Observations in protozoology, with additions to the list of forms known to occur in Iowa and descriptions of some probable new species

Clementina Sinclair Momyer

State University of Iowa

This work has been identified with a Creative Commons Public Domain Mark 1.0. Material in the public domain. No restrictions on use.

This thesis is available at Iowa Research Online: https://ir.uiowa.edu/etd/3989

Recommended Citation
Momyer, Clementina Sinclair. "Observations in protozoology, with additions to the list of forms known to occur in Iowa and descriptions of some probable new species." MS (Master of Science) thesis, State University of Iowa, 1916.
https://doi.org/10.17077/etd.4r8y60wj.

Follow this and additional works at: https://ir.uiowa.edu/etd
OBSERVATIONS IN PROTOZOOLOGY

With additions to the list of forms known to occur in Iowa and descriptions of some probable new species.

A thesis submitted to the faculty of

The Graduate College of

The State University of Iowa

in partial fulfillment of the requirements of

the degree of Master of Science

By

Mrs. Clementina Sinclair (Spencer) Momyer

1916
"A fire mist and a planet,

A crystal and a cell,

A jellyfish and a saurian,

And a cave where cave men dwell,

Then a sense of law and beauty,

A face turned from the sod,

Some call it evolution,

And others call it GOD."

Carroll.
CONTENTS.

Introduction. 2

References. 12

Classification. 13

List of the species herein described. 19

List of species which may be considered an addition to Edmondson’s Protozoa of Iowa. 23

Discussion of the Sarcodina as a group. 25

Description of species of the Sarcodina. 29

Discussion of the Mastigophora as a group. 47

Description of species of the Mastigophora. 50

Discussion of the Infusoria as a group. 71

Description of species of the Infusoria. 78

Index of the genera. 103

Plates with explanations facing.
INTRODUCTION.

It is perhaps expected of a worker in protozoology that she shall begin her thesis with an explanation of her choice of a subject. So much has been written upon the protozoa of fresh waters and their distribution is so general that it might seem as if the field offered little room to any save the most advanced workers.

A great satisfaction and profit are however to be found in personal observation rather than in the mere reading of the conclusions of others. Independent observers often bring out different points in regard to well known forms, and there is always the beckoning possibility of finding something rare or new. Thus it is that the writer, following a long continued interest, has tried to widen as far as possible her first hand knowledge of the protozoa of Iowa, looking forward in the near future to a more comprehensive report upon the protozoa of Arkansas.

The majority of the forms listed here are to be found in Dr. C.H. Edmondson's Protozoa of Iowa; but twenty-seven species representing twenty-two genera may be regarded as an addition to his list, while a few forms, vary so decidedly from all available descriptions that further observations may prove them to be new species.

No attempt has been made to provide these seemingly new forms with names. The more we see of these animals the more

* Eight which are possibly new are marked with an asterisk on pages 23 and 24.
convinced we become of the wisdom of Calkin's statement that no one should name a protozoon except upon the basis of a life history. Under varying conditions and at different stages the protozoa change in such marked manner that it is not only difficult to determine the species or family, but in a few cases the determination of even class becomes a matter of debate. For example, take the beautiful little *Vampyrella* *spirogyrae*, which at times is like an unstalked sucktorian with its capitate tentacles. Commonly it is of heliozoon type, and it has long been placed with the Actinopoda. Again it may be flagellated and appear to belong to the Mastigophora; and finally it becomes amoeboid and suggests the Rhizopoda, with which it is now classified. Or take *Nuclearia* *delicatula*, a form which appears to belong to any one of three subclasses. The appendages of this animal are in turn; 1st, Amoeboid pseudopodia; 2nd, Long heliozoon-like rays; 3rd, Short heliozoon-like spicules; 4th, Capitate, but doubtless not suckorial, rays; 5th, Thread-like, enormous­ly long and intricately branching pseudopodia; 6th, One or more heavy stalks for attachment. Recalling that the protozoa are separated on the basis of their locomotor appendages, it will be seen that such a form as this very nearly meets all require­ments! The most careful observations upon an isolated indi­vidual cannot, then, be considered sufficient for the coining of a new name. The life history must be worked out.

The subject of a natural classification of the protozoa and of the limits of a species is still more or less speculative.
Particularly is this true of the rhizopods, which are often difficult to obtain in large numbers and in active condition. Bacteriological methods of obtaining pure cultures are seldom successful with this group because the animals cannot be indefinitely nourished upon gelatin and glutinous solutions. Furthermore, the rhizopods are usually shy and sluggish creatures living at a much slower rate than the infusoria; and we do not so often have the opportunity of seeing them in division and conjugation. *Paramaecium* and *Stentor*, which multiply rapidly under laboratory conditions, have been carefully studied by many investigators, and Calkins has by artificial selection produced two supposedly distinct species from a single race of *Paramaecium*. The relations of the rhizopods, particularly of such shelled forms as *Difflugia*, and *Centropyxis*, are harder to establish. An examination of the drawings and descriptions in standard works shows that a large proportion of the specimens discussed are empty shells. The same is true of these forms as taken up in the following pages. Good evidence seems to be obtainable for holding many specimens as distinct, and also for considering them as mere intergrading varieties; but again, we need life histories for proof.

*Difflugia constricta* (*Difflugia* or *Arcella marsupiformis*) appears to merge into *Centropyxis ecornis*. Every combination and gradation of size, proportion and color can be found in a short time. Plate VII. Fig. 8., shows a large white, spineless shell commonly called *Difflugia constricta*. Plate XI. Fig. 2.
shows a form found in large numbers, usually brown, but frequently white. When white it does not differ from D. constricta, but because it is usually found in company with the brown Centropyxis aculeata, spined or spineless, it is called ecornis, the white spineless phase of the same species. Leidy\textsuperscript{1} thought it likely that this Centropyxis ecornis is the same as Diffugia constricta, an intergradation between the two genera; and Prof. Calkins in a personal letter to the writer expresses the same opinion.

A very interesting and uncommon variety of Centropyxis aculeata was found in abundance in a sandy bottomed spring branch at Okoboji. Plate XI. Fig. 1. These shells were all large, brown, and composed mainly of cigar-shaped diatoms. The number of spines was variable, but in general appearance, size, and construction the shells were noticeably similar. Unfortunately these did not reproduce, nor long survive laboratory conditions. Deprived of their accustomed species of diatom it would have been interesting to see what they would have used in constructing their shells. Specimens of Diffugia from the same stream had used an entirely different quality of material in making their tests. That there is some selection exercised by these tiny creatures is unquestionable.

\textit{Diffugia pyriformis}, the most variable of all test-bearing rhizopods, has several more or less distinct varieties. An exceedingly long slender shell which is frequently found seems always to be made of relatively large sand grains. Leidy\textsuperscript{1}—Rhizopods of North America, p. 123.
figures it as sometimes incorporating diatom shells, but always large ones, with the sand. From a small aquarium in the University plant house great numbers of this long shelled variety were found. It was not unusual to find in one mount on the slide as many as a dozen or twenty active specimens 300 microns long. These were remarkably uniform in size, proportion, and construction, never finishing off the aperture with the row of minute sand grains so common with the *Diffugia*. The same form was found at Fairport and other places. That the animals were unable to obtain small grains as well as large ones is scarcely tenable. Other forms of this same species do not show such regularities, but the writer has found, both in this state and in Arkansas, a variety of *Diffugia cratera* which is always composed of the minutest particles of sand, and which usually finishes off its flaring collar when the length of 57 microns is reached. Without denying many exceptions which occur more or less frequently in different species and varieties, it seems certain that there is a selection of preferred materials by some types of *Diffugia*, even when there is abundant range of material to be had.

*Arcella vulgaris* has long been known to embrace two varieties, a smooth and a pitted shell. That this is merely a case of dimorphism is indicated in Plate X. Here we see the union (probably conjugation, but possibly reproduction) of the two forms. (A further discussion of this case will be given later).
Amoeba proteus and Amoeba radiosa have been found in characteristically distinct forms since the time of Ehrenburg, and there seems to be little question as to the distinctness of the two species. Yet proteus, among its thousand shapes, imitates radiosa, and radiosa sometimes flattens out and loses its stellate character.

One highly important point in the determination of a species is the position and form of the nucleus. Stein demonstrated, however, that two supposedly distinct species of Stentor were merely different stages of Stentor roeselii, in which the ribbon-like nucleus later becomes moniliform. In the case of Spirostomum, the species teres and ambiguum seem to be separated chiefly on this character of the oval or moniliform nucleus, but Doflein now states that the moniliform nucleus of Ambiguum condenses into oval form before mitotic division. In other cases among the infusoria similar distinctions are made which future observation may eliminate as in the case of Stentor. Complaint is often made of the never ending changes in classification, but these changes prove the injustice of the charge that the systematicist is a mere cataloger. Proper classification is based upon an intimate knowledge of things of primary importance and is ever seeking a more and more natural basis. A changing classification is an indication of live workers. Things must be named in order that they may be discussed, written about, introduced to others, studied more thoroughly, and classified again with greater degree.

2- Lehrbuch der Protozoenkunde, p.968.
of accuracy as knowledge increases. When classification becomes a hard and rigid rule it will be an indication of one of two things, – that research is dead, or that we "know it all".

Thus it is evident that there are none too many workers in protozoology. Though each contribute ever so little to the science, so long as that little be faithfully recorded, the whole may some day be gathered into a form accessible to all who need it for whatever purpose.

The practical use of such knowledge no longer needs to be defended. The discoveries of the last twenty five years in the realm of the pathogenic protozoa alone ought to absolve all microscopy from charges of dilettantism and impracticability. Malaria, rabies, small-pox, scarlet fever (and most exanthematous fevers) dengue fever, yellow fever, trypanosomiasis, syphilis, and possibly cancer, are some of the diseases science is learning to combat through an understanding of their protozoon origin. Diseases of the silk worm, and Texas fever in cattle, both entailing a loss of hundreds of thousands of dollars to the commercial world are due to pathogenic protozoa.

A knowledge of the protozoa of fresh waters, commonly known as non-pathogenic protozoa, is of importance to the chemist who analyzes waters with reference to their healthful qualities. The presence of certain forms indicates that the water is dangerously polluted, while other forms may be entirely innocuous. Certain members of the Euglenoidina, while harmless, impart a violet, or a fishy, or other objectionable odor to potable waters; or the city reservoir may be rendered

1- Walton - Review of the Euglenoidina, p. 349.
unattractive by the red coloring matter of *Euglena sanguinaria*
and by the yellow of *Uroglena*. *Synura uvella*, a colonizing form
(Plate XXVII) imparts an unpleasant rank taste to otherwise
unobjectionable water. The chemist must recognize these or-
ganisms when he sees them and must know what means he can use
to destroy them without poisoning either fish or human beings.

A microscopic examination may tell the chemist as much
about the condition of the reservoir as does a chemical analysis.
If he is able to recognize different species he can often trace
the source of stream supply, seepage into wells, and so on.
Just as the protozoologist is coming more and more to need
chemistry in his work, so the chemist and health officer are
coming to realize their need of protozoology.

The teacher of biology, the research student, and even
the psychologist are giving increasing attention to the uni-
cellular animals; for, as Calkins has said, there is not a
single problem of the biological sciences that the study of the
protozoa does not illuminate. The teacher, trying to explain
the activities of life, of movement, irritability, respiration,
secretion, excretion, digestion, assimilation, mitosis, growth,
and reproduction, finds in the easily accessible single celled
animal a marvelous, perfect, miniature mechanism which in one
hour makes plain to the student points which many books and
lectures only obscure. And to the beginning student, seated
for the first time at his compound microscope, a new physical
world is opened, a new realm of thought unfolds. His interest
and wonder are excited. A view point is gained which will help him over many an otherwise hard and dry place in his later studies. Advanced workers in this field are finding light on senescence, rejuvenescence, and heredity; and when these and many other subjects now regarded as more or less purely academic have reached a working plane much of the credit will be due to protozoon studies. Even the psychologist, searching for the beginnings of consciousness and the mechanist, trying to prove that there are none, could not very well get along without the poor little "long suffering Amoeba".

No one denies the cultural value of the study of birds, flowers and other conspicuously beautiful objects of nature. But because the protozoa are unseen save by those whose work calls them into the microscopic field, there is a general impression that they are uninteresting save as they affect human beings through disease or as they illustrate the problems of specialists. While it is true that we are only just beginning to recognize the important economic relations of the protozoa to man, there is indeed another side of the subject from which it is not unprofitable to approach.

A cultural value, an aesthetic interest, is hidden in every wayside pool and puddle. The dripping moss beside the spring, the damp cracks in the brick walks of the garden, the very moist earth beneath our feet, all teem with millions of tiny creatures whose processes of birth, life, and death are essentially the same as our own. The Chinese carved ivory ball,
the engraved rock crystal bowl, and the snowflake are not more delicate and intricate of design than are the skeletons and cases of some of these single cells. And as our lenses become more powerful, as our methods of technique develop, we realize that there is more and more to see. We find the "simple cell" is composed of differentiated regions comparable to organs of the metazoa. Indeed we are beginning to suspect that the very chromosomes at the limit of vision bear complex and individual characters. The Amoeba, classic illustration of the lowest manifestation of life, is now held to be as far removed from its non-living elements or from that first primitive "arch amoeba" as it is removed on the other side of the scale from Man himself. For all the studies of the chemist and physicist, for all the wise speculations of the mechanist-philosopher, we are still no nearer to solving the mystery of life, for there is no end to the vista of infinity. He must indeed be dull of perception who cannot in the study of this intricate simplicity see "wie gros Gott auch im Kleinen sei".
REFERENCES.


Sand. Etude monographique sur le groupe Infusoire Tentaculiferes. 1901.

Calkins. The Protozoa. 1901.

Roux. Faune Infusorienne des eaux stagnantes des environs de Geneve. 1901.


Edmondson. The Protozoa of Iowa. 1906.


F. Doflein. Lehrbuch der Protozoenkunde. 1911.

Walton. Review of the described species of the order Euglenoidina Bloch. 1913?
CLASSIFICATION.*

Phylum PROTOZOA.

Subphylum SARCODINA. Protozoa with pseudopodia.

Class I. RHIZOPODA. Sarcodina without axial supports in the pseudopodia.

Subclass 1. PROTEOMYXA. Minute organisms with soft miscible pseudopodia which anastomose upon touching. Frequently parasitic. Typical genus: Vampyrella.

Subclass 2. MYCETOZOA. Of unsettled position. Botanists include them with the fungi as a primitive group under the name Myxomycetes, or slime moulds.

Subclass 3. FORAMINIFERA. Rhizopods with fine branching and anastomosing pseudopodia forming a network about the body. Shells when present are calcareous, often having many pores. (Perforina or Imperforina.) Typical genera: Globigerina, Orbiculina.

Subclass 4. AMOEBEA. The more common forms of rhizopods with blunt or lobose pseudopodia which do not anastomose upon touching. With or without shells.

Order 1. GYMNAMOEBOIDA. Body uncovered, although there is in many cases a tendency of the peripheral plasm to harden into a dense membrane. Typical genera: Amoeba, Hyalodiscus. (Provisionally are placed here the organisms of small pox, rabies etc.)

* Classification principally condensed from Calkin's "Protozoology" 1909.
Order 2. TESTACEA. Amoeboid forms with membranous or chitinous shells, or tests composed of different materials cemented to a chitinous base. Pseudopodia simple or branched, never anastomosing. A single opening to shell. Typical genera: Arcella, Cochliopodium, Diffugia, Euglypha, Quadrula.

Class II. ACTINOPODA. With ray-like pseudopodia having an axial support corresponding to the kinetic material of flagella.

Subclass I. HELIOZOA. Fresh water forms with no internal chitinous capsule.

Order 1. APHROTHORACA. Naked forms except during encystment. Typical genera: Actinophrys, (Nuclearia ?)

Order 2. CHLAMYDOPHORA. With soft gelatinous or felted fibrous covering. Typical genus: Heterophrys.

Order 3. CHALARATHORA. With silicious covering of separate or loosely connected spicules. Typical genera: Radiophrys, Acanthocystis.


Subclass II. RADIOLARIA. Marine forms, provided with a capsule of chitin inclosing the nucleus. Skeleton when present composed of acanthin or silica. 20 orders, 739 genera, 4318 species, according to Haeckel.
Subphylum MASTICOPHORA. Protozoa in which the kinoplasm is concentrated in one or more flagella originating in or near the nucleus.

Class I. ZOOMASTICOPHORA. Flagellated forms in which the animal characters predominate.

Subclass I. FLAGELLIDIA. (LISSOFLAGELLATA) Without collars.

Order 1. MKNADIDA. Minute forms, often elastic or amoeboid.

One large flagellum and often one or more secondary flagella. No distinct mouth. Typical genera: Mastigamoeba, Oikomonas, Monas, Anthophysa, Rhipidodendron.

Order 2. HETEROMASTIGIDA. One flagellum directed forward, and one or two directed downward and backward. Typical genera: Heteromita.

Order 3. EUGLENIDA.* Large forms usually with a single flagellum. Chlorophyll and stigmata often developed.

Family 1. EUGLENIDAE. Green chloroleucites and red stigma present. Typical genera: Euglena, Trachelomonas, Phacus.

Family 2. ASTASIIDAE. Green chloroleucites and red stigma absent, Usually free swimming. Saprophytic. Form radial, Typical genus: Astasia.


Subclass II. CHOANOFLAGELLATA. Flagellum surrounded by collar.

Typical genera: Monosiga, Diplosiga.

* The classification of the Euglenida follows Walton.
Class II. PHYTOMASTICOPHORA. Flagellates with plant characteristics clearly marked.

Subclass I. PHYTOFLAGELLATA. With green or yellow chromatophores.

Order 1. CHRYSOFLAGELLIDA. Yellow chromatophores. Typical genera: Mallomonas, Synura, Chilomonas.


(Subclass II. DINOFLAGELLATA) Principally marine.

(Subclass III. CYSTOFLAGELLATA) All marine.
Subphylum INFUSORIA. Protozoa with cilia and two kinds of nuclei, macronucleus and micronucleus.

Class I. CILIATA. Infusoria with cilia during all stages. Mouth and anus usually present.

Order 1. HOLOTRICHIDA. Body uniformly clothed with cilia, with a tendency to lengthen about the mouth. Trichocysts always present in some part of the body.

Suborder 1. GYMNOSTOMINA. Without an undulating membrane about the mouth, which commonly remains closed. Typical genera; Chenia, Lachrymaria, Coleps, Mesodinium, Dileptus.

Suborder 2. TRICHOSTOMIA. With undulating membrane at edge of mouth or in pharynx. Mouth always open. Typical genera: Colpidium, Urocentrum, Paramaecium, Lembadion.

Order 2. HETEROTRICHIDA. Body clothed with cilia, and an adoral zone of membranelles (short fused cilia) Typical genera: Blepharisma, Spirostomum, Stentor, Halteria.

Order 3. HYPOTRICHIDA. Cilia limited to the ventral surface of a flattened body. An adoral zone of membranelles and usually dorsal bristles composed of fused cilia. Typical genera: Stylonichia, Aspidisca.

Order 4. PERITRICHIDA. Cilia reduced to one or two wreaths. (Practically all fresh water forms contained in the family Vorticellidae) Typical genera: Vorticella, Carchesium.

Subclass II. SUCTORIA. With cilia during embryonic stage, adult forms provided with suctorial and piercing tentacles.
Family METACINETIDAE. Thecate forms with walls perforated for tentacles. Stalked. One genus: Metacineta.

Family PODOPHYTAE. Tentacles scattered over a more or less globular surface. No lorica. Often stalked. Typical genus: Podophrya.

Family ACINETIDAE. Naked and stalked, or thecate with or without stalks. Tentacles numerous and all alike. Reproduction by endogenous budding. Typical genera: Acineta, Tokophrya.
List of the species described in this paper.

SARCODINA.

RHIZOPODA. Vampyrella spirogyrae Cienk.

Hyalodiscus limax (Duj.)

Amoeba proteus Pallas.

" verrucosa Ehr.

" radios a Ehr.

" villosa Wall.

Diffugia pyriformis Perty.

" " vas Leidy.

" lobostoma Leidy.

" acuminata Ehr.

" globulosa Duj.

" cratera Leidy.

" corona Wall.

" constricta Leidy.

" urceolata Carter.

" species.

Arcella vulgaris Ehr.

" discoides Ehr.

Centropyxis aculeata Stein.

" " ecornis.

Euglypha alveolata Duj.

" mucronata Leidy.

Trinema enchylis Leidy.

Cochliopodium bilimboeum (Auerbach)
HELIOZOA.

Actinophrya sol Ehr.
Radiophrya viridis Archer.
Nuclearia delicatula Cienk.
Clathrulina elegans Cienk.

MASTIGOPHORA.

Oikomonas species 1.
  "    "  2.
Anthophysa vegetans Mull.
Rhipidodendron splendidum Stein.
Heteromita species.
Euglena viridis Ehr.
  " acus Ehr.
  " deses Ehr.
  " rubra Hardy (From across Minn. line.)
  " new species.
Trachelomonas oblonga punctuata Lemm.
  " urceolata Stokes.
  " piscatoris (Fisher)
  " volvocina Ehr.
  " hispida Stein.
  " species ?
  " new species (From Arkansas.)
Phacus pleuronectes (Mull.)
  " triqueter (Ehr.)
  " longicaudus (Ehr.)
  " pyrum (Ehr.)
MASTIGOPHORA (continued)

Astasia tricophora Ehr.
Anisomema acinus Duj.
Notozelenus orbicularis Stokes
Entosiphon sulcatus (Duj)
Mallomonas fresenii S.K.
Chilomonas paramaecium Ehr.
Synura uvella Ehr.
Diplosiga species.
Haematococcus lacustris Girod.
Unknown species (Ochromonadaceae?)

" " (Chrysomonadinae?)

INFUSORIA.

Coleps hirtus Ehr.
Lachrymaria olor Mull
Dileptus gigas C.and L.
Chenia species.
Loxodes rostrum Ehr.
Chilodon cucullulus Mull.
Glaucoma scintillans Ehr.
Loxocephalus granulosus S.K.
Colpoda cucullus Ehr.
Urocentrum turbo Mull.
Paramoecium caudatum Ehr.
" trichum Stokes.
Lembadion bullinum Perty.
Cyclidium glaucoma Ehr.
Cinetochilum margaretaceum Ehr.
INFUSORIA (continued)

Blepharisma lateritia Ehr.
Spirostomum teres C and L.
Stentor roeselii Ehr.
" ceruleus Ehr.
" polymorphus Mull.
Halteria grandinella Mull.
Strombidium species.
Stylonichia mytilus Ehr.
Stichotricha aculeata Wrz.
Aspidisca costata Duj.
Vorticella campanula Ehr.
Metacineta new species.
Tokophrya species 1.
" " 2.
Podophrya maupasii Butschli.
" libera ? Perty.
Species which may be regarded as an addition to Edmondson's PROTOZOA OF IOWA.

SARCODINA:

Nuclearia delicatula Cienk.
Hyalodiscus limax (Duj.)
Diffugia species
Euglypha mucronata Leidy.

MASTIGOPHORA:

Oikomonas species 1.
  "  "  2.
Rhipidodendron splendidum Stein.
Trachelomonas urceolata Stokes.
  " species ?
*  "  new species (not from Iowa.)
Euglena rubra Hardy.
* "  new species
Phacus triqueter (Ehr.)
Notosolenus orbicularis Stokes.
Mallomonas fresenii S.K.
Synura uvella Ehr.
* Diplosiga species
  Haematococcus lacustris Girod.

* Unknown form (Ochromonadaceae?)
* "  " (Chrysomonadineae?)
INFUSORIA.

Ciliata.
Chenia species.
Colpoda cucullus. Ehr.
Strombidium species.

Suatoria

* Tokophrya species 1.
* " " 2.
Podophrya libera ?
* Metacineta new species.
The protozoa are classified by their locomotor structures into four subphyla, the sarcodina, which move by temporary pseudopodia, being the first. The sarcodina are usually of very simple structure as compared with the higher subphyla, yet their many thousands of species illustrate the various combinations of characters which can be achieved by the single cell without permanent motile organs.

The simplest of animal cells, the proteomyxa, show very little differentiation of inner and outer sarcode. There is little tendency for the peripheral layer to harden into a true ectoplasm, but the entire cell is soft and viscid. In consequence the pseudopodia anastomose upon touching, and food particles once touched are ensnared. There is often no definitely developed contractile vacuole and the nuclear material may be so distributed as to be undetected. In fact many of the older references speak of protozoa without nuclei; but the present view is that no cell is normally without nuclear material in some form.*

Absence of a well defined ectoplasm and consequent anastomosis of pseudopodia is seen in the foraminifera, but here specialization has produced a calcareous shell which is often extremely elaborate in form, with many chambers, a complicated

* Calkins. Protozoology p.28.
canal system, and perforations for countless pseudopodia.

A well developed ectoplasm precluding anastomosis is first seen in the subclass Amoebea. This is due merely to a slight toughening of the cell surface. Food may still be engulfed or pressed through any portion of the thin ectoplasm into the endoplasm; but the sticky, trap-like character has been sacrificed by this specialization. Verworn states that the amoeba has a secretion for holding food, and the writer has seen long trailing flagella of such animals as Chilomonas repeatedly caught by the advancing pseudopodium of an amoeba, but the flagellate was able to escape with some effort. Living infusoria such as Coleps hirtus, one of the most active of all ciliated forms, are sometimes seen ingested in an amoeba, but it is likely that such forms as these are seldom caught unless they happen to be penned up before the slowly advancing rhizopod.

In Amoeba proteus which moves forward with any part of the body there is a tendency for the vacuole as it grows heavier to be pushed into the rear portion of the body or left behind by the moving sarcode. This seems to result in a permanently weak place in the posterior sarcode as soon as a more or less permanent anterior portion has been attained. Amoeba verrucosa, Amoeba radiosa, and Hyalodiscus limax all have developed a firmer ectoplasm than has Amoeba proteus, and move with less change of outline. Amoeba villosa shows this most plainly. As the more fluid endoplasm moves forward the membrane-like ectoplasm collapses into delicate folds like hairs, giving the name villosa.

Cochliopodium shows a definite reticulated membrane which may be called a shell, and Arcella has a chitinous shell, at first somewhat flexible but quickly hardening. Since this shell is chitinous and laid down on the exterior it may be regarded partly as an excretory product like the chitinous exoskeleton in the insects. Many rhizopod shells are composed of definite plates formed in the endoplasm and later extruded, as the silicious plates of Euglypha. (Plate XIII. Fig 1.) The cause of the formation of these plates is speculative. Different types appear to be by-products of internal physiological changes peculiar to the genera exhibiting them.

Polymorphic characters of the ectoplasm and appendages seen in Vampyrella and Nuclearia indicate that some of these so-called "simplest forms" are of rather a high degree of specialization. To be able to pass back and forth from a condition of low cellular organization such as the homogeneous anastomosing stage of the proteomyxa to the more differentiated regions of the heliozoa indicates higher rank than is seen in an organism confined at all times to the simpler structure, or in an organism which merely passes through a low stage in its developmental history.

The endoplasm of the sarcodina likewise exhibits great variations, from the proteomyxa to such forms as the polynucleate Actinospherium, or to the radiolaria which have at least four differentiated regions in concentric layers,¹ and whose intri-

¹. Butschli. Plate 31. Fig 19.
cate skeleton follow the contour of their protoplasmic alveoli.  

It is now held that the single nucleus of the sarcodina unites the substances and functions which in the higher protozoa are separated into three nuclei: the somatic nucleus, the germ nucleus, and the kinentonucleus. Under the functions of the somatic nucleus digestion seems to be of prime importance. Hofer and Verworn cut an amoeba into two parts and demonstrated that the enucleated portion was not able to digest the food mass it already contained, although it continued to live and the vacuole pulsed regularly. The nucleated portion, however, soon rallied and continued its usual activities. Mitosis, as seen in specialized germ cells has long been established and sexual gametes are known to occur in Arcella and other shelled forms. The kinetic nature of the nucleus is indicated in the heliozoa where the axis of the ray is plainly seen to arise from the nucleus and to move at its imbedded base.

There has been a great deal of speculation as to whether the flagellate is derived from the rhizopod or the rhizopod from the flagellate. However this may be, we must admit that even the lowest of the rhizopods exhibits enough complexity to indicate descent from a long line of ancestry.

Subphylum  SARCODINA
Class I.  RHIZOPODA
Subclass  PROTEOMYXA

VAMPYRELLA  Cienkowski.

Body amoeboid or heliozoon-like. Pseudopodia capitate or simple. Flagella developed at times. Endoplasm usually colored. Parasitic on spirogyra.

Vampyrella spirogyrae  Cienk.

Body nearly globular, pseudopodia ray-like, moving with the amoeboid motion of the hyaline periphery. Endoplasm densely and brilliantly orange red, finely granular with a few darker pigment granules. Within a few moments the animal may change from having nearly all capitate pseudopodia to nearly all simple rays. Capitate pseudopodia shot in and out very rapidly. Both kinds may be withdrawn from a considerable portion of the periphery and short amoeboid lobes occasionally appear. Nucleus and vacuoles not visible. Motion a rapid glide in swimming.

Diameter 4 microns, Plate XV. Fig. 4. Plate XIV. Fig.6.

Formerly this organism was classified with the Heliozoa, where the illustration appears in this paper; but both Calkins¹ and Doflein² now place it in the Proteomyxa on the

¹- Protozoology, p. 38.
²- Lehrbuch der Protozoenkunde p. 687.
basis of miscible and anastomosing pseudopodia. Neither of the specimens under my observation exhibited this character. The first one found was the typical brilliant orange red, extremely small and incessantly changing as it swam about. With a string siphon it was kept moist and under observation all day; but its minute size prevented its transfer to another slide, and when its travels during the night took it under a mass of debris it was hopelessly lost. The second specimen found was colorless and established within an algal filament (Plate XIV, Fig. 5.) Edmondson reports having seen this species but once and then only in the colorless phase. His specimen, assumed the interesting flagellated stage, which my two did not,

Subclass AMOEBAE
Order GYMNAFOBIDA
Family AMOEBIDAE

HYALODISCUS Hert. and Lesser.

With a distinction between ectosarc and endosarc, the former being relatively extensive. Body moving without much change in outline.

Hyalodiscus limax (Dujardin)

Body disc shaped or oval, progression snail-like, with a broad, clear anterior portion. Nucleus and contractile vacuole visible without reagents.

Size 44 microns. Plate I.

1. Protozoa of Iowa p. 24. (synonym, Vampyrella lateritia Frese)
So far as I have been able to ascertain this species has not previously been reported in the state. It was obtained in small numbers in December from under an inch of ice on an old stone quarry pond.

AMOEBA Ehrenberg.

With a distinction between the clear ectoplasm and the granular endoplasm. Shape infinitely varied. Pseudopodia never anastomosing.

Amoeba proteus Pallas.

With the characters of the genus. The most variable of the species. Nucleus usually visible without reagents. Contractile vacuole tending to flow in opposite direction from progression of the body as a whole.

Size 3 to 300 microns. Plates II and III.

Amoeba proteus has not been a difficult form to find at any time. Gold fish tanks usually furnished small specimens in profusion, and even in mid winter from under an inch of ice small but active individuals were collected. At times an old jar in the laboratory which for months has appeared to contain nothing of interest will be found to be fairly alive with amoebae. In one such case the container was merely an ounce vial which had been neglected for some months after an examination had showed nothing but a few specimens of Arcella and Euglena. Upon mounting a drop of water from this vial as many as twenty amoebae could be found at a time, none less than a hundred and fifty microns in length.
These were all blue-gray in color and very similar in general appearance and movement. Cultures from gold fish tanks, after being kept in the warmer laboratory for a week, often swarm with extremely minute amoebae. At one time there were in the field as many as sixty ranging from three to fifteen microns in length. It is possible that such cases as this latter are the result of spore swarms sometimes reported of Amoeba but rarely seen. Plate II. Fig. 8.

By careful focusing it may often be seen that the whole undersurface of an amoeba is not flattened out against the slide. Pseudopodia do not merely flow along by contact with the glass, but may be extended from the upper side of the animal and bent downward, pulling the body over into a new position. Fig. 5, Plate II, illustrates this point. The upper shaded pseudopodia are the ones in action, while the lower clear portion is left as a temporary standard. Amoeba may at times progress by a looping something after the manner of a measuring worm, having a space between the attached forward and rear portions of the body and the glass slide.

Digestion is fairly rapid, so that a few minutes after an infusorian is ingested it is rolled up into an inert mass. Figs. 1 and 2, Plate III, show, however, a case in which a Chilomonas paramaecium and an unidentified monad were protected from digestion by an unusually large droplet of water. During the rolling and kneading of the endoplasm as the amoeba made its way along, this food vacuole came so close to the surface
that the active *Chilomonas* was able to break its way out, while the quiescent monad was thrown into the clear water also and revived in a short time.

**Amoeba verrucosa** Ehr.

Body not exhibiting as much change in outline as in *A. proteus*. Ectoplasm wrinkled in several longitudinal lines. A tendency toward an anterior end. Vacuoles several.

Size 40 microns. Plate I.

One specimen only of this form was found in company with *Hyalodiscus limax* from the frozen pond. Edmondson\(^1\) also reports it as being very uncommon in this state.

There were two oval vacuoles lying very close together, apparently about to fuse, but each worked separately throughout the observations.

**Amoeba radiosa** Ehr.

Body star shaped, or spherical with radiating, slender pointed pseudopodia. Motion sluggish. Nucleus not seen without reagents.

Plate I. Fig. 5 to 8.

This species has been found abundantly in most pond waters throughout the year. Edmondson\(^2\) reports it as being 45 microns, the smallest of the genus, but I have repeatedly found it with an expanse of 75 microns. Occasionally a specimen of this distinct type has been seen to

1- *Protozoa of Iowa*, - P. 11.
flatten out much after the manner of *A. proteus*. An active vacuole has not been observed.

**Amoeba villosa** Wallich.

Possessing more of a tendency toward anterior and posterior regions than *A. proteus*. Pseudopodia lobose, motion active. A villous tuft of wrinkled ectosarc at the posterior end. Nucleus usually seen without reagents. Vacuole action slow.

Maximum size of body 130 microns. Plate IV.

That the villous appearance is due to a folding and wrinkling of the ectosarc as the endosarc moves forward is very plainly brought out by careful focusing. The drawings do not bring out this point as clearly as might be desired, but the same principle is illustrated in the collapse of the vacuole in *Actinophrys sol*. [Fig. 4. Plate XVI.] In one case it is the removal of the endosarc, in the other it is the ejection of the fluid which leaves the peripheral membrane-like ectosarc in folds. A very remarkable phenomenon was seen in this species, (Fig. 9. Plate IV.) when an anterior filiform pseudopodium longer than the body proper was drawn in with almost unbelievable rapidity. Such an action is quite contrary to the usual habits not only of *Amoeba villosa* but to those of rhizopoda in general.

Family **ARCELLIDAE**

**DIFFLUGIA** Leclerc.

Amoeboid forms with a test composed of chitinoid
material to which extraneous particles are usually cemented. Pseudopodia simple or often branched.

Edmondson lists nine species of *Diffugia*, the eight described here and *D. spiralis* in addition. I have some varieties which he does not mention, and one *D. species* (Plate VI, Fig. 8) which does not tally with any available description.

**Diffugia pyriformis** Perty.

This is the most variable of all shelled rhizopoda in size, proportion, and in composition of the shell. As it is a very common form and the shell is relatively permanent, it does not take long to find a wide range of variation. Shells may be spined or not, regular or irregular, small and subglobular, or large and much elongated. Variety *vas* Leidy has a constriction on the neck.

The sand grains may form a perfect mosaic with minutest spaces filled in, or they may be separated from each other by the basal substance of the test. Fig. 11, Plate V.

Pseudopodia are usually clear with few granules and seldom branch as much as seen in Fig. 13. Plate V.

Size 30 to 325 microns. Plates V, VI, VII and VIII.

**Diffugia lobostoma** Leidy.

Shell small, subglobular; mouth lobed, usually three or four parted.

Diameter 30 microns. Figs. 3 & 6. Plate VI.

1—Protozoa of Iowa. P. 12.
**Difflugia acuminata** Ehr.

Shell elongated into an acute tip which is often deflected. Two or three spines may be present.

Fig. 2. Plate VI, which I have called *D. pyriformis* seems to approach this form, but the true *acuminata* is figured as having a more acute tip. In this extremely variable genus I question the distinctness of some of these species.

Maximum size, 220 microns. Figs. 4 & 5, Plate VI.

Fig. 1. Plate VII. Fig. 7. Plate VIII.

---

**Difflugia globulosa** Duf.

Shell small, subglobular with mouth truncating the lower end. Usually small grained, very inactive. No spines.

While *globulosa* typically has no spines, Fig. 7, Plate VI, shows an active individual with a large irregular spine-like sand grain eccentric to the summit. I have observed this species but a few times.

Size 70 microns. Plate VI. Fig. 7.

---

**Difflugia cratera** Leidy.

With a broad cylindrical neck having a reflexed rim. Goblet-like.

This form has been found by me but once in this state, but it agreed with individuals of the same species taken elsewhere in being composed of minute sand grains. Edmondson figures it with larger sand grains, while both Leidy and

1- *Protozoa of Iowa*, Plate II.
Conn, show it as having a chitinoid or membranous shell sparsely dotted with sand grains.

  Pseudopodia not observed.

  Size 95 microns. Plate VII. Fig. 2.

**Difflugia corona** Wallich.

Shell nearly globular, large, fundus spined. Mouth toothed. Both spines and teeth may have a base of brown chitin contrasting with the white shell. Spines usually more than four.

This is a very common form in the Okoboji region, but I have not seen it abundant elsewhere. It is a very symmetrical shell and a beautiful one, especially when it has regular "trimmings" of brown chitin.

Size 100 to 175 microns. Plate VII. Fig. 7.

**Difflugia constricta** Leidy.

Shell oval with mouth obliquely truncating. Fundus carried in a backward slant as the animal creeps. Shell white, spined or not.

As already mentioned in my introduction this species seems to intergrade with *Centropyxis aculeata*. Both are described as spined or unspined, and the latter species may have either brown or white shells. The writer has found all varieties in abundance and knows no good distinction to make between them.

Edmondson reports this form as rare, and that Leidy

1. Protozoa of Conn, Plate III.
says only the larger varieties bear spines. My experience does not tally with these observations. Plate XI, Fig. 5, shows a white spineless shell which may as well be called **Diffugia constricta** as **Centropyxis aculeata**.

Size 95 microns. Plate VII. Fig. 8.

**Diffugia urceolata** Carter.

Shell large, urn like, with a wide reflexed rim about the wide mouth.

Only one empty shell of this species was found.

Size 180 microns. Plate VIII. Fig. 2.

**Diffugia** species

Shell hemispherical, proportions like **Arcella**, composition like **Diffugia**. An inverted rim within the mouth as often seen in **Arcella**. Color white.

Only one dead shell was found of this species. It does not correspond to any form described by the authors in my bibliography.

Diameter 70 microns. Plate VI. Fig. 8.

**ARCELLA**  Ehrenberg.

Body hemispherical or flattened. A brown chitinous shell composed of hexagonal plates which often become homogeneous with age, or which appear as mere punctae on the shell. Mouth ventral. Pseudopodia never branched. Nuclei more than one.
Arcella vulgaris Ehr.

Shell variable, more or less hemispherical. Ventral surface often deeply concave with an inverted rim within the mouth. Surface smooth or ornamented with many shallow pits.

Size 45 to 80 microns. Plates IX & X.

This is the commonest of the shelled rhizopods, found not only abundantly in life, but the shells being chitinous are practically insoluble and last indefinitely. They are finally washed very thin and are easily bent or dented. Living shells are very brittle and are often seen crushed under the cover-glass while the animal seems little disturbed in its activities.

Reproduction is of three types. First by outpushing of the sarcode and the formation of a new shell before separation of the daughter cell. Fig. 3. Plate IX. Second by gemmation and third by union of gametes. Plate X shows a series of minute and colorless individuals which were doubtless a product of one of the latter two processes, as they appeared quite suddenly in countless numbers in an old jar in the laboratory (during October). Plate X shows an interesting case of supposed conjugation between two of these young shells, a smooth and a pitted variety. Since the two shells were not seen to approach each other and fuse, there is a possibility that the process was merely reproduction. Many

1- The Protozoa, P. 95. Calkins.
2- Protozoology, Fig. 47. Calkins.
writers record the union of two or more rhizopods but remark upon the rarity of seeing an actual approach and fusion.

Arcella discoidea Ehr.

Similar to the preceding but flat and saucer-like.

Larger and less common. Never pitted.

Size 60 to 130 microns. Plate IX.

CENTROPYXIS Stein.

Similar to Arcella and Diffugia, the brown chitinous shell having additions of sand, diatoms, etc. Usually spined. "Mouth and fundus eccentric in opposite directions".

Centropyxis aculeata Stein. (including variety ecornis.)

A very common form, both brown and white, both spined and spineless. Every gradation into Diffugia constricta has been found.

Size 100 microns. Plate XI.

At Okoboji a large number of individuals were found, all largely composed of diatom shells. After remaining quiet and apparently dead all winter, in the spring specimens of this species became active.

COCHLIOPODIUM Hertwig and Lesser.

A membranous, minutely cancellated shell, highly expansive at mouth. Sarcode filling the shell. Pseudopodia variable.

Cochliopodium bilimbosum (Auerbach)

Diameter 25 microns. Plate XII. Figs. 9 and 10.
There is no doubt about the identification of Figs. 9 & 10, but Figs. 1 to 8 represent a form placed here with great doubt. When revolved the body was seen to be shaped like a football, having a finely granular periphery and center with a space or transparent plasm lying between. No mouth could be made out.

Size 200 microns.

Family EUGLYPHIDAE

EUGLYPHA Dujardin.

Shell transparent, composed of circular imbricating plates which become almost homogeneous. Pseudopodia delicate and geniculate.

Euglypha alveolata Duj.

Fundus rounded. Often spined (See Leidy, Plate 35).

Size 45 microns. Plates XIII and XIV.

Dead shells are of common occurrence, but it is not often that active geniculate pseudopodia have been found as in Fig. 1 and 4. Fig. 1 shows the internal shell plates which are stored around the nucleus and which are extruded with the protoplasmic mass in reproduction by division.1 Figs. 2 & 4 show a checked or latticed shell effect which frequently appears in publications on the protozoa, and which is due to partial obliteration of the circular plates as well as to poor lighting of the specimen. Fig. 4, Plate XIV shows an exceptionally clear arrangement of these plates. In most dead shells, however,

1- Calkins, The Protozoa, P. 55.
the surface appears smooth and glassy save for slightly crimped edge in optical section. Found at Fairport and Iowa City, Iowa.

**Euglypha mucronata** Leidy.

Fundus prolonged into an acute tip.

Size 60 microns. Plate XIII. Fig. 7.

This species is an addition to Edmondson's list. But one dead shell was found, in company with the preceding species.

**TRINEMA** Dujardin.

Shell similar to **Euglypha** with the mouth obliquely truncating the narrow end.

**Trinema enchlyea** Leidy.

This species has not been found in such abundance as **Euglypha**. The encysted animals present the same features of nucleus and vacuole.

Size 40 microns. Plate XIV.

**Class II** ACTINOPODA

Subclass 1. HELIOZOA

Order 1. APHROTHORACA

**ACTINOPHRYYS** Ehrenberg.

Body spherical, not clothed with short spicules or with clear gelatin. Pseudopodia ray like, long. Many vacuoles present, usually more than one contractile. Nucleus conspicuous without reagents.
Actinophrys sol Ehr.

Body much vacuolated. No chlorophyl. Rays often much longer than diameter of body.

Maximum expanse observed, 320 microns. Plates XV, XVI, XVII.

The axis of the actinophriam ray can be traced to the nucleus and is seen to be of a kinetic nature. The rays are turned in varying directions or rarely bent in progression and in the capture of small animals. Very rapid infusoria are often caught by these sluggish creatures, a mere touch being sufficient to impale the softer bodied forms. Sometimes a small monad is slipped up and down a ray many times like a bead on a needle. Figs. 1 and 3, Plate XV, show the capture of two animals which remained alive and active for some twenty minutes, the vacuole in the infusorian continuing to work.

It is very common to find double individuals in Actinophrys, but it is doubtful if these are often cases of conjugation. Sometimes it is plainly division, again it may be something akin to a small colony. Only once have I seen two separate cells approach and fuse (Fig. 2, Plate XVI) and as the nuclei were not observed it is not possible to say whether this was a case of conjugation with fertilization or mere plastogamous conjugation. Most authors confess that the large majority of cases of so called conjugation among rhizopods are similarly doubtful.
The external contractile vacuole in Actinophrys is a permanently thin place in the peripheral plasm or membrane, which upon collapse falls into folds and gives the appearance of a tuft of hairs. It is seldom possible to see this in detail, but occasionally individuals are found showing all the stages as given in Fig. 4, Plate XVI.

**NUCLEARIA** Cienkowski.

Of doubtful systematic position, belonging in some respects in the proteomyxa and in others with Actinophrys in the Heliozoa. Body much more amoeboid than ordinary heliozoans. Pseudopodia extremely variable, amoeboid, ray like, branching, or rarely capitate (not suctorial).

This genus is not recorded by Edmondson.

**Nuolearia delicatula** Cienk.

Body both amoeboid and heliozoan-like, with pseudopodia in turn amoeboid, short spicule-like, long and ray like, delicate and intricately branched, capitate (rarely) but not suctorial, stocky for attachment, and anastomosing in at least one instance under observation. (Fig. 6. Plate XX).

Body 20 to 100 microns. Maximum extent of pseudopodia 315 microns. Plates XVIII, XIX, XX.

This most interesting and problematic species has been found in large numbers in gold fish tanks about town. In a sluggish condition it greatly resembles Actinophrys sol or may at times withdraw nearly all of its rays; but in active state it becomes the most variable amoeboid form within
my knowledge.

Prof. Calkins who kindly confirmed my identification of this species says: "From your sketches I have no hesitation in saying that your organism is one of the questionable heliozoa most closely related to Actinophrys, and you are right in identifying it as *Nuclearia delicatula* Cienk".

In Calkin’s *Protozoology* (1909) he places *Nuclearia* with *Vampyrella* in the Proteomyxa on the basis of its amoeboid character and the rare anastomosis of pseudopodia.

During eight weeks observation these abundant animals were a most interesting study, and their changes would fill many drawing plates.

Nuclei could not definitely be made out, though carmine stain, methylene blue, osmic acid fumes and dilute osmic acid were used. At no time was a contractile vacuole seen nor were the animals seen to divide or take food. Rarely one was seen with an ingested food mass. In Fig. 1, Plate XX, the endoplasm was filled with green globules and in Fig. 7, Plate XX there was an ingested diatom. Fig. 1, Plate XX, shows an individual which I regard as the same species, but which has a gelatinous covering like *Heterophrys*. Conn also records *Nuclearia* with a gelatinous envelope.

Order CHALARATHORACA

**RADIOPHRY**S Archer.

With a silicious covering of separate or loosely connected

1- Protozoa of Conn, P. 18.
spicules. Sometimes with chlorophyll bodies.

**Radiophrys viridis** Archer.

This form is not so abundant as *Actinophrys* but has been found a few times in both the green and the white phase. Following Edmondson¹ I place the colorless form also here.

Size 27 microns. Plate XVII.

Order DESMOTHORACIDA

**CLATHRULINA** Cienkowski.

Spherical body enclosed by a one piece silicious capsule with many openings for radiating pseudopodia. Stalked.

**Clathrulina elegans** Cienk.

Adult form with the characters of the genus. Immature forms naked with a conical outpushing of the globular body at the insertion of the stalk.

Diameter 40 microns. Plate XIV. Fig.6.

Early in October in a laboratory culture of *Actinophrys* and *Sphaerophrya* a very few immature specimens of this species were observed. Only a diagramatic drawing was made at the time, and the forms have not reappeared since then. The stalks were all long and there were no capitate tentacles, otherwise the animals greatly resembled *Sphaerophrya*.

¹- Protozoa of Iowa, P. 26.
MASTIGOPHORA.

The Mastigophora may be characterized as unicellular animals with one or more flagella. Under this heading come many forms on the border line between the fields of the zoologist and the botanist, certain marked plant-like characters being the basis on which many regard the mastigophora as more primitive than the rhizopoda.

Flagella are of many different types. The simplest form is seen in *Euglena* where the single flagellum vibrates or lashes from its base or at any portion throughout its length. *Euglena*, having a metabolic movement of the body proper, is not entirely dependent upon this flagellum, hence the structure is not highly developed from the standpoint of speed, and may be absent without apparent inconvenience to the organism. *Trachelomonas* exhibits a single flagellum of the same type, but more specialized in the point of rapidity. This hard shelled form has no other method of progression and has perhaps concentrated upon the flagellum, another factor in the great speed of the organism being the diminutive size, which means less mass and weight for the flagellum to act upon. In *Astasia* and *Notosolenus* the single flagellum does not move freely at the base, but vibrates only at the tip, which thus furnishes motor power for the whole body. (Plate XXVI, Fig 1.) *Chilomonas* and *Entosaphion* have one strong anterior flagellum and a weak dragging one, which not only acts as a trailing anchor, but which, in *Entosaphion* at least, appears to be adhesive at its tip.
Unequal flagella, both vibrating, are seen in Synura and Anthophysa, while Chlamydomonas has two flagella of equal length, both directed forward and vibrating. Several other forms occur in the mastigophora, but the above mentioned types have been observed by the writer and will be found figured in Plates XXI. and those immediately following.

The flagellum consists of an axial filament surrounded by protoplasm and deeply imbeded in the cell.\(^1\). According to Dobell\(^2\) the origin may be of four types. First: directly in the nucleus as in Dimorphha, or as the ray of the heliozoon. Second: near the nucleus and united to it by a strand, the "zygoplast," as in Monas. Third: in a basal granule not connected with the nucleus, as is illustrated in Walton's monograph on the Euglenoidina.\(^3\) Fourth: in a specialized kineto nucleus. It is thus seen that the flagellum is of very definite origin, and is not merely an outgrowth of the periplast or a large cilium.

The flagellum fissure has long been recognized as a mouth, but Calkins\(^4\) brings out the fact that it also provides an exit for the waste of the anteriorly located contractile vacuole. In Phacus, for instance, the periplast is almost glassy, enduring like a desmid shell after the cell contents have disintegrated, but not being as lasting as a diatom shell. It would be difficult here for the vacuole to discharge through the body wall.

The character of the ectoplasm of the mastigophora has almost as wide a range as in the rhizopoda, from the almost amoeboid Oikomonas to the complex crenulated glassy shell of Mallo-

\(^1\) Walton. p 346. \(^2\) Calkins. Protozoology. p. 46. \(^3\) p. 347. \(^4\) Protozoology. p. 44.
monas, with setose spines. By the use of chlorotone on a too active specimen of Mallomonas the writer was able to make out a somewhat obscure point in reference to the peripheral setae. The action of the chlorotone caused death and immediate expulsion of the protoplasm with the flagella, while the rigid curved setae remained undisturbed on the thin transparent shell, like the spines on a Euglypha.

Reproduction in the mastigophora is by longitudinal division (Plate XXV. A typical case in Phacus.) or by spore formation under the protection of a cyst. (Plate XXV.) Fertilization is known to occur but has not been observed by the writer.

Subphylum  MASTIGOPHORA
Class I.  ZOONASTIGOPHORA
Subclass  FLAGELLIDIA
Order  MONADIDA
Family  CERCOMONADIDAE

OIKOMONAS  Kent.

Minute, plastic, sometimes attached by a temporary posterior prolongation. Flagellum single with a flagellum fissure at the base. Vacuole usually conspicuous.

This genus is not recorded by Edmondson.

Oikomonas species 1.


Length of body 19 microns. Flagellum 20 microns. Plate XXI.

Oikomonas species 2.

Similar to the preceding, but lacking crenulations and posterior tip. Flagellum longer. Vacuole and nucleus not visible. Transparent. Abundant in gold fish tank with Nuclearia.

Body 20 microns. Plate XXI Fig. 8.
Family HETEROMONADIDAE

ANTHOPHYSA St. Vincent.

Colorless monads forming spherical rosettes on ends of much branched stalks. Flagella two, unequal.

Anthophysa vegetans Mull.

Rosette-like clusters of a varying number of zooids, each subpyriform, the larger anterior end having a notch, bearing two unequal flagella. Rosettes free swimming or attached to ends of elaborately branching and often tangled stalks. This stalk may be greyish, diaphanous and finely granular, or erect, brown and horny. "Contractile vacuoles two or more, posteriorly located. Endoplast spherical, subcentral." 1.

Diameter of colony 50 microns. Zooids 7 microns. Plate XXI.

The stem of Anthophysa appears to be chitinous, but Kent speaks of it as more nearly like keratoae, the basal substance of the skeleton of the horny sponge. Kent demonstrated by carmine feeding that this stem is formed by excretion from the converging posterior ends of the monads.

In October some small bottles of Fairpott pond water standing in my laboratory became covered with a thin glistening brownish scum composed entirely of tangled Anthophysa colonies. A few minutes after being transferred to the slide the rosettes usually detached themselves from their stalks, and if further disturbed broke up into groups of eight or ten, swimming off in a rapid spiral. Reagents of any kind always (Kent. Manual of the Infusoria p.267.)
caused separation of the monads.

In December large rosettes without stems were found in quantities beneath an inch of ice. Early in April more rosettes were found, these having short diaphanous stems which often dragged debris as the cluster swam in a rapid counterclockwise spiral. A few stemless clusters may be found in almost any diatomaceous pond water.

**RHIPIDODENDRON Stein.**

Monads ovate, similar to *Anthophysa*, living in a social zoothecium, a rust brown "flabellate or dendriform aggregation of closely approximated tubules," the distal ends of which are each inhabited by a single zooid.

This genus has not been recorded by Edmondson.

**Rhipidodendron splendidum** Stein.

Only a large number of dead fragments of the zoothecia were found, but these were sufficient to identify the beautiful flabellate colony figured by Kent in his Plate XVI. As the tubules were never found growing in more than one layer the species *Rhipidodendron huxleyi* was ruled out. Found in an Iowa City pond.

Maximum length of fragments found 100 microns. Diameter of tubules 3.8 microns. Plate XXI. Fig. 1, 2, and 3.

Order HETEROMASTIGIDA.

**Heteromita Dujardin.**

Form oval, somewhat changeable. No mouth. Flagella two,
anterior one vibrating, the other one trailing.

**Heteromita** species.

Minute, colorless, finely granular, both flagella longer than body, arising from one side near anterior end. Motion vibrating.

Length of body 15 microns Plate XXI. Fig 8.

This seems to be the same form which Edmondson reports under this genus, and figures in his Plate VII.

**Order EUGLENIDA**

**Family EUGLENIDAE**

**EUGLENA** Ehrenberg.

Form usually oblong to spindle shaped. More or less metabolic. Green chloroleucites usually color the endoplasm bright green. Paramylon granules and red stigma present. Vacuole reservoir conspicuous and connected with cytopharynx.

**Euglena viridis** Ehr.

Anterior end notched, bearing the single flagellum at the opening of the cytopharynx. Very metabolic. Periplast striated spirally. Stigmata sometimes multiple and scattered. Walton says; "Many other species have been erroneously classified as *E. viridis* in ordinary biological instruction. The posterior position of the nucleus, together with the single stellate group of chloroleucites, should easily distinguish it from several closely allied forms."¹

¹- The Euglenoidina of Ohio, p. 362.
Size 50 microns. Plate XXII. Figs 1 to 4.

Late summer and early fall are the best time to collect euglenoid forms, when small pools or even the river may be colored with masses collected on the surface and along the edges, yet small active specimens of *Euglena viridis* and *E. acus* have been taken in December from under the ice. This seems rather remarkable when the form is so prone to encyst itself after even a few hours of autumn chill in the laboratory.

**Euglena rubra** Hardy.


Length of body 115 to 230 microns. Plate XXII.

I am indebted to Professor R. B. Wylie for bringing these specimens in formalin from Little Spirit Lake in August, where they were present in great numbers. The flagella are seldom well preserved, but when found are less than half the length of the body. The cytopharynx remains plainly visible, but it is seldom that the vacuole reservoir can be seen. The varied forms may be partly due to the action of the formalin, and may also indicate a metabolic nature of the organism. It is interesting that the spiral marking may be either right handed or left handed, usually the former. Professor Walton regards this specimen as distinct from *Euglena sanguinea*.

which is smaller and has punctuations along the striations.

This is not strictly an Iowa record, as Little Spirit Lake is across the Minnesota border line. The species is one of especial interest, however, and as it is most likely that it may be found on this side of the line it seems proper to mention it here.

**Euglena acus** Ehr.

Body much elongated, not flexed in swimming. Posterior end pointed. Flagellum short, paramylon bodies rod-like, scattered.

Size 115 microns. Plate XXIII.

This common form is very variable in size, and minute specimens may be found almost anywhere in ponds or ditches. It can be told by its rigid position in swimming.

**Euglena deses** Ehr.

Body elongated with squirming movement. Metabolic. Flagellum short or absent. Paramylon in short rods or ovals. Chloroleucites numerous, not always filling the endoplasm. More than one stigma sometimes present. "Nucleus central".

Size 100 microns. Plate XXII.

A fairly common solitary form. The specimen figured is somewhat unusual in having both an anterior and a posterior stigma. The central part of the body was colorless except for the sparsely scattered chloroleucites.

**Euglena new species.**

Elongated, ribbon-like, habitually twisted into three
areas. Conspicuously beaded in longitudinal rows, of which there are seven at the anterior end and only five rather indistinct ones at the posterior end. Flagellum about half as long as the body. Nucleus oval, central, with a larger flattened oval paramylon body before and behind. Vacuole reservoir very large and circular, posterior to the large stigma. Cytopharynx plainly visible. Solitary. Color densely bright green, somewhat clearer at the tail.

Size 190 microns. Plate XXIII.

This remarkable form was found in a vial of water from Fairport, Iowa, which had been standing in my laboratory for some weeks. It was very large and active, and apparently somewhat cramped for space under the cover glass. It would attach the tail to the slide and give its long body a twisted motion in a semicircle. The body as a whole was not metabolic, but the raised beaded lines on the periplast were seen to move forward on one side and at the same time backward on the opposite side.

Professor Walton says in regard to these drawings and notes: "The probabilities are that a new form is represented."

TRACHELOMONAS Ehrenberg.

Shell usually brown, flagellum single, endoplasm green, with stigma and contractile vacuole. Movement rapid, in a forward spiral or spinning on head.

Trachelomonas oblonga punctuata Lemm.

Shell oval, brown, dotted with punctae which show a
spiral arrangement on the aboral end, but which from the side view appear to be irregularly scattered. In optical section the shell appears to be made up of small sections or to have pores. (See figure) Stigma present; chloroleucites two, elongate; flagellum nearly as long as the body and slightly thickened at the tip.

Size 23 microns. Plate XXIV. Fig. 1, 2, and 3.

The spiral arrangement of the punctae at the aboral end seems to have been overlooked in Lemmerman's descriptions and drawings of this form. It is, however, an interesting point, and one which is not brought out except when the active little creature is spinning on its head. The species is not recorded by Edmondson.

**Trachelomonas urceolatus** Stokes.

Shell large, light brown, sparsely dotted. Neck obliquely truncate, a tail-like point at the aboral end into which the shell cavity extends. Dead shells only were found. The species is not recorded by Edmondson.

Size 35 to 40 microns. Plate XXIV. Figs. 4 and 5.

**Trachelomonas piscatoris** (Fisher)


Size 35 microns. Plate XXIV. Fig. 6.

**Trachelomonas volvocina** Ehr.

Shell spherical or slightly elongate, flagellum opening
sometimes with a slightly thickened margin, surface smooth. "Flagellum long". An extremely common form.

Size 20 microns. Plate XXIV. Fig. 7.

**Trachelomonas hispida** Stein.

Oval more or less thickly spined, yellowish-brown, collar low without spines. Endoplasm green. Found in resting stage under ice.

Size 23 microns. Plate XXIV. Fig. 8.

**Trachelomonas species** ?

Shell small, regularly cylindrical rather than oval, without collar or posterior spike. Surface smooth, brown.

Length 14 microns. Plate XXIV. Fig. 9.

As this shell does not conform to any description and was empty when found, it is placed in this group with some doubt.

**Trachelomonas new species** From Arkansas.

In the **Trachelomonas teres** group. Shell brown, oval, with a conspicuous collar flaring at its base and a short rounded posterior appendage into which the cavity of the shell does not extend. Endoplasm green, stigma large.

Size 22.8 microns. Plate XXIV. Fig. 10.

The single specimen found of this interesting type was in an encysted state, and lacked a flagellum. The oval protoplasmic body was somewhat constricted at the equator and had a layer of colorless ectoplasm over the green endoplasm. Three irregular granules (paramylon?) were present. It is the
opinion of Prof. Walton that a new form is represented here, and it is hoped that additional specimens can be obtained later.

**PHACUS** Dujardin.

Flattened, leaf-like, not metabolic, periplast firm and enduring after the disintegration of the endoplasm. Chloroleucites numerous, disc shaped. Paramylon usually large and conspicuous in center of cell. Stigma, vacuole reservoir, and flagellum as in Euglena.

**Phacus pleuronectes** (Mull)

Leaf like with a median fold reaching nearly to center of cell. A short curved posterior appendage; periplast longitudinally striated. Chloroleucites numerous enough to color the endoplasm evenly, or reduced to about seven quite regular rows giving a polka dotted effect. Paramylon usually one large clear disc near the center of the cell. Movement in rapid forward spiral. Common.

Reproduction by longitudinal fission or by division (binary or multiple) within a cyst.

Length 60 microns. Plate XXV. Figs. 6 and 9.

**Phacus triqueter** (Ehr.)

Very similar to the preceding species but having a decided sharp keel extending down the center of the dorsal side, and the central surface deeply concave.

This species has been found more commonly than the
preceeding one but unfortunately is not figured in the plates. Edmondson does not record it.

**Phacus longicauda** (Ehr.)

Very similar to *Phacus pleuronectes* but with much lengthened posterior process, paramylon single, discoid. Flagellum not as long as body.

Length 100 microns. Plate XXV. Figs. 1 to 5, and 7.

This species is not quite so common as the two preceding ones. It has been collected at Okoboji, and one or two may usually be found whenever the other forms of *Phacus* are common. An interesting case of division is figured in Plate XXV. showing the relative plasticity of the periplast at the time of fission. Each new individual is only half an individual, so far as outline is concerned, although of course all the essentials of the cell are present. When the new half is formed it is lighter in color than the original half, and thus it is that in all the forms of *Phacus* (so far as they have come under my observation) individuals are common which are light green or clear on one half and brighter green on the other.

**Phacus pyrum** (Ehr.)

Pear shaped with long posterior process. A deep spiral suture usually makes eight turns about the body. Color densely bright green. Stigma and vacuole reservoir conspicuous.

Size as observed usually less than 15 microns. Plate XXV.
One of the most beautiful and regularly shaped of all protozoon forms. Solitary, and not especially common. According to Walton\(^1\) reproduction is by longitudinal fission without encystment.

My drawing represents the form as I have habitually seen it, with more turns to the spiral than are given in Walton's plate. At times the cell is as clear as green glass showing the spiral on both upper and lower sides at once, thus making a latticed pattern.

**Family ASTASIIDAE.**

**ASTASIA Dujardin**


**Astasia triconhora Ehr.**

With a single flagellum almost as long as the body, rather heavy and extended straight in front, only the tip vibrating as the animal swims. Body colorless or faintly greenish blue. No pharynx. A large posterior vacuole. A very metabolic motion of a rather definite type (see figures).

Length of body alone 30 microns. Plate XXVI.

**Family PERANEMIDAE.**

**NOTOSOLENUS Stokes.**

Body ovoid, strongly flattened, outline somewhat

angled, concave dorsally. Not metabolic. An anterior flagellum and a small secondary one.

**Notosolenus orbicularis** Stokes.

Anterior flagellum $1\frac{1}{3}$ times the length of the body, carried obliquely to the right. Secondary flagellum ventral, appearing as a small longitudinal line through the body. Endoplasm colorless, a circle of minute granules around the periphery. Dorsal concavity very conspicuous and deep. Not abundant.

Body 13 microns, anterior flagellum 20 microns. Plate XXVI.

Edmondson does not record this species. It is separated from his **Notosolenus opocamptus** Stokes by the relatively greater width of the dorsal concavity.

**ENTOSIPHON** Stein.

Oval, flattened, periplast firm and enduring. Anterior border notched, bearing two flagella at the oral aperture. Tube-like pharynx present.

**Entosiphon sulcatus** Duj.

With the characters of the genus. Longitudinally strated. Vacuole anterior on the right side of the long tube-like pharynx. Anterior flagellum longer than body, posterior flagellum trailing for more than the distance of the body behind, adhesive at tip. Motion oscillating. A very common form, especially in infusions.
Body sometimes filled with faintly bluish green granules.

Length of body proper 26 microns. Plate XXVI.

ANISONEMA Dujardin.

Body ovate, not metabolic. A long pharynx leading from the pointed anterior end. Anterior flagellum short and vibrating, posterior flagellum arising near it, but long and trailing. Motion oscillating.

Anisonema acinus Duj.

Ventral surface flattened. Endoplasm transparent. Posterior flagellum twice as long as the body. Anterior flagellum of body length. Pharynx one-third body length.

Length 30 microns. Plate XXVI.

Subclass CHOANOFLAGELLATA

DIPLOSIGA

With a single flagellum and two concentric collars.

Genus not recorded by Edmondson.

Diplosiga species

A minute delicate stalked form, having an elongate parallel sided lorica whose base is drawn into a point and whose distal end flares into a collar. A second less flaring collar within. Flagellum single, body not filling the proximal end of the lorica. Nucleus central, two posterior vacuoles.
Locality; found rather rarely in the goldfish tank which yielded the supply of *Nuclearia*. Dimensions; Stalk 34 microns, lorica from base to top of outer collar 35 microns, flagellum 20 microns.

Plate XXVI. Figures 6, 7, and 8.

At no time was the flagellum in this species seen to wave, although other signs of life were manifested in the vacuoles and in an amoeboid movement within the shell. In one specimen the protoplasm rose to the top of the lorica and protruded in a rather shapeless mass, and was then retracted.

I have been in doubt as to whether the two pairs of lines at the top of the lorica represented the sides of concentric collars or accessory tentacles (*Acineta*?). Professor Calkins of Columbia after seeing the drawings has placed the form with the collared flagellates in the genus *Diplosiga*. The dotted lines in the drawings indicate the probable limits of the collars.

Class II. PHYTOMASTIGOPHORA
Subclass PHYTOFLAGELLATA
Order 1. CHRYSOFLAGELLIDA

*MALLOMONAS* Perty.

Flagellum single, long. Yellow-green chromatophores. No stigma. Shell oval, of glassy looking imbricating circular plates bearing setose spines.
**Mallomonas fresenii** S.K.

With the characters of the genus. Setae not more than thirty, immovable, curved. Endoplasm more green than yellow in the individuals observed. Motion rapid.

Shell (without spines) 25 microns. Plate XXVII.

Only a few specimens of this rare form were found in water from Fairport, Iowa. Some were encysted, others extremely active. Fig. 2, Plate XXVII shows an empty shell with suddenly expelled protoplasm, demonstrating that the spines belong to the shell, rather than to the contents. Edmondson records finding a *Mallomonas* which he considers to be the species *plosilii* although he was not able to make out the structure of the shell.

**SYNURA** Ehrenberg.

Spherical rosettes of about fifty individuals which may or not be covered with delicate spines. Two olive brown band-like chromatophores. Vacuoles numerous. Flagella two, unequal. Not stalked.

This genus is not recorded by Edmondson.

**Synura uvella** Ehr.

Free swimming rosettes joined by an invisible matrix. The individuals found did not bear spines.


Plate XXVII. Fig. 3.

1- Protozoa of Iowa, p. 49.
Found late in March at edge of melting ice pond in Iowa City Park. This plant like colony is a source of offensive tastes and odors in drinking water.¹

CHILOMONAS Ehrenberg.

Without chromatophores. Oval with a deep anterior notch leading to the cytopharynx. Flagella nearly equal, both directed in advance, or one curled back.

Chilomonas paramoecium Ehr.

Small, oval, with mouth at the base of two flagella, one of which is used in progression, the other being adhesive or used as a dragging anchor. Pharynx expanded into a conspicuous cavity. Nucleus central or slightly posterior. A circle of faintly bluish starch granules passing around the periphery of the endoplasm and along both sides of the pharynx. Motion oscillating. Common everywhere.

Plate XXVII.

¹- Calkins. Protozoology p. 72.
Order CHLOROFLAGELLIDA

HAEMATOCOCCUS Agardh.

Body held by protoplasmic threads in a large delicate transparent cyst. With green chromatophores, which may at times be partly or wholly red. Stigma present. Flagella two.

Haematococcus lacustris. Girod.

With the characters of the genus. Free swimming stage; body pyriform, often with a rather pointed anterior end. Chromatophores rounded, very numerous. Stigma large, irregular, anterior to the center. Nucleus seldom distinguishable, central, irregular. Cyst or shell very much larger than body, oval in free swimming stage, spherical in resting stage. Body held in place by radiating protoplasmic threads. Flagella two, often nearly as long as the diameter of the cyst, with stout proximal bases.

Size 30 to 45 microns. Plate XXVII B.

In the late autumn these forms were discovered in water collected in an old geod in the garden. Most of the individuals were almost totally red, but there was enough green to be seen in some of the cells to indicate that there would be a change with the coming of different weather conditions. Very few of the cells were active, and in those which moved
slowly no flagella were detected. A culture was brought into the laboratory and put under various conditions in the hope that the encysted forms would revive, but to no avail. Late in May when the laboratory specimens were still encysted, the geod was examined again, and found to be swarming with active cells of several sizes and stages. As a rule there was less generally distributed red color, and it was possible to see definite stigmata. Motion was sometimes in a forward spiral, but more frequently a mere revolving in one plane. Binary fission and multiple division within a cyst were observed.

Following the description and figure of Butschli¹ I place this Iowa City Haematococcus in the species lacustris. Doflein² describes and figures an apparently identical species as pluvialis. The figure given by the latter author (after Reichnow) brings out the points of a heavier proximal end to the flagella, which was very noticeable in the Iowa City specimens.

¹- Butschli, p. 386, Plate 43.
²- Doflein, p. 517.
Two unknown chlorophyll and stigma bearing flagellates.

On Plate XXVII, will be seen two remarkable forms which I am unable to place, but which seem worthy of mention and figuring, in the hope that at some future time they may be found again.

Figure 5. A minute free swimming form, not metabolic while under observation, yet delicate and plastic in appearance. Color very faint light greenish blue. A large anterior median stigma, and two equal divergent flagella longer than the body. Posterior part of the body drawn out into two short tail-like processes. A large clear central body of undetermined nature.

Professor Walton who has been very kind to examine many of my drawings of the Euglenoida says of this; "This is something quite new to me. I wish very much that I could examine living specimens, undoubtedly an impossibility unless you obtained a culture. I suspect that it may belong to the order Chrysomonadinae."

Figure 6. Body pear or bell shaped, apparently enclosed by a firm clear pellicle or lorica. The posterior end is either concave or has a clear space between the endoplasm and the pellicle giving the effect of a concavity. Endoplasm clear bright green throughout. Pharynx and stigma present. Two pairs of longitudinal folds or striations in the pellicle. Flagella unequal, one as long as the body, the other about half as long, both being directed in advance. A conspicuous, dense disc or sphere near the center of the body, with two small irregular
granules, one apparently within and the other close beside. (paramylon and pyrenoids?). Not metabolic. Motion a rapid forward spiral.

Length of body without flagella 28 microns.

Professor Walton says of this drawing and description: "An extremely interesting form. If you can find out the number of chloroleucites and also be certain that the flagella are always of unequal length, I am inclined to think it may prove something quite new." Unfortunately I have never found but the one specimen.
INFUSORIA.

The infusoria are protozoa with cilia during embryonic life or during the entire life history. They are the most specialized of the protozoa and reach such a stage of regional differentiation that we may paradoxically speak of them as having organs without tissues and without cells.

Cilia, which are the especial character of the subphylum, differ from flagella in being hair-like continuations of the ectosarc, and do not arise in the nucleus. There is, however, a basal granule, the microsome, of nuclear origin and akin to the more deeply lying basal granule of such flagellates as Euglena; and there is in addition, a row of kinetic granules whose contraction along the edge of the cilium gives it its lashing or vibrating movement. There is usually a high degree of coordination of the movement of these cilia, and the motion is under the instant control of the organism.

Cilia in simplest form are seen in the Holotrichida, an order characterized by uniform clothing of cilia in more or less longitudinal or spiral rows. There is always a tendency for these cilia to be longer in the oral region, and the so-called caudal cilia are often longer also, apparently serving as a rudder. Progression in this group is usually forward in a spiral course, and may sometimes proceed in an alternately clockwise and counter clockwise manner. It is also possible for the same forms to swim without revolving, and to go either forward or backward, impelled by internal impulses which in a higher form would be described as capricious.
The fusion of rows of cilia forming membranelles about the oral region characterize the next order, the Heterotrichida. These membranelles or adoral zones still retain much of the appearance of separate cilia, and often do not reveal their true nature until the animal has been slowed down or killed by reagents. The undulating membrane found within the pharynx or at the oral opening in the preceding order is doubtless also a development from separate cilia, although the lines of union are less distinct.

Setae, cirri, and bristles, which appear in limited regions in the Hypotrichida, are a still further development of fused cilia. In some of these forms the cirri have the position, appearance, and movements of feelers, and there is no doubt that there is here a localized sensory function much higher than is seen in the lower groups of ciliates.

In the fourth order, the Peritrichida, the adoral zones of cilia or membranelles are not markedly an advance over those seen in previous groups, but there are, in addition, other kinetic specializations of high rank. The primitive muscle element in the stalk of a Vorticella and the sphincter-like peristome fold of the bell are of great importance from an evolutionary standpoint.

In the discussion of the sarcodina it was noted that the nucleus was the origin of the kinetonucleus, and of all kinetic developments. Here we see a further separation of the primary functions of the nucleus, and find in the infusorian both a germ and a somatic nucleus. The germ nucleus,
or micronucleus, is often invisible without reagents, but the somatic nucleus, or macronucleus, is usually plainly visible as a more finely granular body in the variable endoplasm. It may be single, multiple, or moniliform, and is not necessarily of the same type throughout the life history. In those ciliates having a definite pharynx, the position of the nucleus is at the lower end of this passage in order that digestive fluids may the more easily reach the incoming food. Experiments by Metalnikoff\(^1\) indicate that the alkaline and acid reactions of infusorian digestion are comparable to those of higher organisms.

Regional differentiation of layers is seen in the infusoria to a degree comparable to that seen in the radiolaria. There is first a membranous ectoplasm (pellicle, or cuticulum) which may be soft and delicate, reticulated (Urocentrum), hexagonally pitted with a cilium in the center of each pit (Paramecium), or which may bear separate chitinous armor plates (Colepa), or which may be clear, dense, and smooth with a resistance and endurance recalling the outer periplast of the flagellate Phacus (Stylonichia). Immediately beneath the cuticle the more actively contractile infusoria (Lachrymaria) have threads of primitive muscle elements, the myonemes\(^2\). Next we sometimes find a thick cortical plasm which is neither ectoplasm nor endoplasm. This is seen to best advantage in a Urocentrum which has been slowed down and stained with a weak solution of methylene blue. The cortical plasm is seen to be of considerable

---

1- Protozoology, page 80.
2- Protozoology, page 52.
thickness and radiating in structure. Butschli\textsuperscript{1} states that it is in this region that the trichocysts of Urocentrum are imbedded, but Calkins\textsuperscript{2} brings out the interesting fact that the trichocysts of most infusoria are not entirely imbedded in the cortical plasm, but may penetrate into the endoplasm and occasionally be drawn inward and carried about in the endoplasmic currents. \textit{Stentor} shows a cortical plasm of considerable extent in the narrowed basal end of the body, there being no endoplasmic currents in this portion. Within the endoplasm there are the various granules characteristic of protoplasm, with various food particles in different stages of digestion, and with certain globules of oil and other organic compounds in storage. Besides these, the nuclei, and the vacuole system, there is occasionally a pigment granule or stigma as in the flagellates.

The vacuole system in the infusoria is more complicated than in the mastigophora. Afferent canals, often with extensive ramifications drain the endoplasm into the large vacuoles, which may be multiple or single, and which discharge with a rapidity correlated with the activity of the organism. \textit{Cyolidium} one of the most minute and active of the infusoria discharges its vacuole on an average of seven seconds. The activity of the vacuoles of \textit{Paramecium} varies greatly with the condition of the animal, but in general is fairly rapid and alternating in the anterior and posterior vacuoles. In \textit{Stentor} the afferent canals are conspicuous the entire length of the body.

1-Page 1712.
2-The Protozoa 175.
In the infusoria there is usually an excretory pore rather than a mere rupture of the ectoplasm, and the vacuoles are often comparatively deeply seated in the cell, rather than at the periphery, as in the helioza.

The bodies of the infusoria are often brightly colored. Stentor ceruleus varies from a delicate smoky blue to a dense greenish blue. Blepharisma varies through delicate shade of pink to a pale purplish rose. Nassula exhibits a variety of colors, which Edmondeon^1 attributes to the breaking down of the low plant organisms upon which it feeds. Stentor polymorphus and many other forms are often bright green, the color being due to chlorophyll bodies which have been ingested in plant food and which remain imbedded in the endoplasm, or in some cases the green color is due to symbiotic algal cells.2

Reproduction in the infusoria is by transverse division, in contrast to the longitudinal division of the mastigophora. The division of the micronucleus is preceded by maturation and attended by mytotic phenomena; but the division of the macro-nucleus is amitotic.3 Fertilization is not necessary to reproduction, but conjugation is of very common occurrence, the two cells uniting by their oral faces which to some extent disorganize and allow a pumping, streaming exchange of endoplasm. In the Vorticellidae the conjugants are of unequal size. A minute free swimming microgamete bores its way into the lower part of the bell of an attached, normal sized macrogamete, and does not emerge.4 Spore formation and other phases of reproduction

1- Protozoa of Iowa, p. 72. 3- ibid 191
2- Calkins The Protozoa, p. 174. 4- ibid 195.
have been described by various authors, but have not been observed by the writer and are not within the limits of this paper.

The subclass Suctoria is considered a separate class by some writers, and indeed the adult forms seem to have little in common with other infusoria; but embryonic development shows a ciliated stage indicating the origin of the group. On the other hand there is a certain affinity with the heliozoa. Long suctorial tentacles are shot in and out very much like axial rays and are sometimes seen to originate deeply within the endoplasm.

Embryos are produced as exogenous or endogenous buds. Calkins\(^1\) explains the formation of the latter as a sinking in of the bud-forming area and the covering over of the brood pouch by a membrane, beneath which the little embryos swim about before breaking through to the surface. A portion of the nucleus must migrate from the endoplasm to the bit of invaginated ectoplasm which is to form the new cell. This is quite a different process from the formation of internal embryos in Stentor as reported by Edmondson\(^2\). In Stentor the embryos are formed from segments of the moniliform nucleus, and do not involve any invagination of the ectoplasm.

The suctoria are separated on the basis of symmetry (whether spherical, radial, bilateral) or non-symmetry. There may be a lorica or not, a stalk may be present or absent, and the forms are solitary or colonial.

1- Calkins - Protozoology, p. 96.
2- Protozoa of Iowa, p. 94.
Comparatively few suctorians have been found this year. In the fall a small pond filled with decaying brown leaves yielded several species which multiplied incredibly in the laboratory for several weeks and then disappeared. *Sphaerophrya magna* and the globular stalked phase of *Podophrya fixa* were the most numerous, and with them was associated a new species of *Metacineta*, which is described later. Other suctorians have been found but rarely since.
Subphylum INFUSORIA
Class I. CILIATA
Order 1. HOLOTRICIDA
Suborder GYMNOSTOMINA
Family ENCHELINIDAE

COLEPS Nitsch.

Oval in form. Surface sculptured, giving the effect of plates with deep ciliated furrows between. Mouth terminal, food swallowed.

Coleps hirtus Ehr.

Body barrel shaped, swollen or elongate, not plastic. Surface sculpture typically forming twelve encircling rows of plates, with the addition of a posterior zone bearing three spines, and an anterior circle of deep points. Body clothed with cilia borne in the furrows between "plates"; very long cilia surround the mouth and there are often posterior cilia longer than the three terminal spines. Mouth highly extensile. Nucleus large, in posterior or central region. Vacuole very conspicuous in posterior region. Oil globules often present. A dark red pigment granule has sometimes been found to be present in all the individuals found in one locality. Reproduction by transverse division, the newly formed surface areas not developing the sculpturing until some time after separation. Conjugation of common occurrence, taking place by the union of the oral regions of two cells. During conjugation the habitual position of
the two individuals is such that the long axes of the shells are at an angle. During fission, however, the axis of the one shell is continuous with that of the other. I have never observed conjugation to take place in shells whose surface sculpture indicated very recent division.

On one occasion a *Coleps hirtus* under observation was seen to blow several bubbles of protoplasm from the mouth, the extruded portions retaining a globular shape, and one at least being provided with a small vacuole. These bits of the parent body did not move while under observation.

*Coleps* is a voracious eater, and will swallow objects almost as large as its own body. A number of these creatures will surround a bit of decaying matter and apparently suck and bite and tug with a great deal of strength for so small a body, the sharp spines being used as teeth. Plate XXXV, Fig. 1, shows a *Stentor* whose digestive processes were not as rapid as the means an ingested *Coleps* applied to its own rescue. It was an amusing sight to see the tiny *Coleps* break its way to freedom through the ectoplasm of its captor.

The rolling swimming motion of this form makes it most difficult to observe. When it is spinning on its head or feeding is the best time to observe the surface structure. *Coleps* is often found impaled on the rays of heliozoons. This together with the fact that reagents cause the organism to disintegrate almost instantly, suggests that the "armor plates" are not of an especially hard or dense surface.
Length 50 to 80 microns. Plate XXVIII.

CHENIA Dujardin

Elongate, contractile, uniformly ciliate with longer anterior cilia. Mouth terminal, usually closed. Nucleus divided into small pieces.

Genus not recorded by Edmondson.

Chenia species

Anterior portion narrowed and elongated, with long cilia on dorsal anterior end arranged in a fan shaped row. Mouth not made out. Nucleus moniliform. A row of fourteen vacuoles placed longitudinally.

Size 200 microns. Plate XXVIII, Fig. 2.

Found with decaying vegetation. But one specimen was observed, and upon applying dilute osmic acid it immediately disintegrated.

LACHRYMARIA Ehrenberg.

Mouth terminal, usually closed, on small rounded head bearing a crown of cilia. Neck highly extensile. Body striated either spirally or longitudinally.

Lachrymaria olor (Mull)

With the characters of the genus. Body ovate with pointed posterior end. The neck capable of complete retraction or of extension many times the length of the body. A swan-like form often assumed. Body spirally striate, as many as twenty-five turns to the spiral. "Nucleus double", vacuo
more than one.

Size 225 microns. Plates XXIX and XXX.

Edmondson speaks of the body of this species as being spirally striate in two directions; but as I have observed the species it seems that the striations run in only one direction, the lines of the under side showing through being responsible for the latticed effect. Plate XXIX figures a case of transverse fission in which the double nature of the macronucleus is shown before division, but faintly indicated in the daughter cell, (Fig. 7). In Plate XXX will be seen an example of conjugation by the oral surfaces with alternately tense and flexed positions of the cells and a streaming exchange of protoplasm. This rhythmic motion continued throughout the observations, and appeared to aid in the exchange of cell contents.

Family TRACHELINIDAE

DILEPTUS Dujardin.

Body much elongate, with flexible neck having an open mouth at the base. Nucleus moniliform. Vacuoles in a longitudinal row the entire length of the body. Trichocysts in the neck.

Dileptus gigas C. and L.

Body somewhat flattened, with very long neck and sometimes a tail. A longitudinal row of vacuoles. Short pharynx

1- Protozoa of Iowa, p. 66
always open at base of neck.

Size 250 to 300 microns. Plate XXX, Fig. 1.

A very common form in the fall. The moniliform nature of the nucleus has not been made out.

**LOXODES** Ehrenberg

Flattened with an anterior hook turning to left. No cilia on dorsal surface. An elongated peristome leading to an open pharynx.

**Loxodes rostrum** Ehr.

Body plastic, not contractile, often swimming on side with oral furrow on the left. Nuclei two, vacuoles in longitudinal row. Surface striate. Posterior end truncate transversely.

Size 95 microns. Plate XXXI.

**Family CHLAMYDODONTIDAE**

**CHILODON** Ehrenberg.


**Chilodon cucullulus** Mull.

Body dorsally rounded, especially in young forms. Provided with a very thick smooth pellicle. In side view the inner end of the pharynx of the domed forms is seen to have
a spiral prolongation of the pharynx rods. Nucleus posterior or central, seen without reagents. Vacuole conspicuous in the posterior region.

Size 100 microns (juvenile form). Plate XXXI.

Myriads of these tiny domed creatures have been found in the smallest puddle of water or vial in the laboratory, but the more flattened form which Edmondson¹ says are the adults of the domed form have not so often come under my observation. In the adult the longitudinal striations of the ventral surface are seen through the body, and there is a ciliated groove leading to the open mouth from the right lateral border.

Suborder TRICHOSTOMINA
Family CHILIFERIDAE

GLAUCOMA Ehrenberg.

Oval, ventrally flattened and ventrally ciliated. Mouth ventral with vibratile membranes. Nucleus spherical. The single contractile vacuole conspicuous, posterior to the nucleus.

Glaucoma scintillans Ehr.

Oral aperture to one side on the ventral surface with two small vibrating lips. From the dorsal side the cell appears oval with a fringe of cilia around the smooth convex surface. Endoplasam finely granular.

Size 50 microns Plate XXXI.

¹ Protozoa of Iowa, p. 73.
LOXOCEPHALUS Ehrenberg.

Body elongately oval, ciliated in longitudinal rows with one or more posterior setae.

Loxocephalus granulosus S.K.

Body nearly cylindric, narrower at anterior end, posterior end rounded with a single straight seta nearly as long as the body. Surface longitudinally striated. Mouth and pharynx seen indistinctly near the anterior end behind an obliquely placed wreath of strong cilia. Nucleus spherical, central. Contractile vacuole very active and conspicuous in posterior region. A very active form.

Size 38 microns. Plate XXXI.

Edmondson and other writers figure this species with two strong setae on the margins of the neck. Under favorable lighting it may be seen that there is a complete oblique circlest of these setae.

COLPODA Mull.

Compressed laterally, shape reniform. Mouth ventral in a deep depression, the animal, however frequently swimming on the side.

Colpoda cucullus Ehr.

With generic characters. The animal as observed habitually swims on the side bringing the mouth on the right margin. Oral depression marked, mouth opening into a pharynx which dilates at its lower end into a globular pit. Surface deeply grooved, the lines following the curved outlines of the body.
until they reach the anterior end, where they form crenulations on the right lateral margin anterior to the mouth. Nucleus central, beside the dilated end of the pharynx. Vacuole posterior. Endoplasm packed with dense granules. A fairly common form, but not listed by Edmondson.

Size 65 microns. Plate XXXI, Fig. 6.

Family UROCENTRIDAE

UROCENTRUM Nitzsch.

Pyriform, tapering toward the posterior extremity, and having a more or less strongly marked annular constriction near the center. Two girdles of cilia. A posterior, eccentric tail of fused cilia.

Urocentrum turbo Mull

Form unsymmetrically egg shaped with two wreaths or wide girdles of cilia. Anterior end rounded and smooth, rest of body occasionally clothed with long cilia. Posterior end sometimes with a short axial point. An eccentric tail composed of more or less obviously fused cilia. Mouth always open, with undulating membrane in the pharynx, located in the region of the median annular constriction. Nucleus reniform, or band-like, posterior. Contractile vacuole posterior, supplied by four conspicuous radiating canals. Trichocysts present. Motion, a rapid rolling and tumbling, spinning on head and darting backwards and forwards. The tail is often temporarily attached, or it may drag along a mass of debris.
Common in ponds and infusions with decaying green plants.
Reproduction by transverse fission.

Length 100 microns. Plate XXXII.

This common form is a difficult one to observe satisfactorily on account of its great activity and the fact that the cuticulum disintegrates in the presence of very dilute reagents. Osmic acid fumes are especially deleterious. The best results have been obtained by adding one drop of one percent osmic acid to about a hundred of water which has been colored a light blue with methylene, and putting a single drop of this mixture at the edge of the cover glass. The organism after a few more rapid revolutions than usual will slow down enough to show the lat- ticed markings of the surface, the thick radially-striate cortical plasm with trichocysts, the workings of the afferent canals, and the vacuole. As soon as motion ceases it is seen that the ciliary wreaths are in reality quite wide, and not the mere circlets which they appear to be in motion. Often there is no line of demarcation between the two areas.

Butschli\(^1\) and Roux\(^2\) speak of a third smaller circlet of cilia in the median annular constriction. My observation is rather that at times the whole body surface behind the anterior "skull cap" may be more or less ciliated, the same cilia being invisible until the animal is killed and stained.

Family MICROTHORACIDAE

CINETOCHILUM Perty.

Flattened ventrally, convex dorsally. Mouth ventral and

1- Butschli, p. 1711
2- Roux, p. 69
posterior with vibrating membrane. Ventral surface ciliated with posterior setae.

Cinetochilum margaritaceum Ehr.


Length 25 microns. Plate XXXIII. Fig. 5.

An uncommon form found in pond water.

Family PARAMOECDIDAE

PARAMOECIUM Muller.

"Slipper shaped", entirely ciliated. Trichocytes throughout body surface, especially in oral region. Mouth at end of an oblique groove.

Paramoecium caudatum Ehr.

Body slender, narrower at the anterior region. Oral groove obliquely curving to the center of the body, or past the center. Ciliated pharynx always open. Macronucleus and micronucleus central. Vacuoles two, at opposite ends of the body, supplied by astral canals, and discharging alternately through minute pores.

Size 325 microns. Plate XXXIII.

Both transverse fission and conjugation may often be observed in this most abundant and accessible of all the ciliates. Carmine feeding demonstrates the circulation of
food from the mouth backward and forward again, following the outline of the cell. A very weak solution of hydrochloric acid will bring out the trichocysts. Weak chloro- tone has been used to slow the animals down, but unless the reagent is used sparingly it causes disintegration of the cuticulum.

Paramoecium trichium Stokes.

Form more compact, a shorter oval, than in the preceding. Oral groove extending to the center of the body only. Mouth pyriform in outline, the larger end being anterior. Pharynx distinguishable to a point over two-thirds back from the anterior end of the body. Nucleus large, oval, central. Trichocysts abundant. Surface longitudinally grooved. Endoplasm filled with dense granules. Found rarely.

Size 100 microns. Plate XXXIII.

Family Pleuronemidae

LEMBADION Perty.

Body a ventrally flattened oval. Peristome with undulating membrane occupying a conspicuous portion of the ventral surface, and forming a large oval within the oval body outline. Ciliation complete, with longer posterior cilia.

Lembadion bullinum Perty.

Nucleus posterior. Motion rapid, straight forward or backward. A fairly common species.

Size 60 to 100 microns. Plate XXXIII, Fig. 3.

**CYCLIDIUM** Ehrenberg.

Elongated oval in form. Mouth with an extensile membrane. Cilia very long and rigid; a long posterior springing hair.

*Cyclidium glaucoma* Ehr.

Body an elongate oval, narrowed abruptly at the anterior end. Cuticulum longitudinally striated, with a single very rigid seta extending posteriorly, which acts as a springing hair. Mouth anterior to middle of body with a short undulating membrane which is not seen in young forms. Macronucleus central, micronucleus on side opposite the mouth. Vacuole posterior, discharging every seven seconds. A most active form.

Length of body 28 microns. Plate XXXIII.

**Order** HETEROTRICHIDA

**Family** PLAGIOTOMIDAE

**BLEPHARISMA** Perty.

Flattened, elongate; oral groove hood-like, turning to the left. On left hand border of peristome a row of large cilia, a vibrating membrane on the right side which is usually ventral in swimming. Color pink or red. Very
little contractile.

**Blepharisma lateritia** Ehr.

Anterior end pointed and curved to left in swimming. Oral groove lying on left hand side with membranous edge ventral and ciliated edge dorsal. Body transversely truncate at posterior end. Nucleus large, oval, central. Vacuoles more than one, posterior. Surface finely longitudinally striate. Color pink or rose. Swims on side or revolves.

Size 140 microns. Plate XXXIV.

Found in Iowa City and Cedar Rapids both in autumn and spring.

**SPIROSTOMUM** Ehrenberg.

Elongated, contracting spirally. Body not much flattened. Oral groove straight, extending to middle of body, provided with heavy cilia which are not fused.

**Spirostomum teres** C. and L.

Body very long, rounded at anterior end, transversely truncate posteriorly. Highly contractile spirally; longitudinally striate when extended. Nucleus oval and central. Posterior vacuole irregular and extending in canal-like points anteriorly. Very active.

Size 500 microns. Plate XXXIV. Fig. 2.

Found in "The Slough" at Cedar Rapids.
Family STENTORIDAE

STENTOR Oken.

Trumpet shaped animals with a terminal disc-like peristome, surrounded with a spiral of cilia. Undulating membranes absent. Mouth in a depression at the edge of the disc, on ventral left side. Free swimming or attached. Highly extensile.

Stentor roeselii Ehr.

With generic characters. Body uncolored. Long basal setae present. Body longitudinally striated with rows of cilia. Nucleus usually band-like, sometimes moniliform. Disc spirally striated with rows of fine cilia. Vacuole dorsal near anterior end, fed by a large canal running almost the entire length of the body. The base of the trumpet is more dense and free from endoplasmic granules, having an extension of the cortical plasm.

Maximum extended length 600 microns. Plate XXXV.

Stentor ceruleus Ehr.

Body large, color varying from a delicate smoky blue to a rather greenish blue color. Nucleus moniliform. Not figured.

Stentor polymorphus Mull.

Very similar to the two preceding Stentors, the body being densely green. The largest of the genus. Nucleus moniliform.
Maximum extended length 1500 microns. Plate XXXVI.

The old stone quarry pond on the west side of the Iowa River at all times yields an abundant supply of both Stentor roeselli and Stentor polymorphus. Bits of floating and decayed wood are fairly slimy with masses of these forms, a single individual often being large enough to be seen with the naked eye. Reproduction by oblique fission and by budding have been observed. In the case of budding the parent cell was seen to become a shapeless mass and was thought to be about to disintegrate before the separation of the daughter cell. Some ten minutes after the small daughter cell was free the parent cell resumed its normal form and activities. Conjugation as in the other ciliates takes place by the temporary union of the oral surfaces, the protoplasmic surface at this point being at all times softer than at other places on the body surface. This is seen in the ingestion of food which is pressed into the endoplasm at the base of whatever structure serves as a mouth, and in the rapid disintegration of that region of the cell when too strong reagents are used.

Family HALTERIDAE.

HALTERIA Dujardin.

Minute forms with nearly globular bodies, an anterior spiral wreath of cilia, and an equatorial zone of springing hairs.
Halteria grandinella Mull.

Body usually sub-globular, occasionally somewhat heart shaped. Mouth eccentric within spiral of cilia. Nucleus central. Contractile vacuole lateral, near the nucleus. Motion a forward spiral, interrupted by sudden jumps several times the length of the body. Common.

Body diameter 25 to 30 microns. Plate XXXVI.

STROMBIDIUM. Clap. and Lach.

"Like Halteria but without the bristles. Anterior portion protrusible."

Strombidium species

Plate XXXVI, Fig. 6, shows an individual which seems to belong to this genus; but associated with it was found a second form (Fig. 4.) having the generic characters with the addition of an equatorial girdle of long weak hairs (as in Halteria). The much greater size, the plastic body, protrusible anterior end, swollen lateral vacuole, and absence of any springing motion (even in the form having the equatorial girdle) seem sufficient reason for taking both these forms from the genus Halteria. A large number were found without the girdle, and in those few having the girdle the hairs were so delicate that it was most difficult to make them out at all.

Found associated with Stentor, but did not long survive

1- Conn. P. 62.
laboratory conditions.
Size 60 to 80 microns. Plate XXXVI.

Order HYPOTRICHIDA
Family OXYTRICHIDAE

STYLONICHIA Stein.
With strong marginal cirri in perfect rows and ventral cirri in imperfect rows. Strong frontal cirri with heavy bases, acting as feelers. Anal styles present, with three caudal setae. Body encuirassed.

Stylonichia mytilus Ehr.
With generic characters. Body elongate oval, wider anteriorly, somewhat flattened, peristome and undulating membrane ventral on the left side extending more than half way the length of the animal. Anal styles four, only two extending beyond the posterior end. Caudal setae very long, three in number. The commonest of the hypotrichous ciliates.

Length of body alone 130 microns. Plate XXXVII.

STICHOTRICA Perty.
Elongated, with narrow neck-like portion nearly as long as the oval body proper. Peristome extending to the middle of the body. No anal setae. Nucleus in two widely separated oval parts.

Stichotricha aculaeta Wrz.
Lateral borders of neck-like region fringed with very long
straight hair-like setae. Two oblique rows of heavy ventral setae. Peristome bordered on the right hand with conspicuous cilia. Vacuole large, on the left ventral border near the middle of the body.

Size 190 microns. Plate XXXVII.

Kent\(^1\) describes two long stout, uncinate anterior spines, in this species which I did not observe. He mentions, however, that in swimming these two processes are vibrated so rapidly as to become invisible; and this probably accounts for their omission in my plate.

Family EUPLOTIDAE.

ASPIDISCA Ehrenberg.

Frontal, marginal, and ventral cilia considerably reduced. Macronucleus band-formed. Body round or oval in outline. Flattened ventrally, dorsally convex. Seven scattered ventral cilia and commonly five anal cilia.

Aspidisca costata Duj.

Body a flattened oval dome more or less deeply furrowed. Setae with an almost globular base fitting into a slight fossa. In the specimens examined there were commonly four anterior and four posterior setae on the ventral side. I suspect this small number to be an indication of immaturity. Oral aperture covered ventrally by a short curved membrane, a row of cilia extending above it longitudinally. The observations on this form are not satisfactory to me.

1- Manual of the Infusoria, p. 777
Order PERITRICHIDA

Family VORTICELLIDAE

VORTICELLARIA Linn.

Bell shaped animals with cilia reduced to a spiral or wreath wound to the right. A secondary circle of cilia present at times. Usually provided with a spirally contracting stalk.

A number of species of this genus have been observed, of which only one is given here as a type.

Vorticella campanula Ehr.

Body typically bell shaped, curving inwardly above the central part and swelling outwardly to meet the reflexed peristomial fold. Peristome invaginable with sphincter-like contraction. Ciliary disc often elevated. Bell not annulated. Macronucleus crescent-shaped. Vacuole single. Stalk usually four to six times body length.

Length of body 50 to 150 microns. Plate XXXVIII.

Some observations on the division and encystment of this animal are given on the page facing the plate.

Subclass SUCTORIA

Family PODOPHYIDAE

PODOPHYRA Ehrenberg.

Stalked suctorians, usually spherical, pear, or club shaped. Tentacles usually capitate, in groups or scattered
over the surface. Vacuoles more than one. Lorica not present.

**Podophrya maupasii** Butschli

Pedicel cylindrical, rather thick, slightly curved, enlarging at summit. Body subpherical or club shaped, concave at the base for insertion of stalk. About twelve heavy tentacles not conspicuously capitate, slightly longer than the diameter of the body. (Funnel shaped and not exceeding the diameter of the body, according to Sand.1)

Cytoplasm bluish grey. Nucleus central. Vacuoles two. Total length 42 microns. Plate XXXIX. Figs. 3 and 4. Found in gold fish tank in winter. The species is not recorded by Edmondson.

**Podophrya fixa** Mull.

Body spherical, like a heliozcon with capitate tentacles. Length of stalk several times the diameter of the body. Size 50 microns. Not figured. This form was fairly common in the late autumn in a culture of heliozoa.

**Podophrya libera** Perty?

Only the characteristic annulated cyst of this species was found, and as it did not revive, there must be some question as to the identification. The form may be that of some microscopic plant unknown to me, but in my opinion it is **Podophrya libera** (figured in Plate 76 of Bronn's Klassen und Ordnungen) Plate XXXIX.

1- Sand. Monographique sur le groupe des Infusoires Tentaculifères, p.
TOKOPHRYA Butschli.

No lorica. Pedicel and body form variable. Tentacles straight and capitate, localized or scattered over the body. Form of nucleus very variable. One or several contractile vacuoles. Reproduction (according to Sand) by internal embryos which may be peritrichous, holotrichous, hypotrichous, or without cilia, or in the form of Sphaerophrya or by external ciliated buds.

Tokophera species 1.

Extremely minute subglobular forms borne in small clusters on a slender rigid stalk, in length two or three times the diameter of the body. Endoplasm colorless, much vacuolated, nucleus not visible without reagents. Tentacles borne in a circle near the crown of the body, sometimes extending to a length of twice the body diameter.

Body 4 microns or less. Plate XXXIX. Figures 1 and 2.

Myriads of these minute suctorians were found in the city park during November, and from the same place in April the species was found again, but with dimensions twice as great. Those found in the fall had a body diameter of four microns or less, were in clusters of two to five, or were broken from their common stalk. Each individual always had its own short pedicel in addition to the common stalk. The spring specimens were at least twice as large, sometimes slightly elongated, and were not so numerous. Sand in his monograph on the suctoria does not give any figures or description agreeing with this form, the most nearly approximate being his Tokophera francottei Sand.*

* Monographique sur le groupe des Infusoiræ Tentaculiferæ, p. 250.
Tokophrya species 2.

Body subpyriform, solitary on delicate stalk more than twice the body length. Endoplasm colorless, with a few granules and two posterior contractile vacuoles. Tentacles cylindrical, straight, capitate, as long as the body, borne near the crown and equidistant from each other. Number of tentacles as observed in one specimen (the only one found) four.

Total length 37 microns. Body proper 8 microns. Tentacles 8 microns. Plate XXXIX. Figure 6.

Found in the gold fish tank which earlier in the season yielded a few specimens of Podophrya fixa (Plate XXXIX. Figures 3, and 4.)

This is another species which does not appear in any of my reference books. The most closely approximating form given by Sand is that just referred to under the preceding species, Tokophrya francottei Sand. I have indicated these two unknown Tokophryas as species 1. and 2. since they do not appear to be at all the same and were found in entirely different surroundings.
Family METACINETIDAE

METACINETA Butschli.

With lorica perforated for the exit of the tentacles. The base of the cup is drawn out into a long stalk. A single genus in the family.

Metacineta species (new)

Body incompletely filling a flattened hexagonal lorica with a fascicle of tentacles issuing from each angle. One main tentacle of each group has an axial rod running some distance into the finely granular endoplasm. Nuclear material (?) scattered in irregular granules. Contractile vacuole very large. No apparent aperture to lorica other than the perforations for the tentacles.

Lorica 50 x 61 microns. Average tentacle about 30 microns. Maximum tentacle 133 microns. Plate XL.

This remarkable suctorian was found early in the fall in company with a great many heliozoons in an infusion of pond water, with many half decayed leaves. When it first came under my notice there was a violent commotion in its vicinity owing to the fact that two or three of the long tentacles had pierced a stylonichian longer than its own body. Despite most vigorous efforts the stylonichian was held fast and impaled by more tentacles until in a short time two whole fascicles were imbedded almost to their bases in the victim's body, the flow of protoplasm being plainly seen through the
tentacles.

With a thread siphon this slide was kept moist and under observation for twelve hours. At no time did the body of the Metacinetan move (in fact it was so large that it had little room under the cover glass) but the free tentacles were shot in and out with great rapidity. The central tentacle of each group was less mobile and only gradually increased its length. Seldom did the tentacles curve. The victim, however kept up a frantic struggle for perhaps two hours, and a continuous oscillation of all the cilia and styles for six or eight hours more. About nine P.M. the almost empty cuticulum was abandoned, and the suctorian apparently two well gorged to accomodate even a contractile vacuole, had withdrawn all save the stub of each central tentacle, as in Fig. 2, Plate XL. It was now impossible to distinguish any space between lorica and contents. No nucleus was visible at any time, but throughout the observations a number of scattered fragments resembling nuclear material were noticed, and interpreted as indications of a possible spore forming stage. Hoping to be able to establish the life history of this remarkable new carnivore, I prepared a thread and feeding reservoir for the night; but the night watchman closed the crack at my window, the room became overheated, and the slide dried up. I have not since been so fortunate as to find another.

The species which most nearly approaches this form is *Metacineta mystacina* Ehr., as figured by Butschli (Plate 7, 8). *Metacineta mystacina*, however has a stalk, with the lorica open at the top like a long stemmed vase. Careful focusing upon the
new species did not bring out either stalk or aperture. It does not seem at all likely that they can be the same.
# INDEX OF GENERA.

<table>
<thead>
<tr>
<th>Genera</th>
<th>Page</th>
<th>Genera</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACTINOPHRYS</td>
<td>43</td>
<td>HALTERIA</td>
<td>92</td>
</tr>
<tr>
<td>AMOEBA</td>
<td>31</td>
<td>HETEROMITA</td>
<td>52</td>
</tr>
<tr>
<td>ANISONEMAL</td>
<td>63</td>
<td>* HYALODISCUS</td>
<td>30</td>
</tr>
<tr>
<td>ANTHOPHYSAL</td>
<td>51</td>
<td>LACHRYMARIA</td>
<td>80</td>
</tr>
<tr>
<td>ARCELLA</td>
<td>40</td>
<td>LEMBATION</td>
<td>88</td>
</tr>
<tr>
<td>ASPIDISCA</td>
<td>95</td>
<td>LOXOCEPHALUS</td>
<td>84</td>
</tr>
<tr>
<td>ASTASIA</td>
<td>61</td>
<td>LOXODES</td>
<td>82</td>
</tr>
<tr>
<td>BLEPHARISMA</td>
<td>89</td>
<td>* MALLOMONAS</td>
<td>64</td>
</tr>
<tr>
<td>CENTROPYXIS</td>
<td>40</td>
<td>* METACINETA</td>
<td>100</td>
</tr>
<tr>
<td>* CHENIA</td>
<td>80</td>
<td>NOTOSOLENUS</td>
<td>61</td>
</tr>
<tr>
<td>CHILODON</td>
<td>82</td>
<td>* NUCLEARIA</td>
<td>44</td>
</tr>
<tr>
<td>CHILOMONAS</td>
<td>66</td>
<td>* OIKOMONAS</td>
<td>50</td>
</tr>
<tr>
<td>CINETOCHILUM</td>
<td>86</td>
<td>PARAMOECEIUM</td>
<td>87</td>
</tr>
<tr>
<td>CLATHRULINAE</td>
<td>46</td>
<td>PHACUS</td>
<td>59</td>
</tr>
<tr>
<td>COCHLIOPODIUM</td>
<td>40</td>
<td>PODOPHRYA</td>
<td>96</td>
</tr>
<tr>
<td>COLEPS</td>
<td>78</td>
<td>RADIOPHRYS</td>
<td>45</td>
</tr>
<tr>
<td>COLPODA</td>
<td>84</td>
<td>* RHIPIDODENDRON</td>
<td>52</td>
</tr>
<tr>
<td>CYCLIDIDUM</td>
<td>89</td>
<td>SPIROSTOMUM</td>
<td>90</td>
</tr>
<tr>
<td>DIFFLUGIA</td>
<td>34</td>
<td>STENTOR</td>
<td>91</td>
</tr>
<tr>
<td>DILEPTUS</td>
<td>81</td>
<td>STICHOTRICA</td>
<td>94</td>
</tr>
<tr>
<td>* DIPLOSGA</td>
<td>63</td>
<td>* STROMBIDIDUM</td>
<td>93</td>
</tr>
<tr>
<td>ENTOSIPHON</td>
<td>62</td>
<td>STYLOLICHIA</td>
<td>94</td>
</tr>
<tr>
<td>EUGLENA</td>
<td>53</td>
<td>* SYNURA</td>
<td>65</td>
</tr>
<tr>
<td>EUGLYPHA</td>
<td>41</td>
<td>* TOKOPHRYA</td>
<td>98</td>
</tr>
<tr>
<td>GLAUCOMA</td>
<td>83</td>
<td>TRACHEFOLOMONAS</td>
<td>56</td>
</tr>
<tr>
<td>* HAEMATOCOCCUS</td>
<td>67</td>
<td>TRINEMA</td>
<td>42</td>
</tr>
</tbody>
</table>

( * Genera not recorded by Edmondson. )
UROCENTRUM 85  VAMPYRELLA 29
VORTICELLA 96  * TWO UNKNOWN GENERA 68
Plate I.

1. 2. and 3. Hyalodiscus limax Dujardin. x 1000.
   Views in rapid succession of the same animal. Note the minute dancing organism imprisoned within the contractile vacuole.

4. Amoeba verrucosa Ehrenberg. x 1000. There are two posterior contractile vacuoles.

5. 6. and 7. Amoeba radiosa Ehrenberg. x 1000.

Plate II.

*Amoeba proteus* Ehr. x 500.

1. to 4. Successive forms assumed by one individual in ten minutes. *n.* nucleus; *ps.* the tip of a vertically extended pseudopodium.

5. Imaginary side view of Figure 1. obtained by focusing upon different planes.

6. A very young specimen.

7. The "mulberry form" often assumed when the animal is just transferred to the slide.

8. A swarm of very minute and active amoebae. About sixty were in the field at one time.
Plate III.
Plate III.

*Amoeba proteus* Ehr. x500

1. *Amoeba* with an active *Chilomonas paramecium* and an unidentified Protozoan imprisoned within one large food vacuole. *f.v.* Posterior part of body shows the "mulberry" formation of ectoplasm due to forward flow of endoplasm.

2. Same individual after fifteen minutes. The imprisoned forms, protected from digestion by an unusually large droplet of water, now make their escape and swim away. Arrows show endoplasmic currents.

3. *Amoeba* with lower planes of clear ectoplasmic pseudopodia, and the posterior mulberry formation.

4. *Amoeba* with a large nucleus visible without reagents, and a large oval diatom ingested.

5. *Amoeba* with much vacuolated endoplasm (starved?) and a long pseudopodium which remained fairly constant during many other changes of form.
Plate IV.

Fossil Allium unicolor

In this instance the Allium was found in the vicinity of the northwest corner of the new extension of the District.

Plate IV.

Explanation of the Position of the Plant and the Position of the Plant of the Plant.

As the plant grows with one foot, the position of the plant is maintained.

Plate IV.
Plate IV.

*Amoeba villosa* Wallich. x500.

1. to 8. Successive shapes assumed by one individual in twenty minutes. The villous effect is the result of the withdrawal of endoplasm and the wrinkling of ectoplasm at the posterior part of the body.

9. An individual with one long, tentacle-like pseudopodium which was drawn in with almost instant rapidity.
Plate V.

**Diffuse proliferation**

...
Plate V.

Difflugia pyriformis Perty.

1. to 11. A single specimen, showing successive extensions of pseudopodia during a period of twenty minutes. The sand grains do not appear in the first ten diagrams, which are on a smaller scale. Actual size of animal 135 m. Fig. 11 is x 300.

13. Large grained shell with protoplasm withdrawn into a ball. 288 m. x 300.

13. Small grained shell with active and much branched pseudopodia. 175 m. x 300.
Plate VI.

1. *Difflugia pyriformis* var. Leidy. x 500.

2. *Difflugia pyriformis* Perty. Fairport, Iowa. x 1000.

3. *Difflugia lobostoma* Leidy. x 1000.

4. *Difflugia acuminata* Ehr. x 500.

5. Lateral view of the same shell.


7. *Difflugia globulosa* Duj. With one short pseudopodium, and a large irregular sand grain summit of shell. x 500.

8. *Difflugia* sp. White shell having the proportions of *Arcella vulgaris*, but the construction of *Difflugia*. Apparently empty shell, the mouth being clogged with reddish debris.
Plate VII.


6. *Difflugia acuminata* Ehr. Outline of side view of Fig. 5.

7. *Difflugia corona* Wall. Shell from ventral side, showing the ten brown, chitinous teeth. Four dorsal spines. From Okoboji region. Size 100 microns.

Plate VIII.

1. Differentiation of yolk. x 200. Office of

2. Differentiation of corer x 500.

3. Plate XII. Plate VIII. Plate IX.

4. Differentiation of corer x 500.

5. Differentiation of corer x 500.

6. Differentiation of corer x 500.

7. Corer x 500.
Plate VIII.

1. *Diffugia pyriformis* Perty. x 300. Outline of an empty shell so covered with black sediment that the sandy character was not seen without crushing.

2. *Diffugia urocolata* Carter. x 300.

3. *Diffugia pyriformis* Perty. x 300.

4. 5. and 6. *Diffulgia pyriformis* Perty. A small grained shell. Different views obtained by orientation. 4. and 6. are x 300. 5. much reduced.

7. *Diffugia acuminata* Ehr. x 300.
Plate IX.

Plate IX.

Plate IX.
Plate IX.

1. *Arcella vulgaris* Ehr. Smooth shell with contracted sarcode. x 500.

2. *Arcella vulgaris* Ehr. Pitted shell with contracted sarcode. x 500.

3. *Arcella vulgaris* reproducing. x 500.

4. and 5. *Arcella discoïdes* Ehr. Ventral and lateral views. x 500.

Aroella vulgaris Ehr. Optical sections.

1. to 7. Reproduction (or conjugation?) of two very small colorless individuals, a smooth and a pitted variety. The arrows indicate the change in direction of the flow of protoplasm during a period of eight minutes. Height of one shell 44 microns.

8. Delicate, colorless shell, showing internal attachments of sarcode to wall. Dorsal view. Diameter 57 microns. Thickness of shell wall 1.3 microns.

Plate XI.

Ceratodus fraseri

I show part of coarser variety of fifteen. Figure

Proprietary author's copyright. Original version

A variety according to Mr. White, then back in twelve

Figure of part grown and white

To show spiny spall, ten feet above

Plate X. View of stenole Remains and spall

A figure of spall painted with little spotted material

In the straw prominent Nearly, vicinity of Men's

photographed early and success via early

1850s.

Spall not shown in Letters a few case similar to this

Seem in Fig. 2. Note: Some the spines were striking

Spall near spall with disappointed material and early likeness

Can in the composition. Practically big by this

2 Spall and early spall indicated with spino slit

A new view of stenole stenole or Fig. 1. Grain

x 600.
Plate XI.

Centropyxis aculeata Stein


2. Variety ecornis, the spineless form. Found in large numbers both brown and white.


3b. Ventral view of similar specimen having but two spines.

4. Active individual having very little foreign material in the brown chitinous shell, through which the mouth, protoplasmic body and vacuole are seen.

5. White shell which in lateral view was similar to the one in Fig. 3., save that the spines were straight.


7. Small and very active individual with brown shell.

8. Dorsal view of specimen similar to Fig. 4. Brown.

All x 500.
Plate XII.

1. to 8. *Cochliopodium bilimboosum* Leidy. Successive views of the same animal. 4. to 6. shows the attempted capture of a heliozoon which was later washed away when fresh water was added to the slide. x350.

9, and 10. *Cochliopodium bilimboosum* Leidy. The same animal creeping along a plant filament and later detached. s.h. Shell membrane. x1000.

13. *Cochliopodium bilimboosum* Leidy. Large specimen, with delicate active pseudopodia, which has an ingested diatom and is in the act of taking in two more. The shell membrane does not show the reticulation seen plainly in the preceding specimen.
1. Active animal. Shell showing faint indications of circular, overlapping plates. s.p. shell plates inside.

2. Encysted animal with mass of debris (?) closing mouth of shell.

3. Two empty adherent shells. Found thus in large numbers. Budding or conjugation.

4. Very active animal, showing nucleus, large vacuole, and many ingested diatoms.

5. Cross section of shell, or as seen from above.

6. Three dead adherent shells without apparent plates.

7. *Euglypha mucronata* Leidy. x 1000
Plate XIV.

Trinema enchylis Leidy.

1. and 2. Dead shells showing faint indications of the circular plates seen in Euglypha. x 1000.

3. Showing sarcode, food vacuole and nucleus. x 1000.

Euglypha alveolata Duj.

4. Detail of imbricating circular plates.

Vampyrella apirogyræ Cienk.

5. Amoeboid form established within the cell of apirogyra. Sarcode colorless. x 500. See also next plate.

1. *Actinophrys sol* Ehr. Heavy rayed specimen with an impaled infusorian. x 300.

2. *Actinophrys sol*. Two joined animals with a large ingested diatom. x 500.

3. *Actinophrys sol*. With an impaled *Coleps hirtus* Ehr. partly digested but still showing active ciliary motion. x 500.

Plate XVI.

Vaccination for

3. Compresses. Wound after operation. x 1000

2. Extract a papilloma, cut out and write name on.

1. Extract a papilloma. x 1000

A Portion of Amoeba No. 3, so far reproduced and

Settle in amoeba in No. 3, and to reproduce one

more with thicker ascospores. 2. Settle in amoeba

and observe changes. 1. Settle amoeba.
Plate XVI.

*Actinophrys sol* Ehr.

1. A double individual with two nuclei. Not seen to change. x 500. Several vacuoles active.

2. Conjugation. Nucleus not visible. x 1000.

3. Showing a permanent, external and very active contractile vacuole. x 1000.

4. Detail of vacuole in No. 3., as it discharges and refills. a, a full vacuole. b, a collapsed vacuole with villous ectoplasm. c, d, and e, refilling slowly. f, sudden collapse. Average time of action forty seconds.
Plate XVII.

1. *Actinophrya sol* Ehr. Body diameter 76 microns, longest ray 150 microns. x 500.


PLATE XVIII.

Henry's California.

In the course of a few minutes, the fiends of car-

take possession.

I. L. L. I leave home in the
Plate XVIII.

But possible to imagine the tempest as long as

your own way. Notice the proportions of the body and

their relations to each other. The resemblance is

such that the reader is not surprised.

And remember, California is yours for

April 1, 1800.
Plate XVIII.

_Nuclearia delicatula_ Cienk.

1. to 7. Successive shapes assumed by one individual in the course of a few minutes. a. fascicle of capitate tentacles. N.B. In these drawings it was not possible to indicate the tentacles as fast as they changed. Hence the proportion of capitate and simple tentacles is not exact. The endoplasm is much vacuolated, ectoplasm hyaline. Nucleus not visible. x 1000.
Plate XIX.

Plate XIX.

Plate XIX.
Plate XIX.

*Nuclearia delicatula* Cienk.

1. and 2. Rapid succession views of the same individual.

Endoplasm much vacuolated or filled with clear granules.

x 560.

3. Another individual showing the single heavy pseudopodium frequently present in this species, by which the animal appears to attach itself at times.

x 500.
Plate XX.

Mycelium efflorescens Grevl. x 300

If you cannot base your argument on a diagnosis, you should try to make a diagnosis yourself. A single diagnosis may lead you to make a diagnosis in the same manner.

Plate XX.

Insulation of fibre microfibril. Sample from consomé.

When the sample is heated.

G. Insulin mixture.

G. Resistance to loss of oxygen of permobility.

A small被认为是 with an unrelated section way.

G. Consolute used.
Plate XX.

Nuclearia delicatula Cienk. x 500.

1. An unusual phase in which there is a gelatinous envelope through which the pseudopodia project.

2, 3, and 4. Successive views of the same animal at intervals of three minutes. 4 is the form assumed when the animal is disturbed.

5. Unusually small specimen.

6. Showing a rare case of anastomosis of pseudopodia.

7. A small specimen with an ingested diatom and two non-contractile vacuoles.
Plate XXI.

1. A ray of light perpendicularly entering the eye (X 10000).

2. A ray of light passing through the vitreous humor (X 10000).

3. A ray of light passing through the retina and fovea (X 10000).

Plate XXI.

1. Optical nerve sheath (X 1000).

2. Optic nerve sheath (X 1000).

3. Optic nerve sheath (X 1000).
Plate XXI.

1.2. and 3. *Rhipidodendron splendidum* Stein.  x 1000.
Dead fragments of brown zoöthecium; longest fragment 100 microns; diameter of tubule 3.8 microns.


6. *Oikomonas* species. x 1000.

7. *Oikomonas* species. x 1000.

8. *Heteromita* species. x 1000.
1.2. and 3. *Euglena viridis* Ehr. Showing euglenoid movements. x 500.

**Euglena viridis** Ehr. Mass of encysted cells.

5.6. and 7. *Euglena rubra* Hardy. Preserved in formalin. Striations of pellicle. v.r. vacuole reservoir. ? a somewhat star shaped body found in central or anterior portion of each cell. (paramylon?) x 250.

8. *Euglena desesa* Ehr. stig. stigma. v.r. vacuole reservoir. chl. chloroleucites. x 1000.
Plate XXIII.

A diagram of the spermatozoon of the Cephalopod Octopus.

Plate XXIII.
Plate XXIII.


2. Diagramatic view of the same specimen without details of periplast or the habitual trifolding of the body. Vac. res. Vacuole reservoir; Par. Paramylon bodies. Nu. nucleus.

3. *Euglena acus* Ehr. Showing paramylon rods. End. point where green endoplasm ceases. x 1000.
Plate XXIV.
Plate XXIV.

1. *Trachelomonas oblonga punctuata.* Optical section.  
   st. stigma.  ch. chloroleucites.  x 1000.

2. Same specimen, showing spiral arrangement of punctae at aboral end of shell.

3. Side view of shell, which does not show a definite pattern of punctae.

4. and 5. *Trachelomonas urceolata* Stokes.  x 1000.

6. *Trachelomonas picsatoris* (Fisher)  x 1000.

7. *Trachelomonas volvocina* Ehr.  x 1000.

8. *Trachelomonas hispida* Stein.  x 1000.


10. *Trachelomonas new species.* From Arkansas.  x 1500.  
    encysted state. shaded area green.
Plate XXV.

1. Loss in Cornus (XXV) Continued from Plate XXIV

2. Loss in Cornus (XXV) Continued from Plate XXIV

3. Loss in Cornus (XXV) Continued from Plate XXIV

4. Loss in Cornus (XXV) Continued from Plate XXIV

5. Loss in Cornus (XXV) Continued from Plate XXIV

6. Loss in Cornus (XXV) Continued from Plate XXIV

7. Loss in Cornus (XXV) Continued from Plate XXIV

8. Loss in Cornus (XXV) Continued from Plate XXIV

9. Loss in Cornus (XXV) Continued from Plate XXIV

10. Loss in Cornus (XXV) Continued from Plate XXIV
Plate XXV.

1. Phacus longicaudus (Ehr.) Longitudinal division commenced. x 500. Showing the plasticity of the division stage,

2. and 4. Continuation of process.

5. The left hand individual in Fig.1.

6. Phacus pleuronectes (Mull.) With two stigmata. x 500.

7. Phacus longicaudus (Ehr.) Flagellum absent. x 300.

8. Phacus pyrum Ehr. x 1500.

9. Phacus pleuronectes (Mull.) Encystment and divisions.
   d. a much vacuolated cell. e. and f. Multiple division in unidentified euglenoid cysts.
1. Astasia tricophora Ehr. Successive positions assumed by one individual in a few minutes. x 500.

3. Anisonema acinus Duj. ph. pharynx. x 1000.

4. Notosolenus orbicularis Stokes. sf. secondary flagellum which appears through body substance. b. optical cross section showing dorsal concavity. x 1000.

5. Entosiphon sulcatus Duj. ph. pharyngeal tube. x 1000.


7. Same species showing amoeboid movement within the lorica.

8. A similar specimen of the same species. x 1500.
Plate XXVII.


2. Same specimen suddenly killed with chlorotone. Green endoplasm ejected from the shell-like periplast which bears the setae, and which is composed of imbricating circular plates as in the rhizopod *Euglypha*.


5. **Unknown form** (Chrysomonadinae ?) x 1000.

6. **Unknown form** (Ochromonadaceae ?) x 1000.
Plate XXVII B.


   1. lorica: pr. protoplasmic threads attaching body to shell.
   amy. starch bodies: st. stigma: n. nucleus.  x 1000.

   endoplasm: amy. starch bodies: haem. haematochrome area,
   consisting of a spherical center of deep red, surrounded by
   an irregular mass of lighter red, often shading into green.

3. Resting stage, without haematochrome.

4. 

5. Binary fission within lorica.

6. Multiple division. Four cells in mass, each provided with a
   lorica, a single red stigma, and two flagella. Error: the three
   individuals at the base of the pyramid were not touching.
1. *Colespa hirtus* Ehr. Swallowing a diatom later ejected.

o.p. two rowed oral plate: a.e. anterior equatorial plate.

p.e. posterior equatorial plate: a.p. anal plate. x 800.

2. Diagramatic optical cross section, showing imbricating effect of surface sculpture. x 800.

3. An individual shortly after transverse fission, showing smooth posterior half. x 800.

4. An abnormal individual with bifurcated posterior region. Details of surface omitted. x 500.

5. A peculiarly flattened very active individual which has been observed a few times. a. the normal appearing wide side. b. the thin edge.

6. *Chenia* species. x 500.
Plate XXIX.

*Lachrymaria olor* Mull. x 500.

1. to 5. Division.

6. and 7. Characteristic positions assumed by the posterior individual after separation.

The striations of the cuticulum are omitted in the last five drawings.
Plate XXX.

...
Plate XXX.

1. to \textit{Lachrymaria olor} Mull. Conjugation. Showing the rapidly alternating tense and flexed positions of the cells. Details of endoplasm and of surface omitted. $X$ 500.

Plate XXXI.

1. *Loxodes rostrum* Ehr. ventral view. x 800.

2. and 3. *Chilodon cucullulus* Mull. lateral and dorsal views. x 500. So-called Embryonic stage.

4. *Claucoma scintillans* Ehr. ventral view. x 800.

5. *Loxocephalus granulosus* S.K. x 1000.

6. *Colpoda cucullus* Ehr. Lateral position in which the animal usually swims. The pharynx is seen to dilate into a stomach-like sac. x 500.
Plate XXXII.

Urocentrum turbo Mull.

1. and 2. Beginnings of transverse fission. c.v. contractile vacuole. af.c. afferent canals of vacuole. x 500.

3. 4. and 5. Optical sections of specimens killed with methylene blue and osmic acid. Stages of division. m. mouth: o.g. oil granules: ph. pharynx. n. nucleus: c.v. vacuole. x 500.

Plate XXXIII.

1. *Paramaecium caudatum* Ehr. Ventral side. c.v. vacuoles
with astral canals: o.g. oral groove: m. mouth: f.v. food
masses: ma. macronucleus: tric. trichocysts: x 250.

2. *Paramaecium trichum* Stokes. Mouth uppermost, the posi-
tion in which the animal swims without revolving. Parts
lettered as in preceding figure. x 500.

3. *Lembadion bullinum* Perty. Dorsal view with oral membrane
appearing through body. x 1000. u.m. undulating membrane.

4. *Cyclidium glaucoma* Ehr. u.m. undulating oral membrane;
ma.n. macronucleus: mi. micronucleus: c.v. contractile vacuole:
x 1000.

5. *Cinetochilum margaretaceum* Ehr. Ventral side showing mouth
and vibrating membrane. Dorsal striations showing through.
c.v. vacuoles. x 1000.
Plate XXXIV.


Plate XXXV.

1. *Stentor roeselii* Ehr. Ventral side. With the monili-form nucleus sometimes seen in this form. Observe *Coleps hirtus* (*C. h.* ) escaping through body wall. x 250.


M. Mouth. C.V. Contractile vacuoles. N. Nucleus. ..

B.S. Basal setose cilia.
Plate XXXVI.

1. Stentor polymorphus Mull. Ventral. x 100.

2. Same individual contracted. Dorsal. x 100.

3. Halteria grandinella Mull. x 500.

4. and 5. Strombidium species. x 500.
Plate XXXVII.

1. *Stylonichia mytilus* Ehr. o.m. oral membrane x 500.


3. *Aspidisca costata* Duj. x 500.

All ventral.
Plate XXXVIII.

Vorticella campanula

1. M. mouth, g. gullet, n. nucleus, c.v. vacuole, ax. continuation of axis fibre of stalk. Body 45x38 microns. Stalk 80 microns, diameter 3 microns. x 1000.

2. to 6. Longitudinal division showing development of the posterior cilia and straining movements of daughter cell. Time, thirty minutes.

7. to 11. Development from encysted state.

7. Sudden rupture of cyst, with contents emerging in shapeless mass.

9. A moment later one cilium appears. Cell remains like this for some minutes.


11. After several seconds of violent and shapeless contortions the cell rolls itself out into a cylinder and darts off with great speed.

Time from Fig. 7. to Fig. 11. twenty minutes.
Plate XXXIX.


2. The same species. x 2000. April 17th.

3. *Podophrya maupasii* Butschli. x1000. Showing nucleus and two contractile vacuoles.

4. *Podophrya maupasii* Butschli. x 500.


Plate XL.

[Image of Plate XL]

2. Gorged and quiescent animal 10 hours later. Vacuole gone, and all but central tentacles in each group withdrawn.
FINIS.