PROTOZOA-CILIATA OF A SMALL POND AT LOGY BAY, NEWFOUNDLAND

CHIA-MEI HSU KLEINE

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by

© CHIA-MEI HSU.
B.Sc. (Tunghai Univ.).

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ABSTRACT

The ciliate fauna of a small, freshwater pond at Logy Bay, Newfoundland was studied in 1968-70. A preliminary survey of the seasonal occurrence of the protozoa as affected by ecological parameters was made.

The study pond is quite acidic (pH 4.50-5.15), with high chloride content (99.26 p.p.m.), a wide annual water temperature range (0.5-20.8°C), and a fluctuation of dissolved solid concentration (75-144 p.p.m.).

Twenty-nine ciliate species of 19 genera were determined. Other ciliates belonging to a least 30 taxa were not identified beyond the generic level.

Three groups among the studied ciliates are particularly interesting and demand rediscovery for further study: *Tetrahymena uorax* for its polymorphic life cycle; *Coleps heteracanthus*, *Aspidisca* sp., *Condylostoma* sp., *Dysteria* sp., and *Trachelocerca* sp. which might be new ecotypes of marine ciliates; and *Coleps* sp., *Urotricha* sp., *Microthorax* sp., and *Lembadion* sp., perhaps new species.

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INTRODUCTION

Ciliate protozoa were first examined from the vicinity of Newfoundland by Ehrenberg in 1854. These were marine species, reported by Kent, 1880-1882, pp. 626-627. Little further work was carried out in this field until Lom and Laird (1969) described some parasitic trichodinids from Newfoundland marine fish. Soon afterwards, Lackey and Lackey (1970) published an extensive list of free-living marine microorganisms, including some ciliates, from Logy Bay, near St. John's. However, nobody has previously studied the freshwater ciliate fauna of the Island of Newfoundland in any depth.

Knowledge of the morphology, taxonomy and distribution of Newfoundland's flora and fauna (including the freshwater components) is clearly desirable, as taxonomic and distributional studies of most Newfoundland terrestrial biota are still far from complete. Recognizing the need to be able to make close comparisons with the results of earlier workers, permanent preparations stained by various methods (including "classical" haematoxylin procedures and modern silver impregnation) were employed in the present study to supplement - not to supplant - fresh preparations. The latter were examined by phase-contrast microscopy. In this context it is noted that, to judge from the surprising detail in the figures of such early protozoologists as Ehrenberg, phase-like effects were being obtained about a century before F. Zernike invented this procedure (in 1935). Assisted by modern photomicrographic techniques, this thesis presents a preliminary survey of a primarily taxonomic study of the free-living ciliates of a

small pond at Logy Bay, Avalon Peninsula.

In addition, some data are presented to show that the appearance and disappearance of particular species of protozoa in a particular locality are usually correlated with seasonal changes (Davis, 1969; Wang, 1928). It was felt worthwhile in this context to make a preliminary survey of the seasonal distribution of protozoa as affected by fluctuations of temperature, hydrogen-ion concentration, and dissolved solids, in a small pond in Newfoundland. Comments on the value of various cultivation techniques are also included.

HISTORICAL SUMMARY

The first protozoan to be discovered was found in standing rain water in 1675. A ciliate of the genus *Vorticella*, it was described by van Leeuwenhoek (1677). Ledermüller (1763) was the first to introduce the term 'Infusoria' for all the various microscopic "animalicules" (whether bacteria, algae, or protozoa) developing in infusions exposed to air. The first comprehensive monograph on 'Infusoria' was by O. F. Müller (1773). Bütschli (1880-89) limited the use of 'Infusoria' to Protozoa bearing cilia throughout life, and 'Suctoria' to those with cilia only in the early developmental stages. Doflein (1901) introduced the term 'Ciliophora' to designate a sub-phylum comprising the two classes Ciliata and Suctoria.

Since then, there are two main schemes for classification of protozoa: the pre-war and post-war systems.

The pre-war system was contributed by the pioneer scientists such as Ehrenberg (1832a, b, 1838), Dujardin (1838, 1841), Stein (1854), Claparede and Lachmann (1858-1861), Kent (1880-82), Bütschli (1880-89), Stokes (1888), Schewiakoff (1896).

Shortly before the second world war, Kahl (1930-35) prepared a profusely illustrated, well-documented monograph containing keys to the ciliates of Germany. Kahl's painstaking attention to the comparative morphology and systematics of ciliates at the species level has not yet been surpassed.

The depth of our knowledge has always been benefitted by the improvement of Technology. It was one of Kahl's contemporaries, Klein, who first applied silver nitrate in demonstrating the silver-line system

of ciliates (Klein, 1926, 1958). In 1936, Chatton-Lwoff's method was introduced into France with the now recognized advantages over Klein's. Under this heading, Bodian (1937) also started the so-called 'Protargol' technique (Honigberg and Davenport, 1954; Kozloff, 1961; Dragesco, 1962; Tuffrau, 1967). In 1940, Furgason proposed the newly established genus *Tetrahymena* by applying the silver method to establish systematic relationships on the basis of comparative stomatogenetic data. Studying the life cycle of astomes, de Puytorac (1954, 1959, 1963) revealed basic infraciliary similarities to other groups, e.g., certain members of the order Thigomtrichs. Using morpho-genetic data, Faure-Fremiet (1950) proposed that the suctorians are very closely allied to the holotrichs and that the pertrichs should be considered closer to the holotrichs than to Spirotrichia. The work of Chatton-Lwoff (1935, 1949, 1950) and Faure-Fremiet (1950, 1953, 1959) validated a phylogenetic hypothesis formalized by Corliss (1956). Based on that, a revised system of classification at higher taxonomic levels within the phylum Protozoa was accepted over the older scheme (Honigberg *et al.*, 1964). This revised scheme has been widely accepted.

With the use of the morphogenetic pattern to deduce supposed affinities among the various key genera involved, Small (1967) established a new order 'Scuticociliatida' which includes all pleuromatine hymenostomes, arhynchodine thigmotrichs, and a number of formerly alleged tetrahymenine hymenostomes. This research stimulates advanced understanding of the systematics and evolution of the holotrichs (Lom, 1968; Corliss, 1968; Nobili, 1969). In Russia, Jankowski (1964a, b, 1967) has constructed a strikingly new taxonomic hierarchy of Ciliophora.

MATERIALS AND METHODS

Habitat

Five hundred metres west of the Marine Sciences Research Laboratory (MSRL) (Fig. 1-A) of Memorial University of Newfoundland at Logy Bay, 8 km. north of St. John's, "There is a flat 400 by 800 m. *Chamaedaphne* and *Sphagnum* marsh in which lie various small permanent and temporary pools and which is crossed by a narrow but relatively deep stream (50 to 100 cm. by 50 to 100 cm.)" (Pickavance et al, 1970).

The particular pond of this complex from which all my material was derived is about 50 m. west from the MSRL parking lot, and 10 m. south from the approach road and the roadside stream (Fig. 1-B) which receives an outflow from it after rain (Station 2, Pickavance, pers. comm.).

The shape and size of the pond are quite variable. Its outline changes in accordance with the volume of its contents, the amount of water held increasing with rain and decreasing during warmer and drier weather. Generally, it is long and rather narrow, but shallow. Its width ranges from 1 m. (Fig. 2C) to nearly 4 m. (Fig. 2A, and 3), and it is about 17 m. long. The shallowest part (Fig. 2C) is 18 cm. deep, the deepest 60 cm. (Fig. 2b). There is an emergent rock at the northern end.

Predominant flora (Fig. 4) around the pool consists of the mosses *Sphagnum pulchrum* (Braithw.) Warnst and *Sphagnum palustre* L., Sweet Gale* (*Myrica gale* L.), a cotton grass (*Eriophorum virginicum* L.), and *Juniperus virginiana L.*

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* "Gold-withy" is the vernacular name in Newfoundland (Rouleau, 1956).

PLATE I

Figs. 1 and 2, showing location of the pond.

Fig. 1. The pond is located some 500 m. west from the Marine Research Laboratory (A) and 10 m. from the approach road. A roadside stream (B) received outflow from the pond when it rains.

Fig. 2. The width of the pond ranges from 1 m. (C) to near 4 m. (A). The shallowest part (C) is 18 cm. deep, the deepest 60 cm. (B).


A
B
1


A
B
C
2

PLATE II

Fig. 3. Area "A" of Fig. 2, the widest part of the pond, enlarged to show the emergent rock.

Fig. 4. Detail, showing the collecting ladle at the edge of the pond.

3

4

Sampling:

This project was carried out from 1968 to 1970, the most intensive examinations being made during the period from June 1969 to September 1970, when all physico-chemical readings were taken. During the rest of the time, samples were taken at irregular intervals.

Random samples were obtained by using one-litre capped jars as containers. A white-enamelled ladle was employed in dipping for benthic fauna. Samples were brought back to the laboratory as soon as the physico-chemical conditions had been recorded.

Measurement of physico-chemical factors:

Physico-chemical readings were regularly made in the field from June 1969 to September 1970. Both air and water temperature recordings were made with a mercury thermometer. Concentration of the dissolved solids (D.S.) was measured with a Myron L Dissolved Solids Meter (Model 532 T). The hydrogen ion value was determined using a Porto-Matic pH meter (Model 175). Chloride concentrations were estimated in the laboratory by the Mohr Method (A.P.H.A., 1955).

Preparation of media:

Organisms were concentrated by centrifugation (2500 rpm/ 5 min.). They were then cultured in sterile disposable Petri dishes with 35 ml. of pond water or hay infusion.

The latter was prepared by Turner's method (p. 60, Needham, 1959) modified as follows: to one litre of pond water add 5 gm. of Timothy Hay, *Phleum pratense*, and 10 grains of wheat. Heat to boiling and set aside until cooled. Filter through three layers of gauze into

200 ml. bottles. Each bottle should receive 50 ml. of the hay infusion and be capped for autoclaving (15 lb. 121°C. for 15 min.). The sterilized hay infusion is stored for use.

Four media were used to obtain mixed cultures.

(1) Culture with 35 ml. of hay infusion.

(2) Culture with 35 ml. of pond water added, with a surface sprinkling of Bacto-tryptone (Gruchy, 1955).

(3) Culture with 35 ml. of pond water and four grains of rice.

(4) Culture with 35 ml. of pond water and four grains of wheat.

Cultures were maintained in a brightly lit laboratory at 70° F.

Clone cultures:

When ciliates were present, clonal cultures were attempted to serve axenic development (Elliott, 1953 and Gruchy, 1955).

Preparations of living material:

Fresh preparations were dealt with as recommended by Kudo (1966, p. 1073). A 10% solution of methyl cellulose was used to retard the swimming movements of ciliates (Marsland, 1943). For vital staining, the following dyes were dissolved in absolute alcohol (Kudo, 1966):

Congo red (1:1,000) - when used as an indicator its red colour indicates alkalinity, a change to blue, weak acidity;

Janus green B (1:10,000) - employed for the staining of mitochondria;

Methylene blue (1:10,000) - for staining cytoplasmic granules, the nucleus and cytoplasmic processes;

Neutral red (1:3,000) - when used as an indicator, it becomes yellowish red (alkaline), cherry red (weak acid), or blue (strong acid);

Lugol solution (made up of potassium iodide 1.5 gm. water 25 cc. and iodine 1 gm.) - for staining cilia.

Microphotography was undertaken by means of a Carl-Zeiss Photomicroscope I, utilizing both phase-contrast and interference (Nomarski effect) microscopy.

Preparation of fixed material:

1. Heidenhain's iron haematoxylin was used for nuclear staining (Kudo, 1966).
2. Silver - impregnation methods were employed to demonstrate the cortical configuration.
   a. The dry silver method undertaken was that of Klein (1926, 1958).
   b. The Chatton-Lwoff method (Chatton and Lwoff, 1930 and 1936; Corliss, 1953b; Frankel 1968) was employed when there were sufficient numbers of ciliates in the culture.

RESULTS AND DISCUSSION

EXPERIMENTAL

The physico-chemical factors:

Monthly average records of the pH value, D.S. concentrations and water and air temperatures are given in Table I and Figs. 5, 6, and 7.

In July 1970, the pond dried up at a time of unusual drought and hot weather for Newfoundland (above 80°F). It was replenished on August 10, 1970 after two days' heavy rain. It did not dry up again during the remaining months of the present study. It thus qualifies for the designation of "temporary pond".

Spandl (1926) restricted "temporary pond" to water bodies persisting for no more than 1½ - 2 months. Others (e.g. Shelford, 1913; Kenk, 1949; Rzoska, 1961; Felton et al, 1967; and Moore, 1970) have so designated any pond drying up completely at least once a year. Laird (1956) sharply differentiated "transient ponds" (primarily rain-filled ones in hollows which do not intersect the water table) from permanent ones, but followed Bates (1949) in considering "permanent" and "semi-permanent" (= "temporary") ponds as a continuous cline. It is considered that for all practical purposes my study pond can be characterized as a "semi-permanent" pond.

From the end of December 1969 to the end of February 1970, the pond was usually frozen. Records were taken after chopping a hole in the surface ice with an axe. Prior to this time, the strong winds of winter ensured mixing of the epilimnion with hypolimnion .

TABLE I

Month	Temp. (°C.)		D.S. (p.p.m)	pH.
	Air	Water		
June 1969	14	12.7	-	-
July	23.5	20.5	125	-
Aug.	21.2	19.8	112	4.54
Sept.	20	17.9	93	4.68
Oct.	18.5	13.3	93	4.62
Nov.	7	7.2	144	4.68
Dec.	11	6.8	75	4.70
Jan. 1970	0	0.5	106	4.65
Feb.	- 3	0.5	123	4.50
Mar.	3	7.0	102	4.83
Apr.	6	7.2	85	5.08
May	7.5	7.5	85	5.15
June	12.5	10.7	79	5.13
July	30	-	-	-
Aug.	22.8	20.8	100	4.83
Sept.	20	11	115	4.73

PLATE III

Fig. 5. Temperatures of the pond, June, 1969 to September, 1970.

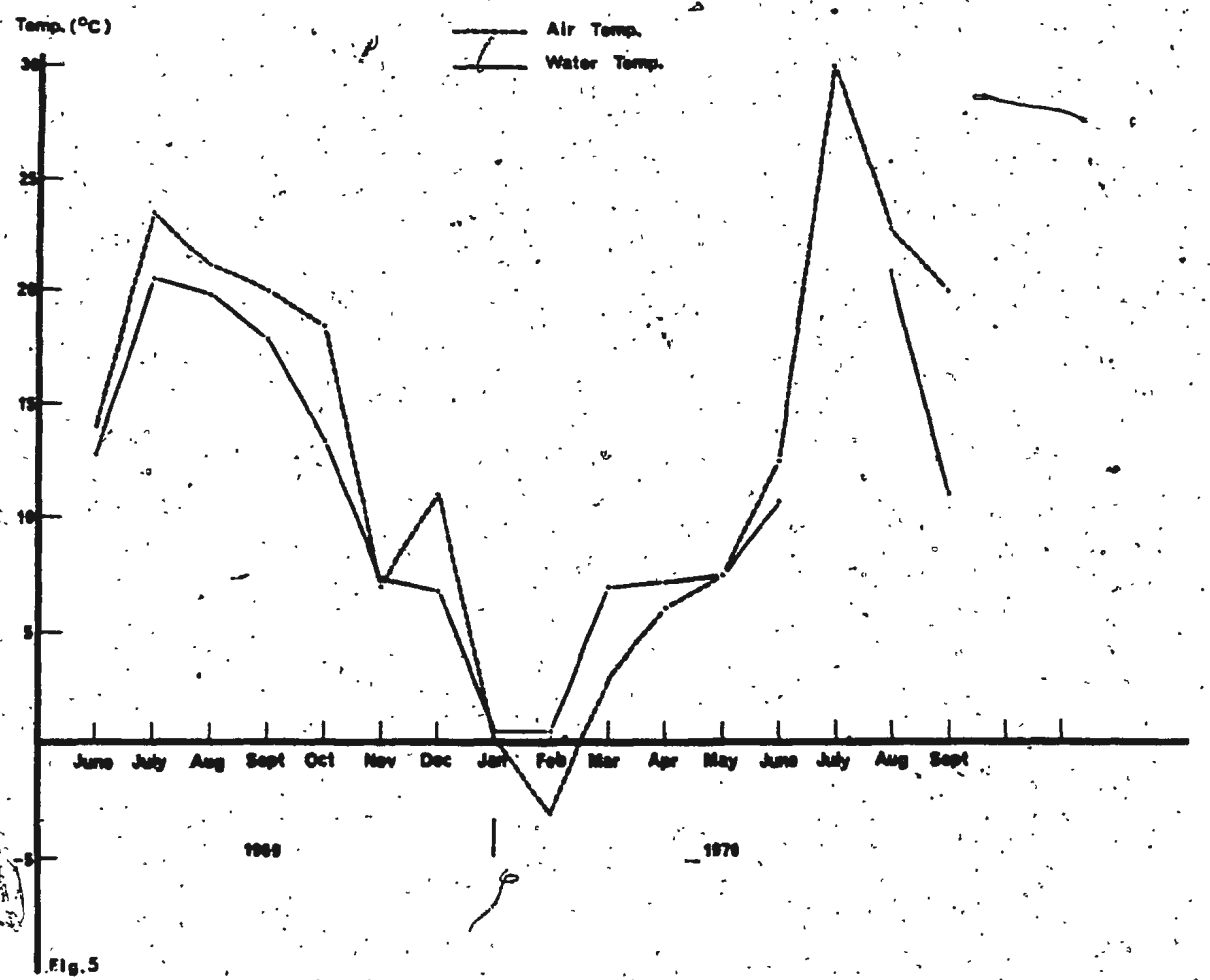
Temp. (°C)
Air Temp.
Water Temp.
30
25
20
15
10
5
0
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
1969
1970

Fig.5

PLATE IV

Fig. 6. Dissolved solids concentration of the pond, July 1969 to September 1970. A and B indicate two peaks of high concentrations of dissolved solids.

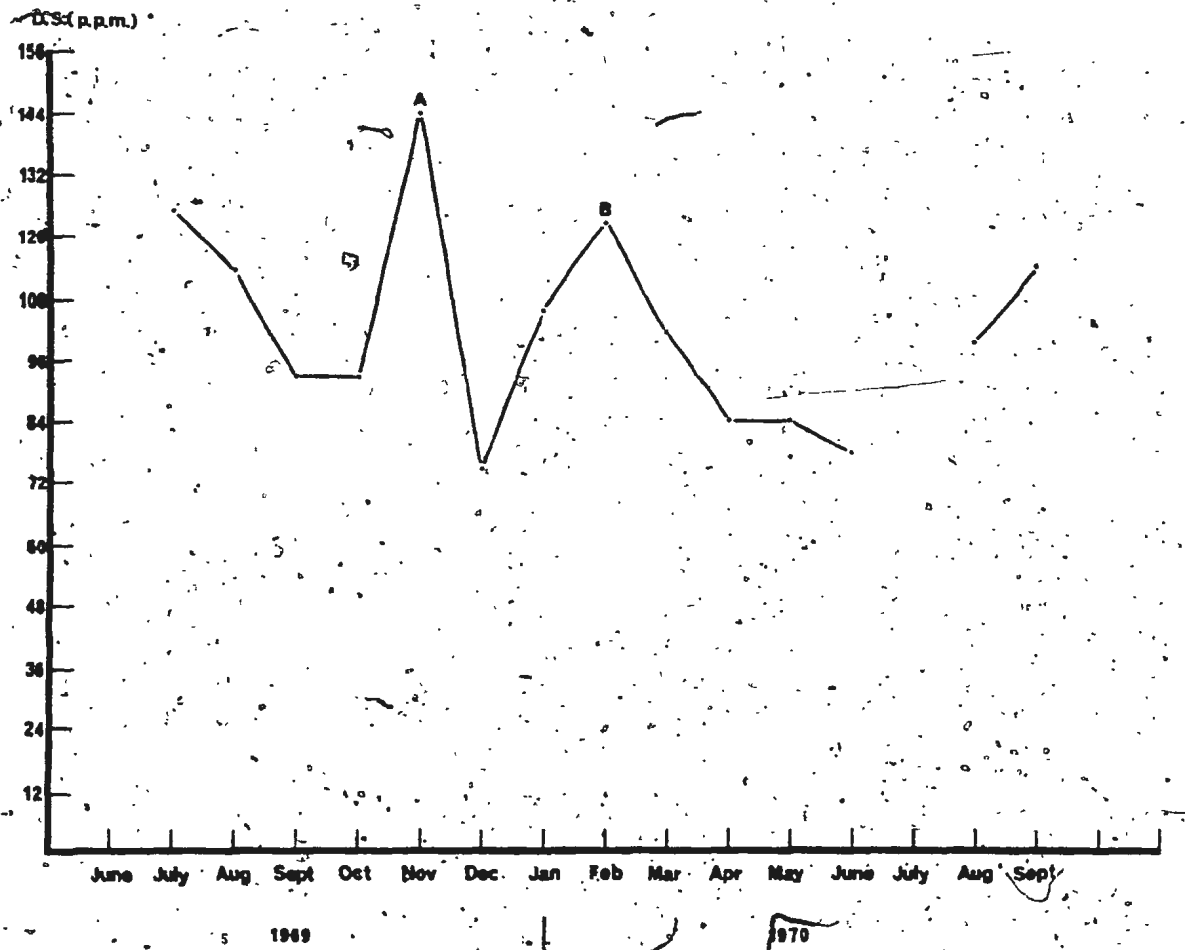
DCS:(p.p.m.)
156
144
132
120
108
96
84
72
60
48
36
24
12
A
B
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
1969
1970

Fig. 6

PLATE V

Fig. 7. Concentration of hydrogen ions of the pond, August 1969 to September 1970.

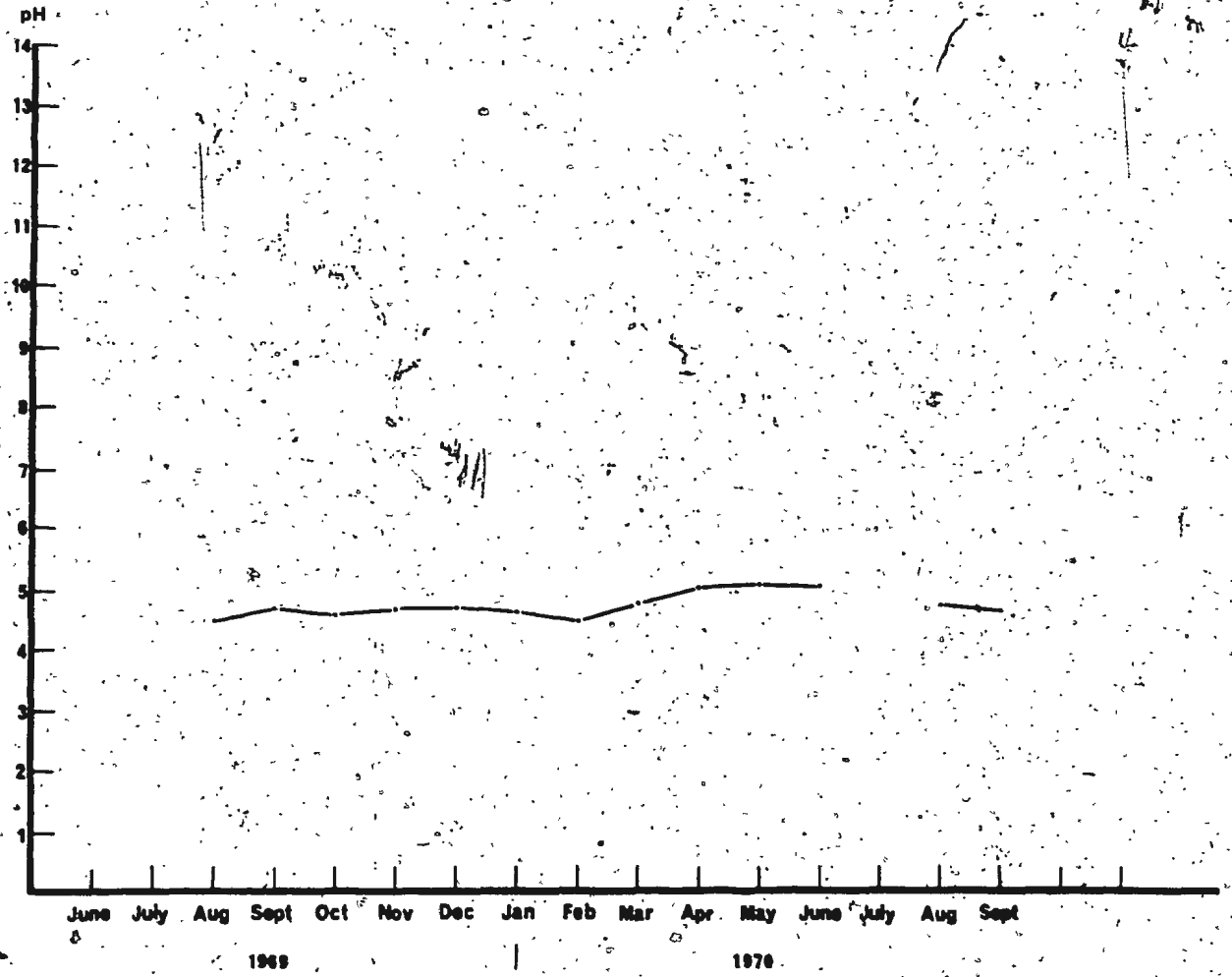
pH
14
13
12
11
10
9
8
7
6
5
4
3
2
1
June
July
Aug
Sept
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
1969
1970

Fig. 7

Following the freezing of the pond surface, however, this mixing was inhibited. The epilimnion was depleted of dissolved substances by organisms which, on their death, sank to hypolimnion and decomposed (Macan, 1970). This explains peak B in Fig. 6.

The other peak in Fig. 6,A, reflects a long hot and dry period without much rain from September to November 1969. Usually, the daily readings of the concentration of dissolved solids vary with the amount of rain received. Data missed from the end of June 1970 to the beginning of August 1970 would probably have reached the highest dissolved solids concentration because of the hot weather and unusually long dry period.

Despite the rapid variation of the temperatures and dissolved solid concentrations, the hydrogen-ion concentration of the pond proved very stable, ranging from pH 4.5 in February 1970 to pH 5.15 in May, 1970. It was generally higher in the summer of 1970 and lower in the winter of 1969,

Juday, Frey, and Wilson (1924) followed variations in the hydrogen-ion concentration with the season and depth in Lake Mendota for the period 1919 - 1922. "They observed that in summer particularly, and to a somewhat lesser extent under the ice in winter, the upper waters had a substantially higher pH than the lower waters. They ascribed the summer differences to the photo-synthetic activity of algae towards the surface and to the decomposition of organic matter in the hypolimnion" (Frey, 1966, p. 33). This may serve to explain the slight increase of pH during the summer of 1970, and the slight decrease in the winter of 1969-70, the latter reflecting the decomposition

of organic matter in the hypolimnion associated with increases in free CO_2 and bound CO_2. However, "at pH values below 6.0 acids other than carbonic may be suspected" (Hutchinson, 1957, p. 683). Data from the present pond are closer to those derived by Frey (1949) from some bay lakes of North Carolina (pH 4.34 - 4.92), these figures not being raised by aeration or boiling. Strøm, (1939, 1942, 1944) reported pH values of 8.0 from lakes in drainage basins influenced by Palaeozoic limestones or into which glacial water flowed.

The present data bear comparison with: pH 3.2 - 4.9 reported by Yoshimura (1934) from several Japanese lakes containing strong mineral acid; pH 3.5 - 3.9 recorded by Wehrle (1927) in *Sphagnum* bog pools near Freiburg in Breisgau, Germany; pH 4.5 - 6.0 from a *Sphagnum* bog in Iowa (Grant and Thorne, 1955); pH 5.2 - 6.1 in Louisiana ponds (Moore, 1951 and 1955) and one of these temporary ponds was reported pH 4.9 - 5.5 by Margavio (1964). "The source of the acid in such waters is probably twofold. Rain water, which contains sulfate, percolating through peat, tends to lose cations and gain H^+ by base exchange with the humus of the peat" (Hutchinson, 1957, p. 682).

The dissolved chloride content of the study pond was found to be 99.26 mg/l on January 11, 1970. This figure is considerably higher than the range of 0.08 - 0.51 mg/l of the English Lake District (Mackereth and Heron, 1954).

Drischel (1940) and Conway (1942) state a formula to calculate the chloride concentrations of ponds. These decrease proportionally to the increasing distance from the sea. They show chloride concentrations ranging down from 70-700 mg/l in ponds 600 m. or less

from the ocean. My study pond is located less than 600 m. from the Atlantic Ocean, its chloride concentration (recorded as 99.26 mg/l on January 11, 1970) falling within the above range.

There is a seasonal fluctuation of chloride content in some localities (Russell and Richards, 1919; Miller, 1914), high winter concentrations doubtless being due to the greater disturbance of the adjacent ocean surface during the winter. Drischel (1940) in fact suggests that a marked seasonal cycle is characteristic of maritime regions. The chloride concentration of the study pond was obtained from the epilimnion, which was covered by ice in January 1970. Regretably, seasonal investigations of the chloride concentrations of the pond were not undertaken.

Aerial chloride transportation can also occur through the wind picking up dry salt from an expanse of arid coastal land from which sea water had evaporated (Holland and Christie, 1909). Typically salt-water ciliates (*Coleps heteracanthus* Noland, and *Trachelocerca* sp.) were discovered in the sample of January 11, 1970. It is possible that wind transportation accounted for the presence of these salt water species.

Cultivation:

Gruchy (1955) used a surface sprinkling of Bacto-tryptone for mass culture from which *Tetrahymena pyriformis* clonal cultures were axenically established. In comparison with other procedures already mentioned, this method was used from the outset as the standard of comparison. Cultures thus fed always formed a thick opaque film on

the top of the medium and smelt very strongly of ammonia. Even after the odour gradually faded, the film was still so opaque that organisms were not observable.

Hay infusion has been very commonly used to grow ciliates. (Turner, Beers, Leray, Jones, in Needham, 1959). However, because the sterile culture used lacked prey such as *Chilomonas* sp. for the ciliates to feed upon (Needham, 1959, p. 60), it was generally unsuccessful.

By contrast, media with either four grains of rice or wheat kernels developed flourishing cultures. In those cultures supplied with rice grains, whitish fungi (Saprolegniaceae, as identified by Dr. O. Olsen) always flourished around the grains. These cultures were always richer in euglenoid phytoflagellates than were those to which wheat kernels were added - a characteristic noted by Brandwein, p. 63 (Needham, 1959). Wheat kernel media always supported more vigorous populations of ciliates than did rice grain media.

Clone cultures:

Large numbers of a single species were necessary for good preparations destined for permanent staining by the Chatton-Lwoff silver impregantion technique. Stock medium (Elliott and Hayes, 1953; Gruchy, 1955) in a depression slide containing a mixture of penicillin G and streptomycin (250 µg/ml each) was used to obtain axenic cultures. However, it proved that immediately after being transferred into the stock medium, ciliates ruptured. It seems, therefore, that other species of ciliates are not able to tolerate the stock medium designed especially for *Tetrahymena pyriformis* Ehrenberg.

Preparations of living material:

A dissecting microscope was only useful as regards the larger ciliates, such as *Paramecium bursaria* Ehrenberg (140 µ), *Spirostomum teres* Claparède and Lachmann, (200 - 500 µ), and *Stylonychia* sp. (150 µ). Smaller ones, e.g. *Cyclidium glaucoma* O.F.M. (17.5 - 25 µ), *Urotricha* sp. (27 µ), *Cyrtolophosis elongata* Schewiakoff (30 µ) and *Halteria* sp. (25 - 50 µ) proved unidentifiable at the low magnifications attainable with this instrument.

Phase microscopy proved indispensable for obtaining comparative data and improving existing taxonomic accounts prepared prior to the availability of this technique. With it, cilia, flagella, fine pseudopodia, stalks and fibrils all showed up to maximum advantage.

As revealed by both the dissecting instrument and high power phase-contrast microscopy, the plankton of the study pond most commonly comprised sarcodinids including *Arcella*, green algae, diatoms, blue-green algae, flagellates, rotifers, gastrotrichs and cladocerans in addition to the ciliates reported in the present study. The occurrence of ciliates often coincided with the appearance of *Arcella* and flagellates (e.g. *Chilomonas paramaecium* Ehrenberg) in considerable abundance.

Preparation of fixed material:

Heidenhain's iron haematoxylin was used for nuclear staining when methylene blue had failed to reveal the nucleus. The results were satisfactory both for holotrichs and spirotrichs.

Silver impregnation was indispensible for revealing the

cortical configuration, such structures as basal granules or kinetosomes of the somatic and buccal cilia, the cytoproct, contractile vacuole pores, and the complex fibril network (Chatton and Lwoff, 1930, 1936; Corliss, 1953b, 1956, 1959a, 1961a, 1963; Klein, 1926, 1958; Lom and Laird, 1969; Thompson, 1960, 1963a, and Boggs, 1965). The several modern techniques under this heading furnished a standard means of demonstrating the bases of the entire somatic and buccal ciliature in whole mounts of organisms at various life-history stages.

Klein's dry method and the Chatton-Lwoff procedure for silver impregnation were used in the present study. Although both were invented more than forty years ago (Klein, 1926; Chatton and Lwoff, 1930), the application and preference of these methods are still not universal (Corliss, 1956; Klein, 1958; Raabe, 1959; Lom, 1961; Thompson 1960 and 1963a; and Lom and Laird, 1969).

The Chatton-Lwoff method provided outstanding advantages over Klein's dry method (Corliss, 1956), if sufficient numbers of a single species (e.g. *Tetrahymena pyriformis* Ehrenberg) were available. However, the technique was handicapped when low numbers or a mixture of species were involved. It was thus unsatisfactory for survey studies, although Frankel's (1968) method utilizing centrifugation to wash out Champy's fixative somewhat decreased the chance of losing organisms. Klein's method reveals the argentophilic infraciliature with less such risk. It is also easier to monitor the mounted organisms by this method, which therefore has much to offer in comparative taxonomy.

With regard to the latter, data concerning the argentophilic infraciliature of ciliates are still very far from complete, being in

fact confined to only a few genera; notably *Condylostoma* (see Suhama, 1961), *Balantidium* (see Kraschenninnikow and Wenrich, 1958), *Cyclidium* (Berger and Thompson, 1960), *Neobursaridium* (see Nilsson, 1962), *Paramecium* (see Lieberman, 1929), *Sathrophilus* (see Thompson, 1963a), *Spirostomum* (see Boggs, 1965), and *Tetrahymena* (see Corliss, 1952a, 1952b, 1953a, 1957, 1959b, 1960). *Tetrahymena* is the only genus for which we can now claim virtually complete comparative argentophilic infraciliature data. Application of silver impregnation for purposes of taxonomic identification is handicapped both by the tremendous lack of specific infraciliature "fingerprints" (Thompson, 1960) and the difficulty of ensuring the development of rich, pure cultures. The need of rediscovery and a full redescription of ciliated protozoa in light of modern technique (silver impregnation) for taxanomic data was discussed by Thompson (1963).

It is important to realize, though, that however sophisticated one's staining procedures may be, fresh preparations still remain indispensable aids to taxonomic identification. As is evident from the photomicrographs reproduced herein, phase microscopy reveals living structural detail scarcely detectable if not altogether invisible by bright-field microscopy, and forms a necessary part of any survey such as this.

SYSTEMATICS

Representatives of 45 ciliate genera were observed from September 1968 to September 1970. Eighteen genera are illustrated by photomicrographs in the following sections. Ecological parameters and data on occurrence for each of the genera and species studied herein are presented in Table II.

Phylum Protozoa

Subphylum Ciliophora

Class Ciliata

Subclass I Holotricha

Order Gymnostomatidae

Suborder Rhabdophorina (=Promstomatina + Pleurostomatina)

Family Colepida

Genus *Coleps**

Family Enchelyidae

Genus *Chilophyra*

Prorodon

Microregma

Platyophrya

Trachelocera

*Urotricha**

---

* Illustrated by photomicrographs.

Family Amphileptidae

Genus *Litonotus*

Suborder Cyrtophorina (= Hypostomatina)

Family Dysteriidae

Genus *Dysteria*

Paratrochilia

Family Chlamydodontidae

Genus *Chilodonella*

Family Nassulidae

Genus *Nassula*

Order Trichostomatida

Family Colpodidae

Genus *Colpoda**

Family Microthoracidae

Genus *Microthorax**

Order Hymenostomatida

Suborder Tetrahymenina

Family Cohnilembidae

Genus *Cohnilembus*

Genus *Uronema*

Family Tetrahymenidae

Genus *Colpidium*

*Tetrahymena**

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* Illustrated by photomicrographs.

Suborder Peniculina

Family Parameciidae

Genus *Paramecium**

Family Frontoniidae

Genus *Balanonema*

Cinetochilum

*Cytrolophosis**

Frontonia

*Lembadion**

Suborder Pleuronematina

Family Pleuronematidae

Genus *Cristigera**

*Cyclidium**

Pleuronema

Subclass Peritricha

Order Peritrichida

Suborder Seesilina

Family Ophrydiidae

Genus *Ophrydium*

Family Vorticellidae

Genus *Vorticella**

Family Epistylididae

Genus *Epistylis**

*Telotrochidium**

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* Illustrated by photomicrographs.

Subclass III Spirotricha

Order Heterotrichida

Suborder Heterotrichina

Family Gyrocorythidae

Genus *Metopus*

Family Spirostomatidae

Genus *Blepharisma**

*Spirostomum**

Family Condylostomatidae

Genus *Condylostoma*

Family Clevelandellidae

Genus *Paraclevelandia*

Order Oligotrichida

Family Halteriidae

Genus *Halteria**

*Strombilidium**

Order Hypotrichida

Family Aspidiscidae

Genus *Aspidisca**

Family Oxytrichidae

Genus *Gonostomum*

Steinia

Oxytricha

Stylonychia

Uroleptus

Urosoma

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* Illustrated by photomicrographs.

TABLE II

ECOLOGICAL PARAMETERS OF STUDY POND.

Genus	species	Date	Temp.(°C.)	D.S.ppm.	pH.
Coleps	*octospinus* Noland, 1925	Aug. to Oct. '69. March, May, June '70	3 - 19.5	79 - 113	4.55 - 5.15
"	*heteracanthus* Noland, 1937	January 14, 1970	0.5	107	4.75
"	sp.	March & June 1970	6.5 & 10.5	78 & 102	4.80 & 5.15
Chilophrya	*utahensis* Pack, 1919	June to Sept. '69 March & April, '70	6.5 - 20.5	85 - 125	4. 5 - 5. 0
Prorodon	*discolor* (Ehrenberg, 1838)	Aug. & Sept. '69	17.5 - 19.5	93 - 110	4. 5 - 4.75
Microregma	sp.	September '69	17.5	93	4.75
Platyophrya	sp.	September '69	17.5	93	4.75
Trachelocerca	sp.	Jan. & March, '70	0.5 & 7	102 & 107	4.75 & 4.80
Urotricha	sp.	All seasons	0.5 - 20.5	78 - 144	4.50 - 5.15
Litonotus	sp.	November '69	7.2	144	4.68
Dysteria	sp.	July '69	12.5	126	-

TABLE II (Cont.)

Genus	species	Date	Temp. (°C.)	D:S.ppm.	pH.
Paratrochilia	*chilodontoides* Kahl, 1933	Sept. 6, '69	17.9	93	4.68
Chilodonella	*uncinata* (Ehrenberg, 1838)	Aug. '69	19.5	110	4.50
Nassula	sp.	Aug. '69	19.5	110	4.50
Colpoda	*cucullus* O.F.M., 1773	Dec. '69 to Apr. '70	0.5 - 8.0	78 - 123	4.75 - 5.00
"	*steini* Maupas, 1883	Mar. Sept. & Nov. '69	7.5 & 17.5	93 & 144	4.75
Microthorax	sp.	July to Oct. '69 March & April '70	7.5 - 20.5	85 - 126	4.75 - 5.00
Cohnilembus	sp.	Aug. & Sept. '69	17.5 & 19.5	93 & 110	4.50 & 4.75
Uronema	sp.	Sept. '69	17.5	93	4.75
Colpidium	sp.	July & Aug. '69	12.5 & 19.5	110 & 126	4.50
Tetrahymena	*vorax* (Kidder, Lilly & Claff, 1940)	July 17, 1969	23.0	126	-
"	*pyriformis* (Ehrenberg, 1830)	All seasons	0.5 - 20.5	78 - 144	4.50 - 5.15
Paramecium	*bursaria* (Ehrenberg, 1833)	All seasons	0.5 - 20.5	78 - 144	4.50 - 5.15

TABLE II (Cont,)

Genus	species	Date	Temp. (°C.)	D.S.ppm.	pH.
Balanonema	*biceps* (Penard, 1922)	September, 1969	17.5	93	4.75
Cinetochilum	*marinum* Kahl, 1930	September, 1969	17.5	93	4.75
Cyrtolophosis	*bursaria* (Schewiakoff, 1893)	April, 1970	7.0	85	5.00
"	*elongata* (Schewiakoff, 1896)	Aug. & Sept. 1969 March 1970	6.5 17.5 19.5	93 - 110	4.55 4.75 4.80
Frontonia	*leucas* (Ehrenberg, 1838)	September, 1969	17.5	93	4.75
Lembadion	sp.	April to June '70	7.0 - 11.5	72 - 87	5.00 - 5.15
Christigera	sp.	All seasons	0.5 - 20.5	78 - 144	4.50 - 5.15
Cyclidium	*glaucoma* O.F.M. 1773	Sept.'69-June,'70	0.5 - 18	78 - 144	4.75 - 5.15
"	*citrullus* Cohn, 1865	Aug. & Sept. 1969	17.5 & 19.5	93 & 110	4.50 & 4.75
"	*elongatum* Schewiakoff, 1896	Nov. & Dec. 1969	6.5 & 7.0	78 & 144	4.75
"	*granulosum* Kahl, 1931	September, 1969	17.5	93	4.75
"	*litomesum* Stokes, 1884	August, 1969	19.5	110	4.50
"	*muscicola* Kahl, 1931	January, 1970	0.5	106	4.75

TABLE II (Cont.)

Genus	species	Date	Temp.(°C.)	D.S.ppm.	pH.
Pleuronema	*marinum* Dujardin, 1841	September, 1969	17.5	93	4.75
Ophrydium	sp.	September, 1969	17.5	93	4.75
Vorticella	sp. (Figs. 84 - 85)	April & May, 1969	-	-	-
"	*microstoma* Ehrenberg, 1830	May to August,'69	12.5 - 20.5	113 - 125	4.50
"	sp. (Figs. 87 - 89)	Nov.'69toJan.'70	0.5 - 7.0	78 - 144	4.75 - 4.80
"	*nebulifera* O.F.M. 1786	Aug. to Oct. 1969	17 - 19.5	93 - 113	4.50 - 4.80
"	sp. (Figs. 90 - 92)	September 1969	17.5	93	4.75
Epistylis	sp.	January 14, 1970	0.5	106	4.75
Telotrochidium	sp.	Dec.'69to Jan.'70 May, 1970	0.5 - 6.5	78 - 107	4.75 - 4.80
Metopus	*striatus* McMurrich, 1884	September 1969	17.5	93	4.75
Blepharisma	*persicinum* Perty, 1852	Sept.'69;June,'70	12.0 & 17.5	78 & 93	4.75 & 5.10
Spirostomum	*teres* Claparède & Lachmann, 1859	All seasons	0.5 - 20.5	78 - 144	4.50 - 5.15

TABLE II (Cont.)

Genus	species	Date	Temp. (°C.)	D.S.ppm.	pH.
Condylostoma	sp.	June, 1970	12.0	78	5.15
Paraclevelandia	sp.	January, 1970	0.5	106	4.75
Halteria	sp.	All seasons	0.5 - 20.5	78 - 144	4.50 - 5.15
Strobilidium	sp.	August, 1969	19.5		
		Jan. to April, '70	0.5 - 7.5	85 - 125	4.50 - 5.00
Aspidisca	sp.	All seasons	0.5 - 20.5	78 - 144	4.50 - 5.15
Gonostomum	sp.	August, 1969	19.5	110	4.50
Steinia	sp.	Nov. & Dec. 1969	6.5 & 7.0	78 & 144	4.75
Oxytricha	sp.	Aug. & Dec. 1969	19.8 & 6.8	112 & 75	4.54 & 4.70
Stylonychia	sp.	Aug. '69 to Apr. '70	0.5 - 19.5	78 - 144	4.50 - 5.00
Uroleptus	*longicaudatus* Stokes, 1886	August, 1969	8	78	4.50
		May & June, 1970	12.5 & 19.5	86 & 110	5.00 & 5.15
Urosoma	sp.	November, 1969	7.5	144	4.75

Subclass Holotricha

Order Gymnostomatida

Suborder Rhabdophorina

Family Colepidae

Genus *Coleps* (according to Corliss, 1961)

Coleps is distinguishable from related genera of holotrichous ciliates by its characteristic armoured exoskeleton, and by the presence of several spine-like processes at the posterior extremity. Its closest relative (genus *Tiarina*) is also armoured, but lacks any spines at the posterior extremity, which tapers to a point. Therefore, the armour and the spines of the present species dictate allocation to the genus *Coleps*.

Coleps octospinus Noland, 1925. Plate VI, Figs. 8 - 10.

Body: 90 to 115μ in length, 40 - 50μ in diameter. Furrowed longitudinally and transversely, barrel-shaped, armoured with cortical plates. Anterior half slightly flattened dorso-ventrally; nearly circular in medial cross-section. Cytostome apical (Fig. 8). External skeleton transversely bisected by a central groove (Fig. 9,D). Posteriorly, the central section is separated from the terminal one by a groove (Fig. 9,E). No such groove anteriorly. Twenty-two to 24 longitudinal rows of plates, in which lattice-like openings allow protoplasm to extrude (see type 1 of Kahl, 1930, p. 132).

Anterior spines: 4 flat, double-pointed spines on the margins of the cytostome just behind the spinous crown. Their size

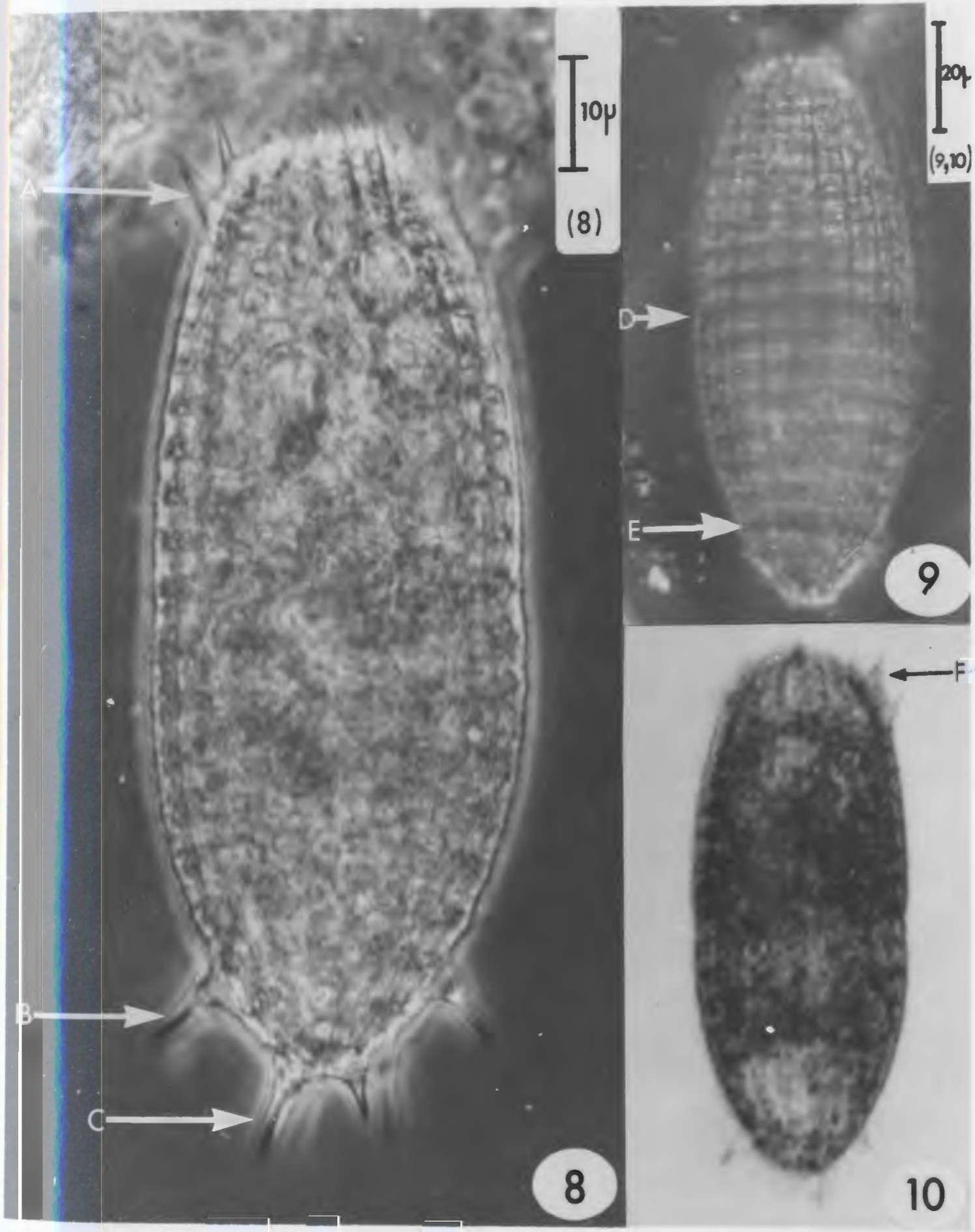
PLATE VI

Figs. 8 - 10 *Coleps octospinus* Noland, 1925

Fig. 8. Showing living example as seen by phase-contrast. (A) thorn-like anterior spine; (B) subterminal posterior spine; (C) terminal posterior spine.

Fig. 9. Showing fresh preparation by Nomarski interference-contrast effect. (D) central groove; (E) posterior groove.

Fig. 10. Showing fresh preparation by phase contrast. The arrow "F" indicates the blade-like anterior spine.


10μ
(8)
A
B
C
8
20μ
(9,10)
D
E
9
F
10

variable, the largest ones along the right margin. Both pairs on the lateral margins blade-like (Fig. 10,F) and transparent. Mid-dorsal and mid-ventral sets of spines thorn-like (Fig. 8). A number of smaller, asymmetrically placed spines behind the spinous crown encircling the cytostome.

Posterior spines: four spines symmetrically located at the margin of the posterior extremity (Fig. 8,C), four sub-terminal ones being alternately placed in the penultimate transverse row of plates (Fig. 8,B). Of more uniform size than the anterior spines, and averaging some 9 μ in length.

Ciliation: uniform somatic ciliation throughout, the cilia slender and sparse and gradually decreasing in length anteriorly. Cilia shortest and more numerous around the cytostome (Fig. 9). One caudal cilium.

Movement: swims rapidly, revolving about the long axis in a counter-clockwise direction (viewed from the rear). Occasionally briefly immobile.

Nucleus: Nucleolus at the centre of the round and posteriorly located macronucleus.

Division: dividing examples were observed several times in March, May and June, 1970. The anterior and posterior halves began to separate along the central groove. The posterior half of the anterior daughter and the anterior half of the posterior one remained lightly-coloured - and indeed transparent - during the formation of their new plates and spines.

Contractile vacuole: located at the posterior end of the anterior division product, its contents discharging through the posterior armour by means of a cytopyge. Protoplasm vacuolated and exhibiting ingested algal material.

Food: mainly algae including diatoms, and smaller ciliates.

Systematic account:

Kahl (1930 and 1932) grouped 14 species of *Coleps* into three categories on the basis of the structure of their exoskeletal plates. The organism under discussion has plates of Kahl's type 1, which occur in *C. hirtus, C. elongatus, C. amphacanthus, C. bicuspis, C. uncinatus* and *C. octospinus*. Noland (1937) described two more species of the genus *Coleps*. However, both of these differ from the present species in having type 3 plates.

Among the six members of Kahl's type 1, only *C. octospinus* has more than four posterior spines. There are two posterior spines in *C. bicuspis;* three in *C. hirtus, C. elongatus* and *C. amphacanthus;* and four in *C. uncinatus*. The Logy Bay species usually has four terminal and four sub-terminal posterior spines. It thus corresponds more closely to *C. octospinus* than to other species of the genus, despite Geiman's (1931) report that the posterior spines vary from seven to eleven in *C. octospinus*.

Finally, its large size (90 - 115μ x 40 - 50μ) double-pointed anterior spines and acid marsh habitat are further useful criteria linking it with *C. octospinus;* to which it is accordingly referred by

its plate structure (Kahl's type 1), the number (eight) and arrangement (four terminal and four subterminal) of the posterior spines, its double pointed anterior spines and the overall size and shape of its body.

Coleps heteracanthus Noland, 1937. Plate VII, Fig. 11.

Body: 90μ in length, 40μ in diameter. Furrowed longitudinally and transversely. Barrel-shaped, armoured with cortical plates. Anterior half slightly flattened dorso-ventrally, nearly circular in medial cross-section. Cytostome apical. External skeleton transversely bisected by a central groove. Kahl's type 3 plates (Fig. 11,b).

One flat, double-pointed spine on the margin of the cytostome just behind the spinous crown. A set of thorn-like spines on the other margin of the cytostome. Posterior spines eight in number, arranged as in *Coleps octospinus*. Uniform somatic ciliation throughout, the cilia slender and sparse and gradually decreasing in length anteriorly. Cilia shortest and more numerous around the cytostome. Two caudal cilia (Fig. 11). Swims rapidly, revolving about the long axis in a counter-clockwise direction as viewed from rear. Two spherical macronuclei, one in each half of the body. Macronucleus (Fig. 11) always with a central red spot in living non-stained material.

Systematic account:

Among the 16 known species of *Coleps*, group three (e.g. *C. incurvus, C. pulcher, C. remanei, C. similis, C. tesselatus, C. spiralis*

PLATE VII

Fig. 11. *Coleps heteracanthus* Noland, 1937.

Showing general appearance and the structure of its plates. (A) Barrel-shaped body with two caudal cilia. (B) Structure of plates, Kahl's type 3. Ma = Macronucleus.

and *C. heteracanthus*) bears comparison with the present species in having Kahl's type 3 structure of plates.

C. remanei is immediately separable from the present species by its giant size (200 - 250 μ), and its numerous posterior spines. *C. incurvus* is easily distinguishable by virtue of its cylindrical body shape and six posterior spines. *C. spiralis* differs in exhibiting definite spiral torsion in its longitudinal rows of plates. The number of posterior spines as well as body size, narrow the choice down to *C. pulcher* (100 μ) and *C. heteracanthus* (74 - 86 μ), for *C. tesselatus* (60 - 70 μ) and *C. similis* 50 - 70 μ) having only three or four posterior spines.

The present species is referable to *C. heteracanthus* rather than *C. pulcher* mainly because its thorns are on only one side anteriorly. The data for the present species fit the description of *C. heteracanthus* (Noland, 1937), which has identical plate structure, thorns on only one side anteriorly, and is of comparable size. However, certain additional characters are evident in the present species. Thus there are a single flat and double-pointed spine in the anterior part of the body, on the side opposite that just mentioned, a spherical macronucleus with a red spot in each half of the unstained body, eight posterior spines, and two caudal cilia.

Coleps sp. (Plate VIII, Figs. 12 - 16).

Armoured body (84 μ in length, based on four specimens, 80 - 86 μ), with spine-like processes both anteriorly and posteriorly (Figs. 12 - 15). Barrel-shaped, elliptical in medial cross-section, longer

PLATE VIII

Figs. 12 - 16. *Coleps* sp.

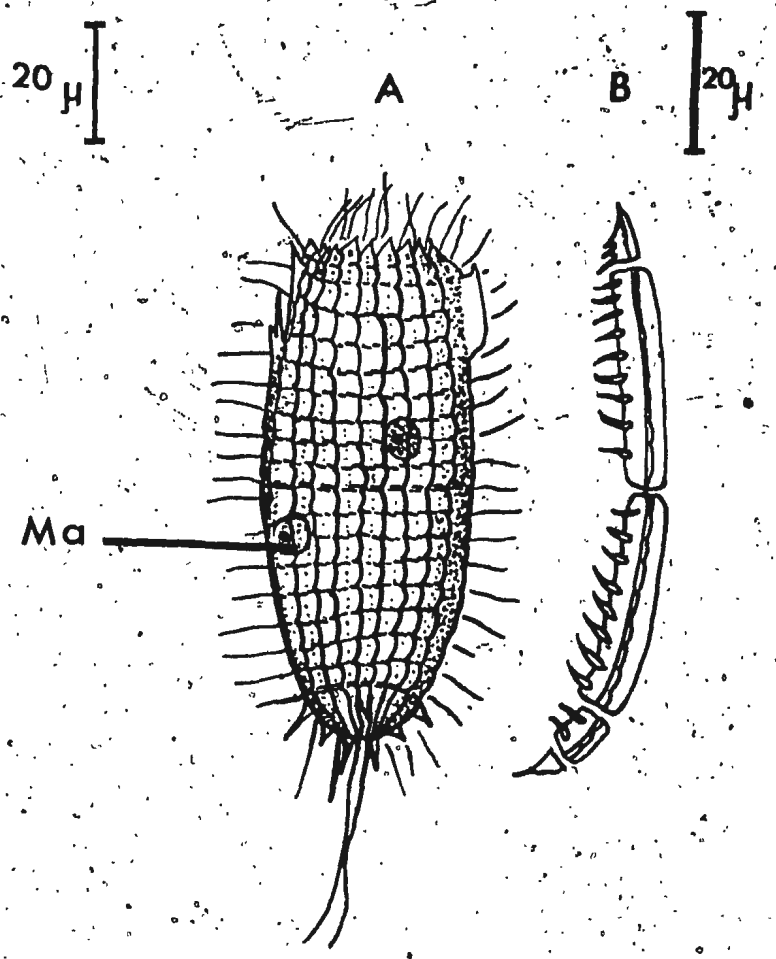
Fig. 12. Showing body shape and dorso-ventral ciliation.

Fig. 13. Showing the three posterior spines, and the mid-dorsal and mid-ventral ones.

Fig. 14. Dorsal view, showing the left anterior spines.

Fig. 15. Dorsal view, showing the right anterior spines.

Fig. 16. Plate structure (x 1,200), referable to Kahl's type 1.



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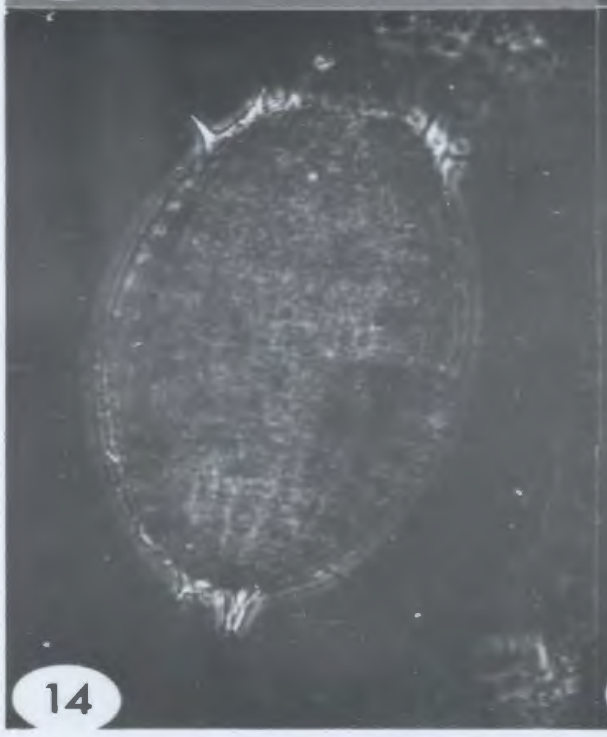
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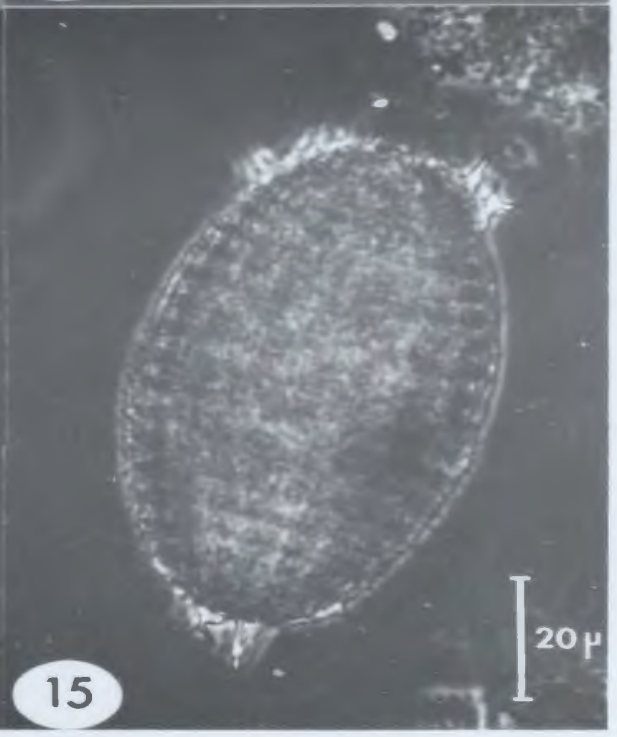
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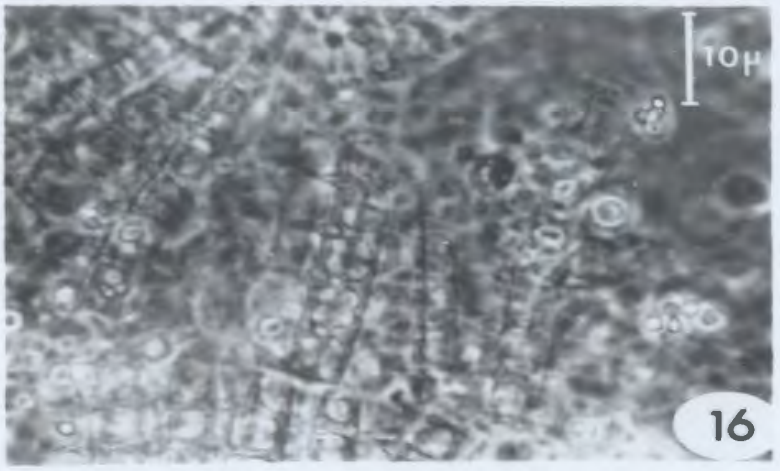
20 µ


10µ
16

diameter, 52.5 μ (Figs. 14 and 15), the shorter (dorso-ventral) one, 43.4 μ (Figs. 12 and 13). Dorsal side more convex than ventral, tapering slightly towards each extremity.

Furrowed longitudinally and transversely with cortical plates of Kahl's type 1 (Fig. 16). Cilia projecting through the interstices between the plates. Ciliation uniformly sparse except for a denser vestiture encircling the cytostome (Fig. 12) and two caudal cilia. Length of somatic cilia, about 11 μ, the caudal ones, 35 μ.

Viewed from the dorsal side, a set of teeth (some 5.2 μ long) projects at each margin anteriorly. The straight set on the left is composed of one single pointed tooth and a wide-angled, double-pointed one (Fig. 14). The right set has a similar single straight tooth anteriorly, but the second and bifurcated one has its points distinctly closer to one another by comparison with its opposite member on the left (Fig. 15). A few thorn-like mid-dorsal and mid-ventral spines (Fig. 13).

Three incurved claw-like spines evenly spaced about the margin of the rounded posterior extremity. That to the left (the smallest) decidedly incurved, 5.2 μ in length. Length of the other two spines, some 8.5 μ (Fig. 13).

Swims leisurely, revolving about the long axis in a counter-clockwise direction (viewed from the rear).

Systematic account:

This armoured, barrel-shaped ciliate with spines both anteriorly and posteriorly belongs to the genus *Coleps*. Two of the 16

known species of *Coleps*, *C. striatus* and *C. trichotus*, do not merit consideration with it on the basis of lacking posterior spines.

Plate structure is accepted as one of the chief specific criteria in the other 14 species. The plates of the present species are referable to Kahl's type 1. This narrows the comparison down to the six species bearing Kahl's type 1 plates (*C. hirtus*, *C. elongatus*, *C. amphacantus*, *C. bicuspis*, *C. uncinatus* and *C. octospinus*).

C. uncinatus and *C. octospinus* are immediately separable from the species under discussion in having more than three posterior spines.

C. hirtus (40 - 65 μ) with its three spines on the margin of the rounded posterior extremity, is closer to the species under discussion. However, it stands apart in that its armour comprises four girdles and in having single caudal cilium. Furthermore, the present species (84 μ long) is very much larger than *C. hirtus*.

The latter stands closer to *C. amphacanthus* (70 - 90 μ long) in body size, in its plump shape, and in having three posterior spines. Nevertheless, it lacks the major features of *C. amphacanthus*, which has three posterior spines arranged in almost linear fashion instead of as a triangle, together with a twisted cytostome about sixty degrees clockwise out of line with the main axis of the posterior margin. Furthermore, *C. amphacanthus* has from four to eight caudal cilia instead of two, as in the present species.

The latter resembles *C. bicuspis* (55 μ) in shape and anterior spination, differing from it mainly by virtue of its larger size, three posterior spines, and two caudal cilia. As regards the spines of

C. bicuspis " These pairs of teeth occupy portions at the anterior end that correspond with those occupied by the two spines at the posterior end " (Noland, 1925, p. 6). The two anterior sets of teeth do not corrspond with the three posterior spines in the present species.

In its specific characters, such as the possession of two caudal cilia, three triangularly arranged posterior spines, and body size, the present species is very close to *C. elongatus* (40 - 55 μ according to Noland, 1925; 65 - 80 μ according to Kahl, 1930). However, the latter is characterized by its slender appearance. The plump shape of the present species (84 μ by 52.5 μ) thus immediately sets it apart from *C. elongatus*. The other major feature distinguishing the present species from *C. elongatus* is its possession of two sets of teeth anteriorly, though differing from other members of *Coleps* in its plate structure, three triangularly arranged posterior spines, two caudal cilia and overall body size and shape, the species described herein requires data based on a sufficiently large population to establish its taxonomic allocation.

Family Holophryidae

Genus *Urotricha* Claparede and Lachmann (according to Corliss, 1961).

Urotricha sp. (Plate IX, Figs. 17-19).

Body spherical to slightly oval (27.3 μ x 24 μ, based on 23 specimens, 20 - 34 μ x 17 - 29 μ), posterior third unciliated save for one long caudal cilium (B in Figs. 18 and 19), ciliation otherwise uniform (Figs. 17 - 19). Cytostome round at anterior surface, surrounded by ring of heavier cilia and lacking significant peristome. No trichocysts observed. Contractile vacuole posterior, macronucleus spherical. Progression both by 'leaping' and steady 'swimming'.

Systematic account:

Having its cyclostome at the naterior surface but lacking a peristome, the small ciliate under consideration bears the main characteristics of *Urotricha*. This genus differs from other members of the Holophryidae in that its rear third is unciliated except for one to several long caudal cilia.

On the basis of body shape, body size, number of caudal cilia and the presence of trichocysts, Kahl (1930) recognized 12 species of *Urotricha*. The present species differs from *U. synuraphaga*, *U. ovata*, *U. obliqua*, and *U. armata* in its absence of trichocysts. Its single caudal cilium further distinguishes it from *U. pusilla*, *U. furcata* and *U. saprophila*. On the basis of body shape, the anteriorly trilateral tapering *U. agilis*, jug-like *U. farcta* and flask-shaped *U. lagenula* do not merit comparison with the spherical to oval species under discussion.

PLATE IX

Figs. 17 - 19. *Urotricha* sp.

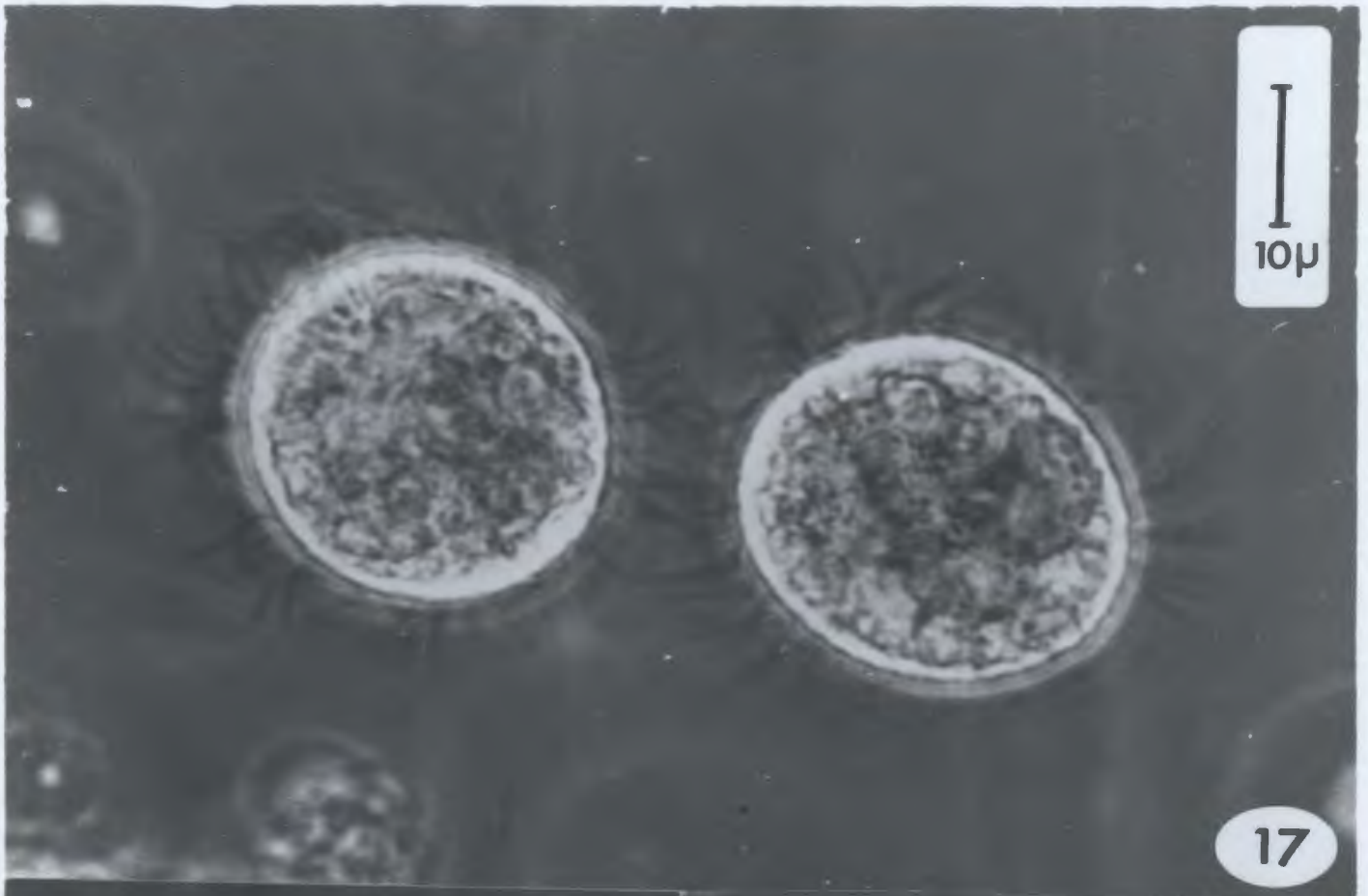
Fig. 17. Showing spherical to slightly oval forms.

Fig. 18. Showing (A) a ring of heavier cilia around cytostome; (B) long single caudal cilium.

Fig. 19. Showing (B) long single caudal cilium and truncate posterior extremity.

The latter is closer to the spherical *U. globosa* (18 μ) than the cylindrical *U. discolor* (25μ). Its body size (27.3 x 24 μ) is closer to the latter than to the former.

Of the known species of *Urotricha*, none have charcteristics quite comparable to those of the species under consideration. However, the establishment of its systematic allocation requires further study of its infraciliary morphology.



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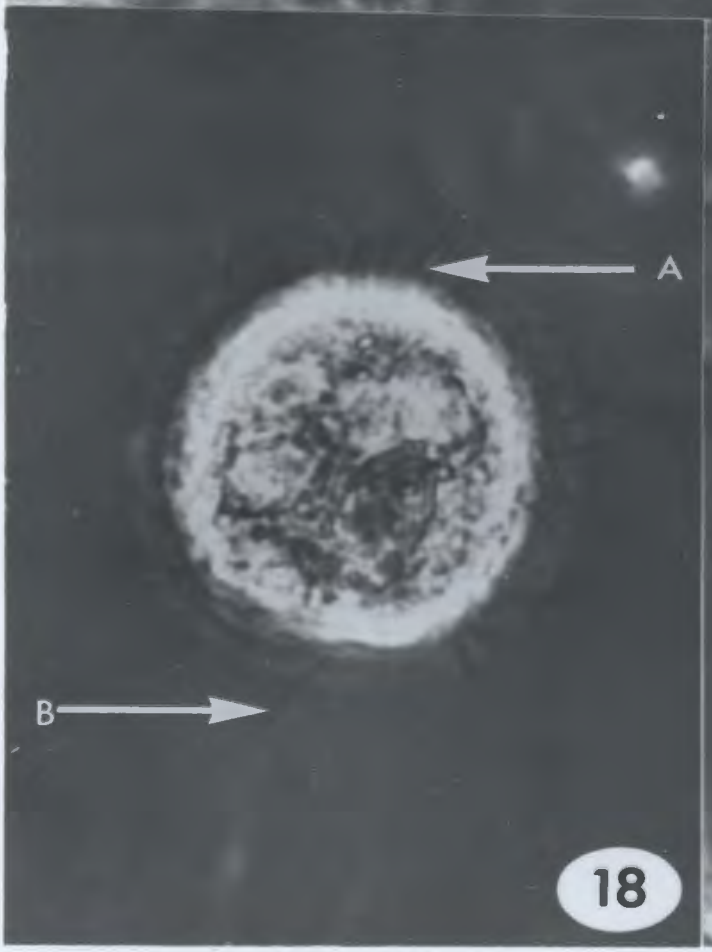

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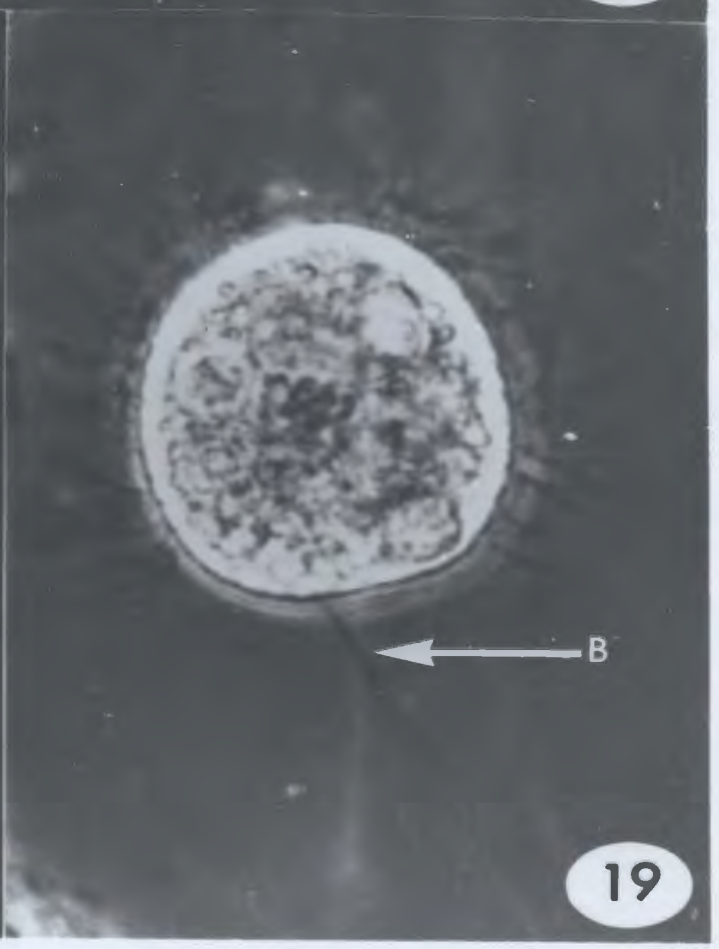


19

Subclass Holotricha

Order Trichostomatida

Family Colpodidae

Genus *Colpoda*

Colpoda cucullus O. F. M., 1773. Plate X, Figs. 20–23.

Size and shape variable, depending upon the amount of food available. In general, reniform and compressed, overall measurements 42 – 64μ x 31 – 45μ (av. 57.8μ x 39.4μ). Right border semi-circular, posterior half of the left border often convex. Oral funnel in the middle of flattened ventral side. Cytostome ventrally located and displaced to the right of the median plane, leading into the peristome cavity and gives rise dorsally to a diagonal groove; its edge bears a ciliated area, but no protruding membrane. Right lateral ciliary field, rotated about 60° to assume an anterior position. It appears as a rather narrow crescent closely adjacent to which lies the anterior extremity of the stomatogenous meridian whose basal bodies are quite small at this level.

Cilia either single or paired. When present singly they are confined to the central posterior body region. Being arranged along pellicular grooves they give the distinctive notched appearance to the preoral keel anteriorly. These, which are deepest at the anterior extremity, form a polygonal figure posteriorly. The number of meridians varies from 29 to 34; anterior keel with six to ten indentations (Figs. 20, 21). Macronucleus with a stellate endosome, central.

PLATE X

Figs. 20 - 23. *Colpoda cucullus* O. F. M. 1773. Figs. 20 and 21 from silver impregnation preparation by the Chatton-Lwoff technique, and viewed by phase-contrast microscopy. Figs. 22 and 23, from life, as seen by Nomarski interference-contrast effect.

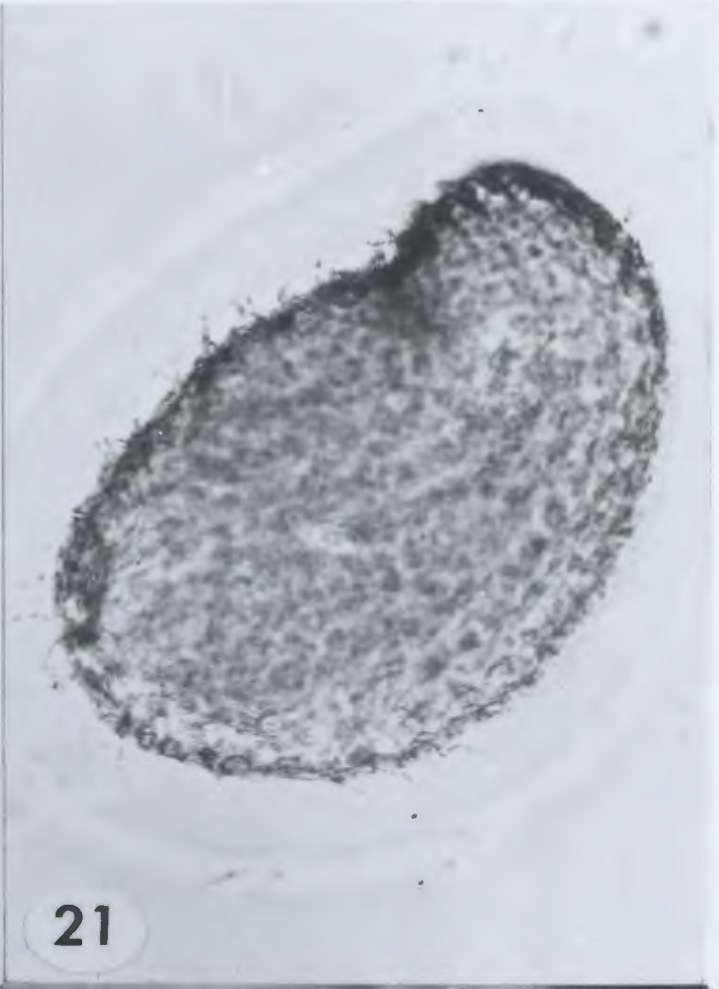
Fig. 20. Showing the left side.

Fig. 21. Showing the right side.

Fig. 22. Focused on the food vacuoles.

Fig. 23. Pointed to the contractile vacuole, indicated by arrow.

20



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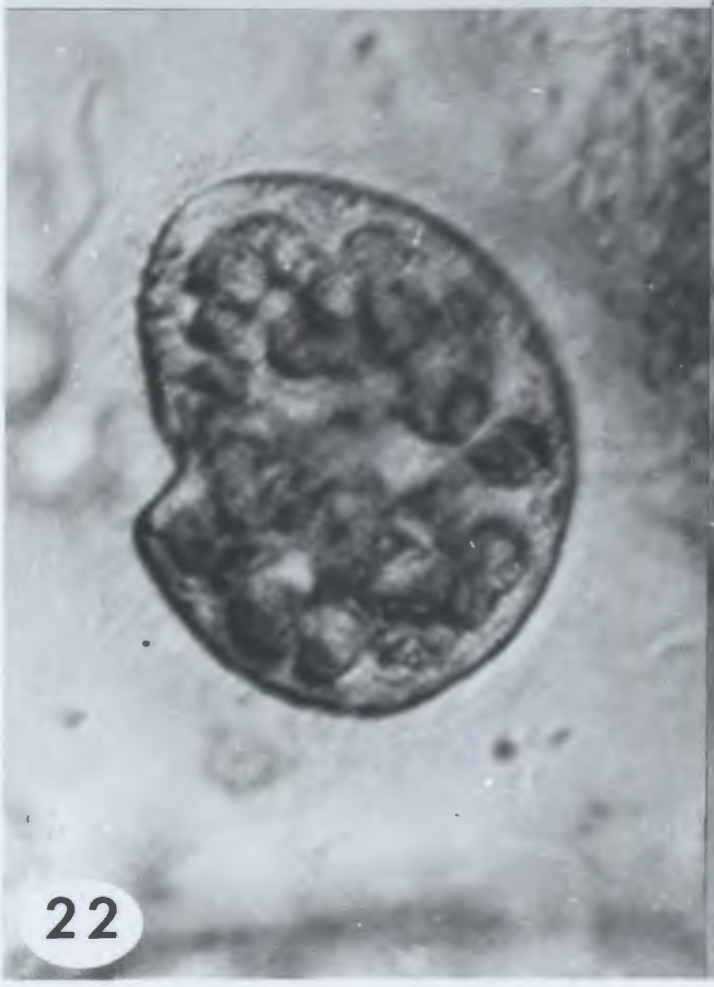

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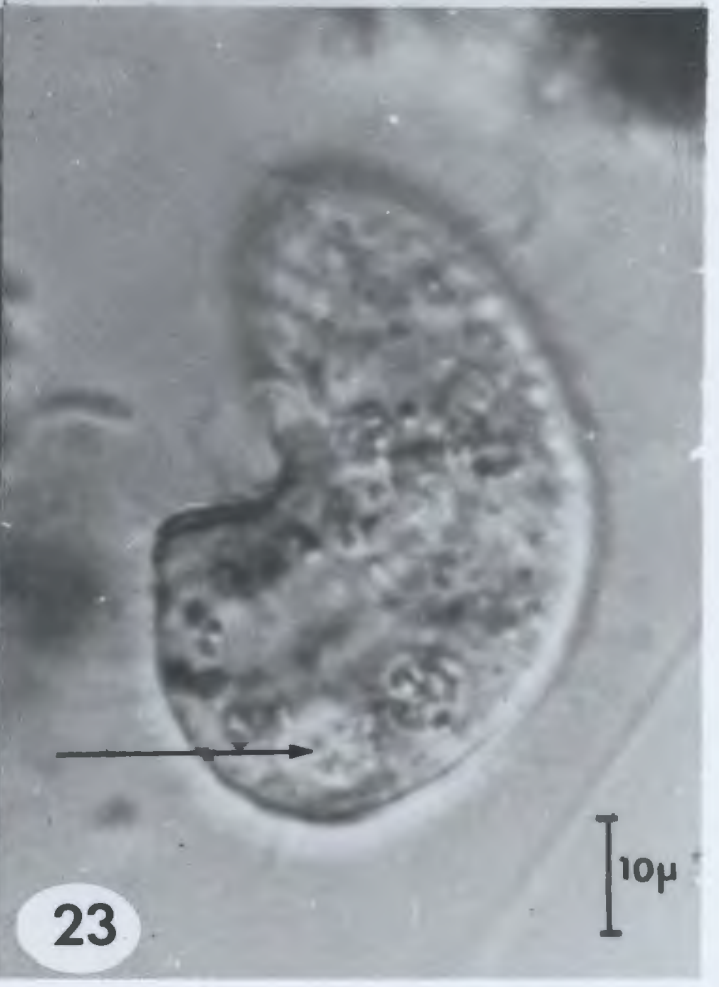


23

10μ

Trichocysts rod-form.

Freshly excysted ciliates exhibit a clear hyaline cytoplasm which rapidly assumes a grayish opacity when food is plentiful due to the accumulation of food vacuoles (Fig. 22). Contractile vacuole posteriorly located (Fig. 23).

Systematic account:

On the basis of size, Burt (1940) divided the *Colpoda* species into two groups: (1) the small forms, *C. steini* and *C. aspera*, averaging about 30μ in length and (2) the large ones, *C. maupasi*, *C. inflata*, and *C. cucullus*, averaging more than 50μ in length. The present species bears comparison with the three whose length ranges from 35μ to 110μ.

The numbers of the pre-oral indentations and the total ciliary meridians of *Colpoda* serve as the significant criteria for accurate species diagnosis. The present species is referable to *C. cucullus* by its size, eight to ten pre-oral indentations and the total number of ciliary meridians. It is easily distinguished from *C. maupasi* (5 pre-oral indentations) and *C. inflata* (6 - 8 pre-oral indentations).

Family Microthoracidae

Genus *Microthorax*

Microthorax sp. Plates XI - XIV, Figs. 24-35.

Small (18 - 24μ long, based on 18 specimens), kidney-shaped, compressed laterally; with delicate keeled armour which is more or less pointed anteriorly and rounded posteriorly; ventral armour with three deep ciliary rows (Figs. 29, 31 and 33); oral depression posterior-ventral (Figs. 24 - 34), with a stiff ectoplasmic lip on right side (Figs. 25, 26 and 28), below which there is a small membrane (Figs. 26 - 28, 31 and 34), and with a small tooth on left margin (Figs. 25 - 27, 30 - 34), no cytopharynx; single macronucleus spherical (Fig. 35), two contractile vacuoles.

Systematic account:

The present species bears the characteristics of *Microthorax* which is distinguishable from other genera in Microthoracidae by its posterior-ventrally located oral depression, without cytopharynx, trichocysts, and trichites.

The Logy Bay species differs from *Microthorax scutiformis*, *M. elegans*, *M. simulans* in its frontal half without deep furrow across ventral-dorsal edge. Its rounded posterior extremity separates the present species from *M. tridentatus*, *M. bidentatus*, *M. glaber*, *M. ungulatus*, *M. spiniger*, and *M. costatus*. Among the rest of the species of *Microthorax* (recognized by Kahl, 1930), *Hemicyclium lucidum* Eberhard, (*Microthorax haliotideus* Penard), *M. pusillus*, *M. auricula* with slightly

PLATE XI

Fig. 24. *Microthorax* sp. Showing small (23.5μ x 12.5μ), kidney form with posterior-ventral oral depression.

PLATE XII

Figs. 25-27. *Microthorax* sp. Showing a small tooth on left margin of oral depression.

PLATE XIII

Figs. 28 - 31. *Microthorax* sp.

Fig. 28. Showing a stiff ectoplasmic lip on right side of oral depression.

Fig. 29. Showing ventral armour with three deep ciliary rows.

Figs. 30 and 31. Showing oral depression with membrane.

PLATE XIV

Figs. 32 - 35. *Microthorax* sp.

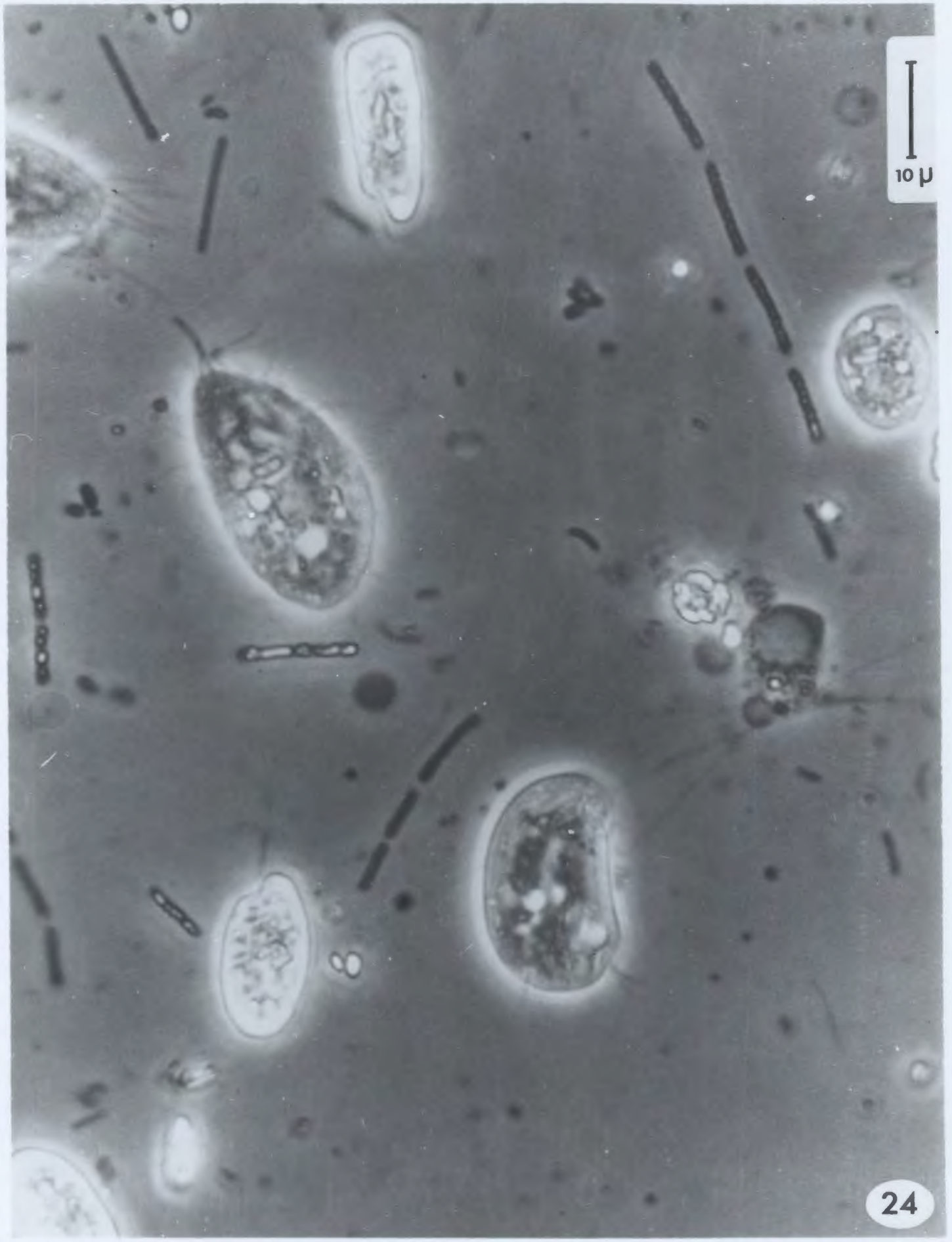
Figs. 32 - 34. Showing posterior-ventral oral depression with a small tooth on left margin.

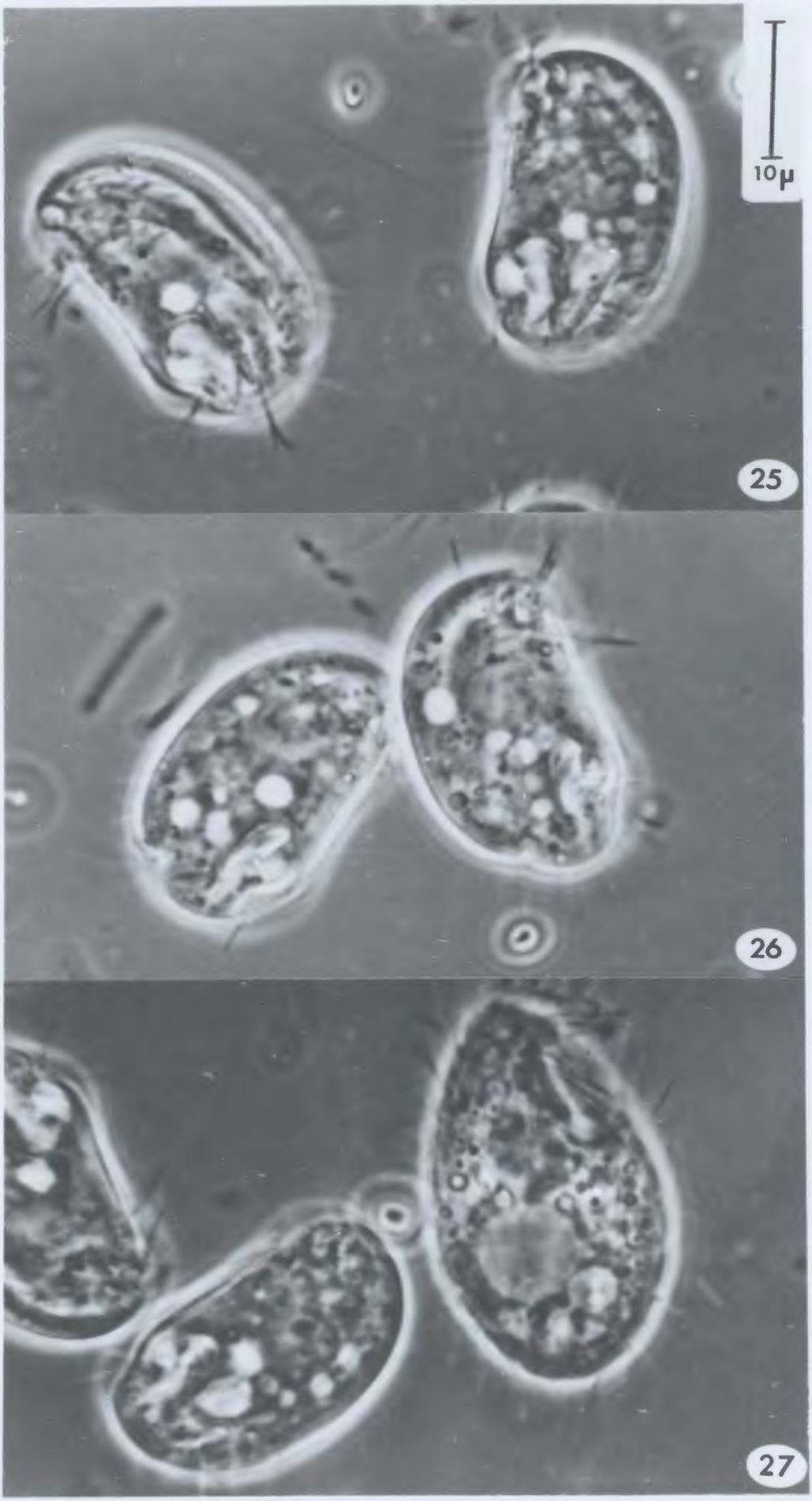
Fig. 35. Showing single spherical macronucleus as stained with methyl green.

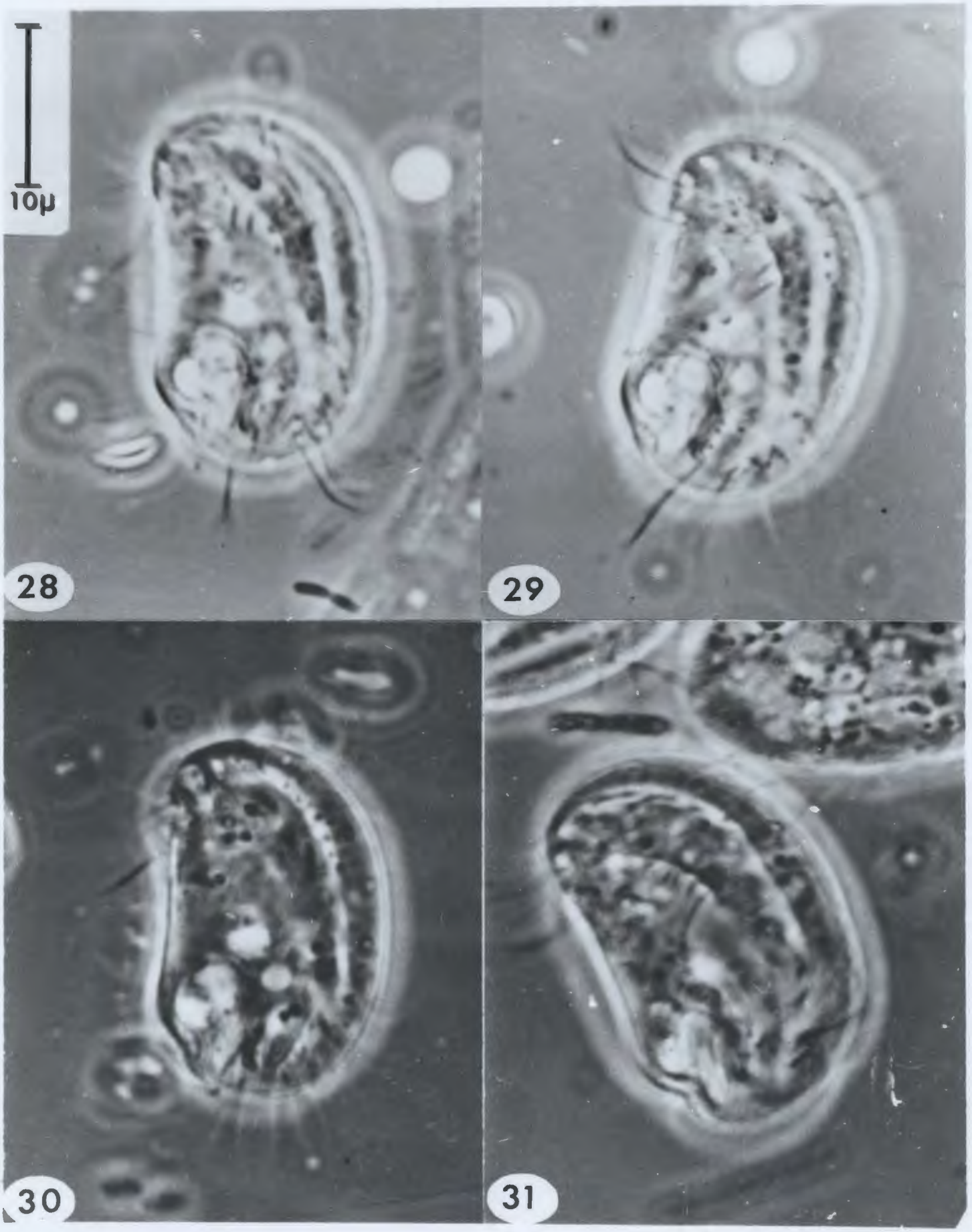
ridged ventral side, thus bear no comparison with the deep-ridged present species.

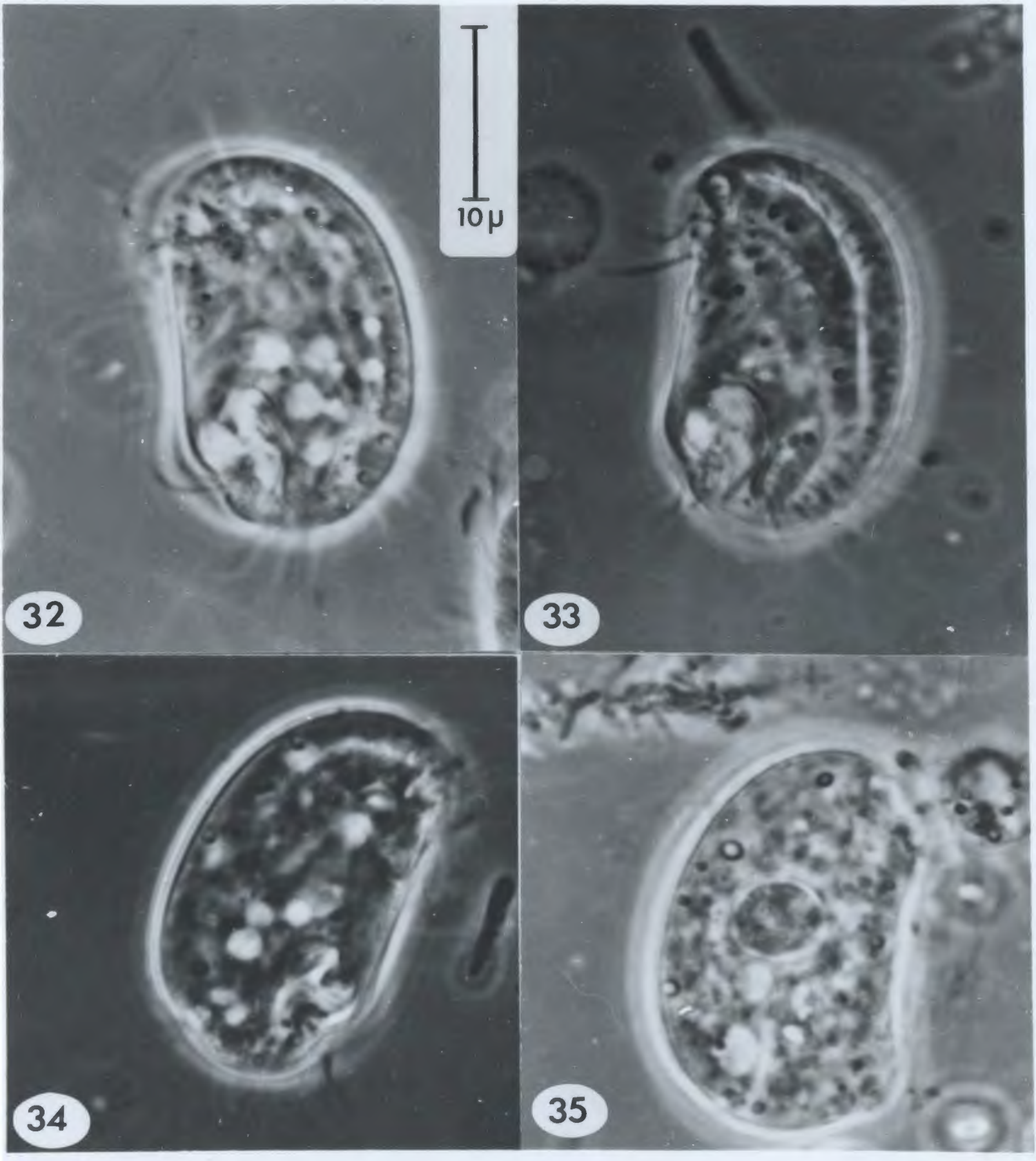
The present species is similar to the remaining two species, *M. sulcatus* and *M. viridis*. The latter with zoochlorellae is distinguishable from the present species. Only *M. sulcatus* resembles the present species in the discussed criteria.

However, the smaller size (18 - 23 µ) and its slanted oral depression with sigmoid edge along ventral posterior edge do not fit the decsription of *Microthorax sulcatus* Engelmann (1861). Its taxonomic allocation, however, should only be determined after extensive further study of the infraciliary structure.


10 µ
24


10μ
25
26
27


10μ
28
29
30
31


10 μ
32
33
34
35

Order Hymenostomatida

Suborder Tetrahymenina

Family Tetrahymenidae

Genus *Tetrahymena* (according to Corliss 1961a).

Furgason's precise taxonomic work (1940) validated the generic name "*Tetrahymena*". This name is derived from the tetrahymenal buccal ciliary apparatus which comprises four membranous structures, one undulating membrane on the right and three membranelles on the left of the buccal cavity. The entire buccal apparatus is typical for the suborder Tetrahymenina (Corliss 1952a, 1953a, 1956). That the direction of the cytostome axis at once distinguishes *Tetrahymena* from such related genera as *Glaucoma*, *Colpidium*, *Loxocephalus* (Furgason, 1940; Corliss, 1952a, 1953a).

Species of the holotrichous genus *Tetrahymena* Furgason, 1940, are typically of small size and covered with fine cilia arranged in longitudinal rows. Their body is pyriform in at least one stage of the life cycle. They possess a rather inconspicuous oral opening equipped with a tetrahymenal buccal ciliary apparatus and located on the ventral surface near the anterior extremity of the body.

Tetrahymena vorax (Kidder, Lilly and Claff, 1940)

Plates XV - XVII, Figs. 36 - 47.

The marked dimorphism of this ciliate was evident by phase contrast microscopy. Silver impregnation preparations were then made.

PLATE XV

Figs. 36 - 39. *Tetrahymena vorax* (Kidder, Lilly and Claff, 1940) from silver impregnation preparation by the Chatton-Lwoff technique, viewed by phase-contrast microscopy.

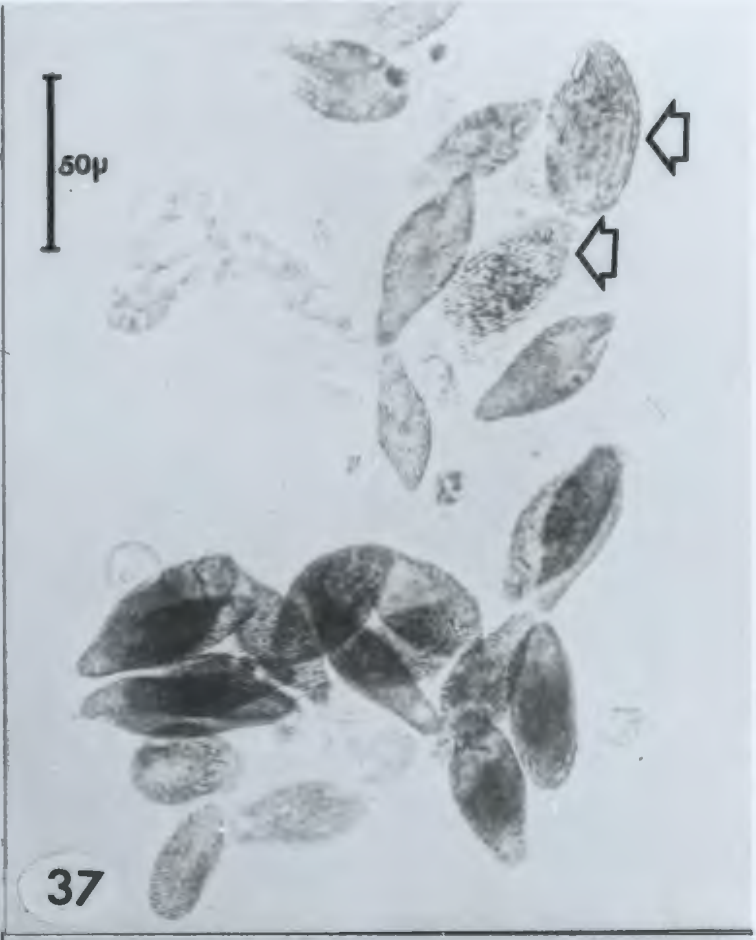
Fig. 36. Showing different stages, for comparison of the size and shape of microstome form with that of macrostome form (pointed one indicated by arrow A).

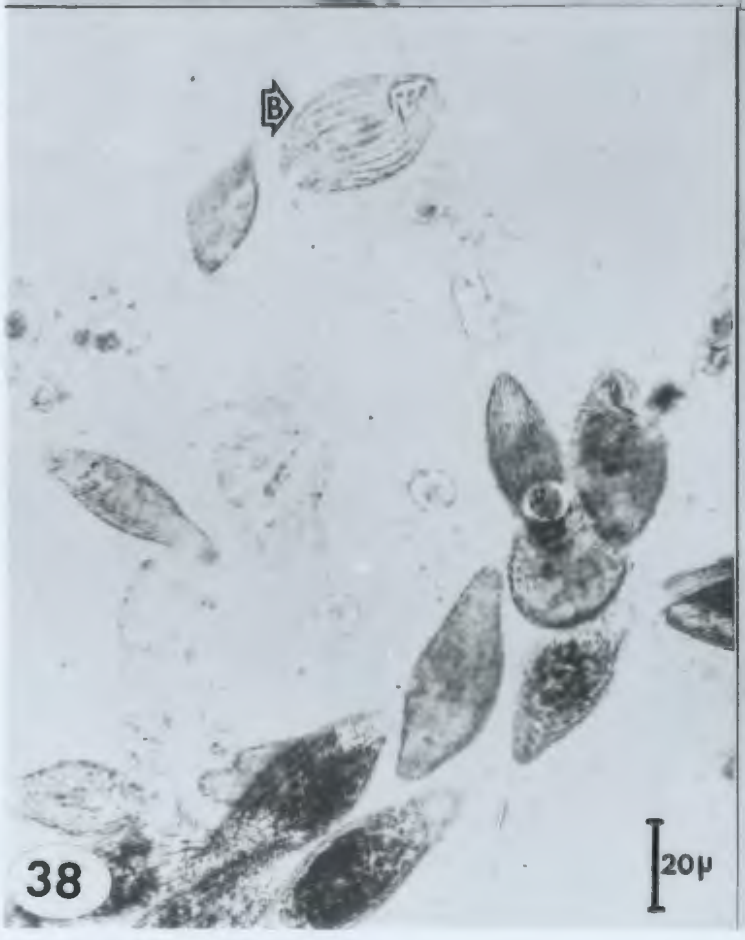
Fig. 37. Showing microstome stage, both the tailed fusiform and pyriform shapes (indicated by arrows).

Fig. 38. Showing different forms. A pointed one is indicated by arrow B.

Fig. 39. Showing both tailed fusiform microform and macrostome. The pointed macrostome tomites are indicated by arrow C.


50μ
A
36


50μ
37


B
20μ
38

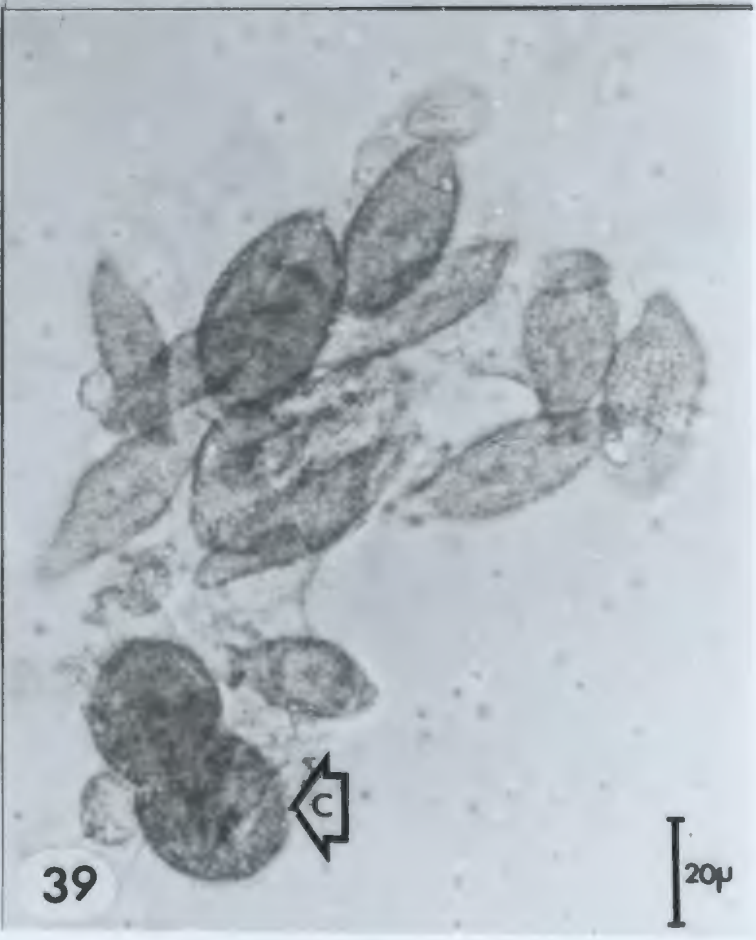

C
20μ
39

PLATE XVI

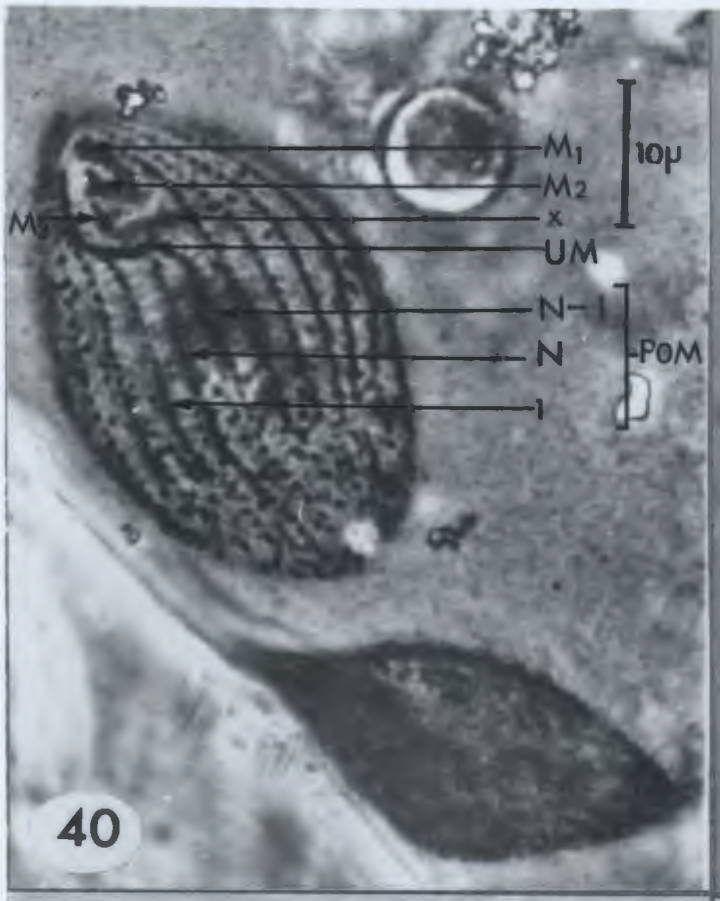
Figs. 40 - 43. *Tetrahymena vorax* (Kidder, Lilly, and Claff, 1940) from silver impregantion preparation by the Chatton-Lwoff technique, viewed by phase-contrast microscopy.

Fig. 40. Showing pyriform microstome from Fig. 38. AZM, adoral zone membranelles; UM, undulating membrane complex; X, unknown structure; POM, post-oral meridians. Notice that the meridians are arranged with uniform regularity anteriorly, joining irregularly at the posterior extremity (cf. Figs. 44 - 47).

Fig. 41. Showing mature macrostome form showing the large pharyngeal pouch and ingested prey.

Fig. 42. Showing the same mature macrostome as shown in Fig. 36. Notice the size, shape and position of the cytostome and the distance between adjacent cilia increased.

Fig. 43. Showing the same macrostome tomites shown in Fig. 39.



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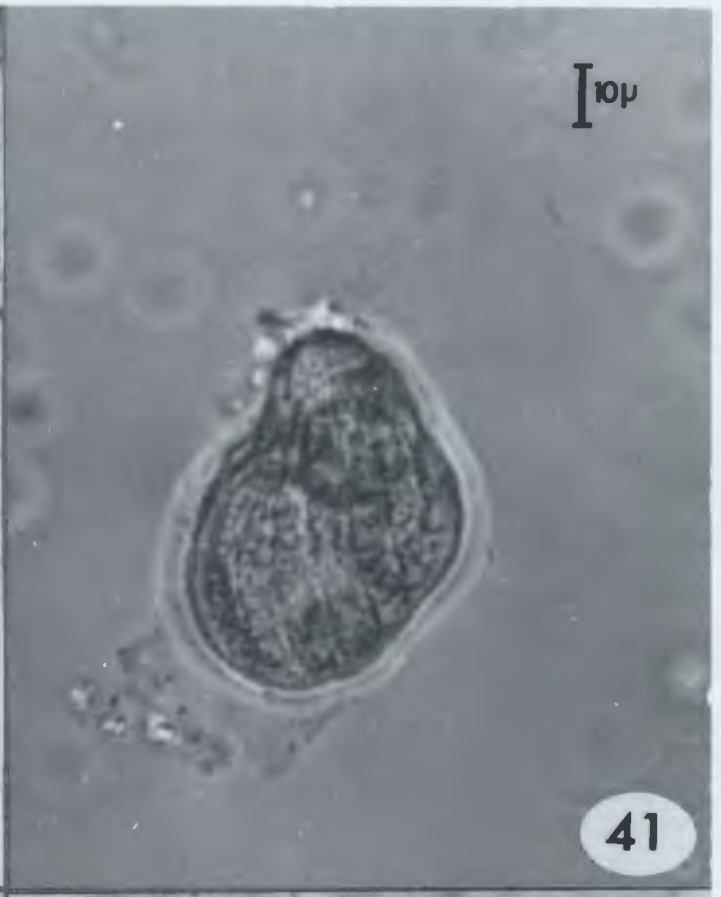

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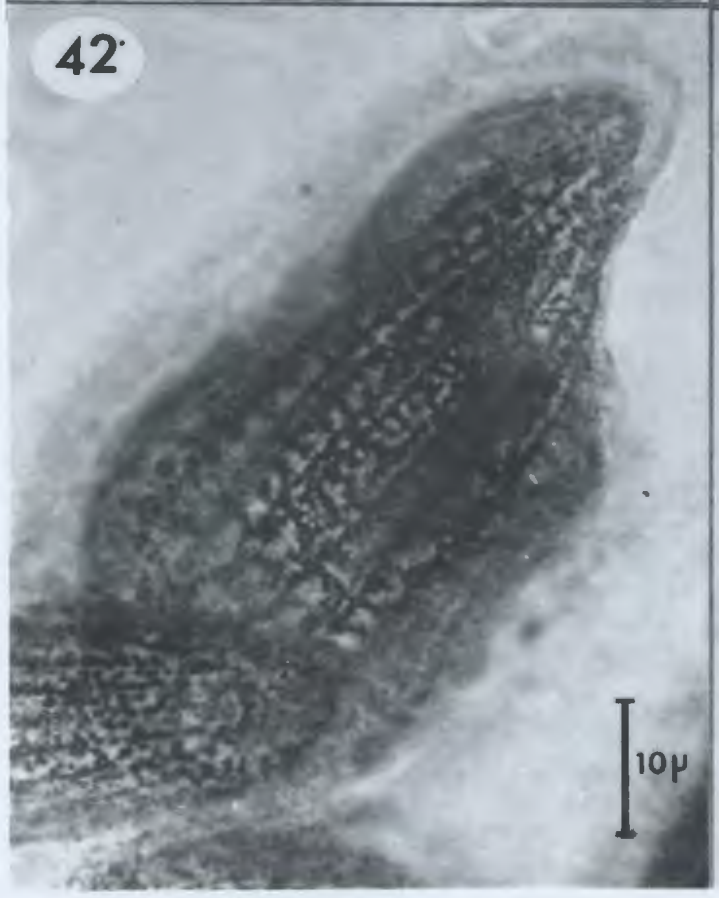

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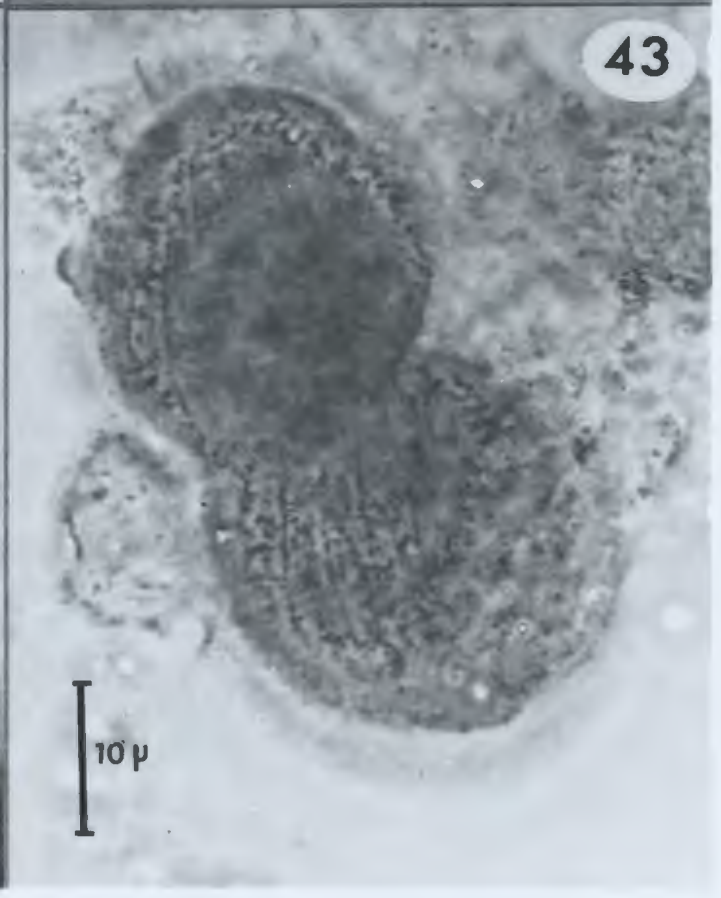


43

PLATE XVII

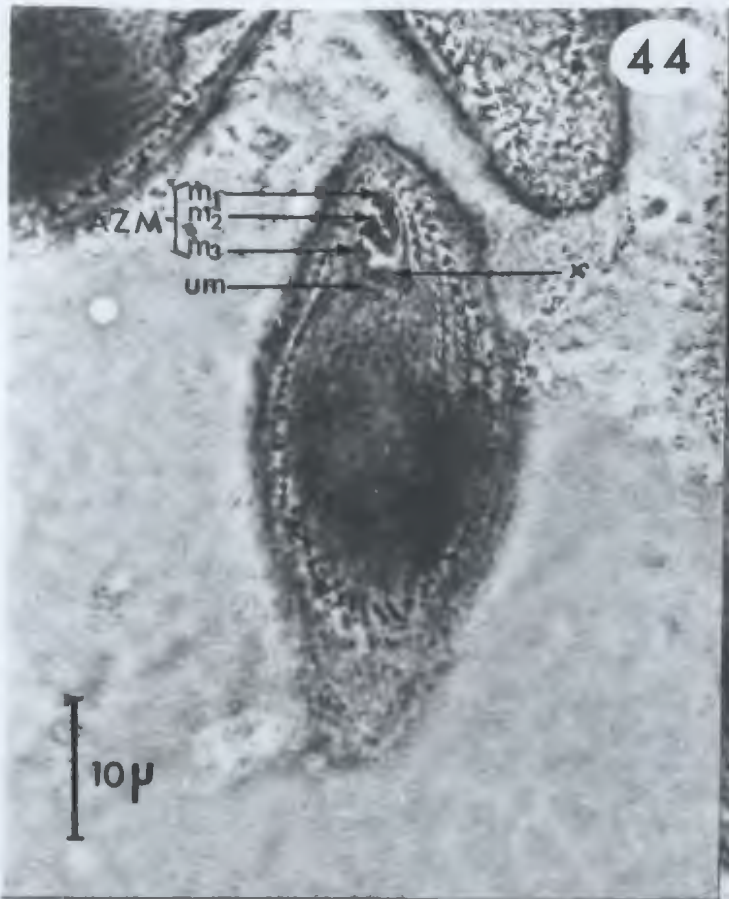
Figs. 44 - 47. *Tetrahymena vorax* (Kidder, Lilly and Claff, 1940) from silver impregnation preparation by the Chatton-Lwoff technique, viewed by phase-contrast microscopy.

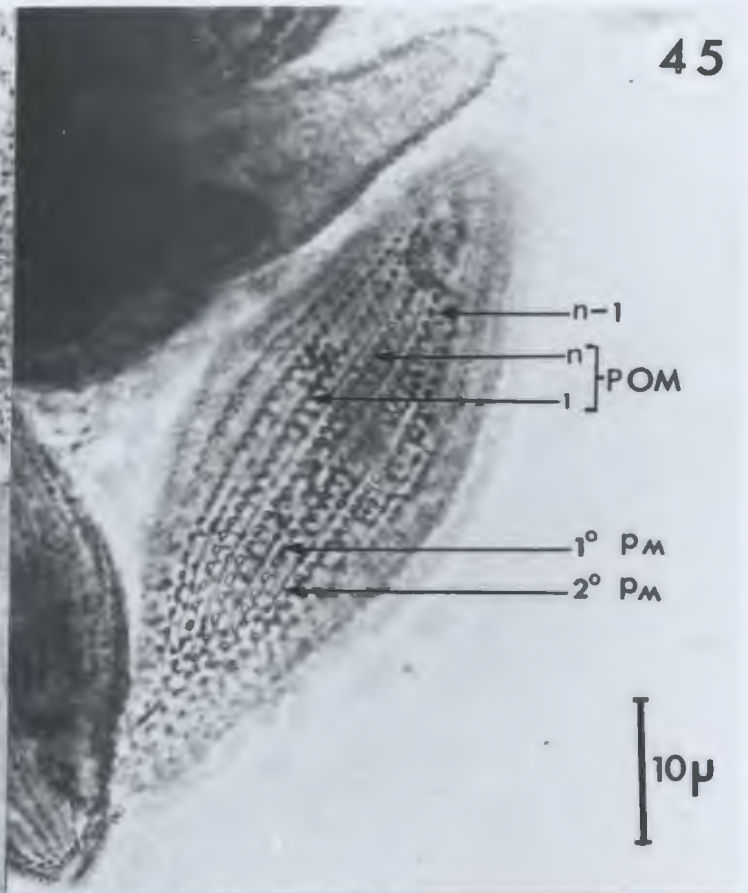
Fig. 44. Showing the buccal apparatus of the tailed fusiform microstome with three AZM and UM and an unknown structure (x).

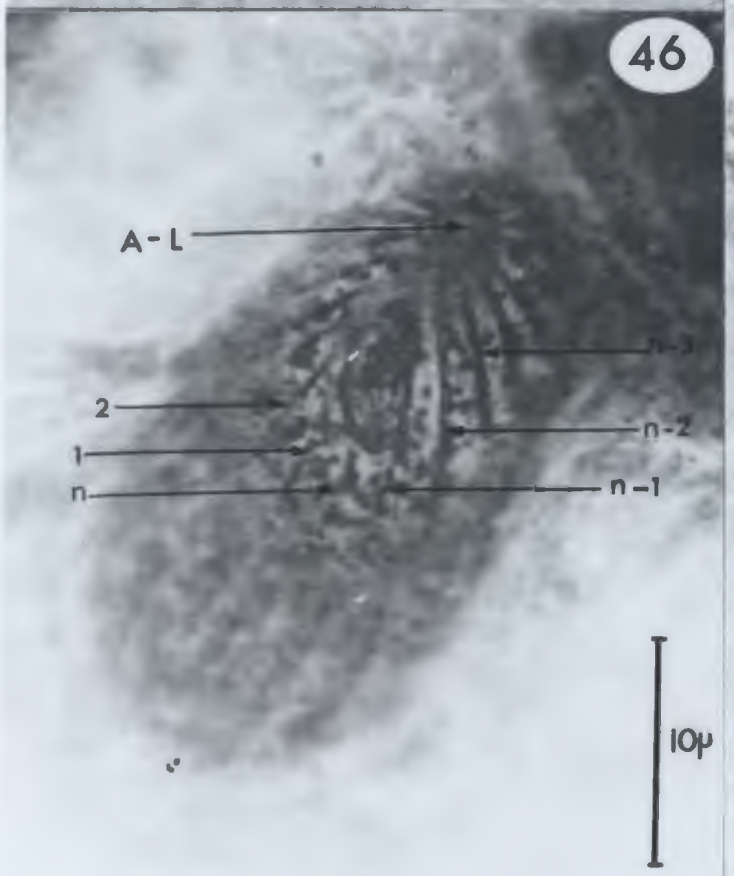
Fig. 45. Showing tailed microstome with body ciliation. Notice two post-oral meridians (POM) and strong secondary meridian (2° PM).

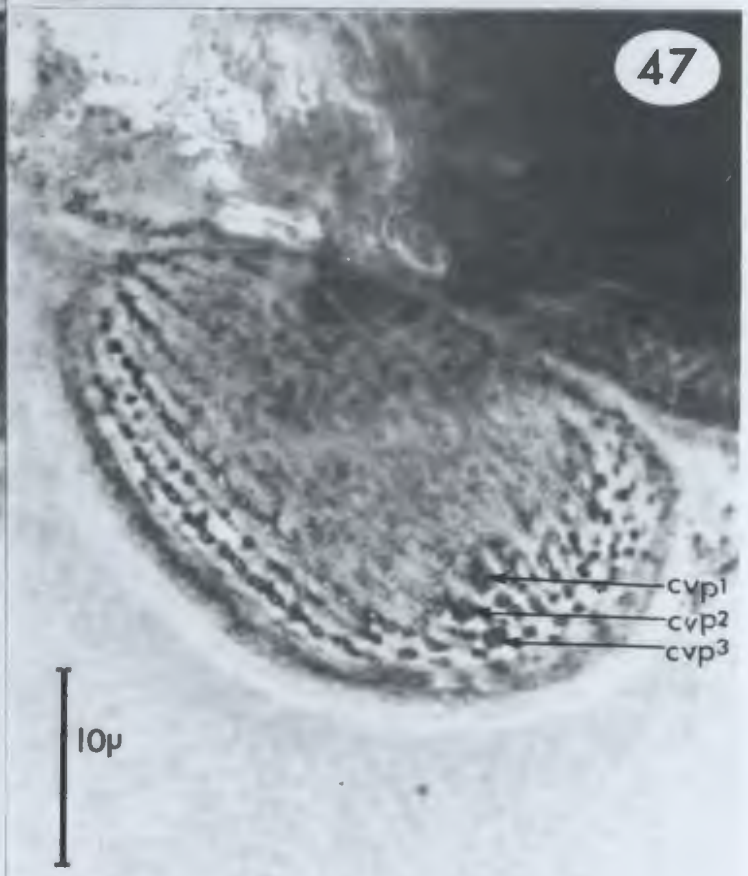
Fig. 46. Illustrating the ciliation around apical loop (A-P) of microform.

Fig. 47. Showing three contractile vacuole pores (CVP) of microstome stage.


44
AZM
m1
m2
m3
um
x
10μ


45
n-1
n
1
POM
1° PM
2° PM
10μ


46
A-L
n-3
2
n-2
1
n
n-1
10μ


47
cvp1
cvp2
cvp3
10μ

The following data are based principally upon silver impregnation material (Chatton-Lwoff method). As necessary, they are supplemented by information derived from live ciliates.

Life cycle.

The changes in body form of the present strain were shown by phase-contrast to be very comparable to Figure 3 of Corliss (1953a). The following descriptions of the pronounced polymorphism exhibited by the present strain are based upon observations of living material as well as mixed staining (neutral red and methylene blue) and (principally) silver impregnation.

1. Tailed microstome stage (Figs. 36-39, 44-47, c.f. Corliss, 1953a, Fig. 3a).

The "thin, tailed organism" reported as the principal form found in nature was seen in both living and stained material. It is a microstome form, i.e. the buccal opening is small. Except for its elongate posterior extremity, slightly larger overall body size, and greater range in number of meridians and contractile vacuole pores, it is practically identical with *T. pyriformis*. Its appearance in silver impregnation preparations is similar to Fig. 3g of Corliss (1953a). These forms are generally very elongate, with long and sharply pointed tails (Figs. 36-38). However, the buccal opening and other morphological features are identical to those described as the "tailed microstome stage" by Corliss (1953a). These forms were probably starved when fixed for silver impregnation.

2. Pyriform microstome stage. (Figs. 37, 38 and 40, c.f. Figs. 3i, j, of Corliss, 1953a).

This was described by Corliss as "a curious stage in that forms in it are morphologically indistinguishable from *T. pyriformis*". It was observed both in live and stained material, together with tailed microstome forms, from which it is derived. Once all the individuals in a culture have reached this stage, they are irreversibly pyriform, and can only be identified as *T. pyriformis*.

3. Transitional stages from tailed microstome to macrostome form (Figs. 3b, 3c of Corliss, 1953a).

In life, where both tailed microstome and pyriform microstome stages were observed, the morphology of the former is subject to marked and rapid change. Within a very few minutes, mature macrostome forms result. A condensed account based upon both living and stained material was given by Corliss (1953a).

4. Mature macrostome stage (Figs. 36, 39 and 41 - 43, cf. figs. 3d, 3e, and 3f of Corliss, 1953a).

Several rounder, broader forms had eventuated from the transitional stages, resulting in the buccal opening sometimes being broader than long. It may be considered as a true trophont-tomont, the active swimming and hunting phase temporarily over. Division of the tomont, as the macrostome form may be properly considered for a short time in its life, proceeds normally with approximately equal distribution of food vacuoles and various other cytoplasmic inclusions to the new resulting tomites, the proter and opisthe (cf. figs. 39 and 43 with fig. 3f of Corliss, 1953a). Corliss (1952a, and 1953a) gave detailed figures and investigations; however, superficially this stage is indistinguishable from the macrostome form of *T. patula*.

Body size: tailed microstome stage 35 - 80μ long; average overall dimensions, 50 x 20μ. Pyriform microstome stage, 30 - 60μ long; average size, 51 x 35μ. Macrostome stage, 65 - 154μ; average size, 98 x 63μ.

Body shape: Shape varies with stage in life cycle. Tailed microstome stage: elongate; anterior extremity bluntly pointed, posteriorly distinct caudal process variable in shape and length. Body elongation accentuated when starved, tails tapering to very sharp tip. Pyriform microstome stage: pyriform to ovoid to cucumber-shaped, indistinguishable from forms of *T. pyriformis*. Macrostome stage: broadly pyriform with rounded, enlarged posterior extremity due to presence of many large food vacuoles.

Macronucleus: in all microstome forms, identical with that described for *T. pyriformis*. It is ovoid to irregularly spherical, and lies across the central portion of the body, often a little posterior to the midline. In macrostome stage, also similar but of greater size, averaging about 25 x 22μ.

Contractile vacuole: usually one contractile vacuole is posteriorly located.

Food vacuoles: in general similar to those in *T. pyriformis* (for detail see descriptions by Maupas, 1883; Bauré-Fremiet, 1906, 1910; Furgason, 1940; Browning, 1951; Corliss, 1953a and Elliott and Clemmons, 1966). Average size of food vacuoles in bacterized cultures: 3.5 - 4.5μ in diameter. In carnivorous forms, diameters of food vacuoles range up to 35 - 40μ; number present in cannibals, generally not over 5; in non-cannibals, 3 - 20, average about 10.

Body ciliation: no apparent differences between ciliary patterns of microstome and macrostome stages. The cilia are arranged in distinct meridians, converging in a uniformly regular manner anteriorly, and joining irregularly at the posterior extremity (Figs. 44 - 47). Distance between adjacent cilia increased in macrostome forms (Figs. 41 - 43). No "caudal cilium" observed.

Buccal overture: pyriform, right margin slightly more rounded than left; greatly enlarged and relatively broadened in macrostome stage; directly in body axis, ventral (Figs. 40, 42 and 44). Adoral zone of membranelles (AZM). Figs 40 and 44. Three membranelles (M_1, M_2, M_3) attached to left dorsal lateral wall of buccal cavity, M_1 furthest to the left. Composed of cilia considerably longer than those of the body.

Undulating membrane complex (UM): Undulating membrane, on right-hand border of buccal cavity. See descriptions by Fauré-Fremiet (1948) and Corliss (1953a).

Pharyngeal pouch: present in macrostome form, presumably associated with development of carnivorous habit. Mode of formation briefly described by Kidder et al. (1940).

Apical loop (A-L): identical with that described for *T. pyriformis* by Corliss (1953a), although proportionately larger and generally open ventrally in macrostome forms.

Ciliary meridians.

Microstome forms: range in number, 17-23; average, 19-21.

Macrostome forms: range, 19-26; average 21-23. Two typical unipolar or post-oral meridians (POM's) with anterior extremity

terminating directly at posterior margin of mouth or in case of meridian 1, a very short distance up left side of buccal opening (Figs. 44 and 45). Occasionally three POM's: meridians 1, n and n-1, last stopping half-way up left side of mouth (Fig. 40). Each meridian comprises two main portions, a primary portion (1°PM) and a secondary portion (2°PM) (Fig. 45). The primary portion is much more prominent and is heavily granular as it bears the basal granules of the body cilia; the secondary portion is a strong fibril. Posteriorly, 2°PM's unite with their respective 1°PM's just before irregular convergence of meridians in polar region. Frequently (e.g. in Fig. 41-43) additional 3°PM fibril is in evidence.

Contractile vacuole pores: three contractile vacuole pores (CVP's) are detectable in Fig. 47, they are probably located in meridians 5 - 9 (for details cf. Corliss, 1953a).

Systematic account:

Among the 13 recognized species of *Tetrahymena*, *T. parasitica* and *T. glaucomaeformis* require redescription. So does *T. faurei*, which has only been reported once.

T. patula, *T. vorax* and *T. paravorax* are strikingly distinguishable from other members of the genus by their ability to undergo a pronounced dimorphism (microstome ↔ macrostome form) during their life cycle. *T. paravorax* is readily separated from its two close associates by several characteristics, notably by its possession of a distinct caudal cilium (Corliss, 1957).

T. vorax and *T. patula* share one of the taxonomic extremes of the genus *Tetrahymena* with *T. pyriformis*. In addition to their ability to undergo microstome ↔ macrostome transformation, there are other similarities between *T. vorax* and *T. patula*. Both are able to form cysts (Fauré-Fremiet, 1949; Williams, 1961), and the overall anatomy of the body and cytostome of *T. vorax* is strikingly similar to normal macrostome stage of *T. patula*.

However, their life cycles are different in certain other respects. The tomont of *T. patula* is able to transform reversibly to either microstome or macrostome tomites. In *T. vorax*, tomites initiate similar reversible transformations. Once the tailed fusiform microstome phase of *T. vorax* is formed from a tomite, it can either transform (reversibly) to macrostome phase or (irreversibly) can become a pyriform microstome. This is not so in *T. patula*. Through the reproductive cyst, the mature tomont can develop into a pyriform microstome (the microstome stage of *T. patula* is commonly so shaped) which may afterwards revert to the macrostome form. On the other hand, the tailed microstome is the form of *T. vorax* commonly found in nature.

The principal differences between *T. vorax* and *T. patula* are based upon the silverline structures. Thus the two POM's, and the location of three CVP's between meridians number five and nine, and the average 19-21 body meridians shown in the present strain are diagnostic of *T. vorax* rather than *T. patula*, which has been reported with four POM's, two to six CVP's (between meridians number 10-15), and an average of 36-42 body meridians (Corliss, 1953a).

Therefore, the characters of the tailed fusiform microstome,

of the life cycle, and of the silverline structures of the strain under consideration fit the data described for *T. vorax* (Corliss, 1953a).

However, there are two points which must be considered before a final conclusion is drawn. Firstly, the present strain has a puzzling structure in the buccal cavity (marked with 'X' in the figures). Secondly, the pyriform microstome forms mentioned above are not identifiable with those of *T. vorax*. These pyriform ciliates are certainly not referable to *T. patula*, the microstome phase of which possesses an average of 36-38 meridians. They might either be "*T. pyriformis*" (the prey and stomatin-Buhse, 1966a and 1966b and 1967 - source of *T. vorax*) or irreversible pyriform microstome forms derived from *T. vorax*. Again, one could be dealing with mixed populations of the two species. This phylogenetic problem can only be solved by future biochemical and serological tests with the strain under discussion, which in the meantime is identified as *Tetrahymena vorax* (Kidder et al., 1940) *sensu latu*.

Tetrahymena pyriformis (Ehrenberg, 1830)

Lwoff, 1947, Plates XVIII, XIX, Figs. 48-57.

Well-fed forms are generally pyriform (Figs. 49-51), starving ones more cylindrical and sometimes becoming extremely attenuated 128-89μ x 15-32μ). Various modifications (e.g. boomerang and banana forms, Fig. 48; ovoid, Figs. 52, 53) have also been observed. Macronucleus, ovoid to irregularly spherical, and across the central portion of the body, often a little posterior to the midline. No micronucleus. One contractile vacuole posteriorly located (Figs. 49-51). Uniform somatic

PLATE XVIII

Figs. 48 - 53. *Tetrahymena pyriformis* (Ehrenberg, 1830).

Fig. 48. Showing a variety of shapes. Photomicrograph from silver impregnation preparation by Klein's dry method, viewed by phase-contrast microscope.

Fig. 49. Showing typical body shape, ciliation, buccal cavity, and the contractile vacuole. Photomicrograph from life, as seen by Nomarski interference-contrast effect.

Fig. 50. Same as Fig. 49, but focused on food vacuoles for comparison with Figs. 51 - 53. The latter represent phase-contrast views of living examples,

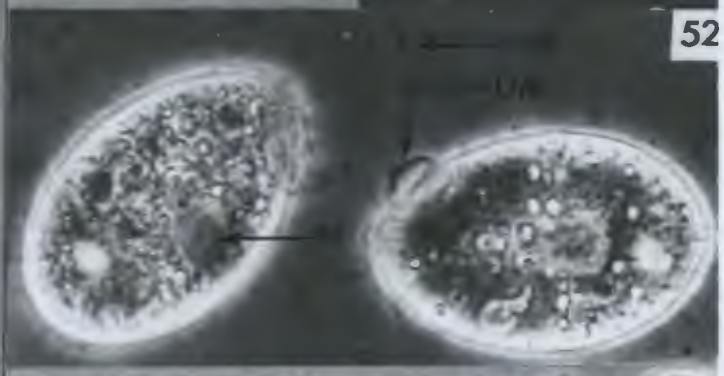
Fig. 51. Showing body shape, ciliation, buccal cavity, and the contracile vacuole.

Fig. 52. Showing well-fed oval individuals with prominent undulating membrane; nucleus (N), food vacuoles and contractile vacuole are detectable inside the cells. The dots (b) around the ciliates are the bacterial food of *T. pyriformis*.

Fig. 53. Food vacuoles showing clearly after staining (neutral red and methylene blue). Photographed by phase-contrast microscopy.


10μ
48


10 μ
50
FV
51


52


10μ
53

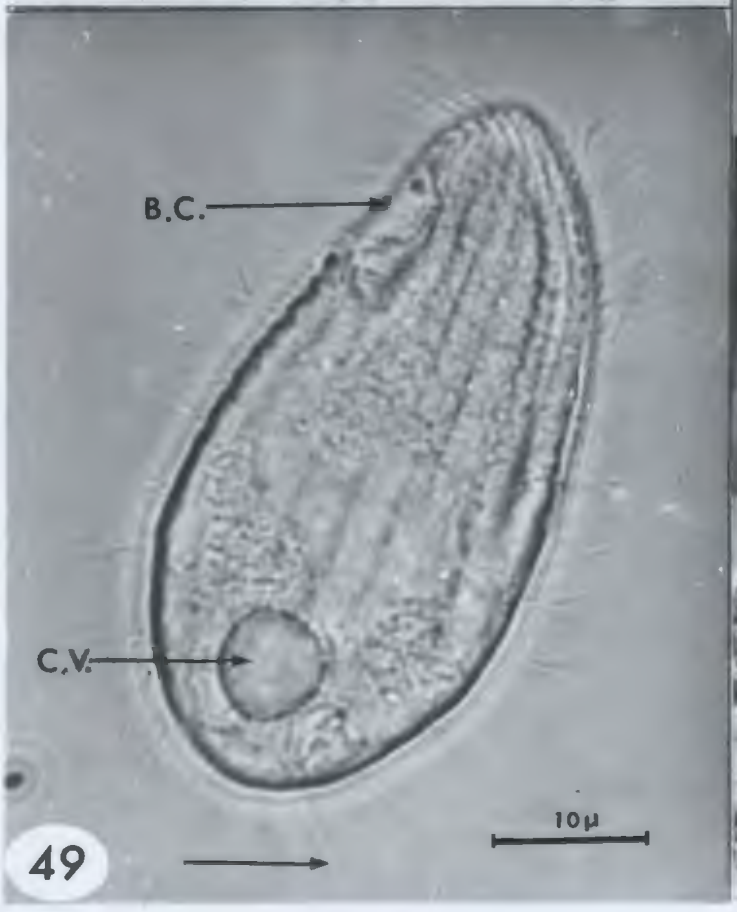

B.C.
C.V.
10 μ
49

PLATE XIX

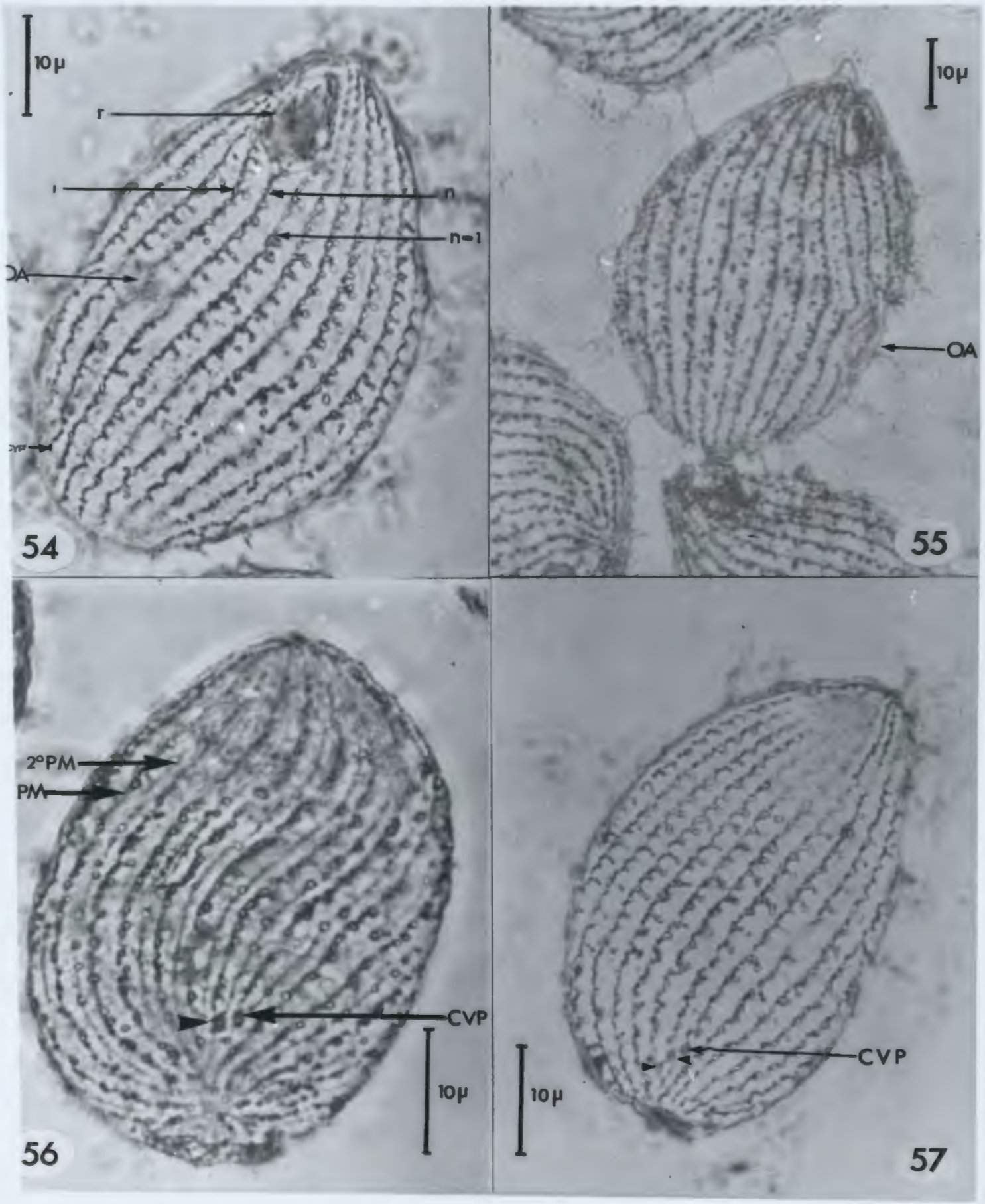
Figs. 54 – 57. *Tetrahymena pyriformis* (Ehrenberg, 1830) from silver impregnation preparations (Klein's dry method) as seen by phase-contrast microscopy.

Fig. 54. Showing body shape, ciliation, the 'ribs' of undulating membrane complex, and meridian number one with cytoproct (CYP) and the early stage of stomatogenesis. OA, oral anlage.

Fig. 55. Showing the later stage of stomatogenesis.

Fig. 56. Showing the location of two contractile vacuole pores (CVP's) and the arrangement of the primary (1°PM) and secondary (2°PM) meridians.

Fig. 57. Showing location of the three CVP's.


10µ
r
i
n
n-1
OA
54
10µ
OA
55
2°PM
PM
CVP
10µ
56
10µ
CVP
57

ciliation (cilia, 5-8μ in length, Fig. 49).

Tetrahymenal buccal ciliature is evident (Fig. 49-51 and 54) and pyriform. Its axis parallel to body axis, about one sixth to one eighth of the body length. Adoral zone membranelles are easily demonstrable by staining (Figs. 52, 54 and 55, cf. figs. 40 and 44). Two postoral meridians (Figs. 54 and 55) Ciliary meridians, 17 - 22. 3° PM fibril is not detectable; otherwise similar to *T. vorax*.

New buccal structure (OA, Figs. 54 and 55) originates in a proliferation of granules of meridian 1 out to left. Resulting granular field, located subequatorially, eventually encroaches upon meridian n. (cf. Chatton, Lwoff, Lwoff and Monod, 1931, and Corliss, 1953a).

Cytoproct (CYP, Fig. 54) located in meridian 1 very near posterior extremity of organism. When detectable, appears as delicate line, actually a slit, lying more or less between 1°PM and 2°PM.

Two contractile vacuole pores (CVP's, Fig. 56) generally located in meridians 5 and 6, at distance of 6 - 14μ from posterior pole of body. When three CVP's are present (Fig. 57), location is generally in meridians 5, 6 and 7 in various positions with regard to 1°PM's and 2°PM's of respective meridians.

When this ciliate is held in a medium rich in bacteria, its food vacuoles are readily seen by light microscopy (Figs. 49 - 51). They are still more clearly demonstrable after staining the ciliates in dilute suspensions of methylene blue (1:10,000) or neutral red (1:30,000) (Fig. 53). Average diameter of food vacuoles in bacterized cultures, 3.5 - 4.5μ (see Maupas, 1883; Fauré-Fremiet, 1906, 1910;

Furgason, 1940; Browning, 1951; Corliss, 1953a and Elliott and Clemmons, 1966).

Systematic account:

Tetrahymena pyriformis was first described by Ehrenberg (1830) as *Leucophrys pyriformis*. Afterwards it acquired many synonyms. There was thus considerable confusion until Corliss thoroughly analysed and systematically reviewed the earlier literature (Corliss, 1951, 1952a, 1952b, 1953a and 1954).

Type species of the genus *Tetrahymena*, *T. pyriformis* is a bacteria-feeder in natural habitats. Characteristically pyriform in shape, it has 17 to 21 meridians and possess strong generic characters - the tetrahymenal buccal apparatus, location of cytoproct on meridian 1, and two contractile vacuole pores. Its approximate size is 50 x 30μ, although there is considerable variation under different conditions. It has a single macronucleus, with or without micronucleus.

The striking similarities between the type species, *T. pyriformis*, and the strain at Logy Bay strongly suggest that the latter is identical to *T. pyriformis*. However, a brief and conservative comparison of the strain at Logy Bay with all the members in the genus is stated as follows.

The strain under consideration can be easily distinguished from *T. rostrata*, *T. corlissi*, *T. setifera* and *T. paravorax* by lacking a caudal cilium and polar basal granule (PBG) complex.

Its free-living habitat contra-indicates allocation to those species that are parasitic, viz., *T. stegomyiae*, *T. parasitica*, *T. limacis*,

T. faurei and *T. chironomi*.

T. patula and *T. vorax* are beyond consideration since the present strain does not show dimorphism (microstome ↔ macrostome) during its life cycle.

Redescription of *T. glaucomaeformis* is needed before any close comparisons can be made.

This situation leads to the suggestion that the present strain should be assigned to *T. pyriformis*.

In sum, the present species is referable to *T. pyriformis* (Ehrenberg, 1830) by its overall morphology, its lack of a caudal cilium and PBG - complex, its life cycle, its number and arrangement of meridians, the number and position of CVP's, the absence of micronucleus, the free-living habit. The specimens illustrated in the photomicrographs (Figs. 48, 54-57) were double-checked and referred to *T. pyriformis* by Dr. J. O. Corliss (Pers. comm. 1969).

Subclass Holotricha

Order Hymenostomatida

Suborder Peniculina

Oral ciliature characterized by peniculi (Fig. 63) located deep in the buccal cavity; often with ciliated vestibule; body uniformly ciliated.

Family Parameciidae

Genus *Paramecium* (according to Corliss, 1961)

Paramecium bursaria Ehrenberg, 1833, Plates XX-XXII, Figs.58-63.

Body 90 - 150μ foot-shaped. More or less flattened, prominently compressed dorso-ventrally, broadly rounded posteriorly, extending obliquely backwards from left to right to beyond the centre of the body. Cytostome situated at the posterior extremity of the groove, giving entry to a distinct cytopharynx. Buccal cavity with one endoral membrane (Fig. 59) and two peniculi (Fig. 63) Trichocysts numerous (Fig. 60). A contractile vacuole deep in the cytoplasm towards each end of the body (Fig. 58). These vacuoles exhibiting rapid and alternate systole/diastole, each with a short discharge pore and six radiating collecting canals (Fig. 58). A single macronucleus, large and reniform. Micronucleus also single, massive, and lying in the cavity of the macronucleus (Figs. 61 and 62).

Systematic position:

Woodruff (1921) pointed out that species of *Paramecium* fall into two groups according to the shape of the body, namely: (a) The

PLATE XX

Fig. 58. *Paramecium bursaria* Ehrenberg, 1833, fresh preparation as seen by Nomarski interference-contrast effect. Uniform ciliation without long caudal cilia evident from the figures. 1. trichocyst; 2. contractile vacuoles; 3. zoochlorellae

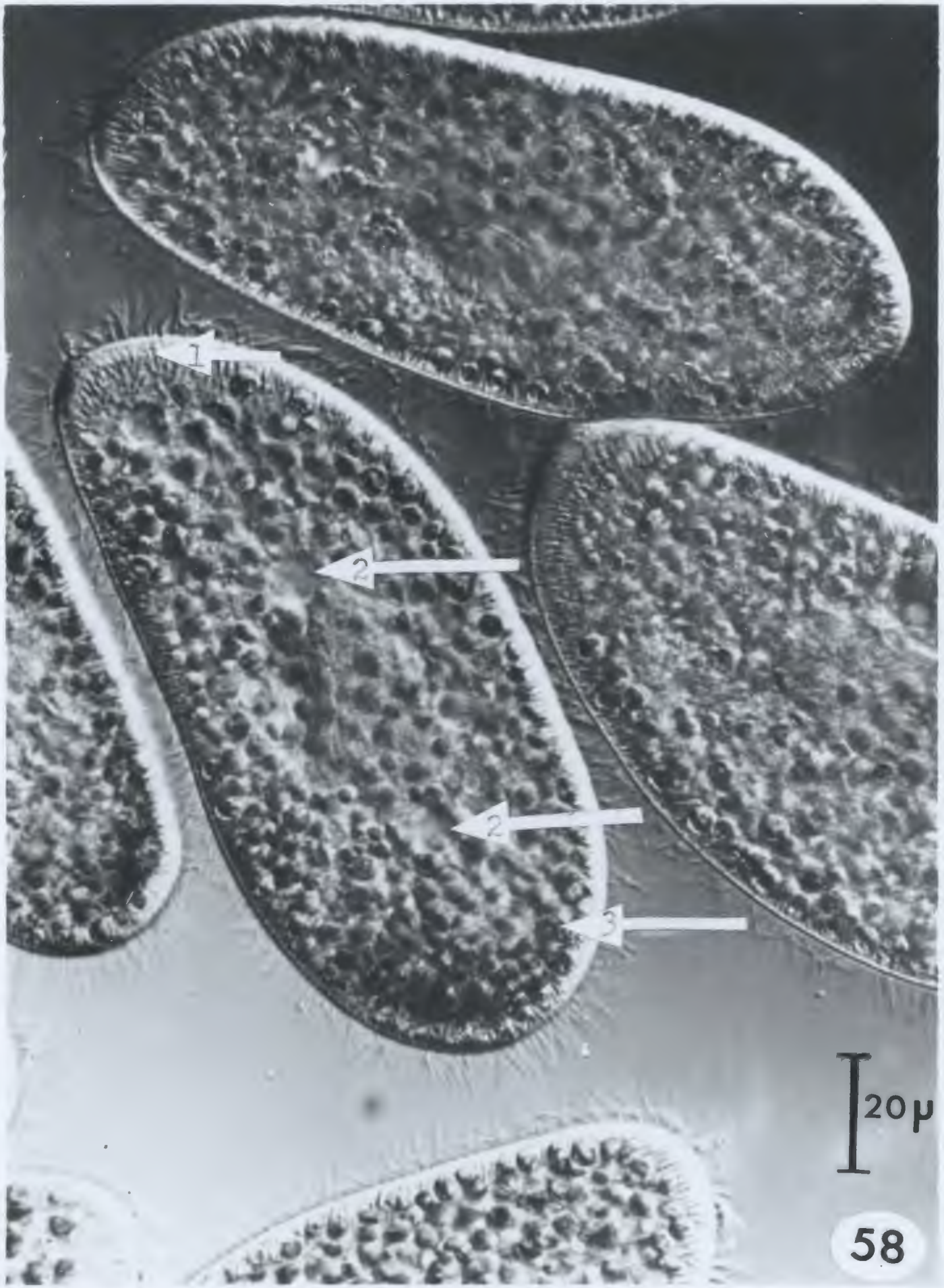

1
2
2
3
20μ
58

PLATE XXI

Figs. 59 – 62. *Paramecium bursaria* Ehrenberg, 1833.

Fig. 59. Showing the endoral membrane around the buccal cavity (by Nomarski interference-contrast effect).

Fig. 60. As seen with Nomarski interference-contrast effect, showing abundant development of trichocysts. Beneath the trichocysts the cortical and endoplasmic layers appear green, because of the presence of numerous zoochorellae.

Figs.61,62. Showing the macronucleus (Ma) and the compact micronucleus (Mi), as stained with methyl green and viewed by bright field.

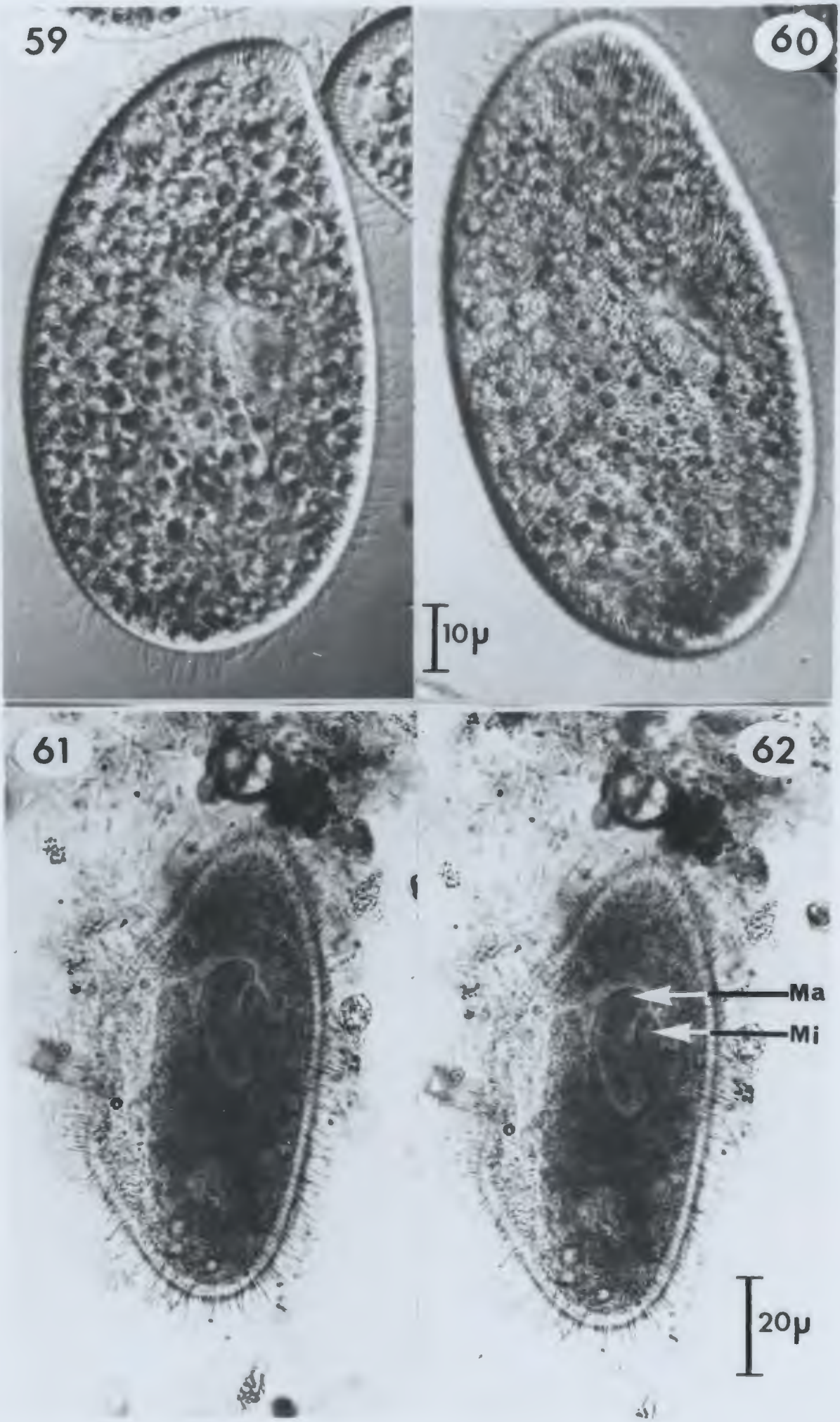
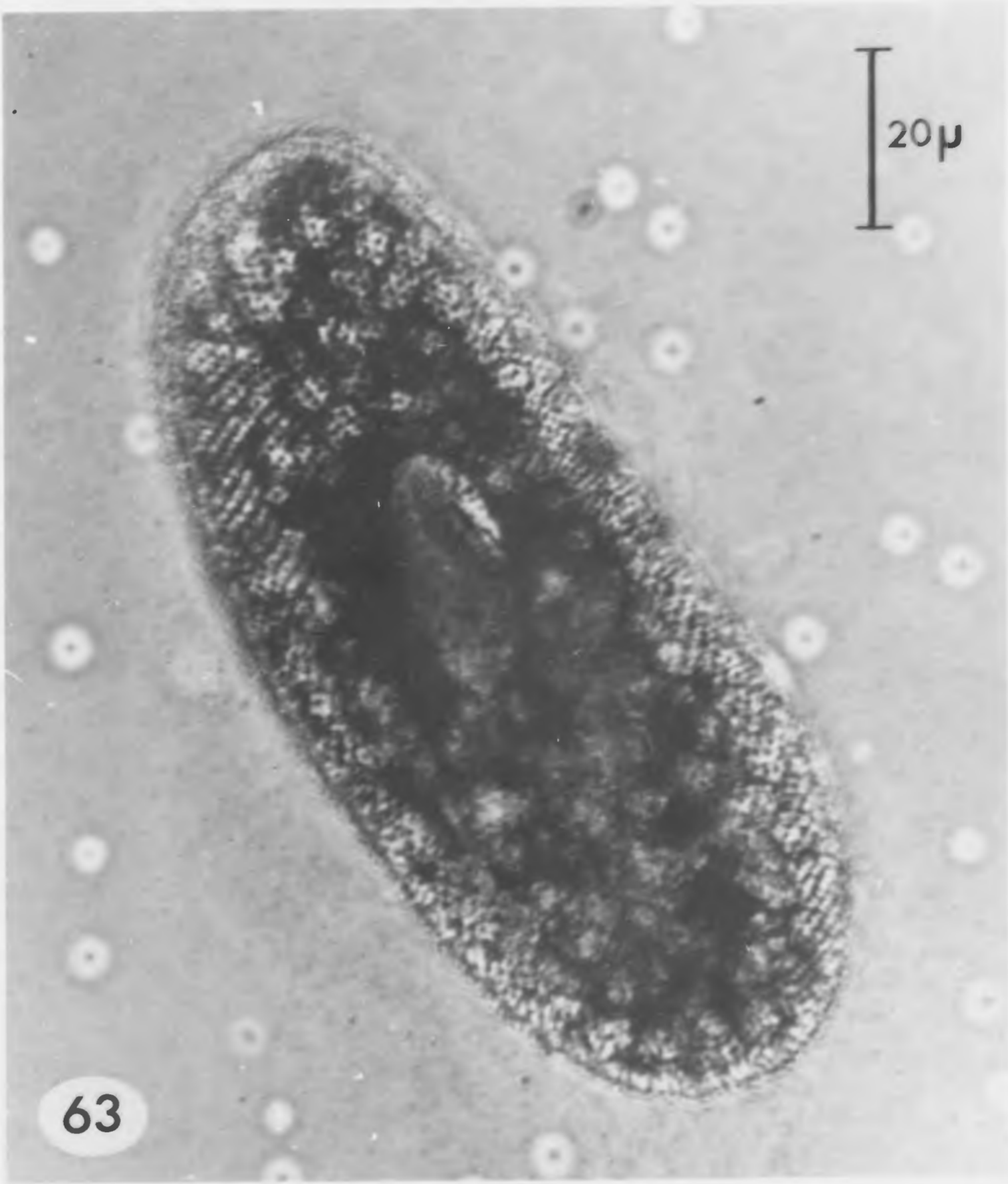

59
60
10μ
61
62
Ma
Mi
20μ

PLATE XXII

Fig. 63. *Paramecium bursaria* Ehrenberg, 1833, impregnated with silver by the Chatton-Lwoff technique, photographed by phase contrast. Showing peniculi located deep in the buccal cavity and body ciliature.


20μ
63

"*aurelia* group" with cigar-shaped bodies, round in cross-section and tapering to a point posteriorly, and (b) the "*bursaria* group", broadly elliptical in cross-section and rounded posteriorly. In either group two types of micronuclear structure may be found. These are (a) the "*caudatum* type", in which the micronucleus is a relatively large, rather compact mass, and (b) the "*aurelia* type", in which the micronuclei are small and distinctly vesicular in organization. On this basis Wenrich (1928) recognized eight well-defined species - *P. aurelia*, *P. caudatum*, *P. multimicronucleata*, *P. trichium*, *P. calkinsi*, *P. polycaryum* and *P. woodruffi*.

The organism under discussion is somewhat compressed dorsoventrally, rounded posteriorly, and typical of the "*bursaria* group" in shape. Its body is not cigar-shaped like that of members of the "*aurelia* group" (which includes *P. aurelia*, *P. caudatum*, and *P. multimicronucleata*). In the "*bursaria* group", *P. trichium* and *P. bursaria* are distinguished from *P. calkinsi*, *P. polycaryum*, and *P. woodruffi* by the former having a single compact micronucleus (*caudatum* type), while the latter have small vesicular micronuclei (*aurelia* type). The length of the present species, 90 - 150μ, is closer to that of *P. trichium* (70 - 90μ). One of the chief features of *P. trichium*, a convoluted discharge tube connected to the contractile vacuoles, was lacking. However, two contractile vacuoles, each with a short discharge pore and six radiating collecting canals, were clearly evident, especially when the water around the example on the slide was drying out. Rapid cyclosis was meanwhile observed in the ciliate. In sum, these criteria indicate that the organism is referable to *P. bursaria* rather than to

any other known species. Moreover, the bright green colour (due to symbiotic zoochlorellae) is itself strongly suggestive of *P. bursaria*, the only well-established member of the genus so characterized.

Two other species, *P. putrinum* and *P. jenningsi* (see Kudo, 1966) must, nevertheless, be taken into consideration. In general morphology, the Newfoundland ciliate does not resemble *P. jenningsi* which is clearly closer to *P. aurelia*. Though it is certainly closer to another representative of the *bursaria* group, *P. putrinum* (80 - 150μ long) in size and shape, it can still be identified with confidence as *P. bursaria* by its two contractile vacuoles and the presence of green zoochlorellae (*P. putrinum* has only a single contractile vacuole and altogether lacks zoochlorellae).

To summarize, *P. bursaria* can easily be recognized by its size (usually 120 - 160μ in length), rounded posterior end, green colour due to the symbiotic zoochlorellae, and rapid cyclosis. To these characters must be added a highly characteristic feature immediately evident from stained examples - the single large compact micronucleus of the *caudatum*-type, which resolves the question of identity beyond any reasonable doubt.

The Logy Bay ciliate under discussion is typical of *P. bursaria* in every respect, except that its length (90 - 150μ) is somewhat less than usual (120 - 160μ). It has two spherical vacuoles, which, depending upon the phase of systole/diastole, show no evidence of radiating canals or appear stellate with radiating canals. The macronucleus is always reniform, the compact micronucleus being situated in its concavity. As is characteristic of *P. bursaria*, the organism is dorso-

ventrally flattened, narrowest and obliquely truncate anteriorly and posteriorly rounded. Its cytoplasm is full of small green algae and cyclosis is rapid.

In the silverline system of *P. bursaria* (Fig. 63), none of the ventral rows of cilia are parallel to the preoral suture in the region anterior to the cytostome. However, they bend towards and terminate against the preoral suture. There are 10.1 rows of cilia in a transverse distance of 12 microns, and 7.0 in a longitudinal distance of 12 microns, there being 70 cilia in an area of 144 square micra on the dorsal surface. These figures are a little higher than those of Lieberman (1929). According to the latter author, *P. bursaria* has 9.75 rows of cilia within a width of 12μ, 6.6 rows within a length of 12μ, and 64.45 in 144 sq. μ.

Family Frontoniidae

Genus *Cyrtolophosis* (according to Kudo, 1966)

Ovoid or ellipsoid; with or without mucilaginous envelope in which it lives, but from which it emerges freely; cytostome near anterior extremity with a pocket-forming membrane; on right side a short row of special stiff cilia, bent ventrally; sparse ciliation spiral to posterior-left.

Kahl (1930) considered that the genus *Balantiophorus* was wrongly established by Schewiakoff, whose proposed species had already described and allocated to the genus *Cyrtolophosis* by Stokes (1888). Corliss included them as "Unassigned Genera" of tetrahymenine hymenostomes (Corliss, 1961a, p. 146). However, Kudo (1966) allocated *Cyrtolophosis* as a member of Frontoniidae. Thus the present classification follows.

Cyrtolophosis (Balantiophorus) bursaria

Schewiakoff, 1893, Plate XXIII, Figs. 64-67.

Body (30μ x 17μ) transparent, ovoid, rounded at both extremities, dorsal surface more convex than the ventral one (Figs. 64 - 67). Left, posterior and right margins of the peristome with a bag-like undulating membrane (Fig. 66), which can be withdrawn into the peristome. Anterior extremity bearing a fascicle of long, distally curved, vibratile hairs (Figs. 65 - 67). Somatic cilia fine and sparse (Fig. 64). No mucilaginous envelope observed. Contractile vacuole posteriorly (Figs. 64 - 67). Macronucleus ovoid, centrally

PLATE XXIII

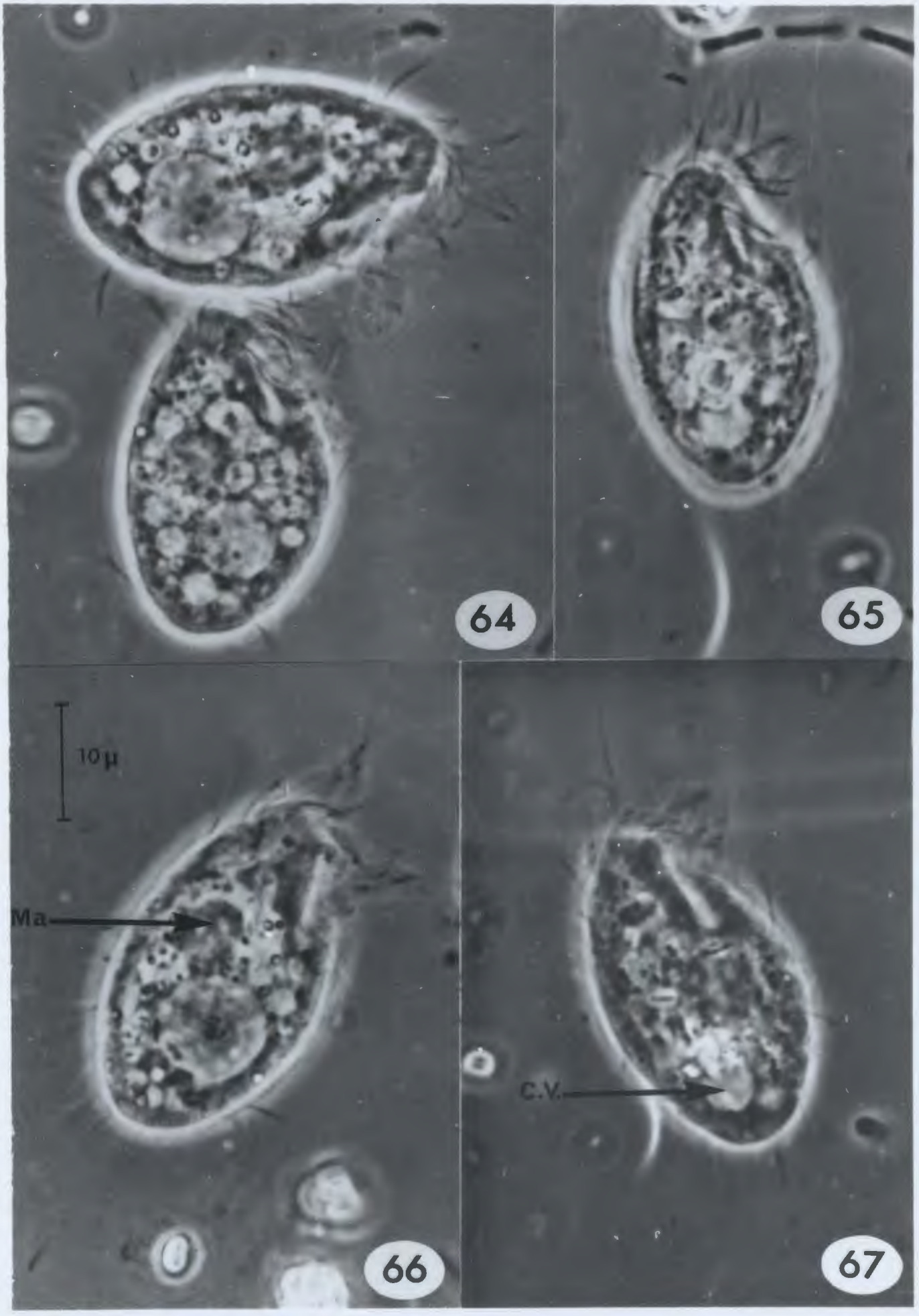
Figs. 64 - 67. *Cyrtolophosis (Balantiophorus) bursaria* Schewiakoff, 1893.

Fig. 64. Showing fine and sparse somatic cilia.

Fig. 65, Showing anterior extremity with a fascicle of long, distally curved, vibratile hairs.

Fig. 66. Showing ovoid, central located macronucleus.

Fig. 67. Showing posteriorly located contractile vacuole.


64
65
10μ
Ma
66
C.V.
67

located (Figs. 64 - 66). Swims jerkily, revolving about the long axis in a counter-clockwise direction as viewed from the rear.

Systematic account:

The above data precisely fit the description of *Cyrtolophosis (Balantiophorus) bursaria* Schewiakoff, 1893. The present species exhibits the general characters of *Cyrtolophosis*, being distinct from *C. elongata*, *C. mucicola* and *C. major* in its ovoid body shape. *C. bursaria* is the only known member of the genus which is ovoid, the other three being elongate-ellipsoid.

Furthermore, the present species (30μ) is distinguishable from *C. elongata* (30μ) in that its contractile vacuole is about one-fifth of the body length from the posterior extremity; and from *C. mucicola* (25-28μ) and *C. major* (45μ) in its appreciably different body size.

For the reasons detailed above, the species under discussion is referable to *Cyrtolophosis (Balantiophorus) bursaria* Schewiakoff, 1893.

Cyrtolophosis (Balantiophorus) elongata

(Schewiakoff, 1896) Plate XXIV, Figs. 68-71.

Body elongate-ellipsoid, 30 x 10μ, the ventro-frontal border obliquely truncate. Anterior cilia longest, about 4μ, the anteriorly placed fascicle of distally vibratile and downwardly curved cilia conspicuous (Fig. 68). Peristome extending from the frontal border for one-third of the length of entire body. Left, posterior and right

PLATE XXIV

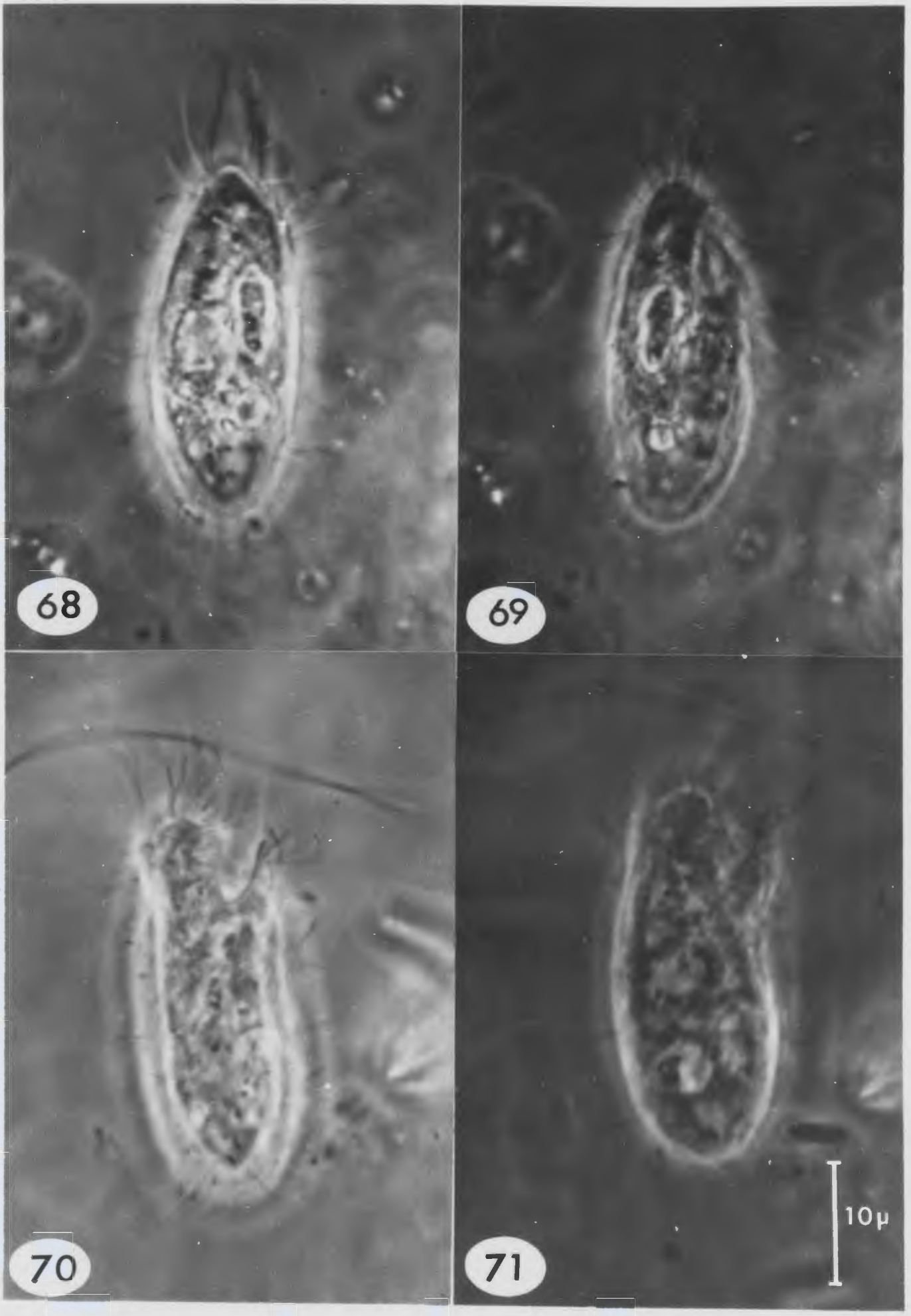
Figs. 68 - 71. *Cyrtolophosis (Balantiophorus) elongata* Schewiakoff, 1896, (phase-contrast).

Fig. 68. Left side of the organism, focused on the elliptical macronucleus and the anterior fascicle of cilia.

Fig. 69. Right side of the organism, showing the right margin of the peristome, with undulating membrane.

Fig. 70. Extension of the peristome, and oral ciliation.

Fig. 71. Focused on the posterior contractile vacuole.


68
69
70
71
10μ

margins of the peristome with a bag-like undulating membrane (Figs. 69 and 70), which can be withdrawn into the peristome. Contractile vacuole single, spherical, posteriorly located (Fig. 71). Macronucleus ellipsoid, and an adjacent micronucleus. No mucilagious envelope observed. Occasionally swims backwards, revolving about the long axis in a counter-clockwise direction as viewed from the rear.

Systematic account:

The available taxonomic data best fit those of *Cyrtolophosis (Balantiophorus) elongata* (30μ x 10μ) which is characterized by a posterior contractile vacuole, long, sparse scattered cilia not arranged in longitudinal rows, and an ellipsoid macronucleus and small micronucleus.

Like *C. elongata* as earlier described it has its contractile vacuole at the posterior extremity - the other three species have it some one-fifth of the body length from this extremity. It is further distinguished from *C. bursaria* by its narrowly elongate body shape, and from *C. major* (45μ) by its smaller size, the lack of diagonal to longitudinal rows of cilia around the body, and an un-notched anterior extremity.

C. mucicola (25-28μ by 9-12μ) is close in size and shape to the Logy Bay ciliate. It is indeed impracticable to differentiate them on these bases or on the location of the contractile vacuole. However, *C. mucicola* is distinct from the present species in its denser vestiture of longitudinally arranged cilia, and in having a spherical macronucleus.

The Logy Bay species is thus considered referable to *C. elongata* Stokes on the basis of the location of its contractile vacuole, its body shape and size, its spherical macronucleus, its un-notched anterior extremity and the arrangement of its cilia.

Family Frontoniidae

Genus *Lembadion* Perty (according to Kudo, 1966)

Lembadion sp. Plate XXV, Figs. 72 and 73.

Body oval (55 - 62μ x 28 - 32μ based on eleven specimens); dorsal side convex, ventral side slightly flattened; striated longitudinally. Posterior extremity rounded, the anterior one with a small dextral process (Fig. 72,A). Cytostome (47μ) three quarters to four-fifths the body length; voluntarily vibratile membrane to its right, projecting from the anterior extremity as a short, conical, hood-like extension, one side of which is inserted on the anterior left-hand margin, the other (Fig. 72,B) being continued as a conspicuous, lamellate membrane for about two-fifths of cytostome. It is then abruptly narrowed, and descending into the cytostome is continued to the posterior extremity. Two contractile vacuoles, the larger (Fig. 72,C) sub-central and near the dorsal surface with a long posterior tubule opening (D of Figs. 72 and 73) at the right side; the smaller (Fig. 72,F) posteriorly placed somewhat to the left side of the median line. Cilia fine and short anteriorly, bundle of caudal cilia (about 23μ long) (Fig. 72,G) sinistrally directed. Macronucleus, (Fig. 72,E) ellipsoid, subterminally located near the left-hand border. Cell division transversely.

Systematic account:

This holotrichous ciliate exhibits the chief features of *Lembadion*, which is characterized by its huge cytostome. The latter

PLATE XXV

Figs. 72 - 73. *Lembadion* sp.

Ventral aspect (phase-contrast)

A. Dextral anterior process.

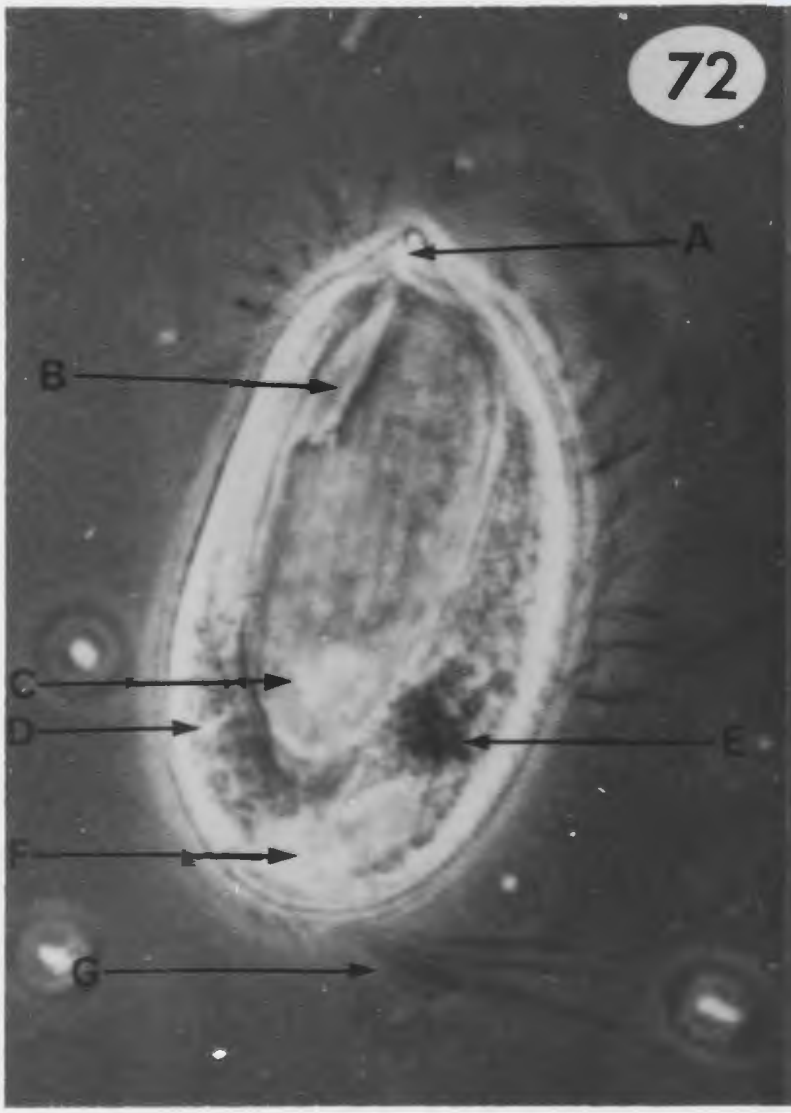
B. Abruptly narrowing right adoral membrane.

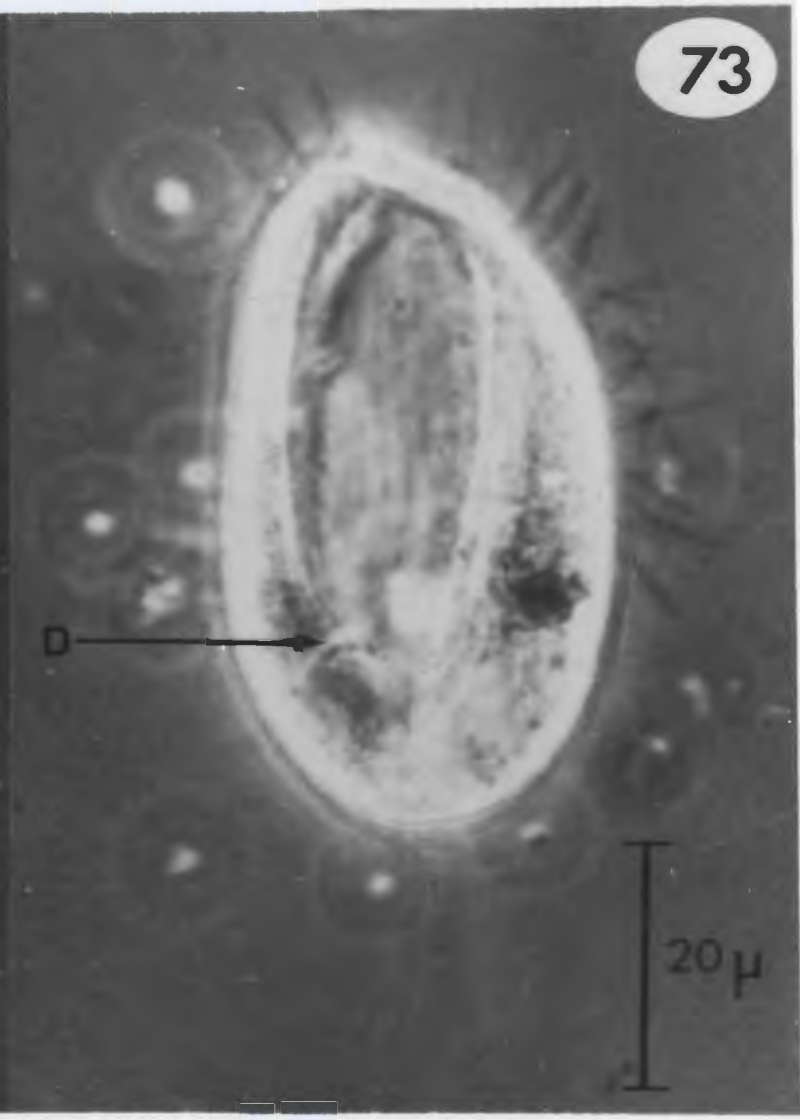
C. The larger contractile vacuole (sub-central and near the dorsal surface) with its tubule (D) opening posteriorly at the right side.

E. Macronucleus.

F. The smaller contractile vacuole.

G. The sinistrally directed caudal cilia.


72
A
B
C
D
E
F
G


73
D
20 μ

occupies at least two thirds of the ventral surface, and while having membranes, lacks membrane-bordered pre-oral peristomal furrow.

Kahl (1930) recognized three species of *Lembadion*[1]. The present species differs from all of these. Ranging from 80 - 200μ in length, they are apparently larger than the Logy Bay ciliate (55 - 62μ). Furthermore, the present species has two contractile vacuoles, and a cytostome with abruptly narrowing membrane two-fifths (20μ in Fig. 72) of the body length from its right anterior extremity.

The present species can be further distinguished from *L. magnum* (100 - 200μ) by the latter's posterior truncation with shorter caudal cilia (one-ninth of the body length). Otherwise the two organisms resemble each other in having a longitudinally striated cuticular surface, and an anteriorly projecting acumination. They both differ from *L. bullinum* and *L. lucens* in that these exhibit a transverse stripe all through the cuticular surface and their anterior extremities do not slant to the right.

---

1 The description in Kahl's key (Kahl 1930, p. 327) is as follows:

1(2) Pell. nur längsgestreift, nicht gefeldert. Vorderende schräg nach l. abfallend, Hinterende verjüngt, mit einem Kamm kurzer Caudalwimpern.

Lembadion (Hymenostoma) magnum Stokes, 1887).

2(1) Pell. durch Querrippen gefeldert. Vorderende nicht stark nach l. abgeschrägt. Hinterende breit gerundet, mit einem Büschel langer Caudalwimpern.

3(4) Grössere Art über 100μ. Vorn mit deutlicher Einkerbung. Dors. mit 30-35 Längsreihen.

Lembadion bullinum Perty, 1852 (*Hymenostoma hymenophora* Stokes, 1884).

4(3) Kleinere Art unter 100μ. Die vordere schwache Einkerbung wird durch die Spitze der undulierenden Mbr. verdeckt, so dass das Infusor vorn zugespitzt erscheint. Dors. ca. 15 Längsreihen.

Lembadion (Thurophora) lucens (Maskell, 1887)

Body size is the second criterion used by Kahl (1930) to classify the species of *Lembadion*. In this respect, *Hymenostoma hymenophora* Stokes, 1884 should not be the synonym of *L. bullinum* Perty, 1852 as Kahl considered. Stokes (1884, in Stokes, 1888) pointed out that *H. hymenophora* differs from other *Lembadion* in its two contractile vacuoles, the abruptly narrowing adoral membrane, the sinistrally directed caudal cilia and 1/500 inch (50.8μ) body length. In accordance with the International Code of Zoological Nomenclature, *H. hymenophora* should stand as *Lembadion hymenophora* (Stokes, 1884), not as a synonym of *L. bullinum* Perty, 1852 - the former is much the smaller and has distinctive characteristics as outlined.

The species under discussion resembles *L. hymenophora* in its shape, possession of two contractile vacuoles and its sinistrally directed caudal cilia. However, it differs from the latter mainly in its longitudinally striated cuticular surface, the location of its macronucleus, and its shorter, abruptly narrowing right adoral membrane. Lacking infraciliary data to compare with the descriptions of Dragesco and Tuffrau (1963), the present species should be further studied before its taxonomic allocation is determined.

Subclass Holotricha

Order Hymenostomatida

Suborder Pleuronematina

Family Pleuronematidae

Genus *Cristigera*

Cristigera sp. Plate XXVI, Figs. 74 - 77.

Small, elliptical (20 x 10μ, Figs. 74 - 77), compressed. Somatic cilia long and sparse (about 10μ); posterior plate without hollow and lacking of cilia except for a single conspicuous caudal cilium (about 20μ, Figs. 74 - 77). Oral aperture close to mid-ventral line with a postoral depression, peristomal furrow continuing back of cytostome to posterior extremity (Figs. 76 - 77). Undulating membrane on right margin of pre-oral groove forming a pocket around rear cytostome. A single contractile vacuole (Figs. 76, 77), posteriorly situated.

Systematic account:

The dorsal side of present organism (Fig. 74) is very similar to *Cyclidium*, but it differs from the latter in its dorso-ventral compressed shape and oral aperture with a postoral depression and peristomal furrow continuing back of cytostome to posterior extremity (Figs. 75 - 77). Thus, it fits the description of *Cristigera* Roux, 1901.

PLATE XXVI

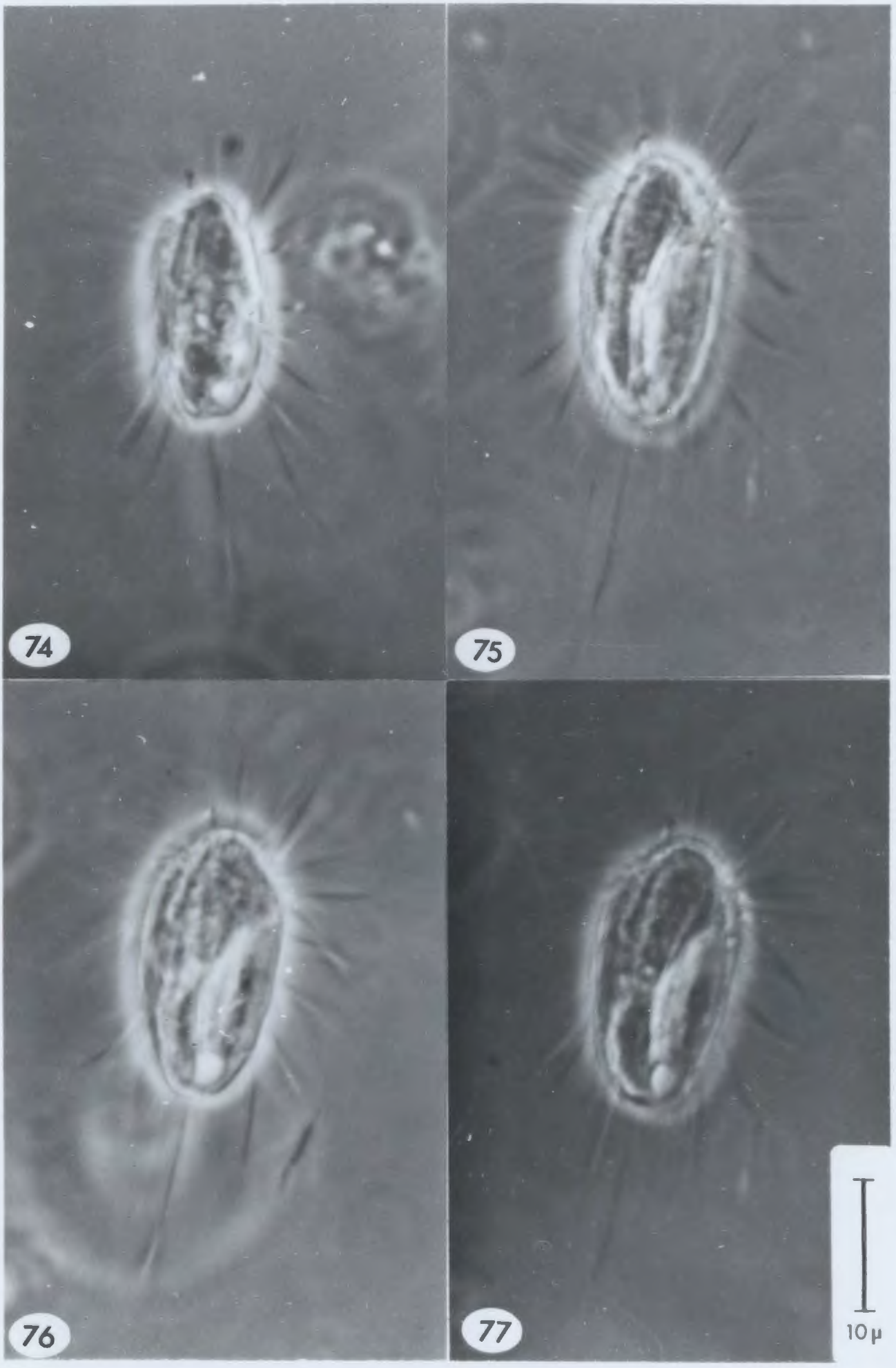
Figs. 74 - 77. *Cristigera* sp. (phase-contrast).

Fig. 74. Showing dorsal aspect.

Fig. 75. Showing body ciliation.

Fig. 76. Focused on long single caudal cilium.

Fig. 77. Showing oral aperture, peristome and single contractile vacuole.


74
75
76
77
10 µ

Family Pleuronematidae

Genus *Cyclidium* (according to Corliss, 1961)

Cyclidium glaucoma O. F. M., 1773, Plate XXVII, Figs. 78-83.

Length, 17.5 - 25μ; breadth, 10 - 17.5μ; average size, 20 × 12.6μ. Form constant and well-defined, ovoid; circular in cross-section (Fig. 79). Somatic cilia long and sparse, their length equalling or exceeding that of the breadth of the body (Figs. 78 - 83), disposed in even longitudinal lines (Fig. 81). Posterior plate without hollow and lacking cilia except for a single conspicuous caudal cilium, twice at least as long as those of the general surface (Figs. 78 and 80). Oral aperture ventral, dominated by the conspicuous undulating membrane, which margins the body and is not thrown into folds. Adoral zone of membranelles hardly recognizable in fresh material. No vestibulum, peristome more or less subequatorial (Figs. 78 and 80). No postoral longitudinal groove. A more or less pronounced area of thigmotactic ciliature is located dorsally (Fig. 81). Macronucleus spheroidal and central (Fig. 78), with an adjacent micronucleus. A single contractile vacuole, posteriorly situated. Cortical layer without trichocysts. Examples undergoing transverse binnary fission were commonly observed (Figs. 82 and 83). Free swimming. Under adverse conditions, cysts are formed after the disappearance of the cilia.

Food: bacteria (Fig. 80). While feeding, the organism remains in one position with spread cilia and beating membranelles.

PLATE XXVII

Figs. 78 - 83. *Cyclidium glaucoma* O. F. M., 1773, living examples by phase-contrast microscopy.

Fig. 78. General appearance.

Fig. 79. Equatorial view in apparent transverse section.

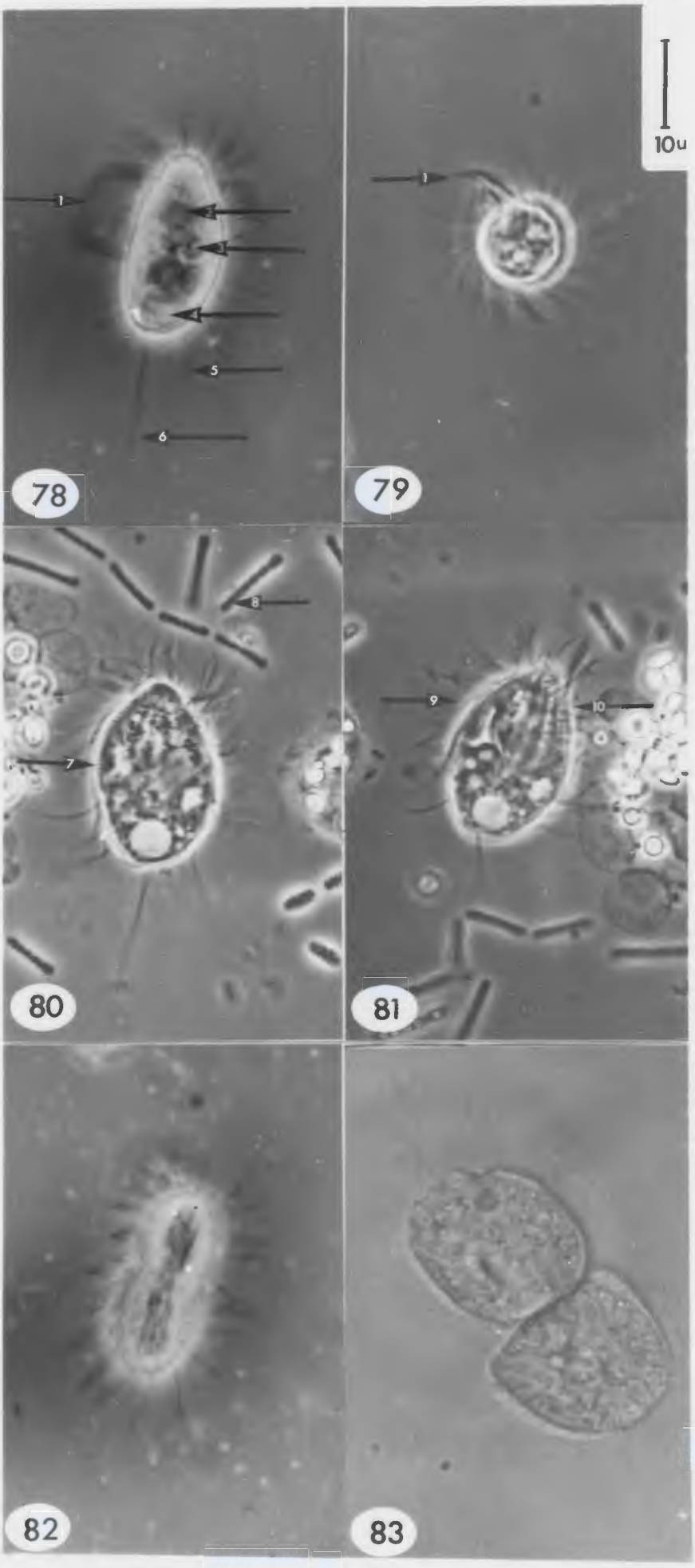
Fig. 80. A stage before cyst formation.

Fig. 81. Ciliation.

Fig. 82. Early binary fission.

Fig. 83. Transverse binary fission completed, the filial cells almost separated.

1. Undulating membrane; 2. Macronucleus; 3. Food vacuole; 4. Contractile vacuole; 5. Somatic cilium; 6. Caudal cilium; 7. Indicates the ribs of the undulating membrane complex; 8. Bacteria; 9. Ventral side; 10. Dorsal side.


10u
1
5
6
78
1
79
8
7
80
9
10
81
82
83

Systematic account:

The small hymenostome under consideration is easily distinguished from six of the seven genera of Pleuronematidae. Thus *Calyptotricha* is loricate; *Pleuronema* is set apart by its giant size (70 - 180μ), and the presence of a semicircular swelling to the left of the peristome; *Pleurocoptes* is a marine ectocommensal; *Ctedoctema* has an oblique peristome; the peristome of *Cristigera* is closer to the mid-ventral line, and there is a postoral depression; while *Histiobalantium* has a pre-oral area about one quarter of the body length. Those characteristics are absent from the present species, which fits the description of the remaining genus, *Cyclidium*, in being ovoid and small (15 - 60μ), with an unciliated and truncate frontal plate anteriorly. Its peristome extends backwards from the anterior extremity for up to three-fifths of the length of the body, the cuticular surface is longitudinally ciliated, the somatic cilia are long and sparse, and there is a single caudal cilium. The right peristomial margin has a membrane which forms a pocket around the cytostomal groove, and the left margin bears either free cilia or a membrane which unites with that on the right. There is no semicircular swelling to the left of oral region, a round macronucleus and prominent micronucleus are present, and there is a posterior contractile vacuole.

Kahl (1930) recognized 30 speties of *Cyclidium*. The present one differs from *C. brandon, C. paucisetum, C. paradoxum, C. curvatum* and *C. helgolandicum* in having a single caudal cilium. *C. litomesum, C. libellus, C. oligotrichum, C. heptatrichum* and *C. veliferum* differ from the Logy Bay species through the reduction of the medial ciliation.

The contractile vacuole of *C. mucicola* and *C. centrale* is centrally located (the present species has a contractile vacuole posteriorly). *C. opisthostoma*, *C. lanuginosum* and *C. flagellatum* do not merit consideration by reason of their reduced posterior ciliation. *C. obliquum* has distinctively oblique ciliation, while *C. terricola* has cilia on the anterior extremity and an altogether unique shape[1]. The long, sparse somatic cilia and the unciliated posterior extremity (save for a single caudal cilium) narrow the choice down to three species, *C. glaucoma*, *C. citrullus* and *C. elongatum*, the remaining ten species[2] being delicate with short cilia (one half to two-thirds of body breadth). *C. citrullus* is characteristically spindle shaped, *C. elongatum*, elongate-ellipsoidal, and *C. glaucoma* broadly ovoid. However, the total composite of criteria differentiating these protozoa, and the overlap of their sizes and shapes, are such that it is difficult to separate them from one another with complete confidence. In terms of body shape, the criteria are so vague that some investigators, e.g. Schewiakoff (Kahl, 1930, p. 376) failed to differentiate them individually. Nevertheless, the present species is distinguishable from *C. citrullus* not only by body shape but by its smaller size (*C. citrullus*, 20 - 30μ) and the absence of an invagination at the point of insertion of the caudal cilium.

---

[1] The description of Kahl's key (Kahl, 1930, p.375) is as follows: 8(9) Moosform ohne abgesetzte Frontalplatte, mit kurzen, derben Trc. *(C. terricola)*.

[2] *C. fuscum*, *C. oblongum*, *C. singulare*, *C. gemmuliferum*, *C. granulosum*, *C. candens*, *C. simulans*, *C. pellucidum*, *C. instabile*, and *C. versatile*.

Sometimes, the present species is so elongate that it appears closer to the elliptical *C. elongatum* than the characteristically ovoid *C. glaucoma*. In addition, its small size (17.5 - 24μ, average 20μ) recalls *C. elongatum* (16 - 24μ, never reaching the 25 - 30μ of *C. glaucoma* - Kahl, 1930). Therefore, its identification as *C. elongatum* might be understandable. Nevertheless, it is more often ovoid than elliptical. Also, while its peristome is more or less subequatorial, it does not occupy more than three-fifths of the body length. This is held to be the critical feature distinguishing it from *C. elongatum*, the peristome of which is about three-quarters of the overall length. As regards the body size, many other investigators besides Kahl (1930) have reported that *C. glaucoma* ranges from 14.7 to 26.1μ in length (Bhatia, 1936; Berger and Thompson, 1960). It might be pointed out, too, that *C. elongatum* Schewiakoff was originally considered to be a variety of *C. glaucoma* (Schewiakoff, 1896).

In sum, the present species is identified as *C. glaucoma* O. F. Müller on the basis of its single caudal cilium, the distribution of its ciliary vestiture, the location of the contractile vacuole, the lack of a posterior invagination and the relative length of its peristome (i.e. up to three-fifths of the overall length).

Subclass Peritricha

Order Peritrichida

Suborder Sessilina

Family Vorticellidae

Genus *Vorticella*, Plates XXVIII - XXXI, Figs. 84 - 94.

Generally, inverted bell form, colorless or yellowish; peristome more or less outwardly extended (Figs. 87-89 and 91-94); colonial or solitary with a contractile stalk (Figs. 84 and 85) attached to submerged objects and aquatic plants (Figs. 84 and 85) or animals; one to two contractile vacuoles (Figs. 87-92). Unbranched stalk with well-developed spasmoneme, thrown into a spiral coil when contractile (Figs. 87-92). Numerous species.

Systematic account:

This group of ciliates (Figs. 84-94) with peristome circular, bordered by membranes running counter-clockwise around it and into a vestibule containing cytostome, cytopyge, and contractile vacuole pore; body ciliation greatly reduced; all characteristics of Peritrichida.

The sessile form clearly remands this group to Sessilina. The contractile stalk attached to the posterior extremity of the body without lorica, assigns this group to Vorticellidae.

Furthermore, the unbranched stalk with spasmoneme well-developed and thrown into a spiral coil when contractile, separates the present group from *Intranstylum* with poorly-developed spasmoneme and from *Zoothamnium* and *Carchesium* with branched stalks.

PLATE XXVIII

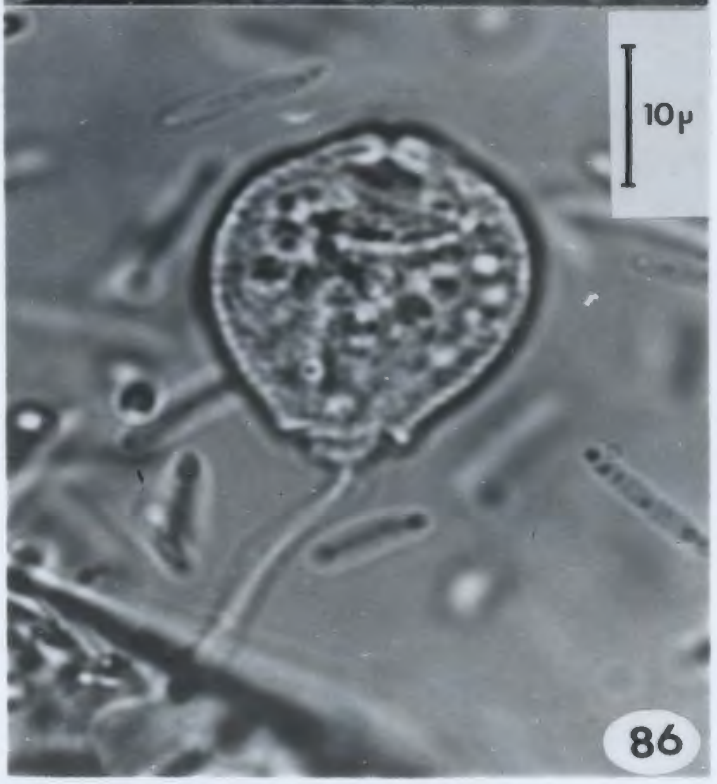
Figs. 84 - 86. *Vorticella* sp.

Figs. 85 & 85. Showing each solitary *Vorticella* sp. with an unbranched contractile stalk attached to submerged objects.

Fig. 85. *Vorticella microstoma* Ehrenberg, 1830, with transverse striation.


100μ
84


100μ
85


10μ
86

Thus this group is referable to *Vorticella* Linnaeus. There are more than 220 described species of *Vorticella* (Noland, 1931). The taxonomic data of the four groups from Logy Bay are briefly recorded as follows:

Vorticella microstoma Ehrenberg 1830, Plate XXVIII,Fig.8b.

Body conical (23 x 20μ) with stalk (18μ); transversely striate. Less twice as long as broad. Peristome narrower than half the body-centre.

Vorticella sp. Plate XXIX, Figs. 87-89.

Surface smooth, broadly campanulate (50 x 34μ). Width of peristome (34μ) less than body length. Greenish, stalk (142μ) more than three times as long as the body.

Vorticella nebulifera O. F. M. 1786, Plate XXXI,Figs.93,94.
var. *similis* (Stokes, 1887).

Smooth body conical (78 x 48μ), occurring in groups. Translucent, flexible body with granular greyish-white colour bands as shown in Fig. 94 and twists on its stalk in graceful attitudes. Peristome oblique, ciliary disc not elevated while body extended (Fig. 94). The contracted form (Fig. 93) is smoothly ovoid.

PLATE XXIX

Figs. 87 - 89. *Vorticella* sp. I.

Fig. 87. Showing an enlarged disc-like anterior region with prominent adoral ciliature which winds counter-clockwise to the cytostome in living material, (phase-contrast).

Figs. 88 & 89. Showing smooth surface and broadly companulate shape. (Nomarski interference-contrast effect).

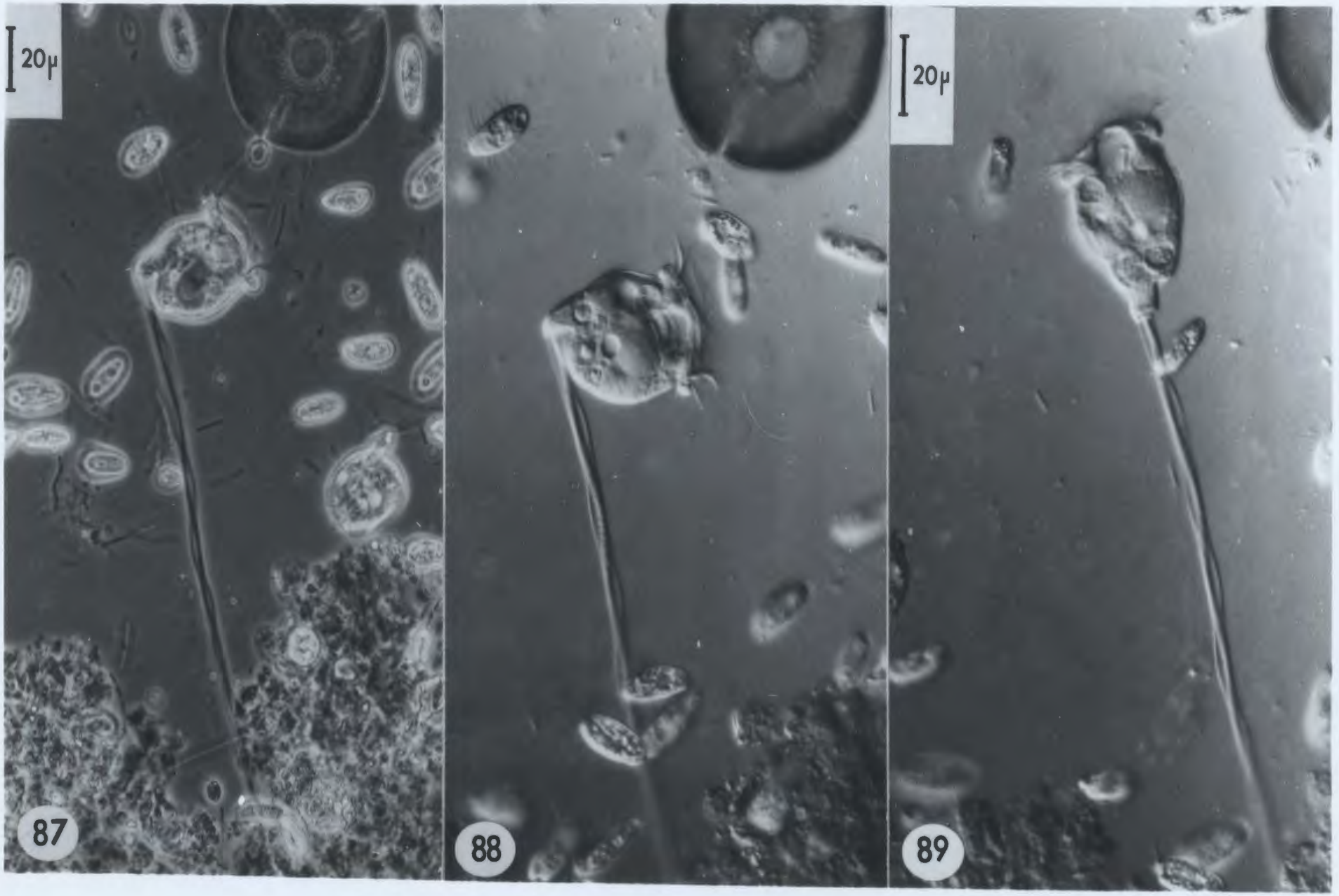

20μ
87
88
20μ
89

PLATE XXX

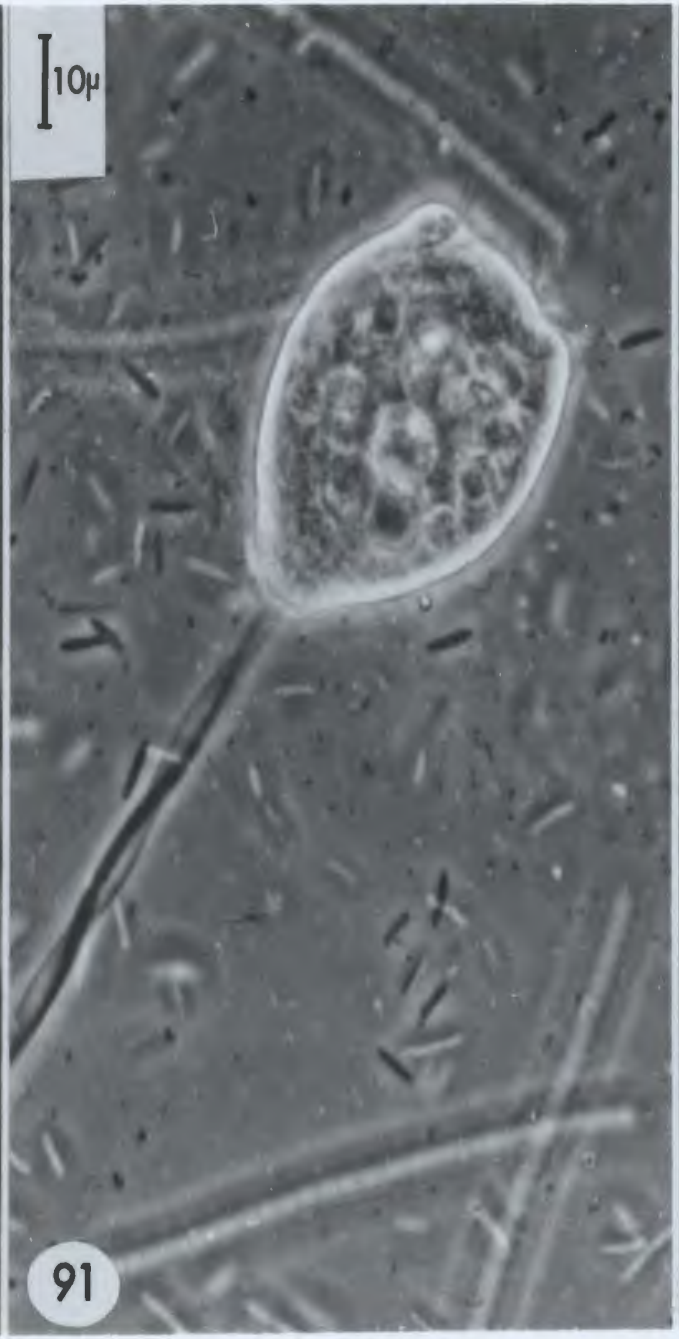
Figs. 90 - 92. *Vorticella* sp. 2.

Fig. 90. Showing contractile form.

Fig. 91. Showing single contractile vacuole centrally located.

Fig. 92. Showing extended form.


10μ
90


10μ
91


10μ
92

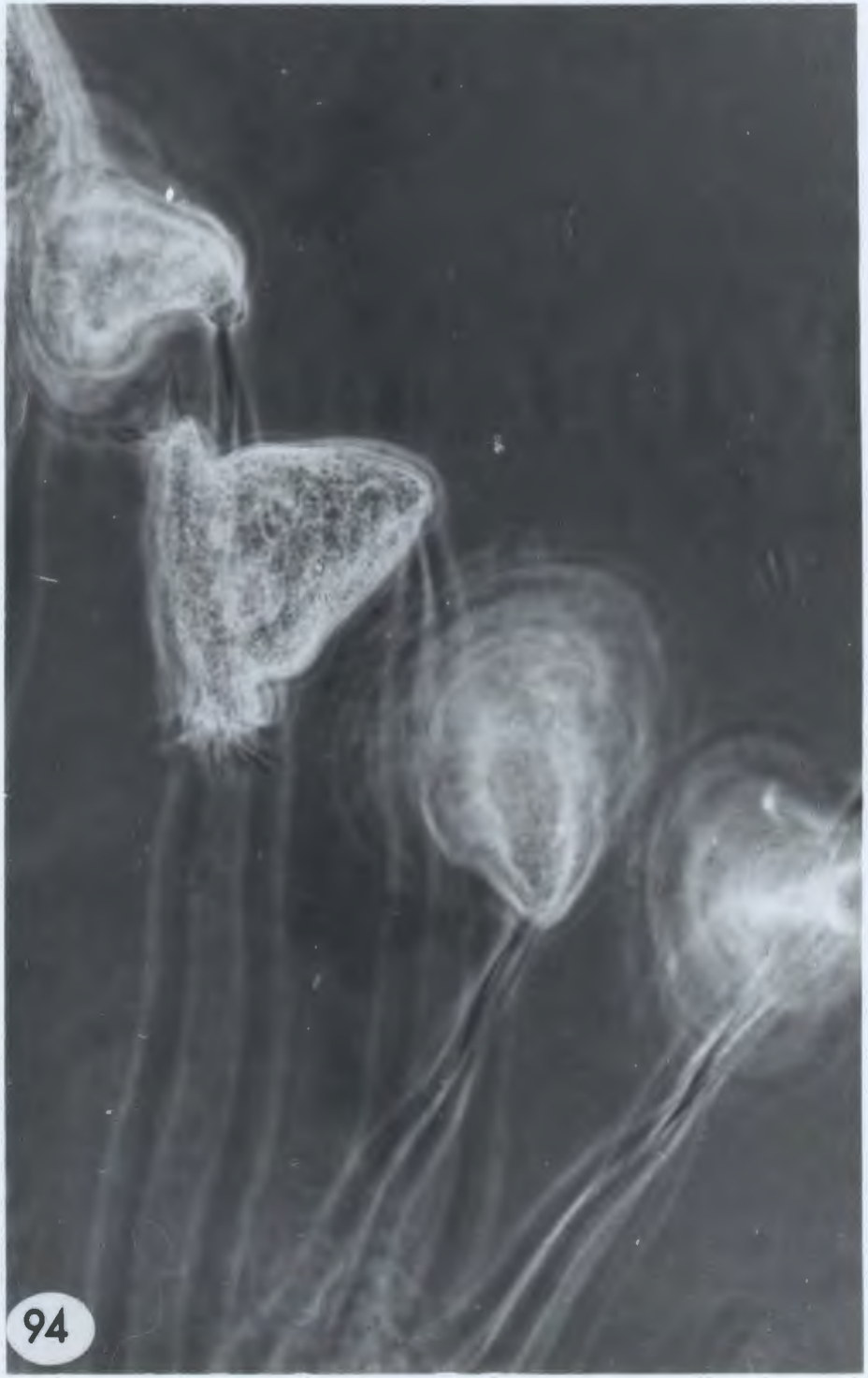
PLATE XXXI

Figs. 93 and 94. *Vorticella nebulifera* O. F. M. 1786, var. *similis* (Stokes, 1887).

Fig. 93. Focused on contractile form.

Fig. 94. Showing peristome, oblique ciliary disc not elevated while body extended.


20μ
93


94

Vorticella sp. Plate XXX, Figs. 90 - 92.

Ovoid body (60 x 43μ) with unbranched stalk (70μ). Transversely striated; single contractile vacuole conspicuously centrally located. Peristome not elevated while body extended (Fig. 92).

Family Epistylidae

Genus *Epistylis*

Epistylis sp. Plates XXXII - XXXIII, Figs. 95-100.

Body longitudinally contractile, fully expanded (300 x 30μ, Fig. 95), contractile (110 x 66μ, Fig. 98). Individuals always on dichotomous non-contractile stalk (Figs. 95 and 97), forming large colonies; pristomial ring prominent; flat cap makes a slight angle with the ring (Fig. 96), gullet with ciliated wall, body full of zoochlorellae(Figs. 99, 100).

Systematic account:

There are six fresh-water genera of Epistylidae (Noland in Edmondson, 1959) which bear comparison with the present organism in having uncontractile stalks.

The main feature of its dichotomous non-contractile stalk with one individual at end of each branch of the stalks (Figs. 95 and 97) separates the present organism from *Systylis*; the latter bears clusters of several dozen individuals at the end of each branch.

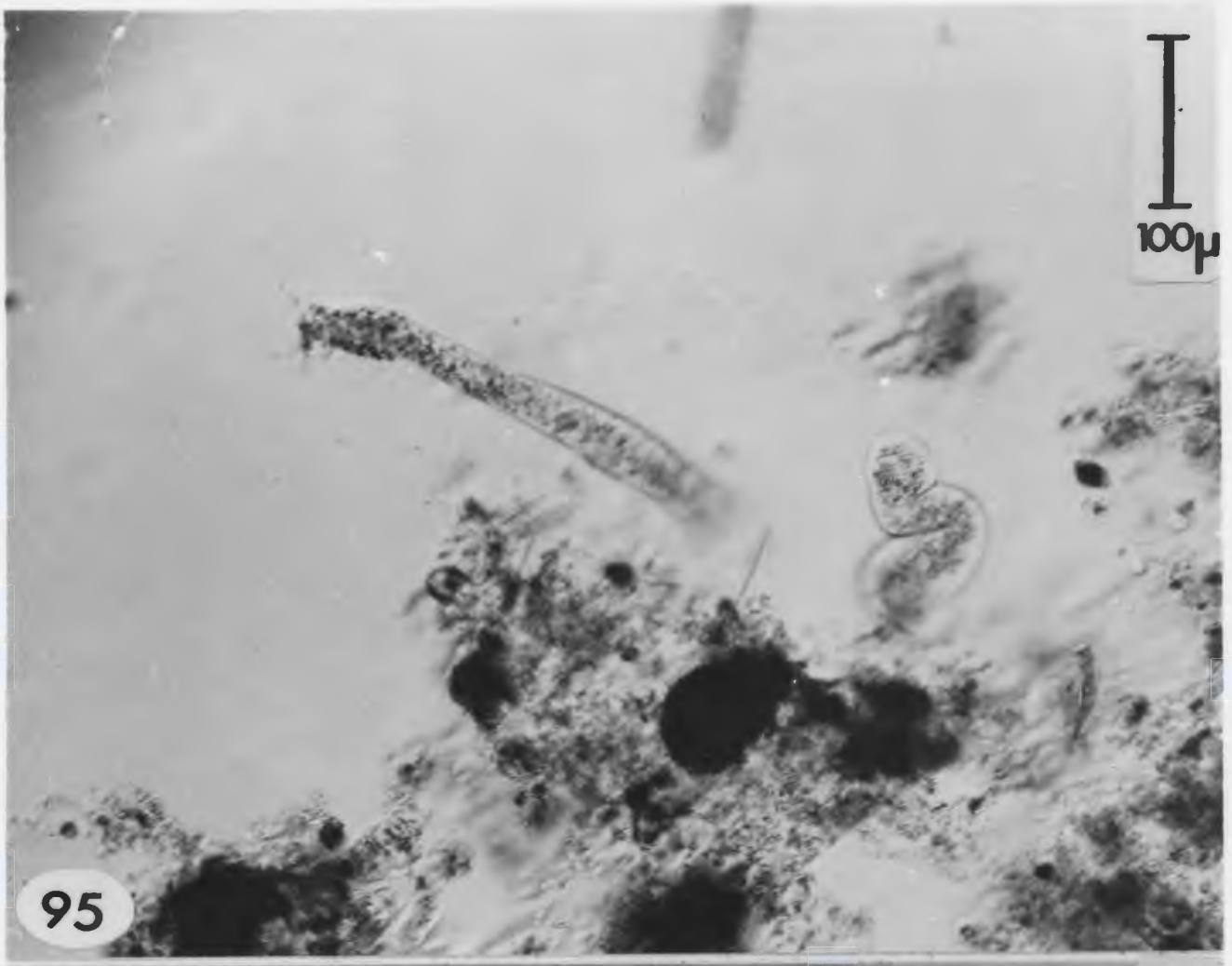
The peristomial membranes make only a little more than one

PLATE XXXII

Figs. 95 and 96. *Epistylis* sp.

Fig. 95. Showing an expanded and a contracted individual on a dichotomous stalk.

Fig. 96. Showing peristomial ring at a slight angle with flat cap.


100µ
95

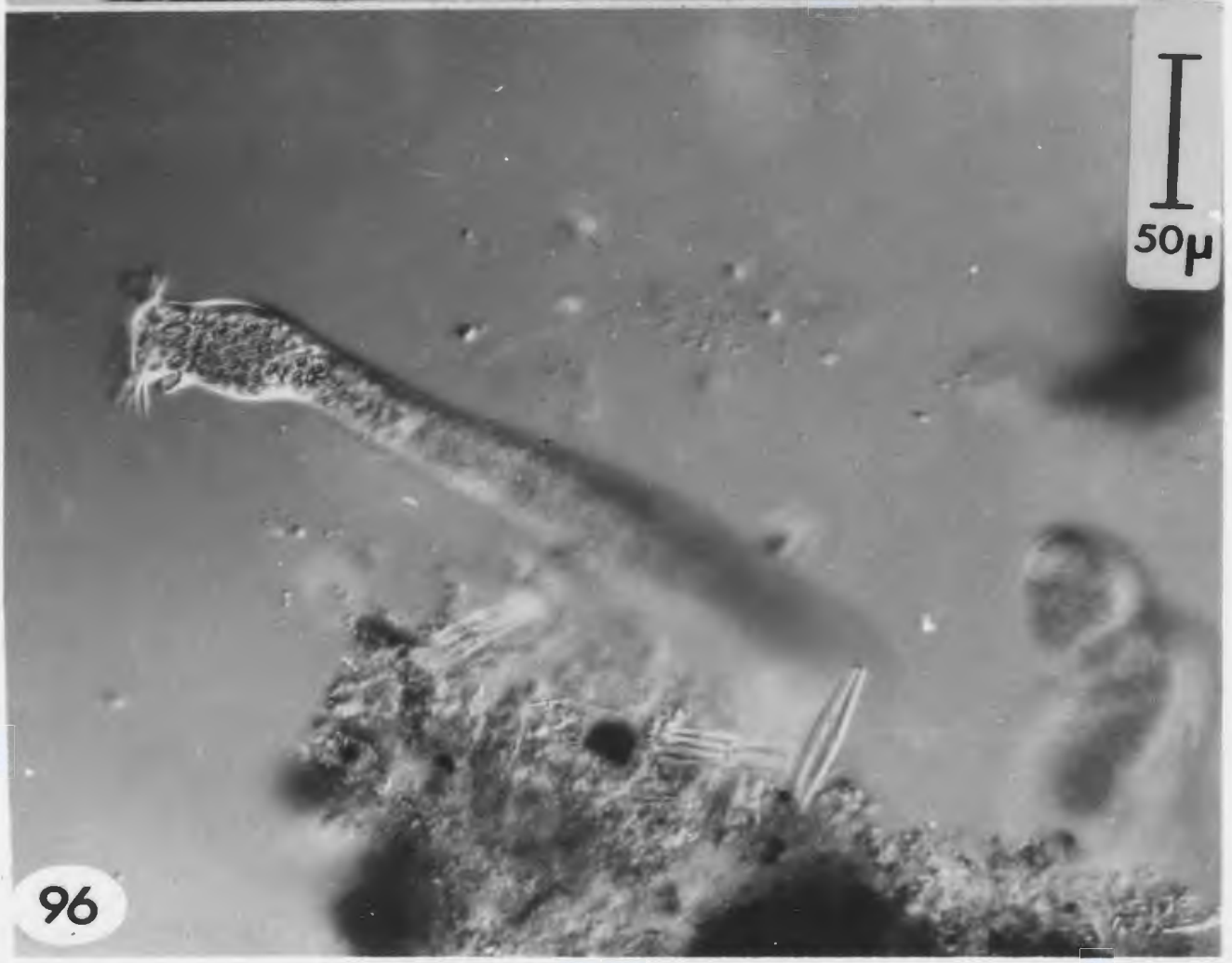

50µ
96

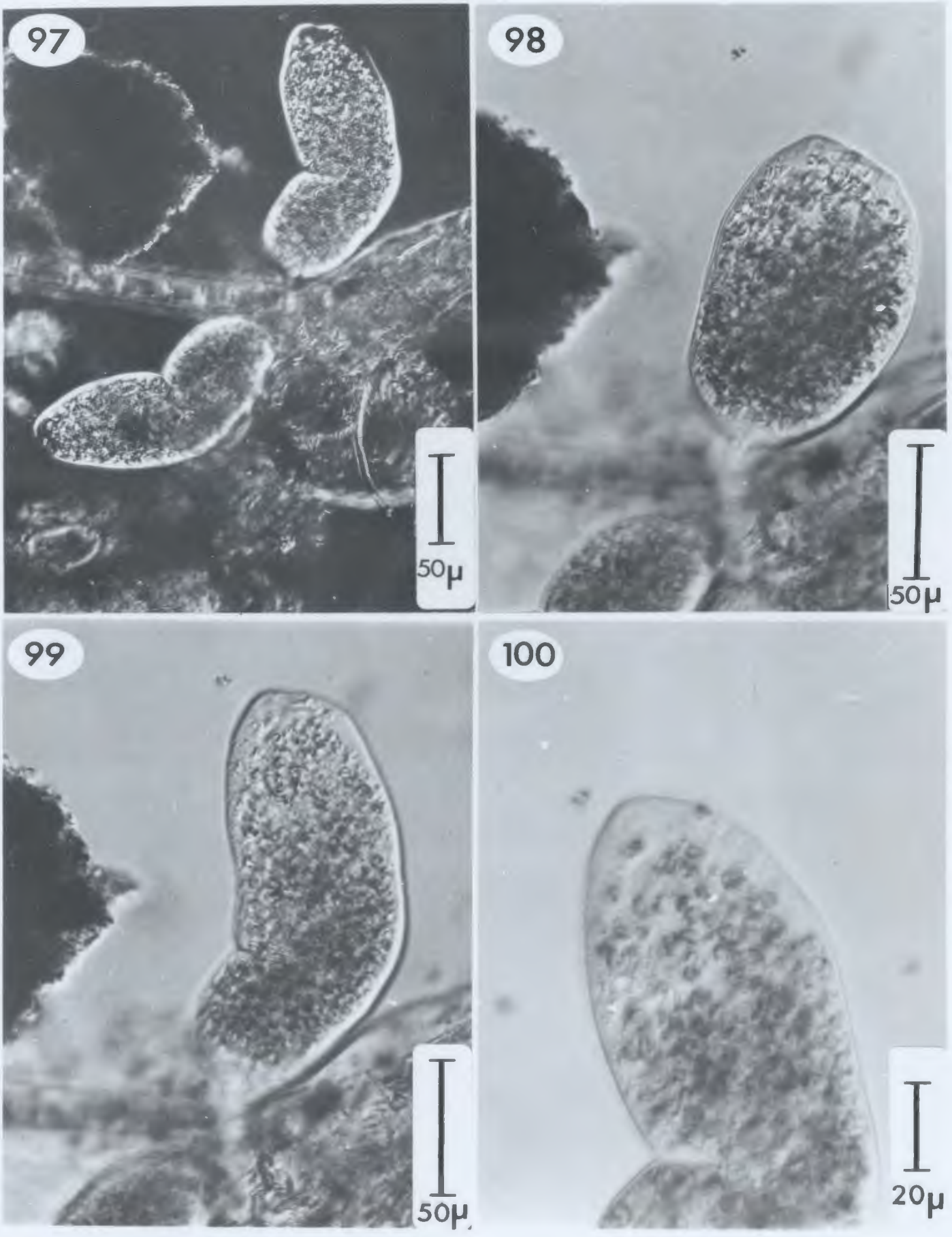
PLATE XXXIII

Figs. 97 - 100. *Epistylis* sp.

Fig. 97. Showing one individual at end of each branch of the dichotomous non-contractile stalk.

Fig. 98. Showing fully contracted form.

Figs. 99 & 100. Focused on zoochlorellae in body.


97
50µ
98
50µ
99
50µ
100
20µ

turn around the peristome of the present organism, distinguishable from the peristomial membranes that make four to six turns around the peristome of *Campanella*. The remaining three genera *Pyxidium*, *Opercularia*, and *Rhabdostyla* with deep peristomial furrow, separating disc and border, bears no comparison with the present organism which has a shallow peristomial furrow, and a disc not set off from border by a deep incision. The data given above fit the description of *Epistylis* Ehrenberg, 1838. Thus, it is referred to *Epistylis*.

Family Astylozoonidae

Genus *Telotrochidium*

Telotrochidium sp. Plate XXXIV, Figs. 101-106.

Entirely free-swimming body contractile from extended campanulate (106 x 60μ, Fig. 101) to globose shape (80 x 70μ, Fig. 106) without caudal appendage. Two ciliary girdles without body ciliation: one developped at a short distance from the anterior and another from posterior extremity; the anterior one with two parallel rows of adoral zone; cytopyge postero-terminal, tubular, permanently visible (Figs. 102-104). Three contractile vacuoles connected with the cytopharynx (Fig. 101), the largest one subcentral (Figs. 101-103 and 105-106). Macronucleus "L" shape band form (Fig. 102-103 and 105). Movement swift, rotating in alternate directions.

Systematic account:

The free-swimming form, with peristome-bearing extremity forward and without body ciliation, are the characteristics of Astylozoonidae.

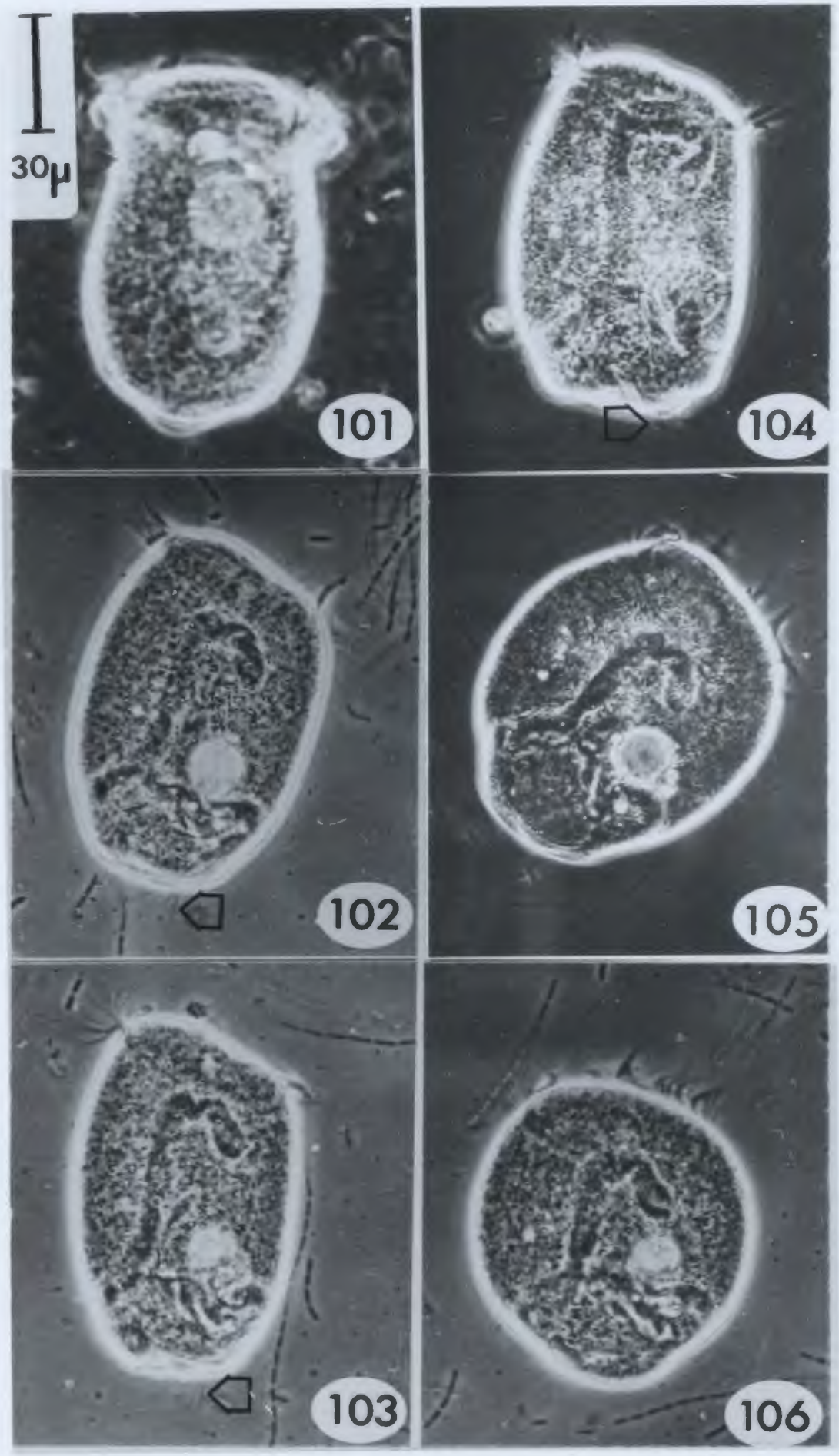
The species under consideration is distinguished from *Astylozoon* by the latter's conical shape and aboral extremity attenuated with one or two thigmotactic stiff cilia; from *Hastatella* by the latter with two to four rings of long conical ectoplasmic processes.

The rounded extremities of the present species without any body ciliation or processes but two ciliary girdles are the main features of *Telotrochidium* which consists of *Telotrochidium crateriforme*

PLATE XXXIV

Figs. 101 – 106. *Telotrochidium* sp.

Showing a series of body contractile from extended campanulate (Fig. 101) to globose (Fig. 106). The arrows in Figs. 102-104 point to the second, posterior girdle.


30μ
101
104
102
105
103
106

Kent (1881-1882) and *Telotrochidium (Opisthonecta) henneguyi* (Fauré-Fremiet). Both of them bear a "C" shape sausage form macronucleus which is different from the present species. Thus the "L" shape band form macronucleus suggests the present species as a new member of the genus. However, Dodd (1962) observed some nuclear changes in cysts of *Telotrochidium henneguyi*. Therefore, the species identification of the present organism remains for further investigation.

Subclass Spirotricha

Order Heterotrichida

Suborder Heterotrichina

Family Spirostomatidae

Genus *Blepharisma*

Blepharisma persicinum Perty, 1852, Plate XXXV, Figs. 107-110.

Pyriform (141 x 66μ), somewhat narrowed anteriorly and posterior extremity acuminate; compressed; left peristomal edge sigmoid (Figs. 109 and 110), and is twisted to right at posterior extremity and connected to oral funnel with membrane; in front of cytostome a large well-developed two-layer undulating membrane on right edge (Figs. 107 and 108); peristome about three quarters of body length; ciliary rows longitudinal; ciliation dense; contracile vacuole and cytopyge terminal; macronucleus in six parts; rose coloured.

Systematic account:

Kahl (1932) recognized 19 species of *Blepharisma*. Only five of them with multimacronuclei bear comparison with the present species. Among these five, the present species is distinguishable from *B. dileptus*, *B. clarissiumum*, and *B. salinarum* by its rose-coloured smaller (less than 150μ) but rather stumpy body.

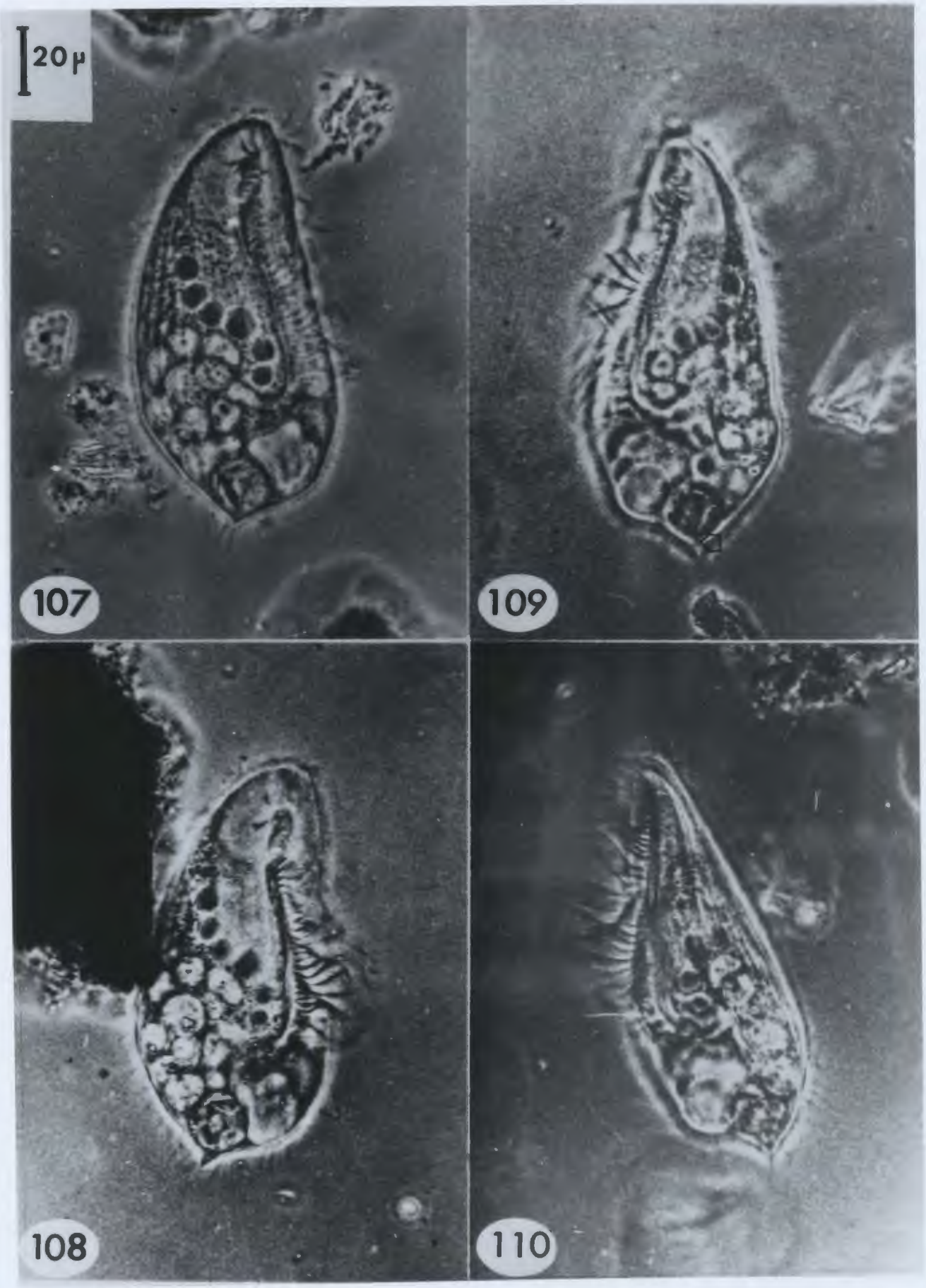
This narrows the choice down to *B. musculus* and *B. persicinum*. The former can be easily distinguished from the present species by its more numerous (7-10) macronuclear parts.

PLATE XXXV

Figs. 107 - 110. *Blepharisma persicinum* Perty, 1852.

Figs. 107 and 108. Showing right edge of cytostome with a large well-developed two-layer undulating membrane. Macronucleus in six parts.

Figs. 109 and 110. Showing sigmoid left peristomal edge; contractile vacuole and cytopyge posteriorly, indicated by the arrow in figure 109.


20 µ
107
109
108
110

The present data fit the descriptions of *B. persicinum* Perty which is characteristically pyriform in shape (80 - 120μ long) with accuminated posterior extremity, the range of peristome from one third to three quarters of body length with sigmoid left edge, well-developed undulating membrane on right, macronucleus in three to six parts, and rose-coloured body. The present species is thus referred to *Blepharisma persicinum* Perty.

Family Spirostomatidae

Genus *Spirostomum* (according to Corliss, 1961)

Spirostomum teres Claparède and Lachmann, 1859,
Plate XXXVI, Figs. 111a, 111b, 112.

Body measuring 200 - 500μ by 20 - 35μ. Slender-elongate, worm-like, 10 - 15 times as long as broad, cylindrical, one side parallel to the other, sometimes slightly swollen medially, rounded anteriorly, usually truncated posteriorly (Figs. 111a, 111b). Ectoplasm with highly developed and contractile myonemes, arranged lengthwise independent of ciliary rows. Endoplasm clear and transparent. Peristome narrow, occupying about one third of the body, closely lined with a band of well developed cilia or membranelles. Cytostome at the base of the peristome (Fig. 111), leading immediately into a cytopharynx which is very simple and difficult to distinguish. Elliptical macronucleus (Fig. 111) often centrally located below the base of the peristome, clearly evident in pressure-immobilized live examples. Micronucleus not observed. Excretory vacuole large and terminal, with

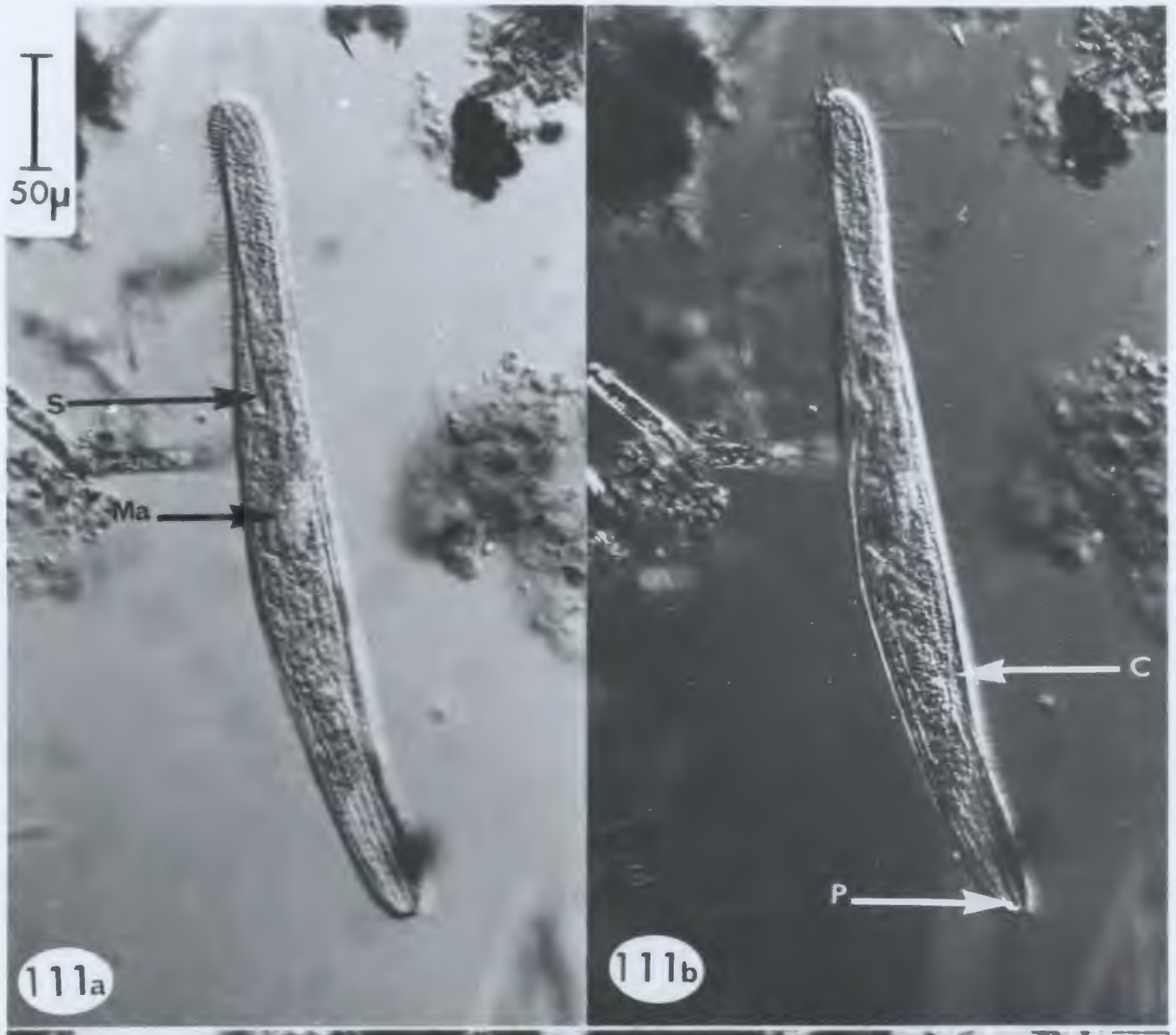
PLATE XXXVI

Figs. 111 and 112. *Spirostomum teres* Claparède and Lachmann, 1959. Unstained living ciliate as seen by Nomarski interference-contrast effect.

Fig. 111a. Ma. oval macronucleus, unlike that of other common members of *Spirostomum* (except *S. filum*), which have a moniliform macronucleus. (S) cytostome located at the base of the peristome which extends for one-third of the body length (that of *S. filum* is only one-fourth of the body length).

Fig. 111b. P. truncated posteriorly, a single contractile vacuole occupying the whole of this part of the body and extending forwards as a long canal (C) (*S. filum* has a tapering, drawn out posterior end).

Fig. 112. Showing transverse binary fission completed, two filial cells almost separated.


50µ
S
Ma
111a
C
P
111b


100µ
112

a long dorsal canal (Fig. 111a, 111b). Transverse binary fission (Fig. 112)

Systematic position:

Kahl (1932) recognized seven species of *Spirostomum* (*S. ambiguum*, *S. minus*, *S. intermedium*, *S. inflatum*, *S. loxodes*, *S. filum* and *S. teres*). Only in *S. teres* and *S. filum* is the macronucleus oval or elliptical in shape. In the other five species, this structure is moniliform. An unidentified but possibly new species referred to by Seshachar and Padmavathi, 1956, has a cylindrical and elongate macronucleus in the vegetative stage. During binary fission, though, this organelle becomes condensed into an oval or polymorphic mass. The macronucleus is always oval in *S. teres*, and may be clearly observed either with or without staining in the living animal. *S. teres* (200 - 500μ) is generally longer than *S. filum* (200 - 300μ). Anteriorly rounded and posteriorly truncated, *S. teres* is characterized by one body side parallel to the other. In *S. filum*, though, there is a tapering, drawn-out posterior extremity. The peristome is about, or more than, one-third of the body length in *S. teres*, but only one-fourth the body length in *S. filum*. Therefore, the chief features distinguishing *S. teres* from other members of the genus are the oval shape of the macronucleus, the parallel-sided body shape and the elongate peristome.

Subclass Spirotricha

Order Oligotrichida

Family Halteriidae

Genus *Halteria*

Halteria sp. Plate XXXVII, Figs. 113 and 114.

Body turbinate (av. 25 x 20μ; Figs. 113 and 114); anterior border bears conspicuous adoral zone, unclosed adoral membranelles well-developed; a small membrane on right edge and cirri (Fig. 114,A) on left. Macronucleus oval; a micronucleus. Contractile vacuole left of cytostome. A zone of long cirri or bristles (Fig. 114,B) develops around the equatorial region, the sudden flexure of which appendages enable the body to progress through the water by a series of leaping movements, in addition to their ordinary swimming motions.

Systematic account:

The present ciliate is easily recognized as *Halteria* by its peculiar movements in the water, which consist of a slow rolling or rotary motion, interrupted at short intervals by a sudden leap backwards or to one side and its turbinate body with equatorial zone of bristles.

However, the present organism clearly bears the main features of Oligotrichida, e.g. the greatly reduced body ciliation and well-developed adoral membranelles extended beyond the anterior extremity.

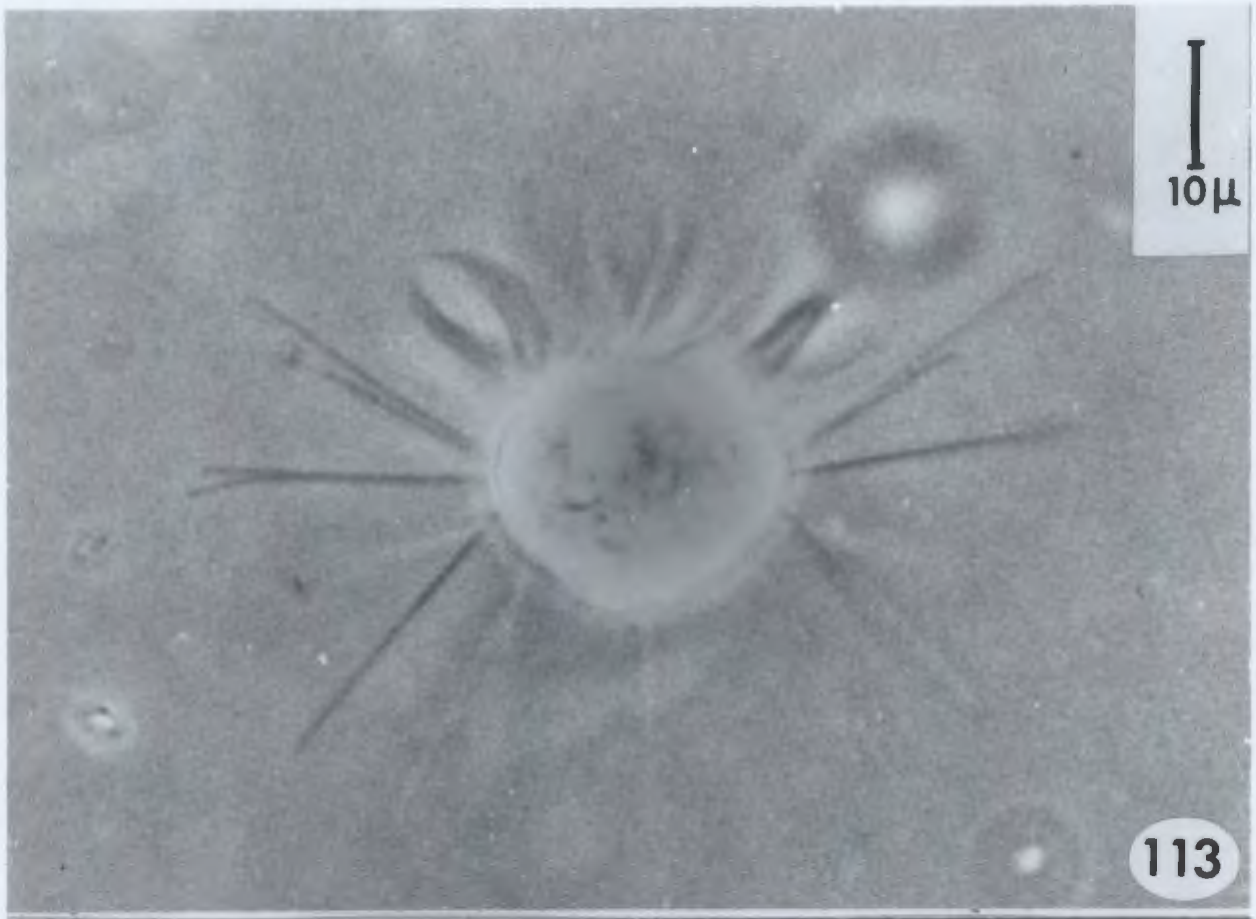
There are only two families of Oligatrichida, Halteriidae and Strobiliidae (Kudo, 1966). The present organism is clearly

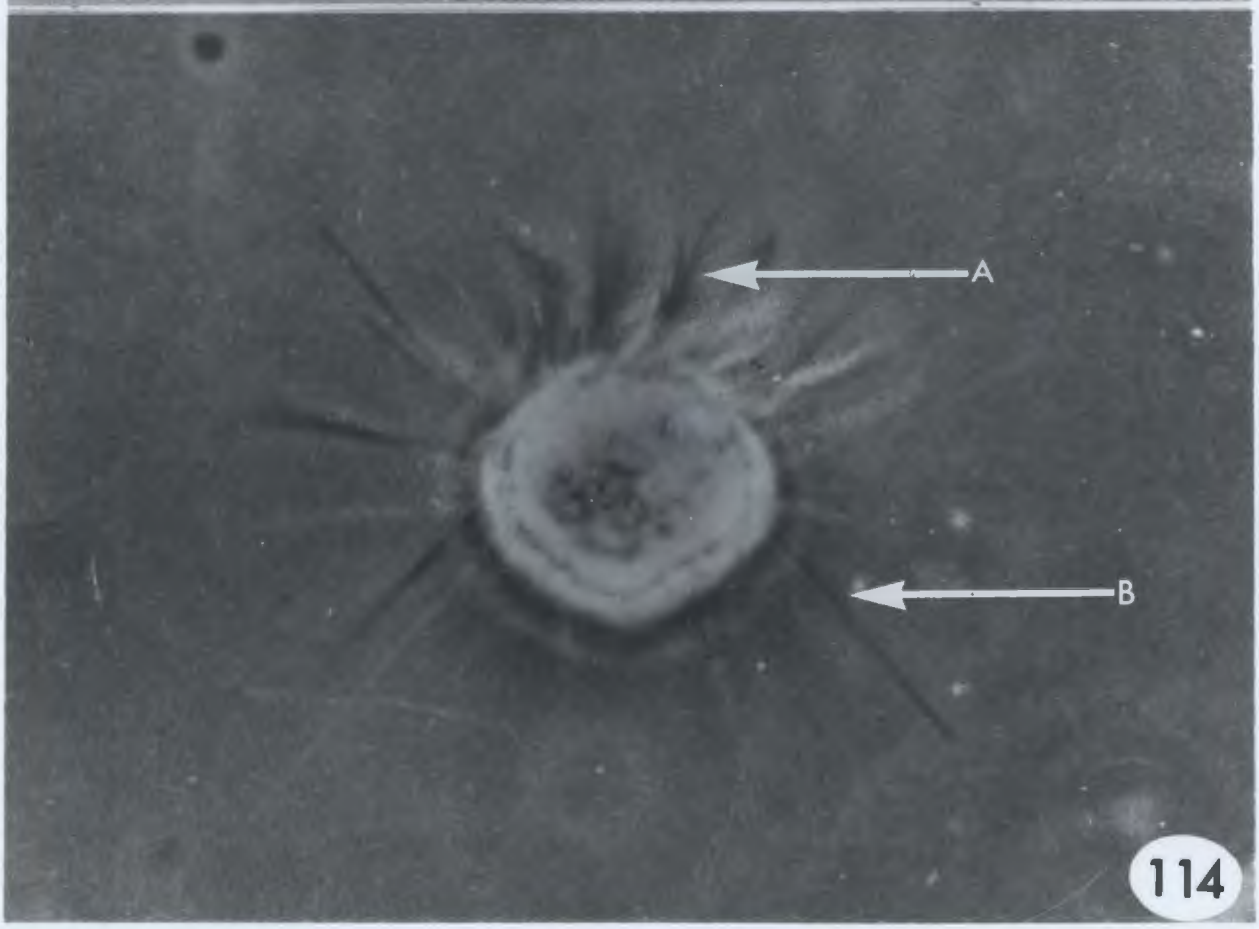
PLATE XXXVII

Figs. 113 and 114. *Halteria* sp.

Fig. 113. Showing turbinate shape with body ciliation.

Fig. 114. Showing unclosed well-developed membranelles and cirri (A) around cytostome and a tuft of bristles (B) around equatorial zone.


10µ
113


A
B
114

distinguishable from Strobiliidae because the latter's cytostome is encircled by adoral membranelles (see Noland in Edmondson, 1966) and allocated to Halteriidae for bearing unclosed adoral membranelles.

Among the three genera of Halteriidae, the present organism is well separated from *Tontonia*, for the latter has well-developed apical collar and a long cytoplasmic (contractile) caudal process; and from *Strombidium* which bears no body bristles or cirri. The organism under consideration bears the generic features of *Halteria* - the greatly reduced body ciliation except equatorial zone of body bristles, the well-developed unclosed adoral membranelles around cytostome. Thus the ciliate under discussion is therefore referable to *Halteria* Dujardin.

Family Strobilidiidae

Genus *Strobilidium*

Strobilidium sp. Plate XXXVIII, Figs. 115, 116.

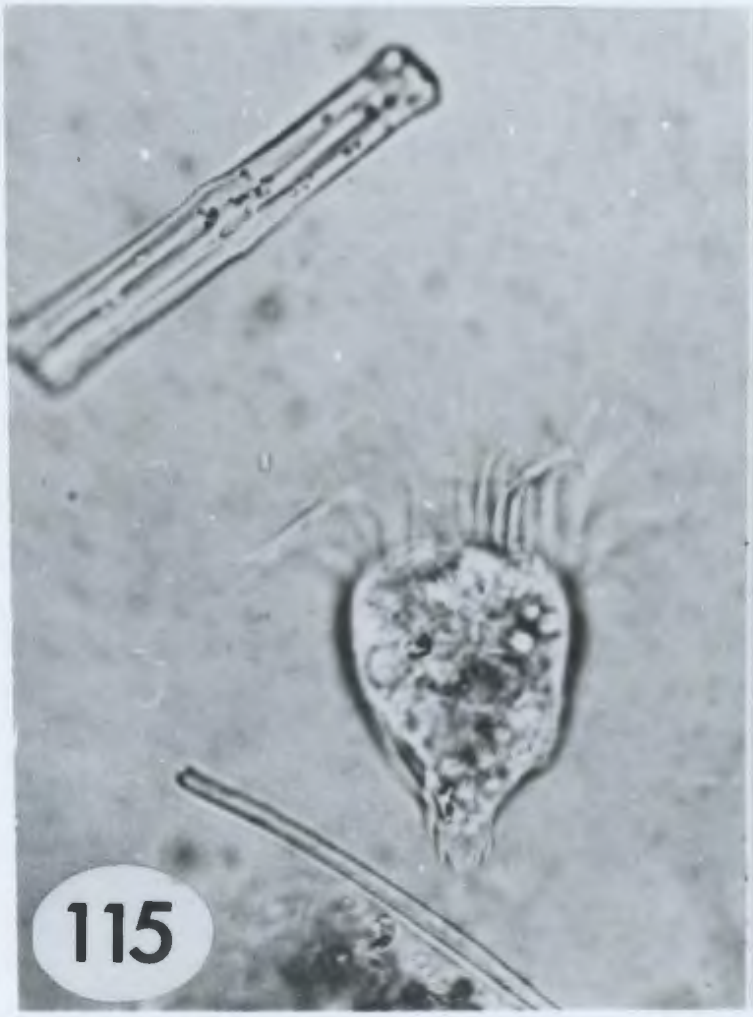
Body turnip-shaped (av. 47 x 34μ, Figs. 115 and 116); adoral membranelles form a spiral crown at the anterior extremity (Fig. 116) without cytopharynx and lateral border with rounded elevation anteriorly; the posterior extremity tapering and truncate; cuticular surface smooth, except at the posterior region (Fig. 115), where there are a few longitudinal ridges which often extend slightly beyond the termination of the body. Horseshoe-shaped macronucleus anterior; a micronucleus; a contractile vacuole.

PLATE XXXVIII

Figs. 115 and 116. *Strobilidium* sp.

Fig. 115. Showing truncate posterior extremity and closed adoral membranelles.

Fig. 116. Showing a spiral crown at anterior extremity with rounded elevation laterally.


115


20 µ
116

Systematic account:

Similar to Halteriidae, the present organism also bears the characteristics of Oligotrichida, the greatly reduced body ciliation nearly absent and the well-developed ador membranelles extended beyond the anterior extremity of the body. However, it is distinguishable from Halteriidae by its closed adoral membranelles form a spiral crown at the anterior extremity while Halteriidae with unclosed adoral membranelles. These discussed criteria fit exactly the description of Strobilidiidae (Kahl, 1930-1935).

There is only one genus of Strobilidiidae, *Strobilidium* Schewiakoff (see Noland in Edmondson, 1966; Kudo, 1966) of which the present organism bears the generic features - turnip body shape, cytostome at anterior extremity without cytopharynx, with horshshoe-shaped macronucleus.

Lateral border with rounded elevation near anterior extremity, posterior extremity truncate of the present species strongly suggest allocation to *Strombilidium gyrans* Stokes (1885). However, no detailed comparison with other members of *Strombilidium* were made, therefore the species under discussion is left as *Strombilidium* sp.

Subclass Spirotricha

Order Hypotrichida

Family Aspidiciдae

Genus *Aspidisca*

Aspidisca sp. Plate XXXIX, Figs. 117 - 120.

Small (29 x 25μ); ovoid (Figs. 117-120); inflexible; right and dorsal side convex (Figs. 117 and 118), ventral side flattened (Figs. 119 and 120); dorsal surface conspicuously ridged with spines (Fig. 118); adoral zone poorly developed, cirri reduced in number and are limited to frontals and anals; macronucleus horseshoe-shaped; single contractile vacuole; benthic species.

Systematic account:

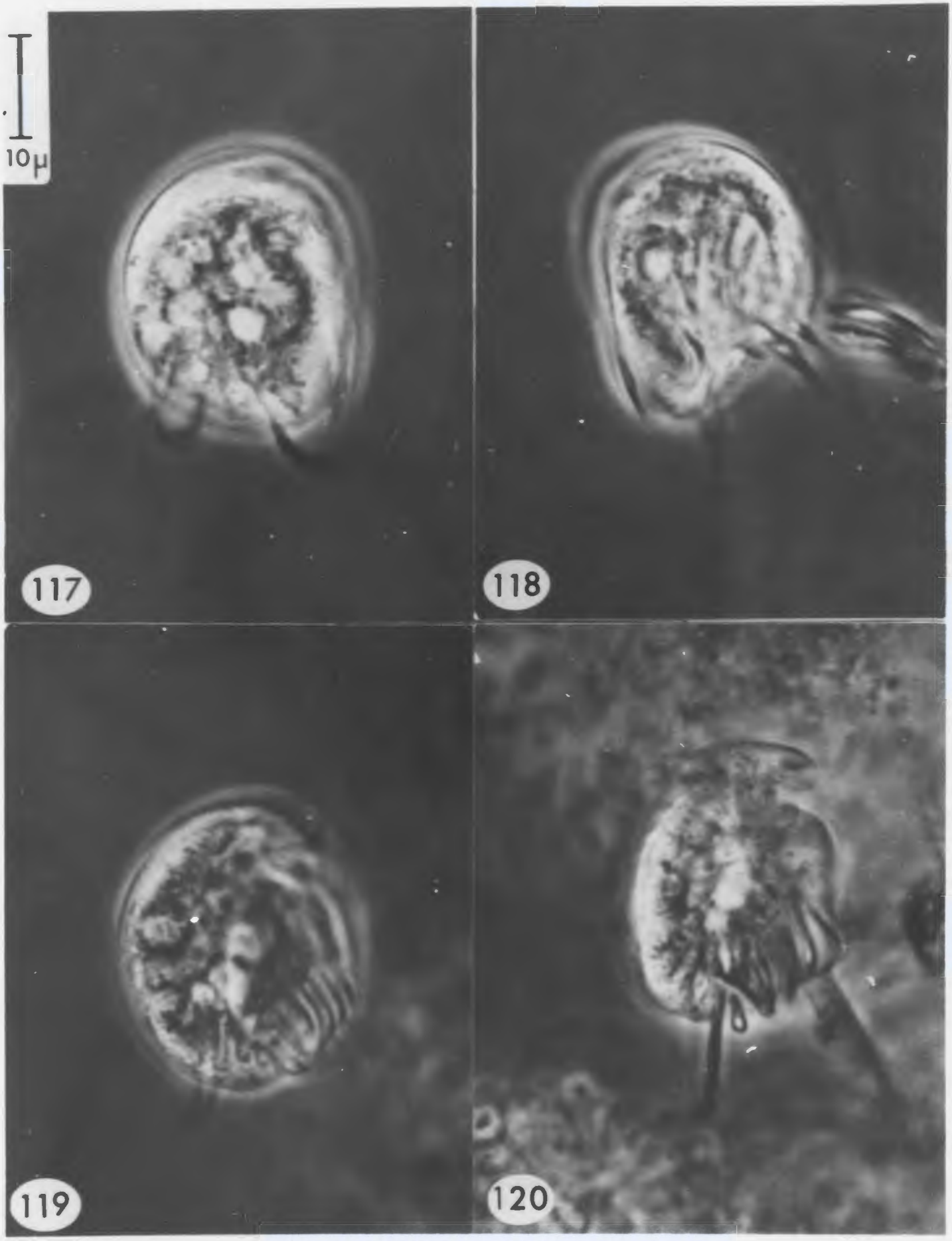
Reduced zone of adoral membranelles of the present organism differentiatesit from all other families of Hypotrichida in that the latter bear well developed conspicuous adoral membranelles. The ovoid body with rudimentary adoral membranelles and seven frontal-ventral, five to twelve anal cirri fits the characteristics of *Aspidisca* Ehrenberg, 1830.

PLATE XXXIX

Figs. 117 - 120. *Aspidisca* sp.

Figs. 117 and 118. Showing ovoid shape; right and dorsal side convex; spines on ridged dorsal surface.

Figs. 119 and 120. Showing flattened ventral side with poorly developed adoral zone and reduced cirri.


10μ
117
118
119
120

The following genera and species were also recovered in samples from the study pond at Logy Bay. The ecological data for each are presented in Table II but illustrations are not included. Systematic positions of the different groups are presented at the beginning of the systematic section.

Chilophrya utahensis Pack, 1919.

Body tube-shaped (56 x 10 - 84 x 15μ); cytostome anteriorly surrounded by protrusible rods; on one side there is a flap process; macronucleus small, central; contractile vacuole terminal; endoplasm with zoochlorellae.

Prorodon discolor (Ehrenberg, 1838).

Ovoidal (105 - 130μ x 70 - 85μ); gullet trichites double, conspicuous, their external ends slightly below surface level; contractile vacuole terminal; macronucleus ellipsoid; micronucleus hemispherical.

Microregma sp.

Small (23 - 27μ in length), ovoid; dorsal side convex; ventral side flat, with a small slit-like cytostome near anterior extremity, surrounded by longer cilia; single long caudal cilium; contractile vacuole posteriorly.

Matyophrya sp.

Compressed; elongate ovoid (22.4 - 33μ in length); asymmetrical; dorsal surface convex, ventral surface partly concave; uniform ciliation with spiral striation; cytostome anteriorly; macronucleus round; single contractile vacuole posteriorly.

Trachelocerca sp.

Elongate, flask-shaped; more or less extensible, with drawn-out anterior extremity; without any ring-furrow anteriorly; when contracted (84μ in length) pellicular striae not spiral; cytostome anteriorly, surrounded by a ridge containing short trichocysts, cytopharynx with trichocysts; nucleus contains peculiar crystal-like bodies; body full of green coloured zoochlorellae;when extended 120μ in length; single contractile vacuole posteriorly located.

Litonotus sp.

Elongate flask-shape (48μ in length); with flattened neck and tail, both of which are moderately contractile; neck stout, bent towards the dorsal side; cytostome a long slit (two-fifths of body length), anteriorly located; posterior extremity bluntly rounded; one terminal or several (in one row) contractile vacuoles; two spherical macronuclei between which a micronucleus is located.

Dysteria sp.

Ovate (50 x 30μ); dorsal convex, ventral concave; left ventral non-ciliated; post-oral ciliation is continuation of pre-oral to right of cytostome and parallel to right margin; cytostome in a furrow near right side; posterior stylus conspicuous; two contractile vacuole centrally located.

Paratrochilia chilodontoides Kahl, 1933.

Rounded anteriorly, narrowed posteriorly (30 - 35 x 20 - 22μ); right side more convex than left side; cytostome anterior with cytopharynx and pre-oral membrane; the broad side of funnel-shaped cytopharynx anteriorly; on the left edge two to three bulges; one hem of cilia surrounded the dorsal knoll, otherwise unciliated dorsal surface; two contractile vacuoles in the right side of ventral surface.

Chilodonella uncinata (Ehrenberg, 1838).

Ovoid (48 - 67μ long); dorso-ventrally flattened; dorsal surface convex, ventral surface flat; about eleven ventral ciliary rows; anteriorly flattened dorsal surface with a cross-row of bristles; cytostome round; oral basket conspicuous, protrusible; macronucleus rounded; contractile vacuoles variable in number.

Nassula sp.

Ovate (160 x 83μ); ventral flat, dorsal convex; cytostome one-quarter from anterior extremity; body bent to left near cytostome; opening of oral basket deep, in a vestibule with a membrane; macronucleus spherical, central; contractile vacuole large, with accessory vacuoles and opens ventrally through a tubule-pore.

Colpoda steini Maupas, 1883.

Small reniform (15 - 42μ); cytostome about two-fifths from the anterior extremity, and with a bundle of long membranellae; five to six pre-oral ridges; paired and single cilia; one pair of long caudal cilia; twelve meridians.

Cohnilembus sp.

Slender spindle form (50μ long); peristome from anterior extremity to the middle of body, curved to right, with two membranes on right edge; a few longer caudal cilia; macronucleus oval, central; contractile vacuole posterior.

Uronema sp.

Elongate oval (45μ long); slightly flattened; non-ciliated anteriorly; inconspicuous peristome with ciliated left edge; cytostome in the anterior half, with a small tongue-like membrane; cytopharynx indistinct; macronucleus spherical, central; contractile vacuole terminal.

Colpidium sp.

Elongate reniform (42 - 70μ long); 55 - 60 ciliary meridians; triangular cytostome about one-tenth the body length from anterior extremity towards right side; a small ectoplasmic flange along right border of cytostome which shows an undulating membrane on right and three membranellae on left; pre-oral suture curved to left; macronucleus oval, central.

Balanonema biceps (Penard, 1922).

Body ellipsoid (40 - 48μ long); no cilia in the middle region; but with plug-like extremities; cytostome inconspicuous; single long caudal cilium; oval macronucleus posterior to central contractile vacuole.

Cinetochilum marinum Kahl, 1930.

Oval (18 - 22μ long); highly flattened; cilia on flat ventral surface only; cytostome right of median line in posterior half, with a membrane on both edges which form a pocket; oblique non-ciliated post-oral field leads to left posterior extremity; four caudal cilia; macronucleus spherical, central; contractile vacuole terminal.

Frontonia leucas Ehrenberg, 1838.

Ellipsoid (200 - 250μ long); anterior extremity more broadly rounded than posterior extremity; flattened; oral groove in anterior third ventral surface; cytostome with a complex organization (see Kudo, p. 907); a long narrow post-oral groove which is ordinarily nearly closed; cytopharynx with numerous strong fibrils; ciliary rows close and uniform; ectoplasm with numerous trichocysts; feeds on filamentous algae.

Cyclidium citrullus Cohn, 1865.

Spindle shape (20 - 30μ); peristome about two-thirds of body length, dominated by the conspicuous undulating membrane. Spherical macronucleus in the anterior half. Otherwise, very similar to *Cyclidium glaucoma*, O. F. M.

Cyclidium elongatum Schewiakoff, 1896.

Elongate ellipsoid (16 - 24μ); peristome about three-quarters of body length. Otherwise, very similar to *Cyclidium glaucoma*, O. F. M.

Cyclidium granulosum Kahl, 1931.

More pyriform (36 - 40μ) than elongate-oval; other characteristics fit the descriptions of Kahl (1931).

Cyclidium litomesum Stokes, 1884.

Cylindrical (40μ), the length about two and one-half times the width, the extremities subequally rounded. Cytostome situated slightly behind the centre of the ventral surface. No ciliation in the middle dorsal part of body. The cilia posteriorly situated diverse in length, some of them longer than body length.

Cyclidium muscicola Kahl, 1931.

Small, moss shape (14 - 17μ), similar to *Cyclidium glaucoma*, O. F. M., but contractile vacuole in the middle of the body.

Pleuronema marinum Dujardin, 1841.

Elongate-ovoid (62 - 75μ long); peristome in two-thirds body length anteriorly; a conspicuous membrane at both edges; semicircular swelling to left near oral area; no cytopharynx; close striation longitudinal; single long caudal cilium; trichocysts distinct; macronucleus round; a contractile vacuole.

Ophrydium sp.

Cylindrical (200 - 300μ long) with a contractile neck; posterior end pointed; variable number of individuals in a common mucilaginous mass; pellicle usually cross-striated; with many zoochlorellae.

Metopus striatus McMurrich, 1884.

Body form changeable; when extended oblong or fusiform (64-85μ long); peristome conspicuous, slightly spirally diagonal, beginning at the anterior end and reaching the middle of body; when contracted, peristome much spirally coiled; cytopharynx short; body ciliation uniform, longitudinal spiral; long cilia at extremities; conspicuous contractile vacuole terminal; macronucleus oval.

Condylostoma sp.

Ellipsoid (132 - 143μ long); truncate anteriorly, rounded posteriorly; slightly flattened; peristome wide anteriorly and V-shaped, peristomal field not ciliated; a large membrane on right edge and adoral zone on left; macronucleus moniliform; several contractile vacuoles with canal; cytopyge posterior.

Paraclevelandia sp.

Oval (22 - 27μ long); body rigid; posterior extremity truncated obliquely to left; peristome posterior without projection; one macronucleus and one micronucleus.

Gonostomum sp.

Flattened, elongate (118 - 127μ long); flexible; eight frontals; one or two oblique ventral rows of short cirri; four or five anals; two marginal rows; adoral zone well-developed.

Steinia sp.

Rounded ellipsoid (148 - 172μ x 80 - 140μ); rounded both extremity; right border of peristome curves left, or spirals into a pit in peristome; few frontal cirri, usually eight in three groups; no continuous long rows of cirri; two macronuclei; one contractile vacuole in the middle.

Oxytricha sp.

Ellipsoid (100 - 140μ long); flexible; ventral surface flattened; dorsal surface convex; eight frontals; five ventrals; five anals; short caudals; macronucleus in two parts.

Stylonychia sp.

Ovoid to reniform (100 - 126μ long); not flexible; ventral surface flat; dorsal surface convex; eight frontals, five ventrals; five anals; marginals; three caudals, with short dorsal bristles.

Uroleptus longicaudatus Stokes, 1886.

Elongate body (about 200μ long) drawn out into a tail-like portion; three frontals; two to four rows of ventral cirri; marginals; no anals; sometimes rose or violet coloured.

Urosoma sp.

Similar to *Oxytricha;* but posterior portion drawn out and very narrowed; 160 - 175μ long.

CONCLUSIONS.

"Protozoa inhabit microhabitats, ... Each microhabitat is an ecological community of producers and consumers with definite relations to each other (Picken, 1937)" said Bamforth (1963). In consideration of the relations between producers and consumers, Felton et al. (1967) suggested that bacteria in the pond ecosystem play a role in the nitrogen, carbon and energy cycles as decomposers and transformers, as a source of nutrients and as members of the food chain. However, "A complete picture of the role of micro-organisms in the natural history of the pond must await further data, particularly about fungi and protozoa" (Felton et al. 1967).

As is well known, ciliated Protozoa may be found wherever there is moisture without deleterious substances. The same species may often be found in both littoral marine waters and inland freshwater lakes, ponds, and pools. Although many species are cosmopolitan, they tend to accumulate in certain places where the environments best suit their needs. Hence, it is necessary to know their natural distribution as well as their ecological parameters.

The pond under study is highly acidic (pH values between 4.50 - 5.15). It also has a high chloride content (99.26 p.p.m.), and a wide annual water temperature range (0.5 - 20.8°C), besides a fluctuation of dissolved solid content (75 - 144 p.p.m.). During the period of regular sampling from June 1969 to September 1970, it dried completely in July 1970, and thus can be defined as a "semi-permanent" pond (Laird, 1956).

For free-living ciliates, suitable culture media would supply sufficient population for their infraciliary analysis. Lacking complete descriptions of infraciliature, many of the taxa presented herein need further study in order to allocate their systematic status.

Forty-five genera of Ciliophora were reported which include many cosmopolitan species.

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ADDENDUM

THE RELATIONSHIP BETWEEN CARNIVOROUS *Tetrahymena vorax* AND THE PREY

On 17 July 1969, *T. vorax* was collected from the pond water at 23°C., with dissolved solid concentration 126 p.p.m. (see p. 28) and cultured in hay infusion with a surface sprinkling of bacto-tryptone at room temperature (22°C). *Tetrahymena pyriformis*, *Paramecium bursaria*, and *Urotricha* sp. were examined in the same collection.

The marked dimorphism of the ciliate under discussion was evident by phase contrast microscopy as stated on page 55. The pyriform microstomes were examined from silver impregnation preparations which also bear the tailed microstomes and the carnivorous macrostomes of *T. vorax*.

The event of the holotrich eating its prey was observed as follows:

The microstome form of *T. vorax* started to broaden, and the mouth became larger and more open beneath the microstome oral cavity.

Back of the oral cavity, a pharyngeal pouch appeared which was continuous with the outsides through the mouth opening. The pharyngeal pouch increased in size until it was ready to reach the posterior extremity. At this period, the vacuole occupied the greatest volume of the cell with the protoplasm surrounding it in a thin film.

After this microstome-macrostome transformation, the difficult task for the macrostome was to capture and digest its first prey.

As the mouth was open and large, the membranelles created strong currents into the "pharyngeal pouch"; eventually a prey was drawn in.

The macrostome immediately became quite active and swam in circles with the mouth directed toward the inner part of the circle. The prey swam about in the vacuole in an entirely normal manner. Eventually, the macrostome protoplasm closed down until the "pharyngeal pouch", with its trapped prey, was cut off from the mouth region.

The enclosed prey continued to swim about, but the fluid content of the vacuole decreased slowly; the protoplasm of the macrostome and prey came to lie close together, and the motion of the latter was restricted. Eventually, the prey lost all activity, and digestion was under way.

As the digestion proceeded, the macrostome increased in size, and afterwards it was able to capture preys much more rapidly.

The event was first described by Kidder et al. (1940), and also reported later by Corliss (1953a), Williams (1961), and Buhse (1966a). Recently, Buhse (1966a & b, 1967, 1968, and 1970) has actively studied the transformation in *T. vorax*. Briefly, Buhse (1967) followed Claff's (1947) study and found that the transformation in *T. vorax* was induced by suspending microstomes in a transforming principle, stomatin, released by the potential prey, *T. pyriformis*. This process occurs in four and a half hours after stomatin addition (Buhse & Carmeron, 1968). Some analysis of stomatogenesis was done by scanning electron and light microscopy (Buhse, Corliss, & Holsen, 1970). This oral replacement is preceded by RNA synthesis and protein synthesis which are stimulated by stomatin (Buhse & Carmeron, 1968).

According to Buhse's work (1962), in nature the microstome→macrostome transformation of *T. vorax* is associated only with living *T. pyriformis*. Once the prey, *T. pyriformis*, has been exhausted, the reverse transformation, which always involves division of the carnivorous macrostome to form two tailed microstomes, occurs (Kidder et al., 1940; Williams, 1961; and Buhse, 1966b). Evidently, the presence of *T. pyriformis* in the same collection with *T. vorax* on 17 July 1969 could explain the occurrence of the carnivorous *T. vorax* -- *T. pyriformis* was the source of the microstome → macrostome transforming principle, stomatin, and the prey of the carnivorous macrostome.

Since the irreversible pyriform microstome was described (Kidder et al., 1940; and Corliss, 1953a) as "a curious stage in that forms in it are morphologically indistinguishable from *T. pyriformis*" (quoted on page 60), it had been very uncertain whether the pyriform holotrich is just a stage of *T. vorax* or the true *T. pyriformis* if it is present in the same preparation with the other forms of *T. vorax*. As stated on page 65, "They might either be '*T. pyriformis*' (the prey and stomatin-...-source of *T. vorax*) or irreversible pyriform microstome forms derived from *T. vorax*," (see the last paragraph of *T. vorax*, p. 65).

The allocation of *T. vorax* strains V_1 and PP which had been reported to be irreversible pyriform microstomes of *T. vorax* (Kidder et al., 1940, and Corliss, 1953) was questioned by Loefer et al. (1958), and Shaw and Williams (1963). Their data from nutritional and serological experiments indicate that the strains V_1 and PP are actually strains of *T. pyriformis*. Later, both the immunological (Corbett and Sweeney, 1966) and the somatic infraciliature (Loefer et al., 1966)

studies support the view of Shaw and Williams. Consequently, *T. vorax* strains V, PP and V_1 are proposed to be *T. pyriformis* (Loefer et al., 1966). This leaves *T. vorax* represented by two extant strains, V_2 and Tur, both of which are polymorphic.

Therefore, it is most likely that the non-transformable, pyriform *Tetrahymena* in the same preparation with *T. vorax* of the present study is *T. pyriformis* - the source of stomatin and the prey of *T. vorax*.