demonstrated. For details, see a paper by the author on "The movements and motor reflexes of the Flagellata and Ciliata," in the American Journal of Physiology, January, 1900.

solutions of these compounds at all, and may be said to be negatively chemotactic toward them.

In the former group (substances toward which the Paramecia show positive chemotaxis) belong all acids, and salts whose solutions have an acid reaction or contain hydrogen ions, as in salts of the heavy metals. In the group of substances toward which the Paramecia are negatively chemotactic belong all alkalies and substances having an alkaline reaction, as well as almost all compounds which contain ions of the alkali and earth alkali metals in their solutions. Certain substances take an intermediate place. Containing the ions of an alkali or earth alkali metal, they produce the motor reaction when the Paramecia enter a drop of fluid containing them; but having likewise hydrogen ions, they also cause the animals to react when they leave the drop. Examples of such substances are potassium and ammonium bichromate. In these cases the hydrogen ions seem to be active (in their characteristic way) in a more dilute solution, and, therefore, farther from the center of a diffusing drop than are the ions of the metals. The Paramecia, therefore, enter the outer margin of the drop and are unable to leave it, while at the same time they are unable to pass to the center of the drop. They thus gather in a ring about the drop, leaving the center empty.

The classification of substances into those toward which the Paramecia are positively chemotactic on the one hand and those toward which they are negatively chemotactic on the other, thus follows the lines of a chemical classification; the former including acids, the latter alkalies and salts of the alkali and earth alkali metals.

Experimentation showed that the relative injuriousness of solutions has comparatively little to do with the nature of the chemotaxis. Paramecia are repelled strongly by many substances that are scarcely injurious at all, while they enter without hesitation other substances in which they are at once killed. The repellent powers of different chemical compounds are in no way proportional to their injurious effects.

The researches on chemotaxis have thus far been restricted almost entirely to Paramecium, but the general laws obtained for this animal promise to throw much light on related phenomena in others.

As described above, positive and negative chemotaxis, or the collecting in or avoidance of certain chemicals, takes place through the mechanism of the general motor reaction first described. The only activity of the Paramecia concerned in it all is the swimming backward, turning toward the aboral side, then swimming forward, when stimulated. The qualitative differences that seem apparent in their reactions toward different substances depend merely upon what does and what does not act as a stimulus.

The mechanism of collecting in or avoiding agencies or conditions, other than chemical, is exactly the same as that just described. In the case of temperature, for example, certain grades of heat or cold produce motor reaction, so that the Paramecia do not enter these; or, if already within a zone of such temperature, they continue moving about violently till a chance movement carries them into a region where the temperature is not such as to cause a reaction; there they remain. In general, therefore, the Paramecia gather and remain in substances or conditions which do not cause the motor reaction, while they leave empty such substances or conditions as do cause their one motor reaction. It follows that they collect in regions of a certain temperature, avoiding great heat or cold, and that they collect in water holding in solution substances of an acid character, avoiding alkaline solutions. Under natural conditions, their collecting into regions acidulated by carbon dioxide excreted by themselves is particularly noticeable. It results in bringing the Paramecia together in dense swarms. To this is to be added, as a second factor in bringing the Paramecia together, the fact that contact with solids of a loose fibrous texture likewise tends to quiet the Paramecia, so that they collect about such solids. In the fluids in which the Paramecia live, such solids are present as masses of bacterial zoogloea, upon which the Paramecia will usually be seen to be collected in swarms.

The ordinary life of a Paramecium may then be summarized somewhat as follows: In the free water, as long as the animal is unstimulated, it swims forward in a spiral course, revolving on its long axis. But it comes in contact here and there with changes in the environment—regions of higher or lower temperature, or of greater or less amounts of certain chemicals in solution, or with mechanical obstructions. If these changes are of such a nature as to act as a stimulus, the Paramecium thereupon swims backward a short distance, turns toward one side (in a direction which is an entirely random one so far as outer objects are concerned) and continues forward. This reaction is repeated as often as the Paramecium comes in contact with any source of stimulus. Certain solutions or conditions cause no reaction. Thus the Paramecium may pass by chance into a group of other Paramecia, where the water is charged with carbon dioxide, which they have excreted. Now, the surrounding water containing *no* carbon dioxide causes the reaction, so the Paramecium remains with the others. Or, if it comes in contact with a loose, soft body it stops, only the oral cilia continuing to be active. These constantly carry a stream of water to the mouth, and if the solid is by chance a bit of bacterial zoogloea, this stream carries many bacteria into the mouth of the animal, so that they serve as food. But if no bacteria are present, the Paramecium nevertheless remains indefinitely against the bit of solid, especially if joined by other individuals, so that they are in a region containing carbon dioxide (excreted by themselves).

This resting condition may be brought to an end by too high or too low a temperature, by the diffusion of an alkali into the water, or by various other conditions that tend to produce a motor reaction. The Paramecium then continues on its way in some chance direction till it comes again into conditions which do not act as a stimulus.

Thus the life of the animals is extremely simple; they have but one mode of reaction to outer conditions—by swimming backward, turning, swimming forward—while under other conditions their activity largely ceases.

It is obvious that such simple activities, while they do result in keeping Paramecia out of certain conditions and bringing them into others, would not be adequate for preserving the animals under complicated and changing conditions. The Paramecia show no indication of intelligence or even of choice, reacting to everything in the same manner, if they react at all. They have no power of adapting their actions to their needs. Chance is the main factor in bringing the Paramecium into proper conditions and giving it food, and if the chances are not favorable the animals must soon die. This agrees perfectly with the facts observed in cultures of these and similar animals. So long as the conditions are exactly right—bacterial zoogloea covering everything, so that the Paramecia can not miss it, and the chemical condition of the water entirely favorable—the animals swarm and multiply by thousands. A slight change occurs in the conditions, and soon scarcely a Paramecium is to be found, though a few hours previously the water was milky with them. As in the case of plants, the proper conditions are the chief requisite for growth and multiplication;

these infusoria appear and disappear in the culture jar about as the lower algæ do. The power of movement, regulated in the simple manner above described, is correlated with the fact that, unlike plants, they live upon solid food (bacteria) and are therefore more likely to get this food if they can move about here and there. But the bacteria must be abundant in any case, for the Paramecia have no power of searching for them, or of choosing them rather than any other substance.

In future work it is hoped to determine how far the results gained on Paramecium are applicable to the Protozoa as a class, as well as to extend these researches to higher groups, building upon the foundation obtained by a study of these lowest organisms. In this way it is hoped that the laws which govern the movements and migrations of animals, the causes of their appearance and disappearance at certain places or under given conditions, and in fact much of their relations to the conditions surrounding them in the lake, may in time be made out. It is the belief of the writer that this is the most direct and certain way of unraveling the complicated network of relations which make up the life of the lake.

In addition to the study of the reactions of the animals above summarized, some faunistic work was carried on. An examination was made of the waters on and about South Bass Island, with the purpose of determining the abundance and general character of the Protozoan fauna. The swampy waters of this region were found to swarm with Protozoa of all sorts, offering unlimited supplies of material for work on the group in experimental or other lines. Unfortunately, the literature was not at hand for complete identification of all the species observed, so that critical systematic work, of the sort done on the Rotatoria, could not be carried on for the Protozoa. Only those could be positively identified that agreed completely with species described in the standard works on the Protozoa—Leidy's *Rhizopoda*, Kent's *Manual of the Infusoria*, Bütschli's *Protozoen*, Eyferth's *Die einfachsten Lebensformen des Thier-und Pflanzenreiches*, Blochmann's *Die mikroskopische Thierwelt des Süsswassers*, Pritchard's *Infusoria*, Ehrenberg's *Die Infusionsthierchen als vollkommene Organismen*, etc.

The following list therefore contains the names of such species only as could be fully identified, and comprises thus but a fraction of the Protozoan fauna of the region. It is given in order to show something of the character of the abundant Protozoan fauna of these waters, as well as to point out forms that are of especial interest as favorable objects for investigation. Especial attention was paid to forms which from their size, or from the possibility of securing them in great abundance, promise to be particularly favorable for experimental work.

LIST OF SOME OF THE PROTOZOA FOUND IN THE WATERS ABOUT SOUTH BASS ISLAND, IN LAKE ERIE, DURING THE SUMMER OF 1898.

The waters examined were the same as those mentioned in the account of the Rotatoria. The list includes 68 species, distributed among the different groups as follows: Rhizopoda 13, Heliozoa 1, Mastigophora 21, Ciliata 32, Suctoria 1.

RHIZOPODA.

1. **Amœba proteus** Leidy. Taken in a water-bottle collection from the upper 3 feet of the surface of Lake Erie, 1 mile west of South Bass Island; also on *Elodea* from East Harbor and in the swamps on South Bass Island.
2. **Amœba villosa** Wallich. In the water-bottle collection from the upper 3 feet of the water of Lake Erie, 1 mile west of South Bass Island.
3. **Amœba radiosa** Ehrenberg. In the water-bottle collection from the upper 3 feet of the water of Lake Erie, 1 mile west of South Bass Island; also on *Elodea* from East Harbor, Lake Erie.
4. **Pamphagus hyalinus** Ehr. In surface towings in Put-in Bay Harbor, Lake Erie.
5. **Cochliopodium bilimbosum** Auerbach. In water-bottle collection from upper 3 feet of water of Lake Erie, 1 mile west of South Bass Island; also on *Elodea* from East Harbor, Lake Erie.
6. **Difflugia lobostoma** Leidy. In towings in Put-in Bay Harbor, Lake Erie; also from East Swamp on South Bass Island.
7. **Difflugia corona** Wallich. In surface towings from Put-in Bay Harbor, Lake Erie; also from East Harbor, Lake Erie; from Portage River, Ohio, and land-locked pools on Starve Island.
8. **Difflugia globulosa** Duj. In water-bottle collection from the surface 3 feet of Lake Erie, 1 mile west of South Bass Island; from surface towings in Put-in Bay Harbor; from East Harbor, and from the swamps on South Bass Island.
9. **Difflugia constricta** Ehr. In *Utricularia* from Portage River, Ohio.
10. **Difflugia pyriformis** Perty. In the swamp near the fish-hatchery on South Bass Island; in *Utricularia* from Portage River, Ohio.
11. **Arcella vulgaris** Ehr. In surface towings in Put-in Bay Harbor, Lake Erie; in East Harbor on *Elodea;* in the swamps on South Bass Island; from Portage River, Ohio.
12. **Centropyxis aculeata** Stein. In swamps on South Bass Island.
13. **Euglypha alveolata** Duj. Swamps on South Bass Island.

HELIOZOA.

14. **Acanthocystis chætophora** Schrank. In plankton haul from Lake Erie, just west of South Bass Island; on *Elodea* from East Harbor, Lake Erie.

MASTIGOPHORA.

15. **Oikomonas termo** J. Clark. Abundant on floating flocculent material on the surface of Lake Erie, northeast of North Bass Island.
16. **Anthophysa vegetans** Müller. On *Elodea* from East Harbor, Lake Erie; from swamp on South Bass Island.
17. **Dinobryon sertularia** Ehr. On vegetation from East Harbor, Lake Erie.
18. **Euglena viridis** Ehr. In water-bottle collection from upper 3 feet of Lake Erie, taken 1 mile west of South Bass Island. Abundant in swampy parts of East Harbor, Lake Erie, and in the swamps on South Bass Island.
19. **Euglena spirogyra** Ehr. East Swamp, South Bass Island; Portage River, Ohio.
20. **Euglena oxyuris** Schm. East Swamp, South Bass Island.
21. **Amblyophis viridis** Ehr. East Swamp, South Bass Island.
22. **Colacium steinii** Kent. On *Diaptomus* sp. in surface towings from Lake Erie.
23. **Colacium vesiculosum** Ehr. On *Cyclops* in towings taken 2¼ miles north of Kelley Island, in Lake Erie; on *Polyarthra platyptera* and various crustaceans in swamps on South Bass Island.
24. **Trachelomonas hispida** Perty. In East Swamp, on South Bass Island; from Portage River, Ohio.
25. **Trachelomonas volvocina** Ehr. Amid filamentous algæ from East Harbor, Lake Erie; from Portage River, Ohio; from swamps on South Bass Island.

26. Trachelomonas aspera Ehr. Swamp on South Bass Island.

27. Trachelomonas armata Ehr. In aquatic vegetation from East Harbor, Lake Erie, and from East Swamp on South Bass Island.

28. Phacus longicaudus Ehr. From East Harbor, Lake Erie, and from swamps on South Bass Island.

29. Phacus triqueter Ehr. East Harbor, Lake Erie, and East Swamp, South Bass Island.

30. Astasia trichophora Ehr. On *Elodea* from East Harbor, Lake Erie.

31. Entosiphon sulcatum Duj. In jar of decaying *Nelumbo lutea* from East Harbor, Lake Erie.

32. Synura uvella Ehr. East Swamp, South Bass Island.

33. Chilomonas paramecium Ehr. Abundant in decaying water-plants from any part of Lake Erie or the swamps on South Bass Island. This is one of the species that can always be procured in unlimited quantities at any time.

34. Monosiga steinii Kent. On stems of *Epistylis plicatilis* from East Swamp, South Bass Island.

35. Peridinium tabulatum Ehr. In water-bottle collection from upper 3 feet of Lake Erie, 1 mile west of South Bass Island; also in aquatic plants from East Harbor, Lake Erie, and from the swamps on South Bass Island.

CILIATA.

36. Trachelocerca olor O. F. M. In *Utricularia* from Portage River, Ohio.

37. Coleps hirtus Ehr. Swamp near fish-hatchery on South Bass Island.

38. Amphileptus meleagris Ehr. In aquatic plants from East Harbor, Lake Erie.

39. Amphileptus margaritifer Ehr. In aquatic vegetation from Put-in Bay Harbor and East Harbor, Lake Erie.

40. Lionotus fasciola Ehr. In aquatic plants from East Harbor, Lake Erie.

41. Loxophyllum meleagris Ehr. On *Myriophyllum* from East Harbor, Lake Erie.

42. Trachelius ovum Ehr. On *Utricularia* from Portage River, Ohio.

43. Dileptus anser O. F. M. On aquatic plants from Put-in Bay Harbor, Lake Erie, and the swamps near the fish-hatchery on South Bass Island.

44. Nassula ornata Ehr. East Harbor, Lake Erie; Portage River, Ohio; East Swamp, South Bass Island.

45. Glaucoma scintillans Ehr. Common in cultures of decaying lake plants.

46. Colpidium cucullus Schrank. Abundant in infusions of decaying *Ceratophyllum* from the bottom of Put-in Bay Harbor, Lake Erie.

47. Paramecium caudatum Ehr. Abundant in cultures of decaying lake plants from the bottom of Put-in Bay Harbor, Lake Erie. See pp. 105–110 for an account of the laws of the movements of this animal.

48. Urocentrum turbo O. F. M. Abundant in decaying *Ceratophyllum* from the bottom of Put-in Bay Harbor, Lake Erie; also in water from East Swamp on South Bass Island.

49. Cyclidium glaucoma Ehr. In jar of decaying *Nelumbo lutea* from East Harbor, Lake Erie; many.

50. Spirostomum ambiguum Ehr. East Harbor, Lake Erie, and the swamps on South Bass Island.

51. Bursaria truncatella Müller. This enormous infusorian was common in the swamp near the fish-hatchery on South Bass Island.

52. Stentor cæruleus Ehr. In aquatic vegetation from East Harbor, Lake Erie, from Portage River, Ohio, and the swamps on South Bass Island.

53. Stentor igneus Ehr. In *Elodea* from East Harbor, Lake Erie.

54. Strombidium turbo C. and L. In decaying *Nitella* from East Harbor, Lake Erie.

55. Halteria grandinella Müller. Many in *Utricularia* from Portage River, Ohio.

56. Tintinnopsis cylindrica Daday. An empty shell of what appears to be this species, recently described by Daday, was taken in the water-bottle collection from the upper 3 feet of Lake Erie, 1 mile west of South Bass Island.

57. Codonella cratera Leidy. In towings from Put-in Bay Harbor, Lake Erie. This seems to be the same as the European *Codonella lacustris*, but Leidy's name has the priority.

58. Holosticha mystacea Stein. In the water-bottle collection from the upper 3 feet of Lake Erie, 1 mile west of South Bass Island.

59. Uroleptus musculus Müller. Few in decaying *Nitella* from East Harbor, Lake Erie.

60. Oxytricha fallax Stein. Common in decaying *Ceratophyllum* from the bottom of Put-in Bay Harbor, Lake Erie.

61. **Trichodina pediculus** Ehr. On *Diaptomus* from towings in Put-in Bay Harbor; on *Hydra* from East Harbor, Lake Erie.

62. **Vorticella convallaria** L. Very abundant on algæ from East Swamp, South Bass Island.

63. **Vorticella chlorostigma** Ehr. Forming large green patches visible to the naked eye, on the vegetation from East Swamp, South Bass Island.

64. **Vorticella rhabdostyloides** Kellicott. Common on *Anabæna* in towings from Lake Erie.

65. **Zoothamnium arbuscula** Ehr. In surface towings in Put-in Bay Harbor, Lake Erie, attached to floating matter.

66. **Epistylis plicatilis** Ehr. Abundant on *Chara* from East Swamp, South Bass Island, in company with *Megalotrocha alboflavicans*.

67. **Vaginicola crystallina** Ehr. On aquatic plants from East Swamp, South Bass Island. What seems the same form is often found on *Fragillaria* in towings from Lake Erie; these specimens are always much smaller, however.

SUCTORIA.

68. **Acineta mystacina** Ehr. On floating floccose material taken with the tow net in Put-in Bay Harbor, Lake Erie.

While the fauna inhabiting the plants of the bottom and about the shores of this part of Lake Erie is very rich in Protozoa, both in the number of species and of individuals, the open waters of the lake contain very few. Though 22 species are included in the list, as taken from the waters of the lake away from shore, most of these were present in very small numbers, and none were abundant. The species of the foregoing list found in the open waters of the lake, and on that account apparently to be considered limnetic, are the following:

Amœba proteus.	*Acanthocystis chætophora.*	*Holosticha mystacea.*
Amœba villosa.	*Oikomonas termo.*	*Trichodina pediculus.*
Amœba radiosa.	*Euglena viridis.*	*Vorticella rhabdostyloides.*
Pamphagus hyalinus.	*Colacium steinii.*	*Zoothamnium arbuscula.*
Cochliopodium bilimbosum.	*Colacium vesiculosum.*	*Vaginicola crystallina* (?).
Difflugia corona.	*Peridinium tabulatum.*	*Acineta mystacina.*
Difflugia globulosa.	*Tintinnopsis cylindrica.*	
Arcella vulgaris.	*Codonella cratera.*	

This list includes a number of species not usually recorded from open-lake waters; these are chiefly due to Professor Reighard's collections with the water bottle, which were made as follows: A large corked bottle was sunk in the lake to the desired depth, the cork pulled from the mouth, and the water allowed to fill the bottle. The water thus secured was then filtered, so as to prevent the escape of even the most minute organisms. Collections were thus made from the open lake 1 mile from any land, where the water was 6 fathoms deep. Water was taken from the surface layer not more than 3 feet below the surface. Collections so made contained regularly a number of minute Protozoa not usually accounted limnetic, namely:

Amœba proteus.	*Cochliopodium bilimbosum.*	*Peridinium tabulatum.*
Amœba villosa.	*Difflugia globulosa.*	*Tintinnopsis cylindrica* (only once).
Amœba radiosa.	*Euglena viridis* (once).	*Holosticha mystacea.*

The list is remarkable especially for the three species of *Amœba* and one of *Cochliopodium*. These rhizopods are very minute, and would be lost by the usual methods of collecting. Continued thorough plankton work of the sort carried on by Professor Reighard may show that these are proper members of the limnetic fauna.

Difflugia globulosa was one of the very commonest limnetic forms in all sorts of collections from the open lake.

The passive limnetic forms included in the preceding list are:

Oikomonas termo, on floating floccose material.
Colacium steinii, on *Diaptomus*.
Colacium vesiculosum, on *Cyclops*.
Vorticella rhabdostyloides, on *Anabæna*.
Zoothamnium arbuscula, on floating material.
Vaginicola crystallina (?) on *Fragillaria*.
Acineta mystacina, on floating floccose material.

The following species may be noted as of special interest because of their fitness as objects of investigation in experimental or other lines:

Chilomonas paramecium is a flagellate form that can always be procured in unlimited numbers by simply allowing the aquatic plants to decay in jars. The necessity for large numbers in carrying on experimental work needs no emphasis. The ease with which a Protozoan can be cultivated in the laboratory is almost the most important element in its availability for investigation.

The species of *Euglena*, *Phacus*, and *Trachelomonas* are always to be had in large numbers from East Swamp, South Bass Island.

Trachelius ovum, *Dileptus anser*, and *Nassula ornata* are ciliates which are valuable for certain sorts of work on account of their large size. The same is true to a more pronounced degree of *Spirostomum ambiguum*, and especially of *Bursaria truncatella*. The latter is an enormous creature for a unicellular animal, being a millimeter or more in diameter. It could thus be handled in the same individual way as many of the large Metazoa. This animal was always procurable in small numbers from the swamp near the fish-hatchery on South Bass Island. Doubtless a little experimentation would discover a means of cultivating them in large numbers. Perhaps there is no other Protozoan that would be so favorable an object for an investigation into the effects of localized stimuli and into the question of the localization of functions in the Protozoan body or related problems.

Other ciliates that could always be procured in large numbers are *Glaucoma scintillans*, *Colpidium cucullus*, *Paramecium caudatum*, *Urocentrum turbo*, *Cyclidium glaucoma*, and *Vorticella convallaria*.

For Rhizopoda, three species of *Difflugia*—*D. globulosa*, *D. lobostoma*, and *D. corona*—are particularly abundant and might be used for work on this group. Cultures properly managed usually resulted in obtaining large numbers of various species of *Amœba*.

Species of *Volvox*, *Eudorina*, *Pandorina*, etc., swarm in East Swamp, South Bass Island; they are not included in the foregoing list. A study of the physiology of these creatures, transitional as they are between Protozoa and Metazoa, promises much of interest.

DARTMOUTH COLLEGE, *Hanover, N. H.*, *May 25, 1899.*

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