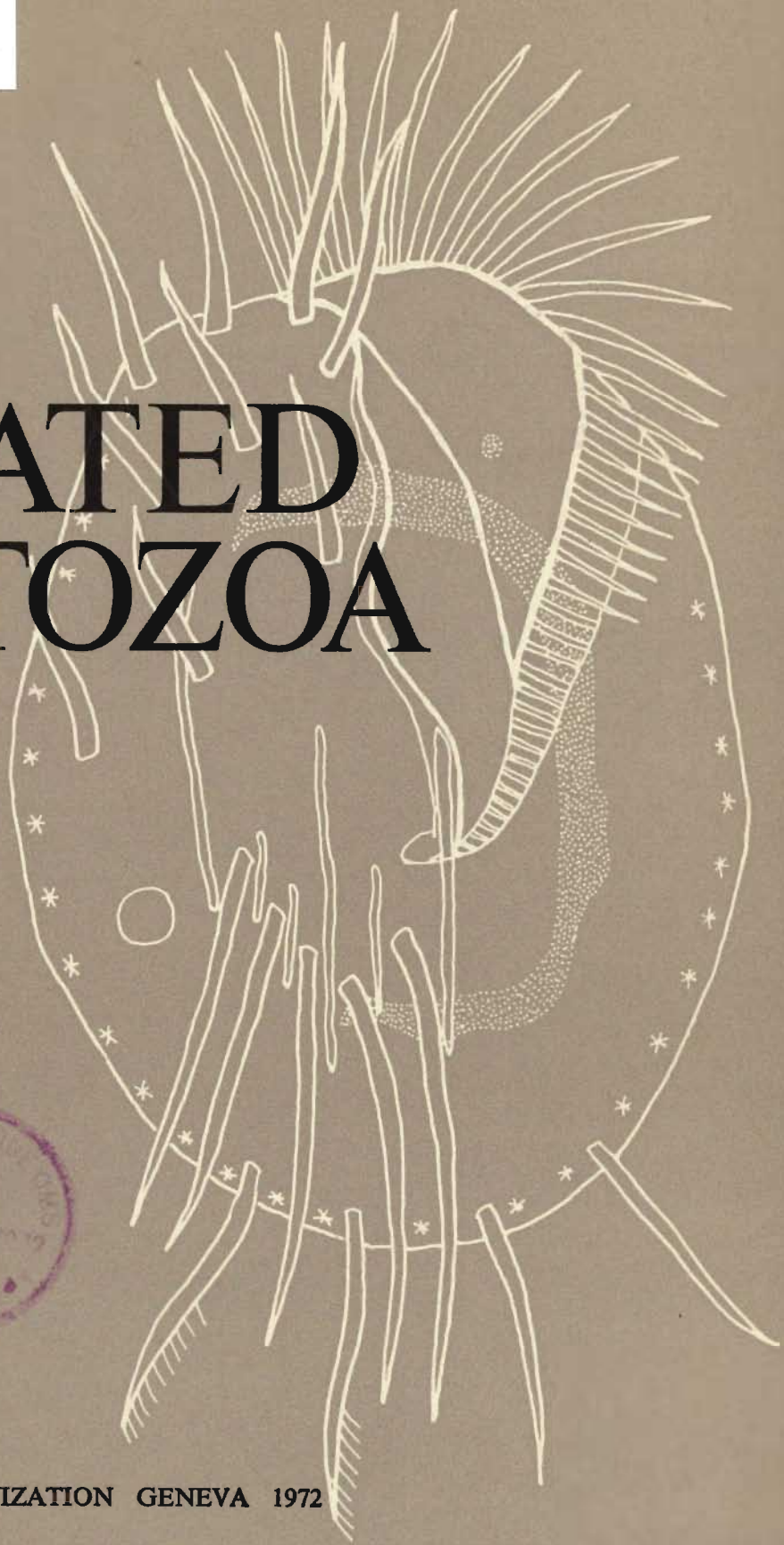
CILIATED PROTOZOA

HARTMUT BICK



WORLD HEALTH ORGANIZATION GENEVA 1972

CILIATED PROTOZOA

An illustrated guide to the species used as biological indicators in freshwater biology

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WORLD HEALTH ORGANIZATION

GENEVA

1972

PRINTED IN SWITZERLAND

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INTRODUCTION

Many species of ciliated protozoa are used as indicators for the ecological monitoring of water quality and they can also be used in ecological studies of aquatic habitats in which mosquitos and other vectors and intermediate hosts of disease organisms are breeding. However, taxonomic difficulties are frequently experienced by investigators and this illustrated guide has therefore been prepared as a service to freshwater biologists in the fields of vector control and sanitary engineering. The guide includes a taxonomic key to the most important families and genera of non-parasitic freshwater ciliates and 84 species descriptions dealing with morphological and ecological features of the ciliated protozoa employed in biological methods for assessing water quality. In order to allow broad comparisons to be made between the various species and genera, 135 species are illustrated.

When ciliated protozoa are to be identified, the following points should be remembered. A general feature of the Class Ciliatea is the presence of hairlike structures called cilia. The cilia, or compound ciliary structures, serve as organelles of locomotion or feeding or both. In contrast to the other classes of the Phylum Protozoa, two kinds of nuclei, the macronucleus and the micronucleus, are always present.

Species identifications of ciliates are based on the size and shape of the body, and on the structure and arrangement of certain organelles, such as the ciliation, macronucleus, contractile vacuole, and pellicle. Shape and size are best determined in living animals since specimens killed and stored in preserving fluids such as formol and ethanol cannot in general be identified at all. Most ciliates being rather small (size range: 10 μm–1 mm; average size about 20–200 μm), it is always necessary to use a high-power microscope (magnification range: $\times$100–1 000) for identifications. The use of phase-contrast microscopy is frequently helpful. In view of the rapid movements of many ciliates, it is useful to slow down the organisms by adding a small drop of methyl cellulose [1] to the biological material.

A quick method of determining the shape of nuclei is to kill and stain simultaneously with methyl-green–acetic acid,[2] the stain being allowed to run under the cover glass. In order to determine the ciliation of spirotrich ciliates, a drop of a saturated aqueous solution of mercuric chloride may be added to the sample.

Material to be examined for ciliated protozoa may be bottom sediments, sludge, scrapings from stones or plants, and plankton samples (taken by means of a plankton net with a mesh smaller than 25 μm). The sample may be concentrated by centrifugation. A very promising method for the evaluation of water quality is the investigation of the periphyton community (*Aufwuchs*) living on an artificial substrate such as a microscope slide. Slides are exposed in bodies of water for 4–8 weeks and then may be used directly for microscopic analysis (Sládecková, 1960; Wilbert, 1969). The number of species of ciliated protozoa occurring in the periphyton community

[1] Prepared by dissolving 10 g of methyl cellulose in 90 ml of hot water.

[2] Prepared by dissolving 0.1 g of methyl green dye in 99 ml of water and adding 1 ml of glacial acetic acid.

is very high; Wilbert (1969) and Nusch (1969) listed about 140 species of free-swimming and creeping ciliate and about 30 species of sessile ciliate, in the periphyton of ponds and reservoirs.

Ciliates should always be identified in a small drop of material placed on a microscope slide and covered with a cover glass. In order to make individual counts of ciliates, a Sedgewick–Rafter cell or a Kolkwitz chamber (a plankton-counting chamber containing 0.5 ml of fluid) may be used; low-power objectives only (magnification approx. $\times 125$) can be used with these chambers. When ciliates are counted in a chamber, their movements must be slowed down by adding methyl cellulose to the medium or stopped by adding a drop of aqueous Lugol's iodine solution.[1] When periphyton communities growing on artificially exposed microscope slides are to be counted the counts may be made directly from the slide, calculating the number of individuals per cm^2.

[1] To prepare this reagent, dissolve 6 g of potassium iodide in 40 ml of water, dissolve 4 g of iodine crystals in the solution, and add water up to 100 ml.

SYNOPSIS OF THE MOST IMPORTANT TAXA OF NON-PARASITIC CILIATES

Nomenclature and classification as recommended by the Committee on Taxonomy and Taxonomic Problems of the Society of Protozoologists [1]

Phylum *PROTOZOA*

Class *CILIATEA*

Subclass *HOLOTRICHIA*

Order GYMNOSTOMATIDA

Suborder RHABDOPHORINA (= PROSTOMATINA + PLEUROSTOMATINA)

Family COLEPIDAE
Family ENCHELYIDAE
Family AMPHILEPTIDAE
Family ACTINOBOLINIDAE [2]
Family DIDINIDAE
Family TRACHELIIDAE
Family LOXODIDAE [2]
Family SPATHIDIIDAE [2]
Family METACYSTIDAE [2]

Suborder CYRTOPHORINA (= HYPOSTOMATINA)

Family DYSTERIIDAE [2]
Family CHLAMYDODONTIDAE (= CHILODONELLIDAE)
Family NASSULIDAE [2]

Order TRICHOSTOMATIDA

Family COLPODIDAE
Family MICROTHORACIDAE [2]
Family PLAGIOPYLIDAE
Family TRIMYEMIDAE
Family MARYNIDAE [2]

Order HYMENOSTOMATIDA

Suborder TETRAHYMENINA

Unassigned tetrahymenine hymenostomes *sensu* Corliss (1961)
Family OPHRYOGLENIDAE [2]
Family COHNILEMBIDAE (= LEMBIDAE)
Family TETRAHYMENIDAE

Suborder PENICULINA

Family PARAMECIIDAE
Family CINETOCHILIDAE
Family UROCENTRIDAE
Family FRONTONIIDAE

Suborder PLEURONEMATINA

Family PLEURONEMATIDAE (= CYCLIDIIDAE)

Subclass *PERITRICHIA*

Order PERITRICHIDA

Suborder SESSILINA

Family OPHRYDIIDAE
Family VORTICELLIDAE
Family EPISTYLIDAE
Family VAGINICOLIDAE
Family LAGENOPHRYIDAE [2]
Family SCYPHIIDAE [2]
Family ASTYLOZOIDAE [2]

Suborder MOBILINA

Family URCEOLARIIDAE [2]

[1] Honigberg et al. (1964); see also Corliss (1961).
[2] Family is included in the key (p. 10) but no species descriptions are given.

Subclass *SUCTORIA*

Family PODOPHRYIDAE
Family DENDROSOMATIDAE
Family DISCOPHRYIDAE

Subclass *SPIROTRICHIA*

Order HETEROTRICHIDA

Family BURSARIIDAE [1]
Family STENTORIDAE
Family GYROCORYTHIDAE (= METOPIDAE = CAENOMORPHIDAE)
Family SPIROSTOMATIDAE
Family CONDYLOSTOMATIDAE [1]
Family FOLLICULINIDAE [1]

Order OLIGOTRICHIDA

Family HALTERIIDAE
Family STROBILIDIIDAE [1]

Order TINTINNIDA

Family TINTINNIDIIDAE

Order ODONTOSTOMATIDA (= CTENOSTOMATIDA)

Family DISCOMORPHELLIDAE (= DISCOMORPHIDAE)
Family EPALXELLIDAE (= EPALXIDAE)

Order HYPOTRICHIDA

Family ASPIDISCIDAE
Family EUPLOTIDAE
Family OXYTRICHIDAE

[1] Family is included in the key (p. 10) but no species descriptions are given.

KEY TO FAMILIES AND GENERA

The key offered below is basically dichotomous and consists of a question and a counter-question; the questions are numbered 1, 2, 3, etc., and the appropriate counter-questions are placed in parentheses: (2), 2 (1), 3 (40), etc. Each question leads either to a new pair of contrasting features or to the taxon sought. Each terminal point of the key is indicated by an asterisk (*).

This key is designed for use with live non-parasitic ciliates. Nearly all species mentioned are illustrated either in the key itself or in the individual species characterizations. In these illustrations, simple somatic ciliation is frequently represented by dots only. The scale line on the figures is equivalent to 10 μm unless otherwise indicated. The terms right and left refer to the organism itself and not to the drawing.

Although the key was designed primarily for the identification of ciliated protozoa used in ecological monitoring of water quality, it was necessary to include additional species in order to allow broad comparisons to be made between the various taxa. Those using the key should remember that about 5 000 species of ciliated protozoa have been described and where the identification of any specimen is in doubt, more complete monographs (e.g., Kahl, 1930–35) should be consulted.

Useful keys to the genera of ciliated protozoa are found in Noland (1959) and Matthes & Wenzel (1966). Full descriptions of many genera and species are included in Kudo (1966).

KEY TO FAMILIES AND GENERA

1 (2). Mature stages without any cilia but with suctorial tentacles; typically sessile . . . . . Subclass Suctoria *

Five families, predominantly stalked, without or with lorica, reproduction by budding, migratory larvae with cilia (Fig. 1D);

e.g., Podophryidae (Fig. 1A, 1B), body form regular, with or without stalk, suctorial tentacles distributed on entire surface or arranged in groups, budding exogenous—*Podophrya fixa* O. F. Müller (see Fig. 67; p. 130), *Metacineta mystacina* (Ehrenberg) (see Fig. 68; p. 132); *Sphaerophrya soliformis* Lauterborn (see Fig. 69; p. 134);

Dendrosomatidae (Fig. 1C), body form irregular or branching, suctorial tentacles in clusters, neither lorica nor stalk, budding endogenous—*Dendrosoma radians* Ehrenberg (see Fig. 70; p. 136);

Discophryidae (Fig. 71), body form regular, with or without stalk, without lorica, small number of tentacles arranged in groups, budding endogenous—*Heliophrya rotunda* (Hentschel) (see Fig. 71; p. 138).

2 (1). Cilia present in active stages; only encysted specimens without cilia 3

3 (40). Somatic ciliation absent or restricted to either a posterior ciliary girdle or few groups of longer cilia, always with conspicuous buccal ciliation at anterior pole; body ovoid, spherical or bell-shaped; many species stalked and sessile; with or without lorica 4

4 (33). Buccal ciliation running counterclockwise into the buccal cavity (vestibulum); predominantly sessile and stalked, solitary or colonial, mature sessile stages generally without somatic ciliation; some motile species and the migratory larval forms of sessile species equipped posteriorly with a ciliary girdle (Subclass Peritrichia, Order Peritrichida) . . . 5

5 (10). Motile, without stalk; ectozoic or free-swimming 6

6 (7). Without posterior girdle of cilia, rear end with 1 or 2 stiff cilia (Fig. 2A), sometimes with spine-like processes below buccal area (Fig. 2B) . . . . . Family Astylozoidae *

e.g., *Astylozoon* Engelmann (Fig. 2A), *Hastatella* Erlanger (Fig. 2B).

7 (6). With posterior girdle of cilia 8

8 (9). Free-swimming, no attaching organelle . . . . . *Telotrochidium* Kent * (Fig. 2C) or larvae (" telotrochs ") of sessile Peritrichida *

9 (8). Ectozoic on *Hydra*, planarians, fishes, tadpoles, etc., sometimes planktonic; body axis shortened, attaching organelle on the aboral pole (Fig. 3A) . . . . . Suborder Mobilina *

Family Urceolariidae, e.g., *Trichodina pediculus* (O. F. Müller) (Fig. 3A).

10 (5). Sessile, occurring on various living and non-living substrates; solitary or colonial; some forms loricate (Suborder Sessilina) 11

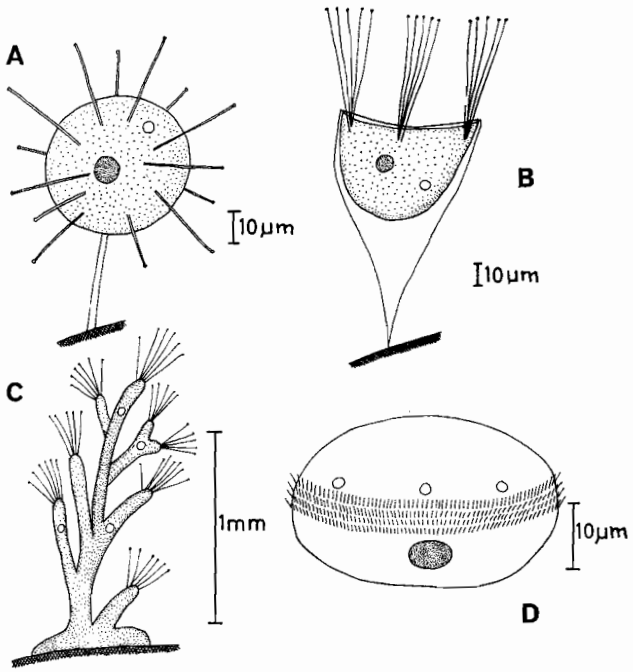

Fig. 1. Suctoria, diagrammatic representations:
A, *Podophrya fixa* O. F. Müller;
B, *Metacineta* Bütschli;
C, *Dendrosoma* Ehrenberg;
D, migratory larva of *Trichophrya* Claparède & Lachmann (Dendrosomatidae).

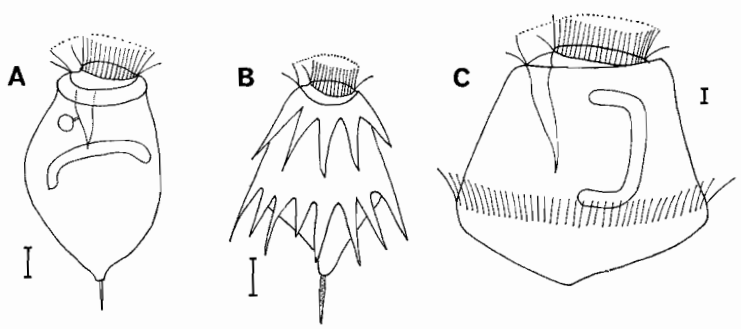

Fig. 2. Peritrichia, diagrammatic representations:
A, *Astylozoon* Engelmann (Astylozoidae);
B, *Hastatella* Erlanger (Astylozoidae);
C, *Telotrochidium* Kent (Epistylidae).

11 (12). Oral end pulled out into a long contractile neck; contractile vacuole in the middle of the cell and connecting with buccal cavity by long canal (Fig. 3B); some species form large gelatinous colonies . . . . . Family Ophrydiidae *

Ophrydium Bory St. Vincent (Fig. 3B)—
O. versatile (O. F. Müller) and *O. sessile* Kent (see p. 104).

12 (11). Not as described above 13

13 (30). Without lorica 14

14 (15). Without stalk . . . . . Family Scyphidiidae *

e.g., *Scyphidia* Dujardin (Fig. 3C).

15 (14). With stalk 16

16 (21). Stalk contractile by myonemes 17

17 (18). Stalk unbranched; solitary . . . . . *Vorticella* L. * (Fig. 4A, 4B)

V. campanula Ehrenberg (see Fig. 5B; p. 108);
V. convallaria L. (see Fig. 57; p. 110);
V. microstoma Ehrenberg (see Fig. 55; p. 106);
V. nebulifera O. F. Müller, var. *similis* (Stokes) (see p. 112);
V. striata Dujardin var. *octava* (Stokes) (see Fig. 58; p. 113).

18 (17). Stalk branched; colonial 19

19 (20). Myonemes of all stalks of a colony are continuous (Fig. 4C), therefore the whole colony contracts or expand simultaneously . . . . . *Zoothamnium* Bory St. Vincent *

20 (19). Myonemes in stalks are not continuous (Fig. 4D), therefore individual stalks contract or expand independently . . . . . *Carchesium* Ehrenberg *

C. polypinum L. (see Fig. 59; p. 114).

21 (16). Stalk not contractile (Family Epistylidae) 22

22 (25). Buccal area with a disk that is separated from the peristomial border by a deep incision (Fig. 4E, 4F) 23

23 (24). Stalk dichotomous-branched . . . . . *Opercularia* Stein * (Fig. 4E)

O. nutans (Ehrenberg) (see Fig. 63; p. 122);
O. coarctata (Claparède & Lachmann) (see Fig. 62; p. 120).

24 (23). Stalk unbranched; predominantly attached to insect larvae and other animals . . . . . *Pyxidiella* Corliss * (Fig. 4F)

25 (22). Buccal area with a disk that is not set off from the border by a deep incision (Fig. 4G) . . 26

26 (27). Stalk unbranched . . . . . *Rhabdostyla* Kent * (Fig. 4G)

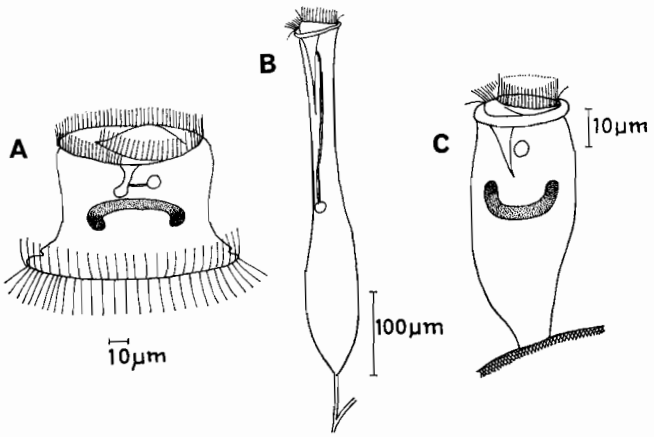

Fig. 3. Peritrichia *(continued)*:
A, *Trichodina pediculus* (O. F. Müller) Ehrenberg (Urceolariidae);
B, *Ophrydium* Bory St. Vincent (Ophrydiidae), diagrammatic representation;
C, *Scyphidia* Dujardin (Scyphidiidae), diagrammatic representation.

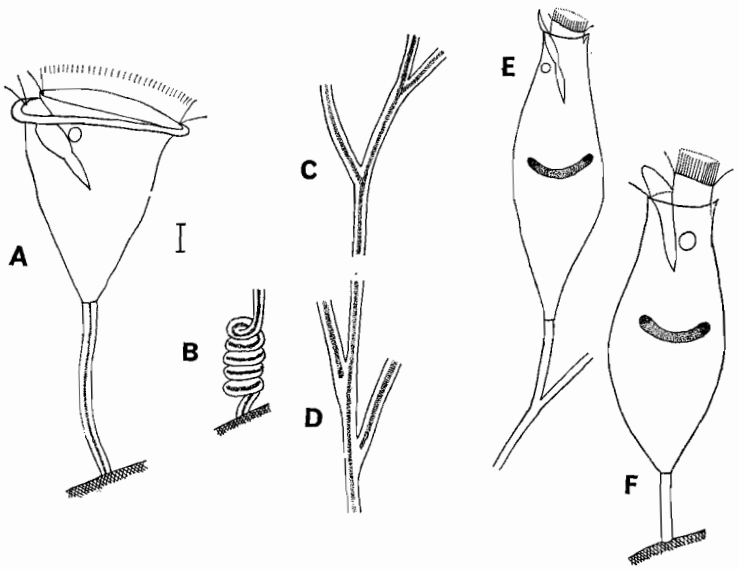

Fig. 4A–4F. Peritrichia *(continued)*, diagrammatic representations:
A, *Vorticella* L. (Vorticellidae);
B, contracted stalk of *Vorticella*;
C, stalk of *Zoothamnium* Bory St. Vincent, branching point;
D, stalk of *Carchesium* Ehrenberg, branching point;
E, *Opercularia* Stein (Epistylidae);
F, *Pyxidiella* Corliss (Epistylidae);

27 (26). Stalk branched 28

28 (29). Adoral zone with 4–6 turns . . . . . *Campanella umbellaria* L. * (Fig. 61)

29 (28). Adoral zone with about one turn . . . . . *Epistylis* Ehrenberg *
E. plicatilis Ehrenberg (Fig. 60).

30 (13). With lorica 31

31 (32). When extended, only the peristomial portion protrudes beyond lorica . . . . . Family Lagenophryidae *
e.g., *Lagenophrys vaginicola* Stein (Fig. 4H).

32 (31). When extended, the anterior part of the body extends beyond lorica . . . . . Family Vaginicolidae *
e.g., *Cothurnia* Ehrenberg (Fig. 4I);
Platycola truncata Fromentel (see Fig. 65; p. 126);
Thuricola folliculata (O. F. Müller) (see Fig. 66; p. 128);
Vaginicola ingenita (O. F. Müller) (see Fig. 64; p. 124).

33 (4). Buccal ciliation running clockwise into the buccal cavity; predominantly motile; some species with vase-like lorica; somatic ciliation absent or sparse, never with posterior girdle of cilia (subclass Spirotrichia *partim*) 34

34 (35). Case-bearing (Fig. 5A) . . . . . Order Tintinnida *
e.g., *Tintinnidium fluviatile* Stein (see Fig. 5A; p. 157).
Free-swimming or sessile.

35 (34). Without case (Fig. 5B–5D) (Order Oligotrichida) 36

36 (37). Adoral zone of membranelles forming a circle at the anterior pole with the mouth inside it (Fig. 5B) . . . . . Family Strobilidiidae *
e.g., *Strobilidium gyrans* (Stokes) (Fig. 5B); according to Liebmann (1962), this is an oligosaprobic indicator organism but sometimes occurring under beta-mesosaprobic conditions.

37 (36). Adoral zone of membranelles not forming a circle; mouth somewhat ventral (Fig. 5C, 5D) (Family Halteriidae) 38

38 (39). Long tactile cilia in the equatorial zone of the body . . . . . *Halteria* Dujardin * (Fig. 5C)
e.g., *H. grandinella* (O. F. Müller) Dujardin (see p. 156)

39 (38). Without tactile cilia . . . . . *Strombidium* Claparède & Lachmann *
e.g., *S. viride* Stein (Fig. 5D); with zoochlorellae.

40 (3). Somatic ciliation present, with or without conspicuous buccal ciliation; in case of sparse somatic ciliation no predominant buccal ciliation at anterior pole present; few forms sessile or loricated, predominantly motile 41

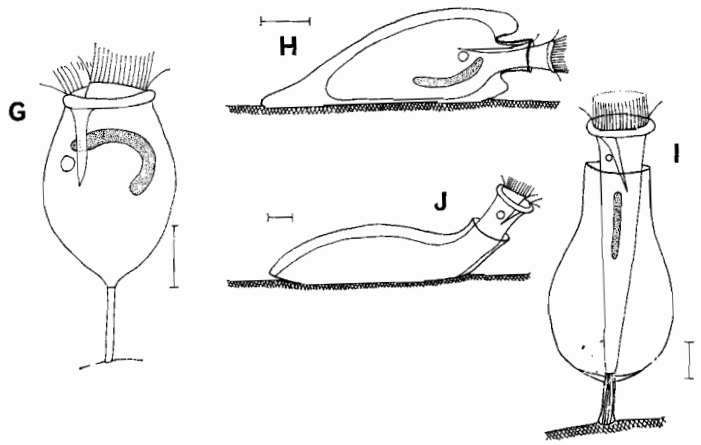

Fig. 4G–4J. Peritrichia *(continued)*, diagrammatic representations; Fig. 4G and 4H redrawn from Kahl (1935).
G, *Rhabdostyla pyriformis* (Perty), Epistylidae;
H, *Lagenophrys vaginicola* Stein (Lagenophryidae), lateral view;
I, *Cothurnia* Ehrenberg (Vaginicolidae), lateral view;
J, *Platycola* Kent (Vaginicolidae), lateral view.

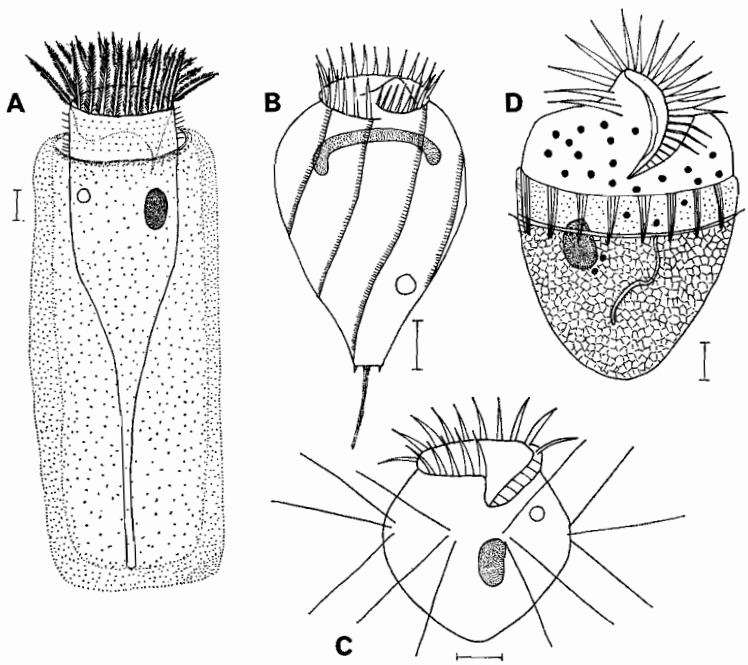

Fig. 5. Tintinnida (A) and Oligotrichida (B, C and D); Fig. 5B and Fig. 5D redrawn from Kahl (1932).
A, *Tintinnidium fluviatile* Stein;
B, *Strobilidium gyrans* (Stokes);
C, *Halteria grandinella* (O. F. Müller) Dujardin;
D, *Strombidium viride* Stein.

41 (42). Body laterally compressed, flattened, wedge-shaped, often with spines and bizarre excisions; sparse ciliation; no cirri; buccal cavity with 8 rather inconspicuous membranelles (Fig. 6A); rather small ciliates (below 100 μm); occurring in putrefying sludge rich in hydrogen sulfide (" sapropel ") . . . . . Order Odontostomatida *

Family Discomorphellidae—*Discomorphella pectinata* (Levander) (see Fig. 80; p. 158).

Family Epalxellidae (Fig. 6A)—

Saprodinium dentatum Lauterborn (see Fig. 83; p. 164);

Epalxella striata (Kahl) (see Fig. 81; p. 160);

Pelodinium reniforme Lauterborn (see Fig. 82; p. 162).

42 (41). Not as described above 43

43 (72). Locomotor ciliation restricted to the ventral surface of the dorsoventrally flattened body; with strong cilia or cirri (= groups of cilia fused into a single organelle) arranged in definable groups; dorsal surface naked or with tiny sensory cilia (" tactile bristles "); buccal area always with adoral zone of membranelles (= short double or triple rows of cilia fused into pennant-like blades) leading clockwise to the mouth (Fig. 6B, 6C, 7,8). Order Hypotrichida 44

44 (45). Small inconspicuous buccal area located laterally, only few small adoral membranelles; cirri limited to a small anterior group of 7 " frontoventrals " and a group of posterior " transversals " (5–12); small ovoid body; dorsal side without cilia, sometimes ribbed . . . . . Family Aspidiscidae *

Only one genus:

Aspidisca Ehrenberg (Fig. 6B)—

A. costata (Dujardin) (see Fig. 84; p. 166);

A. lynceus Ehrenberg (see Fig. 85; p. 168).

45 (44). Buccal area with well-developed adoral zone of membranelles in the anterior region; ventral surface with locomotory cilia or cirri; dorsal surface with only small, tactile bristles that are mostly inconspicuous 46

46 (47). No longitudinal rows of cilia or cirri, but the well-developed cirri restricted to groups of frontoventrals, transversals, and caudals (Fig. 6C) . . . . . Family Euplotidae *

e.g., *Euplotes* Ehrenberg (Fig. 6C)—

E. affinis Dujardin (see Fig. 87; p. 172);

E. patella (O. F. Müller) Ehrenberg (see Fig. 86; p. 170).

47 (46). Longitudinal rows of cilia or cirri present, at least " marginals " on each side of the ventral surface; dorsoventrally flattened (Family Oxytrichidae) 48

48 (53). Peristome-bearing anterior part of the body narrowed (Fig. 7); ventral and marginal rows of cirri run spirally (Fig. 7A, 7C); ciliary rows sometimes reduced (Fig. 7B) 49

49 (50). Narrowed anterior part less than one-quarter of the body length; not drawn out into slender form. Often with gelatinous tubes . . . . . *Strongylidium* Sterki * (Fig. 7A)

50 (49). Narrowed anterior part over one-quarter of the body length; very long and slender (Fig. 7B, 7C) 51

51 (52). Peristome-bearing anterior part extensile and contractile. With lorica; attached to substrate . . . . . *Chaetospira* Lachmann * (Fig. 7B)

C. muelleri Lachmann (see Fig. 7B; p. 186);

C. remex Hudson (see Fig. 94; p. 187).

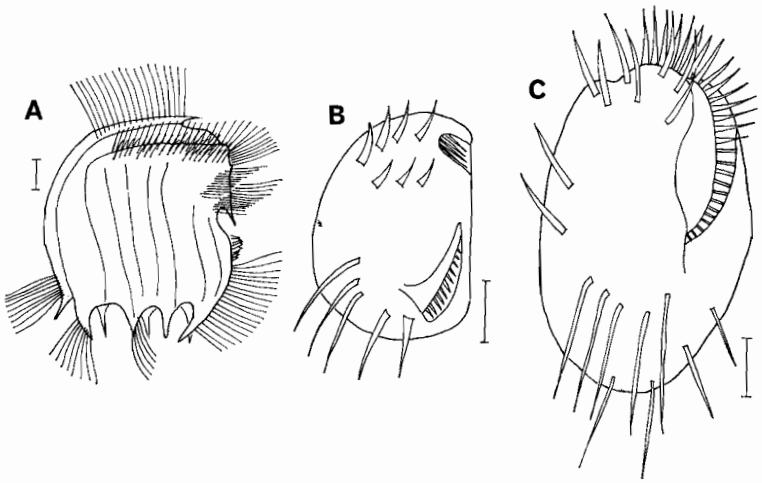

Fig. 6. Odontostomatida (A) and Hypotrichida (B and C), diagrammatic representations:
A, *Saprodinium* Lauterborn;
B, *Aspidisca* Ehrenberg;
C, *Euplotes* Ehrenberg.

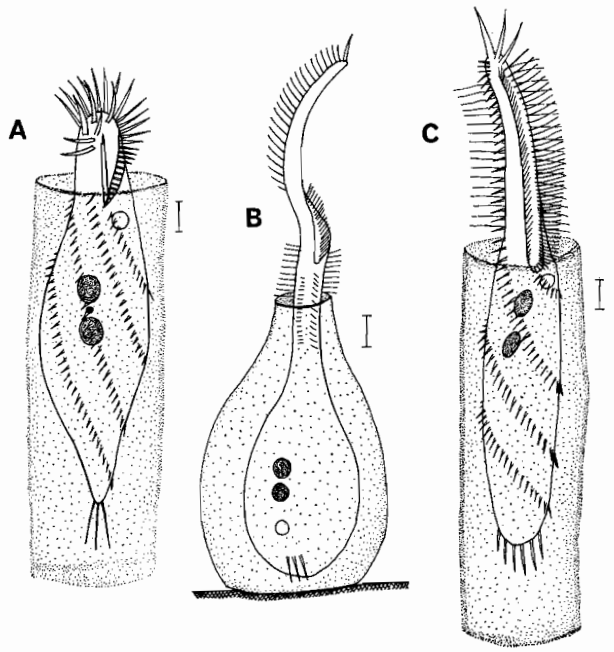

Fig. 7. Hypotrichida, Oxytrichidae; Fig. 7A and 7C redrawn, with modifications, from Kahl (1932), Fig. 7B redrawn from various sources.
A, *Strongylidium crassum* Sterki;
B, *Chaetospira muelleri* Lachmann, extended;
C, *Stichotricha secunda* Perty.

52 (51). Peristome-bearing part not contractile; sometimes in mucilaginous tubes, which may be branched. Posterior part of the body with or without cirri . . . *Stichotricha* Perty * (Fig. 7C)

53 (48). Peristome-bearing zone not narrowed; ventral and marginal rows of cirri not running spirally 54

54 (57). Elongated body drawn out into a tail-like portion 55

55 (56). With usually 2 rows of ventral cirri (plus right and left marginal rows) (Fig. 8A) . . . . . *Uroleptus* Ehrenberg *
e.g., *U. piscis* (O. F. Müller) Stein (Fig. 8A); according to Kolkwitz (1950), this is a beta-mesosaprobic indicator organism.

56 (55). Ventral cirri restricted to 5–8 (Fig. 8B) . . . . . *Urosoma* Kowalewski *

57 (54). Body not drawn out into a tail-like portion 58

58 (63). Ventral cirri predominantly in rows 59

59 (60). Ventral cirri predominantly on 1 oblique row, few isolated ventral cirri behind the buccal area and in the posterior region, no caudal cilia, right and left marginals meet as a continuous row posteriorly . . . . . *Gastrostyla* Engelmann *
e.g., *G. steini* Engelmann (see Fig. 93; p. 184).

60 (59). Two or more rows of ventral cirri (plus right and left marginal rows) 61

61 (62). Four or more rows of ventral cirri . . . . . *Urostyla* Ehrenberg *
e.g., *U. weissei* (Stein) (see Fig. 90; p. 178).

62 (61). Two rows of ventral cirri, 3 strong frontal cirri . . . . . *Holosticha* Wrzesniowski * (Fig. 8C)
Numerous species.

63 (58). Ventral cirri arranged in groups and restricted in number (mostly 5 ventrals); right and left rows of marginal cirri present; predominantly 8 frontals and 5 transversals (*Oxytricha* group. There are great similarities between the following five genera; in any case of doubt, consult comprehensive books such as Kahl (1932)) 64

64 (65). Right border of buccal area curves left, or spirals into a pit in buccal area (Fig. 8D) . . . . . *Steinia* Diesing *

65 (64). Right border of buccal area not curved (Fig. 9A, 9B) 66

66 (67). Right and left marginal rows of cirri meet as a continuous row posteriorly, without caudal cirri; two very similar genera . . . . . *Oxytricha* Bory St. Vincent * (Fig. 9A)
Body quite flexible, bends easily to right or left; e.g., *O. saprobia* Kahl (Fig. 9A), *O. fallax* Stein (see Fig. 91; p. 180).

. . . . . *Histriculus* Corliss *
Body stiff, only slight dorsoventral bending (in case of doubt look for No. 71).

67 (66). Marginal rows of cirri interrupted at posterior end, the interruption may be covered by the long transversals or the caudals 68

68 (69). Without caudals, sometimes very distinct dorsal tactile bristles that may be confused with caudals; body rather flexible . . . . . *Tachysoma* Stokes *
e.g., *T. pellionella* (O. F. Müller) (see Fig. 92; p. 182).

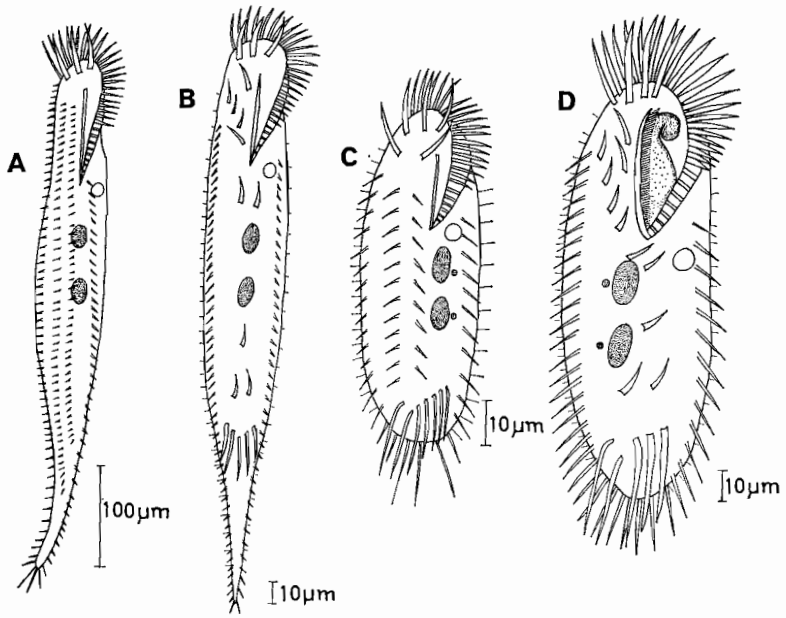

Fig. 8. Hypotrichida, Oxytrichidae (*continued*) ; Fig. 8C and 8D redrawn, with some modifications, from Kahl (1932).
A, *Uroleptus piscis* (O. F. Müller) Stein;
B, *Urosoma cienkowski* Kowalewski;
C, *Holosticha algivora* Kahl;
D, *Steinia platystoma* (Ehrenberg) Stein.

69 (68). With caudals 70

70 (71). Body not flexible; 3 conspicuous long caudals that show very often fringes at the end; body ovoid to reniform . . . . . *Stylonychia* Ehrenberg *
e.g., *S. mytilus* Ehrenberg (see Fig. 88; p. 174); *S. putrina* (Stokes) (see Fig. 89; p. 176).

71 (70). Body flexible, bends easily to right and left; 3 (or 4) rather smooth and sometimes inconspicuous caudals; body mostly long ellipsoid . . . . . *Opisthotricha* Kent * (Fig. 9B)

72 (43). Body not dorsoventrally flattened, or in case of flattened body no cirri present, and buccal area without adoral zone of membranelles; body surface wholly or partly ciliated; with or without buccal ciliation 73

73 (74). Body medusoid with a long posterior spine; ciliation limited to the spiral peristome region, and to 1 or 2 dorsal rows of thick flexible cirri . . . . . *Caenomorpha* Perty * (Order Heterotrichida)
C. medusula Perty (see Fig. 77; p. 150).

74 (73). Not as described above 75

75 (90). Buccal area (" peristome ") bordered by a long adoral zone of membranelles, at least the proximal part of the zone is curved clockwise to the mouth (e.g., Fig. 10A); commonly uniform ciliation all over the body; body size often very large (Order Heterotrichida) . . 76

76 (77). Anterior part of the body twisted; adoral zone of membranelles oblique or spiral, starting anterior left and turning to posterior right . . . . . Family Gyrocorythidae * (= Metopidae)

Brachonella spiralis (Smith) Jankowski (see Fig. 76; p. 148);
Metopus es (O. F. Müller) Kahl (see Fig. 75; p. 146).

77 (76). Not as described above 78

78 (79). Peristome deeply sunken into the anterior part of the body forming a funnel-like cavity (Fig. 9C) . . . . . Family Bursariidae *

e.g., *Bursaridium pseudobursaria* (Fauré-Fremiet) Kahl (Fig. 9C).

79 (78). Peristome on surface level 80

80 (83). Peristome linear, narrow, adoral zone of membranelles very long, though sometimes inconspicuous; large, often elongated forms (Spirostomatidae) 81

81 (82). Conspicuous undulating membrane on right side of peristome; body spindle-form or ellipsoid, always somewhat narrowed anteriorly; dense ciliation; several species rose-coloured . . . . . *Blepharisma* Perty *

B. lateritium (Ehrenberg) (Fig. 10A); according to Kolkwitz (1950), this is a beta-mesosaprobic indicator organism.

82 (81). No undulating membrane present; body elongated, cylindrical, somewhat compressed, highly contractile; contractile vacuole terminal, large, with long dorsal canal . . . . . *Spirostomum* Ehrenberg *

S. ambiguum (O. F. Müller) Ehrenberg (see Fig. 78; p. 152);
S. teres Claparède & Lachmann (see Fig. 79; p. 154).

83 (80). Peristome broad, often circular in outline 84

84 (85). Peristome large triangular, wide at anterior end and V-shaped; peristomial field not ciliated but with a large membrane on right edge and adoral zone of membranelles on left . . . . . Family Condylostomatidae *

e.g., *Condylostoma* Bory St. Vincent (Fig. 10B).

85 (84). Peristome not as described above; peristomial field ciliated, without membrane 86

86 (87). Anterior end of the body extended into 2 wings bearing the adoral zone of membranelles (Fig. 10C); with flask-like pseudochitinous lorica attached to plants or other substrate . . . . . Family Folliculinidae *

Mostly marine, only one freshwater species—namely, *Folliculina bolteni* Kent (Fig. 10C)

87 (86). Anterior part without wing-like processes; free-swimming or attached; often housed in mucilaginous tubes (Stentoridae) 88

88 (89). Body trumpet-shaped (when extended, on account of its high degree of contractibility, the body may change its shape very greatly); adoral zone of membranelles encircles peristome on spiral form; contractile vacuole located in the anterior region . . . . . *Stentor* Oken *

S. coeruleus Ehrenberg (see Fig. 72; p. 140);
S. muelleri (Bory St. Vincent) (see p. 144);
S. polymorphus (O. F. Müller) (see Fig. 74; p. 144);
S. roeseli Ehrenberg (see Fig. 73; p. 142).

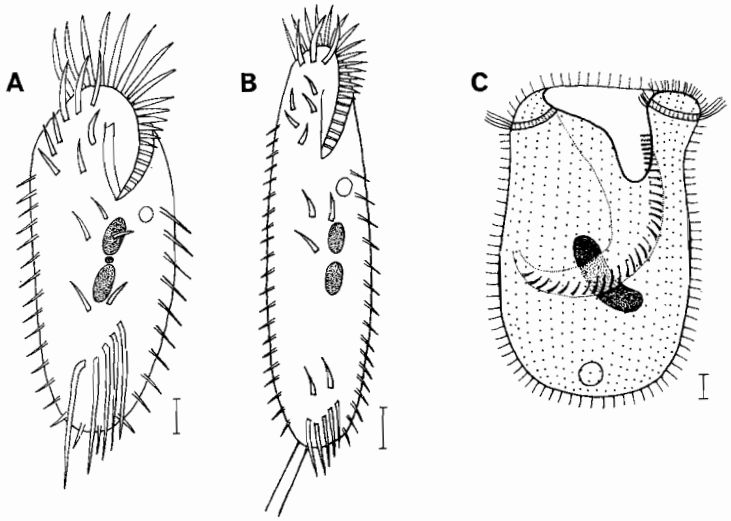

Fig. 9. Hypotrichida, Oxytrichidae (*continued*) (A and B), and Heterotrichida (C):
A, *Oxytricha saprobia* Kahl;
B, *Opisthotricha similis* Engelmann;
C, *Bursaridium pseudobursaria* (Fauré-Fremiet) Kahl, Bursariidae.

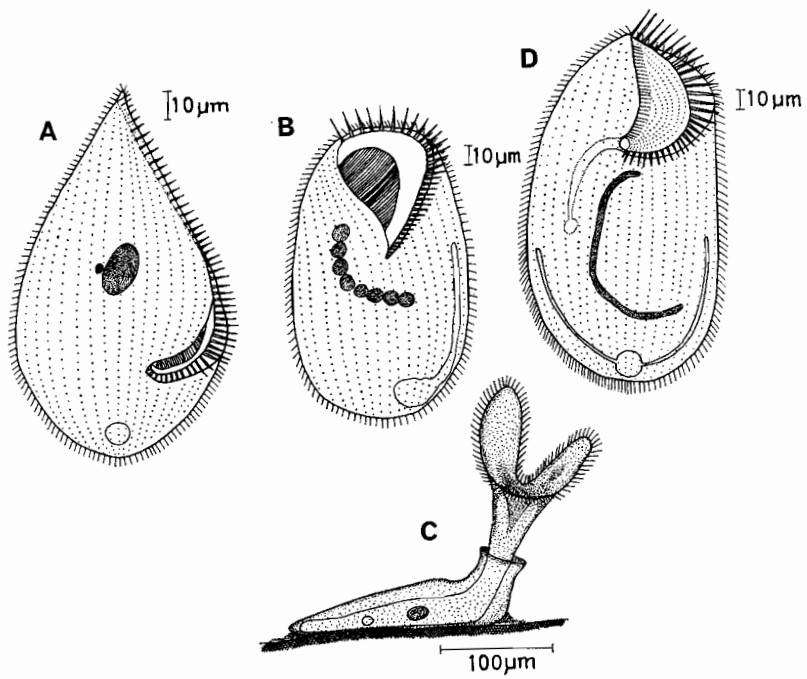

Fig. 10. Heterotrichida (*continued*); Fig. 10B redrawn from Kahl (1932), Fig. 10C and 10D redrawn from various sources.
A, *Blepharisma lateritium* (Ehrenberg), Spirostomatidae;
B, *Condylostoma vorticella* (Ehrenberg), Condylostomatidae;
C, *Folliculina bolteni* Kent, Folliculinidae;
D, *Climacostomum virens* (Ehrenberg), Stentoridae.

89 (88). Body ovoid, flattened. Noncontractile. Peristome ventral, near to the anterior pole (Fig. 10D). Contractile vacuole with 2 long canals . . . . *Climacostomum* Stein * (Fig. 10D)

90 (75). Buccal area without a long adoral zone of membranelles; oral ciliation lacking *or* consisting of simple cilia *or* composed of few predominantly inconspicuous membranous organelles 91

91 (124). Cytostome near or at surface; no oral ciliation; sometimes mouth a nearly invisible lateral slit opening only when feeding; margins of the slit are provided with trichocysts (cf., line 109) (Order Gymnostomatida) 92

92 (97). Circular mouth located mid-ventrally; gullet wall with fused armature of rods (" trichites "); body often dorsoventrally flattened and ciliation restricted to ventral surface (Suborder Cyrtophorina) 93

93 (94). Ciliation all over the body but dorsal ciliation usually less dense than that of the ventral surface . . . . . Family Nassulidae *

e.g., *Nassula gracilis* Kahl (Fig. 11A); according to Liebmann (1962), this is an oligosaprobic indicator organism.

94 (93). Ciliation only on the ventral surface 95

95 (96). With movable posterior stylus (Fig. 11B) . . . . . Family Dysteriidae *

e.g., *Trochilia minuta* (Roux) (Fig. 11B); according to Kolkwitz (1950), this is a beta-mesosaprobic indicator organism.

96 (95). Without stylus . . . . . Family Chlamydodontidae *

e.g., *Chilodonella cucullulus* (O. F. Müller) (see Fig. 34; p. 58); *Chilodonella uncinata* Ehrenberg (see Fig. 35; p. 60); *Phascolodon vorticella* Stein (Fig. 11C).

97 (92). The circular or slit-like mouth at or near anterior pole *or* lateral (Suborder Rhabdophorina) 98

98 (99). With pseudochitinous lorica, sedentary; cytostome terminal; uniform ciliation, sometimes one or more caudal cilia; with peculiar ectoplasmic alveolar zone . . . Family Metacystidae *

Predominantly in sapropelic habitats, feeding on sulfur-bacteria (especially purple-coloured bacteria); e.g., *Metacystis* Cohn (Fig. 12A); *Vasicola* Tatem (Fig. 12B).

99 (98). Not as described above 100

100 (101). With pellicular armour consisting of many small plates; barrel-shaped body; mouth at anterior pole . . . . . Family Colepidae *

e.g., *Coleps* Nitzsch—*C. hirtus* Nitzsch (see Fig. 22; p. 34).

101 (100). Not as described above 102

102 (103). With retractable tentacles in addition to uniform covering of somatic ciliation; tentacles extending in all directions when at rest, but retracted and inconspicuous when swimming; cytostome located anteriorly . . . . . Family Actinobolinida *

e.g., *Actinobolina* Strand (Fig. 12C); *Enchelyomorpha vermicularis* (Smith) Kahl, Fig. 12D). According to Liebmann (1962), this is a polysaprobic indicator organism; ecology is similar to that of *Trimyema compressum* (p. 68).

103 (102). Not as described above 104

104 (105). Mouth apical, often at the tip of a blunt cone, and surrounded by an unciliated area; cytopharynx with trichites (" toxicysts "), the mouth may be surrounded by retractile

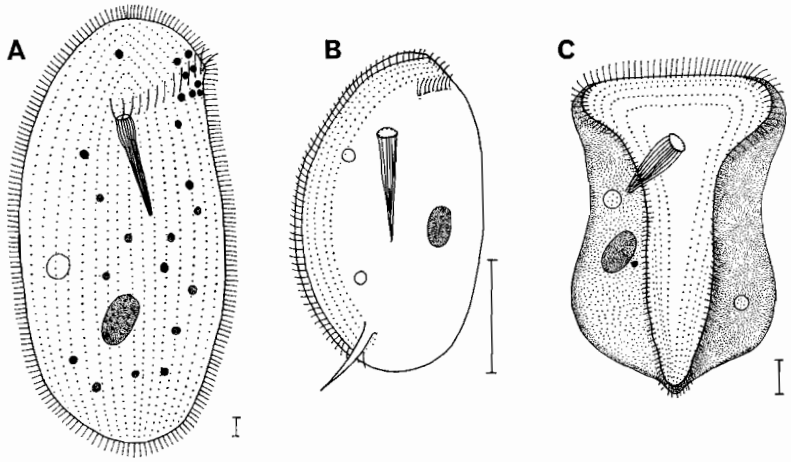

Fig. 11. Gymnostomatida, Cyrtophorina, ventral views:
A, *Nassula gracilis* Kahl (= *N. elegans* Blochmann), Nassulidae;
B, *Trochilia minuta* (Roux), Dysteriidae;
C, *Phascolodon vorticella* Stein, Chlamydodontidae.

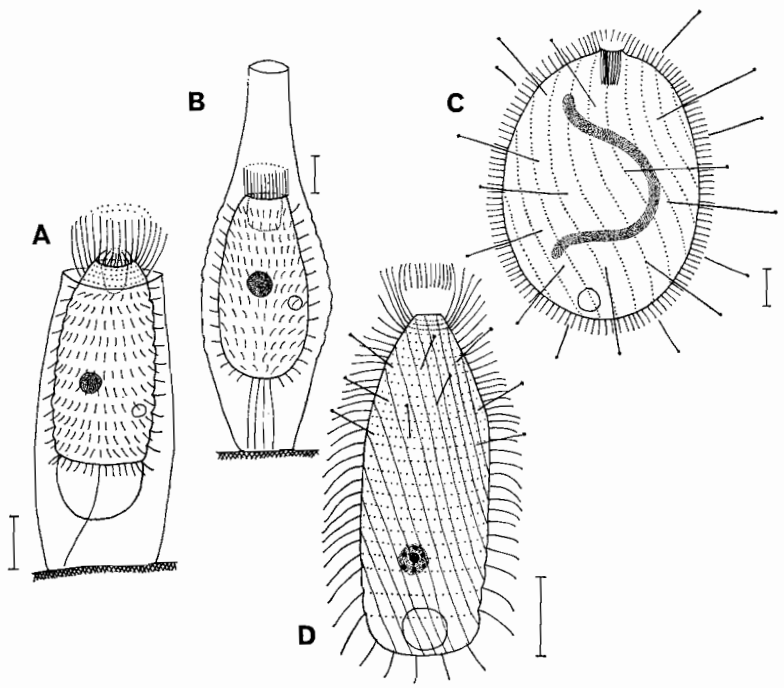

Fig. 12. Gymnostomatida, Rhabdophorina; Fig. 12B redrawn from Kahl (1930), Fig. 12D redrawn from various sources.
A, *Metacystis* sp., Metacystidae;
B, *Vasicola ciliata* Tatem, Metacystidae;
C, *Actinobolina radians* Stein, Actinobolinidae;
D, *Enchelyomorpha vermicularis* (Smith) Kahl, Actinobolinidae.

tentacles; body encircled by 1 or more rings of strong cilia, elsewhere naked or with short cilia . . . . . Family Didinidae * (Fig. 13A–13D)

e.g., *Didinium balbiani*, Bütschli (Fig. 13A);
D. nasutum (O. F. Müller) (see Fig. 31; p. 52);
Mesodinium Stein (Fig. 13B);
Askenasia Blochmann (Fig. 13C);
Acropisthium Perty (Fig. 13D).

105 (104). Not as described above 106

106 (107). Round mouth located laterally at the base of an anterior proboscis; body completely ciliated . . . . . Family Tracheliidae *

e.g., *Trachelius ovum* Ehrenberg (see Fig. 32; p. 54);
Dileptus anser (O. F. Müller) (see Fig. 33; p. 56).

107 (106). Not as described above.

108 (109). Mouth round or slightly elongated; if slit-like, very short, not over one-half the body width, located at or near the anterior pole, in some species located at the distal end of a long neck; body ciliation commonly complete and uniform, occasionally elongated caudal cilia present . . . . . Family Enchelyidae *

A large family with more than 30 genera;

e.g., *Lacrymaria* Bory St. Vincent; with a long contractile proboscis; near mouth, a ring-like constriction with a circle of longer cilia—*L. olor* (O. F. Müller) (see Fig. 24; p. 38).

Urotricha Claparède & Lachmann; posterior part of the body unciliated except 1 or a few caudal cilia—*U. farcta* Claparède & Lachmann (see Fig. 23; p. 36).

Platyophrya Kahl; laterally compressed, front end bent over, small subapical mouth slit-like or circular, rows of cilia running spirally—*P. vorax* Kahl (Fig. 14A).

Prorodon Ehrenberg; body somewhat irregular ovoid–cylindrical, mouth oval, gullet trichites double, very conspicuous; numerous species—*P. teres* Ehrenberg (Fig. 14B) has been classed as an alpha-mesosaprobic indicator-organism (Liebmann, 1962).

Holophrya Ehrenberg; body regular ovoid-ellipsoid, mouth round, with or without tiny trichites—*H. nigricans* Lauterborn (Fig. 14C).

109 (108). Mouth slit-like, apical or lateral, very often nearly invisible except when the animal is feeding; margins of the mouth-slit very often provided with trichocysts [1] 110

110 (111). Mouth-slit apically on a nonciliated ridge, sometimes extending down one side of the body . . . . . Family Spathidiidae *

e.g., *Spathidium* Dujardin (Fig. 15A); flask- or sack-shaped, laterally compressed, predominantly carnivorous; *Homalozoon vermiculare* (Stokes) (Fig. 15B), vermiform, flattened, ciliation only on right side, left side with longitudinal ridge, carnivorous, 650–1 500 μm in length, oligosaprobic and beta-mesosaprobic.

111 (110). Mouth-slit not apical, but lateral 112

112 (113). Mouth-slit on the concave side of the laterally compressed body (Fig. 15C); ciliation only on the right side . . . . . Family Loxodidae *

Only one genus: *Loxodes* Ehrenberg (Fig. 15C); feeding on algae and bacteria.

[1] i.e., Rod-like bodies that shoot out slender threads into the surrounding water when mechanically or chemically stimulated.

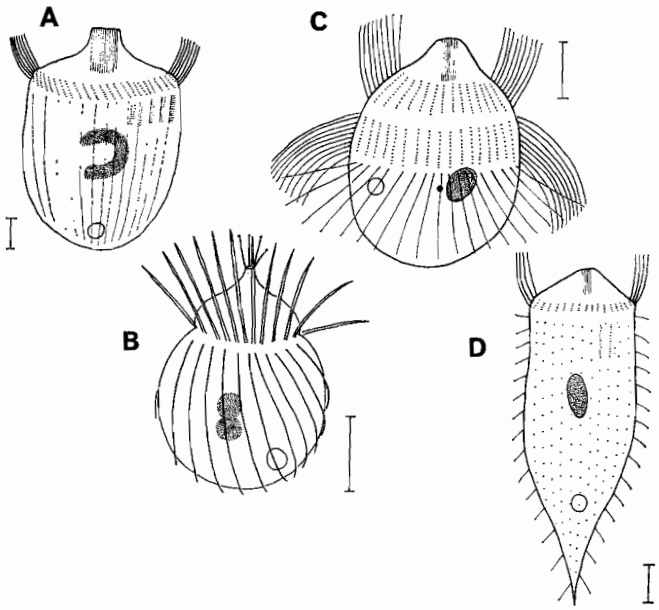

Fig. 13. Gymnostomatida, Rhabdophorina, Didinidae; Fig. 13B–13D redrawn from Kahl (1930).
A, *Didinium balbiani* Bütschli;
B, *Mesodinium pulex* Claparède & Lachmann;
C, *Askenasia volvox* Claparède & Lachmann;
D, *Acropisthium mutabile* Perty.

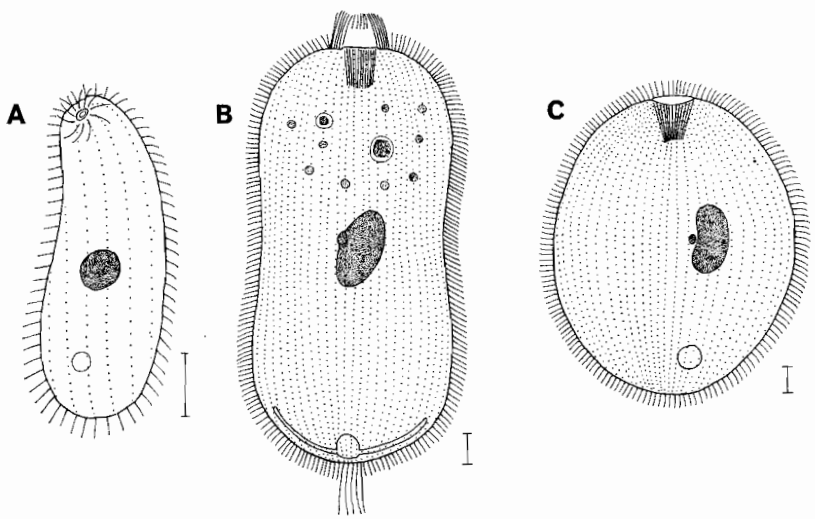

Fig. 14. Gymnostomatida, Rhabdophorina, Enchelyidae; Fig. 14A and 14C redrawn from Kahl (1930).
A, *Platyophrya vorax* Kahl, left side view;
B, *Prorodon teres* Ehrenberg, ventral view;
C, *Holophrya nigricans* Lauterborn.

113 (112). Mouth-slit located along the convex side of tapering anterior part of the laterally compressed body. Predominantly carnivorous (Family Amphileptidae) 114

114 (117). Entire body surface ciliated 115

115 (116). Ventral (= oral) ridge with closely arranged conspicuous trichocysts; mouth extends back beyond middle of the body . . . . . *Bryophyllum* Kahl * (Fig. 16A)

116 (115). Ventral ridge only with tiny trichocysts; mouth not extending back beyond middle of the body . . . . . *Amphileptus* Ehrenberg *
e.g., *Amphileptus claparedei* Stein (see Fig. 29; p. 48).

117 (114). Right side of the body completely ciliated, left side only ciliated in the dorsal (= aboral) region or nonciliated 118

118 (119). Right side with about 12 rows of cilia; left side only with 4 rows on the dorsal part . . . . . *Acineria incurvata* Dujardin * (see Fig. 30; p. 50)

119 (118). Ciliation restricted to right side of the body 120

120 (121). Trichocysts on dorsal (= aboral) as well as ventral (= oral) margin, dorsal trichocysts often arranged in warts; body with thin wide margins . . . *Loxophyllum* Dujardin * (Fig. 16B)

121 (120). No trichocysts on dorsal margin 122

122 (123). One terminal contractile vacuole . . . . . *Litonotus* Wrzesniowski *
e.g., *L. fasciola* Ehrenberg (see Fig. 26; p. 42); *L. lamella* Ehrenberg, Schewiakoff (see Fig. 25; p. 40).

123 (122). Two or more contractile vacuoles arranged in rows . . . . . *Hemiophrys* Wrzesniowski *
e.g., *H. bivacuolata* Kahl (see Fig. 27; p. 44); *H. pleurosigma* (Stokes) (see Fig. 28; p. 46).

124 (91). Cytostome at the inner end of a buccal cavity containing membranous organelles or cilia 125

125 (126). Cigar- or foot-shaped; uniform body ciliation, long, broad ciliated oral groove (" vestibulum ") leading into the buccal cavity; buccal ciliation characterized by " peniculi ", which are located very deep in the buccal cavity (and therefore hardly distinguishable without special preparation techniques); 2 contractile vacuoles . . . . . Family Parameciidae * (Order Hymenostomatida, Suborder Peniculina)
Only one genus: *Paramecium;*
e.g., *P. bursaria* Ehrenberg (see Fig. 45; p. 84);
P. caudatum Ehrenberg (see Fig. 44; p. 82);
P. putrinum Claparède & Lachmann (see Fig. 46; p. 86);
P. trichium Stokes (see Fig. 47; p. 88).

126 (125). Not as described above 127

127 (128). Cilia restricted to one or more girdles encircling the body, long caudal cilia; buccal cavity subequatorial . . . Family Urocentridae * (Order Hymenostomatida, Suborder Peniculina)
Two genera with one species in each:
Urocentrum turbo (O. F. Müller) (Fig. 49; p. 92);
Urozona buetschlii Schewiakoff (see Fig. 50; p. 94).

128 (127). Not as described above 129

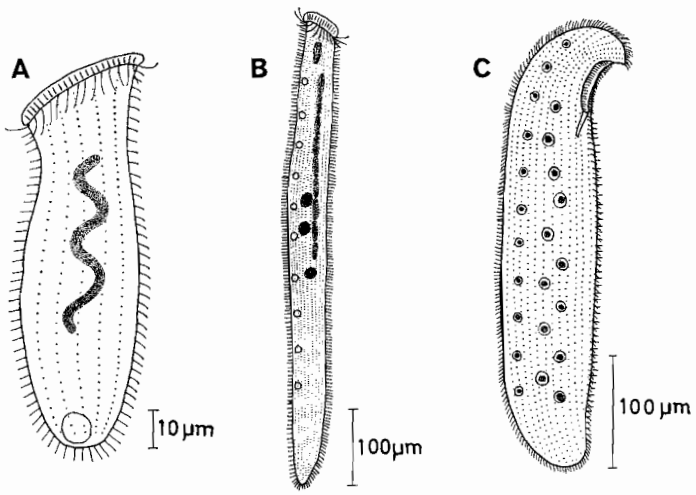

Fig. 15. Gymnostomatida, Rhabdophorina (*continued*):
A, *Spathidium* Dujardin, Spathidiidae, diagrammatic representation;
B, *Homalozoon vermiculare* (Stokes), Spathidiidae; right side;
C, *Loxodes magnus* Stokes, Loxodidae; right side.

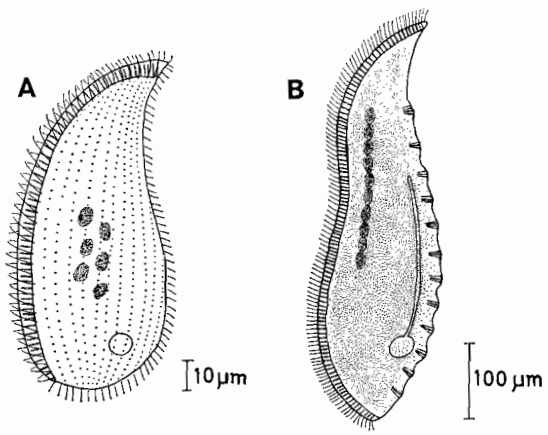

Fig. 16. Gymnostomatida, Rhabdophorina, Amphileptidae:
A, *Bryophyllum* Kahl, left side, diagrammatic representation;
B, *Loxophyllum meleagris* Dujardin, left side.

129 (130). Small ovoid body, flattened; cilia on flat ventral surface only, 3–4 caudal cilia; buccal cavity in the right posterior half . . . . . Family Cinetochilidae *
Only one genus: *Cinetochilum* Perty; e.g., *C. margaritaceum* (see Fig. 48; p. 90).

130 (129). Not as described above 131

131 (132). Ovoid to ellipsoid, flattened; ciliation complete; buccal cavity lies in anterior third of the cell, with preoral suture and a long narrow postoral groove, which is ordinarily nearly closed; 1 or 2 contractile vacuoles, with collecting canals . *Frontonia* Ehrenberg* (Fig. 17A)
Family Frontoniidae *sensu* Corliss; e.g., *F. acuminata* Ehrenberg (see p. 96).

132 (131). Not as described above 133

133 (158). Undulating membranes within or leading into the buccal cavity 134

134 (135). With a conspicuous external undulating membrane running from anterior pole to mouth (Fig. 17C), the membrane extends to the right margin of the buccal cavity and forms a pocket around the posterior end; mouth in the middle section or posterior half of the body; sparse ciliation, very often predominant caudal cilium present (in case of doubt see lines 145 and 151) . . . . . Suborder Pleuronematina *
Only one family (Pleuronematidae) including 7 genera;
e.g., *Cyclidium citrullus* Cohn (see Fig. 51; p. 98);
C. glaucoma (O. F. Müller) (see Fig. 52; p. 100);
C. lanuginosum Penard (Fig. 52; p. 102);
Calyptotricha pleuronemoides Phillips (Fig. 17B);
Ctedoctema Stokes (Fig. 17C).

135 (134). Not as described above, above all no preoral furrow bordered by membranes but with membranes in the buccal cavity itself; membranous organelles mostly of " tetrahymenal " type, 1 undulating membrane and 3 membranelles, which are predominantly inconspicuous, large membranes sometimes present . . . . . Suborder Tetrahymenina
Suborder (lines 136–157) with some 50 genera, often difficult to identify without special preparation techniques; the following key includes only a very limited number of genera and species.

136 (137). Buccal cavity occupying three-quarters to four-fifths of body length; the buccal cavity bears on its left side a large membrane (Fig. 17D), and on its right a number of narrow rows of short free cilia . . . . . *Lembadion* Perty * (Fig. 17D)

137 (136). Not as described above 138

138 (139). Small, hook-shaped buccal cavity (Fig. 18A), often small refractile granulae in the cytoplasm near mouth; multiple reproduction within a cyst; non-parasitic (feeding on carrion, e.g., dead rotifers) or parasitic . . . . . Family Ophryoglenidae *
e.g., *Ophryoglena* Ehrenberg (Fig. 18A).

139 (138). Not as described above 140

140 (141). With a mucilaginous case from which it emerges freely (Fig. 18B); mouth near anterior pole with a pocket-forming membrane, very small animals . . . *Cyrtolophosis* Stokes * (Fig. 18B)

141 (140). Without mucilaginous case; morphology not as described above 142

142 (153). With one long caudal cilium 143

143 (146). With bare frontal plate at anterior pole; posterior pole with complete ciliation 144

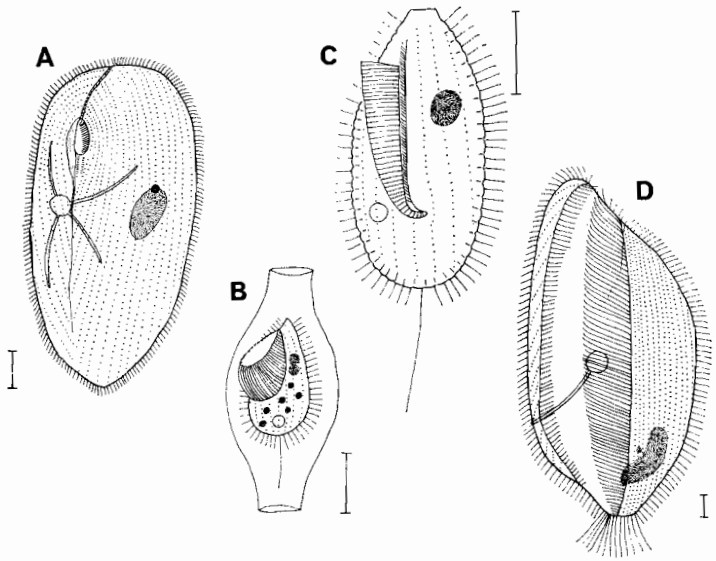

Fig. 17. Hymenostomatida; Fig. 17A and 17D redrawn from Kahl (1931).
A, *Frontonia acuminata* Ehrenberg var. *angusta* Kahl, Frontoniidae;
B, *Calyptotricha pleuronemoides* Phillips, Pleuronematidae;
C, *Ctedoctema acanthocrypta* Stokes, Pleuronematidae;
D, *Lembadion magnum* (Stokes), Frontoniidae, ventral view.

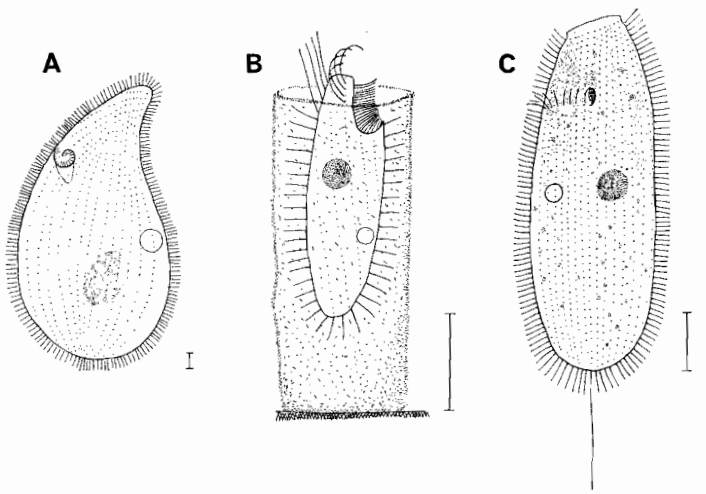

Fig. 18. Hymenostomatida (*continued*); Fig. 18A redrawn from Gajewskaja (1933).
A, *Ophryoglena pelagica* Gajewskaja, Ophryoglenidae;
B, *Cyrtolophosis mucicola* Stokes;
C, *Loxocephalus plagius* (Stokes), Tetrahymenidae.

144 (145). Endoplasm granulated, often darkly coloured; crescentic buccal cavity on slightly flattened area near anterior end. With a transverse row of conspicuous cilia running to the right edge of the buccal cavity (Fig. 18C); contractile vacuole in the middle of the body or near posterior pole . . . . . *Loxocephalus* Eberhard * (Fig. 18C) Family Tetrahymenidae.

145 (144). Endoplasm not granulated; narrow preoral groove leads from the frontal plate to the triangular-shaped buccal cavity; contractile vacuole terminal . *Uronema* Dujardin * (Fig. 19A) Family Cohnilembidae.

146 (143). No unciliated frontal plate 147

147 (148). Reniform, compressed; mouth in the middle of the body; macronucleus anterior . . . . . *Dexiotrichides centralis* (Stokes) * (Fig. 19B; p. 70)

148 (147). Not as described above 149

149 (150). Highly flattened, ovoid or ellipsoid; small buccal cavity located towards the right side, surrounded by horseshoe-shaped ciliary furrows; front margin indented by furrows; macronucleus in posterior half of the body . . . . . *Platynematum* Kahl * e.g., *P. sociale* (Penard) (Fig. 19C; p. 71).

150 (149). Not as described above 151

151 (152). Slender and spindle-shaped; buccal cavity running from anterior pole to the middle of the body or farther; curved to right, with double undulating membranes on right edge . . . . . *Cohnilembus* Kahl * Family Cohnilembidae, e.g., *C. pusillus* Quennerstedt (Fig. 20A, for details see p. 73).

152 (151). Ovoid, flattened; buccal cavity in the anterior one-third near to the right margin; oral membranes (Fig. 20B) forming a pocket; macronucleus in the middle of the body . . . . . *Sathrophilus* Stokes * Family Tetrahymenidae; *S. putrinus* Kahl (Fig. 20B), feeding on bacteria; probably alpha-mesosaprobic indicator organism.

153 (142). Without a long caudal cilium (Family Tetrahymenidae *partim*) 154

154 (155). Body outline indented at mouth, small triangular buccal cavity one-quarter of the way from anterior end toward right side; in the preoral area the dorsal ciliary rows curve right to the ventral " preoral suture " . . . . . *Colpidium* Stein * *C. colpoda* Ehrenberg (see Fig. 43; p. 80); *C. campylum* Stokes (see Fig. 42; p. 78).

155 (154). Without oral indentation 156

156 (157). Axis of buccal cavity oblique to body axis . . . . . *Glaucoma* Ehrenberg * e.g., *G. scintillans* Ehrenberg (see Fig. 41; p. 76).

157 (156). Axis of buccal cavity nearly parallel to body axis . . . . . *Tetrahymena* Furgason * e.g., *T. pyriformis* Ehrenberg, Lwoff (see Fig. 40; p. 74).

158 (133). Buccal cavity with cilia; no membranes present (Trichostomatida) 159

159 (160). With gelatinous tube-like lorica which may be branched dichotomously (Fig. 20C); with a terminal cone-like protuberance bearing longer cilia, the cone is surrounded by a circular adoral groove leading to the buccal cavity . . . . . Family Marynidae * e.g., *Maryna socialis* Gruber (Fig. 20C).

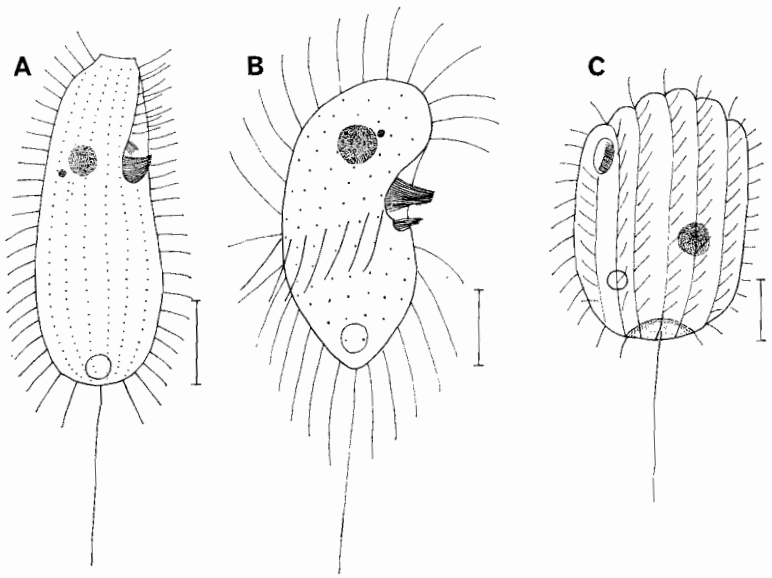

Fig. 19. Hymenostomatida (*continued*); Fig. 19B redrawn from Kahl (1931).
A, *Uronema marinum* Dujardin, Cohnilembidae;
B, *Dexiotrichides centralis* (Stokes);
C, *Platynematum sociale* (Penard).

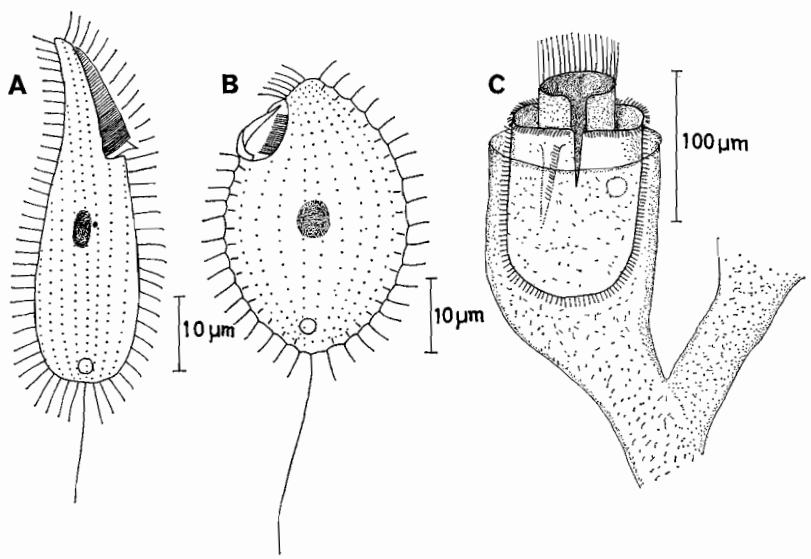

Fig. 20. Hymenostomatida (*continued*: A and B) and Marynidae (C); Fig. 20A–20C redrawn, with modifications, from Kahl (1931).
A, *Cohnilembus pusillus* Quennerstedt, Cohnilembidae;
B, *Sathrophilus putrinus* Kahl, Tetrahymenidae;
C, *Maryna socialis* Gruber.

160 (159). Not as described above 161

161 (162). Body flattened by lateral compressions; rigid pellicle, sparse ciliation predominantly on the right side; mouth on the slightly convex ventral face . . . . . Family Microthoracidae *

e.g., *Microthorax* Engelmann (Fig. 21A), mouth near to the posterior end;
Leptopharynx Mermod (= *Trichopelma* Levander) (Fig. 21B, 21C), mouth in anterior half of the cell, gullet with trichites.

162 (161). Not as described above 163

163 (164). Ciliation restricted to 3–4 spiral rows on the anterior body surface, and 1 long caudal cilium; body ovoid, anterior and posterior end of the cell pointed . . . . . Family Trimyemidae *

Trimyema compressum Lackey (see Fig. 39; p. 68).

164 (163). Not as described above 165

165 (166). Oral groove transverse, in anterior fourth of the body . . . . . Family Plagiopylidae *

e.g., *Plagiopyla nasuta* Stein (see Fig. 38; p. 66).

166 (165). Oral groove funnel-like at an indentation, near the middle of one side of the body. . . . . Family Colpodidae *

e.g., *Colpoda cucullus* O. F. Müller (see Fig. 37; p. 64);
C. steini (Maupas) Enriques (see Fig. 36; p. 62).

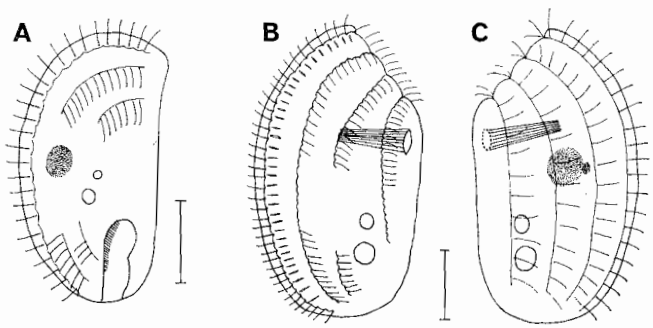

Fig. 21. Microthoracidae:
A, *Microthorax pusillus* Engelmann;
B and C, *Leptopharynx sphagnetorum* (Levander); ventral view (B), dorsal view (C);

SPECIES DESCRIPTIONS

The descriptions are arranged in taxonomic order following that of the key in the previous section. The family and genus are shown for each species described. Where no species descriptions are given, families are mentioned in the same order as in the Synopsis (p. 7) with examples of genera and references to figures in the key.

Subclass HOLOTRICHIA
Order GYMNOSTOMATIDA
Suborder RHABDOPHORINA

Family Colepidae
Genus *Coleps*

COLEPS HIRTUS Nitzsch (Fig. 22)

Morphology

Length 55–65 μm; barrel-shaped, constant body form; regularly arranged ectoplasmatic plates: two main groups of plates (I and II in Fig. 22) with 4 meridional rows of " windows " each; 15–20 longitudinal rows of platelets; mouth at the anterior pole, surrounded by special platelets; 3 spinous processes at the posterior end; uniform ciliation over the whole body except for 1 long caudal cilium; 1 spherical macronucleus; contractile vacuole near the posterior end.

Other species of the genus *Coleps* may show very similar features; in doubtful cases, make sure of the construction of the main plates and caudal spines. For further information see Kahl (1930).

Food

Feeds saprophytically upon other protozoons or rotifers, etc., and on algae, flagellates, and small ciliates, which are captured alive.

Occurrence and ecology

Cosmopolitan in distribution, occurring in all types of water containing organic detritus. Its occurrence in large numbers indicates beta-mesosaprobic conditions (Liebmann, 1962); single specimens may be found in more-or-less polluted waters. Sometimes planktonic in reservoirs, lakes, and ponds.

Ecological characteristics (Bick, 1968)

The following tabulation shows the main ecological characteristics of this species:

	Extreme tolerances	*Optimal ranges*
temperature (°C)	2–30	—
pH	4.7–9.4	6.5–7.5
dissolved O_2 (mg/l)	0.1–18.0	0.1–0.5
free CO_2 (mg/l)	0–140	10–15
NH_4^+ (mg/l)	0–26	0.1–0.5
free NH_3 (mg/l)	0–0.2	0–0.05
NO_2^- (mg/l)	0–34	0
H_2S (mg/l)	0–1.0	0
brackish water (seawater type)	up to 3.5 g of total salt content per litre	below 0.25 g of total salt content per litre
bacteria (plate counts on peptone agar)	300–20 000 000 ml	—

Saprobiology

From these ecological parameters, *C. hirtus* only indicates beta-mesosaprobic conditions in self-purification zones following the discharge of domestic sewage containing large amounts of faecal material.

Under such conditions, the ammonia content is one of the main environmental factors; on account of the low tolerance of *C. hirtus* to NH_4^+ and free ammonia, the ciliate is unable to exist in the alpha-mesosaprobic and polysaprobic zones, which have a high content of NH_4^+ and free ammonia, respectively. In the case of pollution due to factors other than sewage (e.g., cellulose or other carbohydrates without nitrogenous compounds), *C. hirtus* may occur under conditions characterized by a low oxygen content and large amounts of free carbon dioxide (i.e., under conditions very similar to those prevailing in alpha-mesosaprobic and polysaprobic environments, but lacking ammonia).

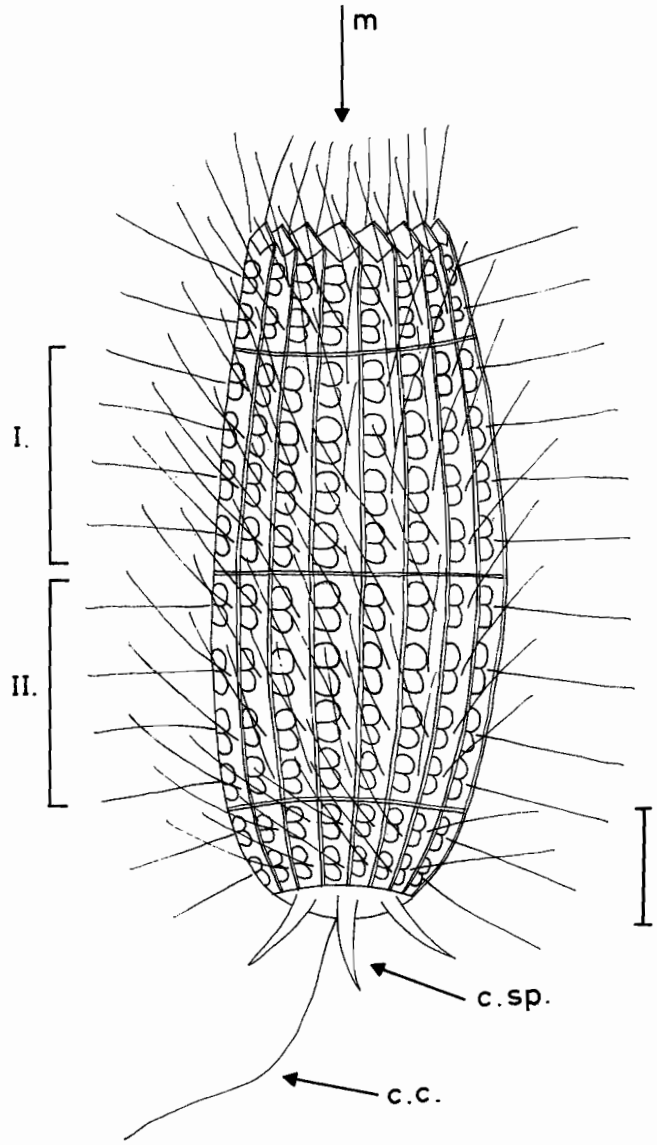

Fig. 22. *Coleps hirtus* Nitzsch. I, II = Main plates.

Family Enchelyidae
Genus *Urotricha*

UROTRICHA FARCTA Claparède & Lachmann (Fig. 23)

Morphology

Length 20–30 μm; body conical; uniform ciliation except in the posterior region which is without cilia except for 1 oblique caudal cilium; cytostome at anterior pole, surrounded by small flaps; 1 spherical macronucleus located in the anterior half of cell; 1 micronucleus; 1 contractile vacuole near the posterior end (Kahl, 1930).

Food

Small flagellates (e.g., *Ochromonas*), bacteria.

Occurrence and ecology

Reported in Europe and North America; found throughout the year in stagnant fresh water with putrefying plant materials (e.g., forest pools with decaying leaves, sewage oxidation ponds).

Ecological characteristics (Bick, 1968)

	Extreme tolerances
temperature (°C)	0–25
pH	6.8–8.2
dissolved O_2 (mg/l)	0–14.0
free CO_2 (mg/l)	0–72
NH_4^+ (mg/l)	0–15
bacteria (direct counts)	1 000 000–170 000 000/ml

Saprobiology

This is an alpha-mesosaprobic indicator organism (Liebmann, 1962); the ecological characteristics quoted above support this classification.

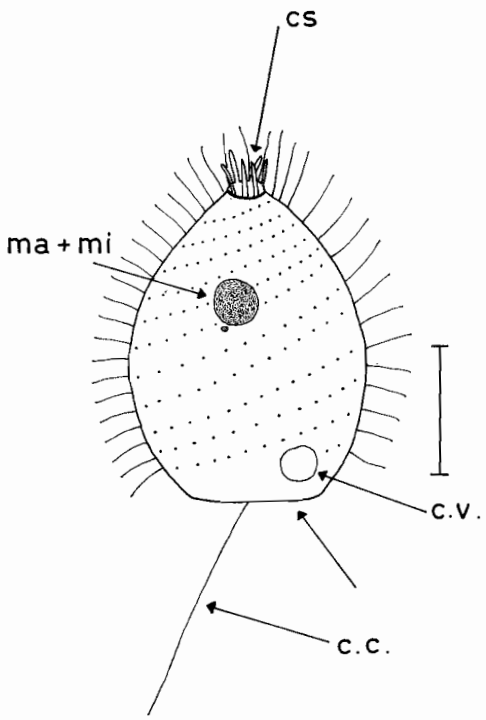

Fig. 23. *Urotricha farcta* Claparède & Lachmann. Arrows indicate the main features used for identification.

Family Enchelyidae
Genus *Lacrymaria*

LACRYMARIA OLOR (O. F. Müller) (Fig. 24)

Morphology

Length 400 μm (when fully extended, up to 1.2 mm); body elongated, flask-shaped with a long and highly contractile proboscis anteriorly, very polymorphic, body ciliation rather short and dense; a circle of longer cilia is present at the head-like anterior part of the proboscis, which is marked by a ring-like constriction; cytostome at anterior pole, supported by trichites, 2 spherical macronuclei and a single micronucleus between them; 2 contractile vacuoles (Kahl, 1930; Kudo, 1966).

Food

Carnivorous, feeding on ciliates; when about to feed the body is hidden among detritus while the fully extended proboscis is searching for prey.

Occurrence and ecology

Widely distributed in stagnant and slowly flowing water; according to Kahl (1930), occurs in saline, brackish, and fresh water.

Ecological characteristics (Bick, unpublished data)

	Extreme tolerances
temperature (°C)	0–25
pH	6.4–7.5
dissolved oxygen (mg/l)	0.2–12
free CO_2 (mg/l)	0–56
NH_4^+ (mg/l)	0–10
H_2S (mg/l)	up to 0.5

Saprobiology

According to Kolkwitz (1950), this is an oligosaprobic indicator organism that may occur also in the beta-mesosaprobic zone. The ecological characteristics given above do not support Kolkwitz's opinion. *L. olor* is able to withstand comparatively high concentrations of NH_4^+ and low levels of dissolved oxygen. It is assumed that the optimum for the species are beta-mesosaprobic conditions; single specimens may occur in the alpha-mesosaprobic zone as well as in the oligosaprobic zone.

Saprobiological classification [1]

bos	aos	bms	ams	ps	i (= indicator value)
—	2	6	2	—	3

[1] i.e., the 10-points method of Zelinka & Marvan (1961); for an explanation refer to the glossary (p. 193).

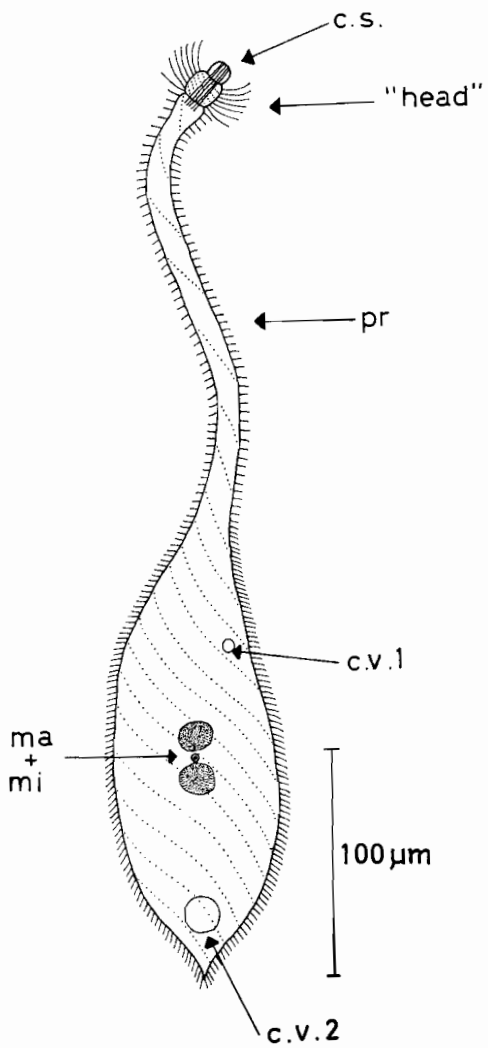

Fig. 24. *Lacrymaria olor* (O. F. Müller). Arrows indicate the main features used for identification.

Family Amphileptidae
Genus *Litonotus*

LITONOTUS LAMELLA (Ehrenberg) Schewiakoff (Fig. 25)

The name is commonly, but according to Corliss (1960) wrongly, spelled " *Lionotus* ".

Morphology

Length 40–200 μm; body laterally compressed, anterior and posterior parts flattened, ventral side convex, neck bent towards the dorsal side; mouth slit-like, about one-third of the central side, clearly visible only when the ciliate is feeding; cilia only on the right side, large individuals with 10–15 longitudinal rows of cilia, smaller specimens with about 3 rows only; left side without any cilia; trichocysts at the edge of the mouth-slit and at the posterior pole; 2 spherical macronuclei, between which a micronucleus is located; contractile vacuole single, close to the posterior end (for further morphological details see Dragesco (1966a)).

Food

Carnivorous, feeding on ciliates (e.g., *Cyclidium*, *Uronema*) and flagellates (e.g., *Ochromonas*).

Occurrence and ecology

Probably cosmopolitan in distribution.

Ecological characteristics (Bick, 1968)

	Extreme tolerances	*Optimal ranges*
temperature (°C)	0–30	—
pH	6.0–9.4	6.5–7.5
dissolved O_2 (mg/l)	0–13.0	0–0.1
free CO_2 (mg/l)	0–64	10–20
NH_4^+ (mg/l)	0–30	0–2
free NH_3 (mg/l)	0–0.6	0
H_2S (mg/l)	0–5	0
brackish water (seawater type)	up to 35 g of total salt content per litre	fresh water
athalassogenic natron lake water	up to 3.5 g of total salt content per litre	fresh water
bacteria (plate counts on peptone agar)	400–11 000 000/ml	—

Saprobiology

According to Kolkwitz (1950), *L. lamella* is a beta-mesosaprobic indicator organism. However, the ecological characteristics given above suggest that it is alpha-mesosaprobic. The species is carnivorous and therefore not directly dependent on bacteria. It feeds mainly on bacteria-eating organisms, many of which occur under alpha-mesosaprobic conditions.

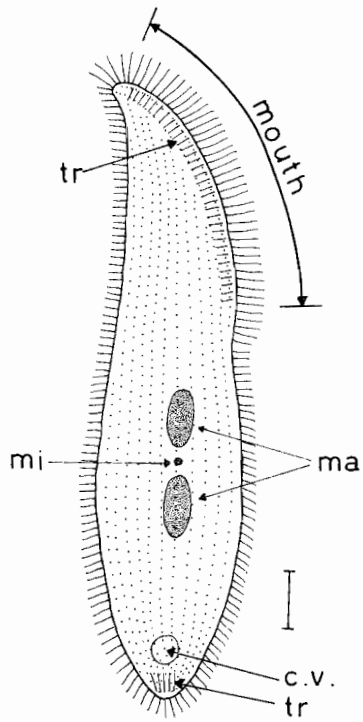

Fig. 25. *Litonotus lamella* (Ehrenberg), right lateral view.

Family Amphileptidae
Genus *Litonotus*

LITONOTUS FASCIOLA (Ehrenberg) (Fig. 26)

Morphology

Length 100 μm; body elongated, laterally compressed; right side flat, left side more or less convex; anterior and posterior parts flattened and hyaline; neck bent towards the dorsal side; mouth (cytostome) a long slit, about one-third to one-half the total length of the body; cilia on right side only; a single contractile vacuole near the posterior end; 2 spherical macronuclei, between which a single micronucleus is situated. For further details see Kahl (1931).

Food

Carnivorous, feeding on ciliates and flagellates.

Occurrence and ecology

Probably cosmopolitan in distribution; according to Liebmann (1962), the species occurs in all types of water polluted with putrescible organic material.

Ecological characteristics (Noland, 1925; Bick, unpublished data)

	Extreme tolerances
temperature (°C)	0–21
pH	7.1–8.0
dissolved O_2 (mg/l)	0.3–6.0
H_2S	0
The species occurs in fresh water and in seawater	with a total salt content of about 30 g/l (see Bock, 1952).

Saprobiological classification

According to Zelinka & Marvan (1961) (1) and Sládeček (1964) (2) this is an alpha-mesosaprobic indicator organism (Liebmann, 1962).

	bos	aos	bms	ams	ps	i
(1)	—	—	—	3	7	3
(2)	—	—	1	8	1	4

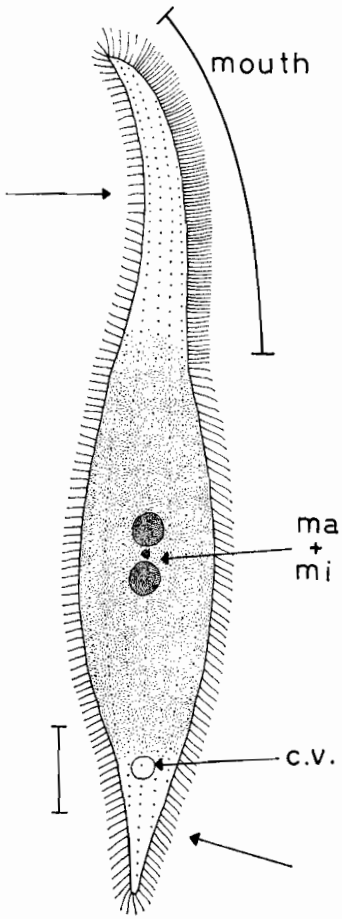

Fig. 26. *Litonotus fasciola* (Ehrenberg), right lateral view. Arrows indicate the main features used for identification.

Family Amphileptidae
Genus *Hemiophrys*

HEMIOPHRYS BIVACUOLATA Kahl (Fig. 27)

According to Šrámek-Hušek (1954), this species includes two different morphological and ecological types—namely,

(1) *H. bivacuolata* form *typica* (Fig. 27 A);

(2) *H. bivacuolata* form *polysaprobica* (Fig. 27 B).

Morphology

The genus *Hemiophrys* itself is characterized by the following features (Kahl, 1931): body laterally compressed, flask-shaped, right *and* left side more or less flat, cilia only on the right side, ventral side convex, with a long slit-like mouth; differs from the genus *Litonotus* in having 2 or more contractile vacuoles (*Litonotus* constantly has only a single contractile vacuole); 2 spherical macronuclei in close contact with a single micronucleus located between them. *H. bivacuolata* form *typica* (Fig. 27 A) is 80–135 μm long; body elongated; anterior part slightly curved towards the dorsal side, not neck-like; cytoplasm hyaline, strong trichocysts in the anterior region; 2 contractile vacuoles; moderately metabolic in shape. *H. bivacuolata* form *polysaprobica* (Fig. 27B) is 90–150 μm long; posterior part very broad; anterior part neck-like, strongly curved dorsally; anterior region hyaline, posterior part granulated and appearing dark; 2 contractile vacuoles; trichocysts tiny and indistinct; very metabolic in shape.

Food

Both ecotypes are carnivorous, feeding on ciliates and flagellates.

Occurrence and ecology

Reported from Europe; *H. bivacuolata* form *typica* occurs under oligo- and beta-mesosaprobic conditions; the form *polysaprobica*, on the other hand, is restricted to waters heavily polluted with putrescible material (e.g., domestic sewage) and is associated with *Colpidium campylum* and *Glaucoma scintillans*. *H. bivacuolata* form *polysaprobica* has been classified as polysaprobic indicator organism (Šrámek-Hušek, 1954).

Saprobiological classification

Calculated from data given by Šrámek-Hušek (1954):

bos	aos	bms	ams	ps	i
—	+	1	3	6	3

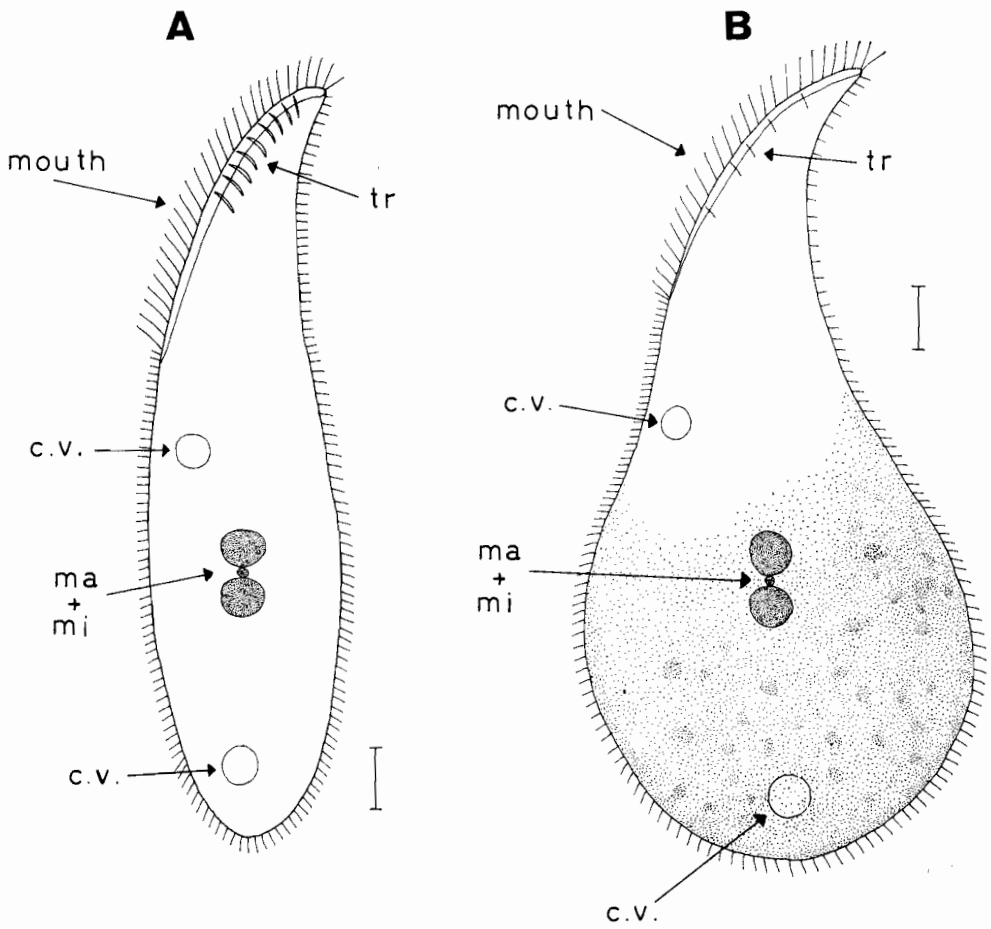

Fig. 27. A, *Hemiophrys bivacuolata* form *typica*, left lateral view. B, *Hemiophrys* form *polysaprobica*, left lateral view; redrawn after Šrámek-Hušek (1954).

Family Amphileptidae
Genus *Hemiophrys*

HEMIOPHRYS PLEUROSIGMA (Stokes) (Fig. 28)

Morphology (Kahl, 1931)

Length 300 μm; for generic features see *Hemiophrys bivacuolata* (p. 44); body sigmoid; left side without cilia except for single rows near the ventral and dorsal margins; right side with about 20 rows of cilia; a group of strong trichocysts at the anterior pole and individual trichocysts throughout the anterior region; a single micronucleus located in a tiny tunnel connecting the 2 macronuclei; numerous contractile vacuoles arranged in a ventral and a dorsal row.

Food

Carnivorous, feeding on ciliates and flagellates.

Occurrence and ecology

Reported from Europe in pools, ponds, reservoirs, slowly running waters, associated with *Coleps hirtus*, *Colpidium campylum*, *Halteria grandinella*, *Paramecium caudatum*, *Stentor roeseli*, *Urocentrum turbo*.

Ecological characteristics (Bick, unpublished data)

	Extreme tolerances
temperature (°C)	3–25
pH	6.2–7.5
dissolved O_2 (mg/l)	0.2–10
free CO_2 (mg/l)	0–52
NH_4^+ (mg/l)	0–18
brackish water (seawater type)	up to 3.5 g of total salt content per litre
bacteria (plate counts on peptone agar)	up to 18 000 000/ml

Saprobiology

According to Šrámek-Hušek (1956), *H. pleurosigma* occurs most frequently in beta-mesosaprobic and oligosaprobic environments. However, the ecological data published above do not support this statement.

Saprobiological classification

bos	aos	bms	ams	ps	i
—	1	4	5	—	2

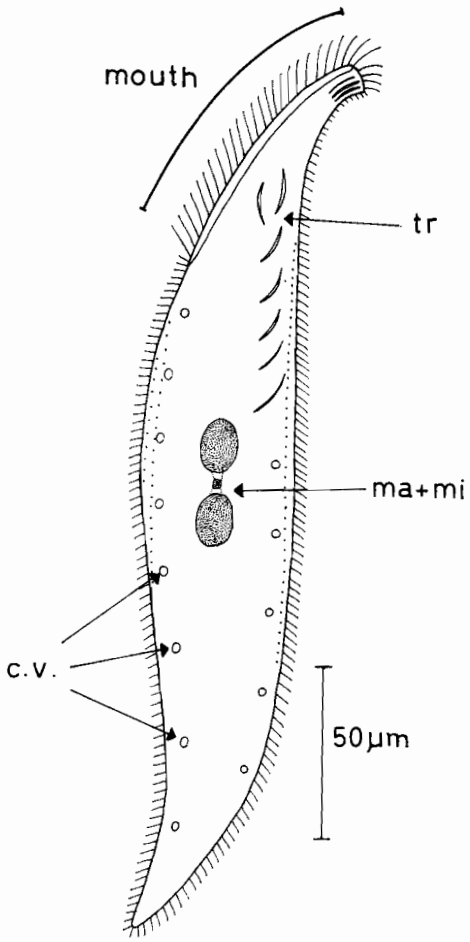

Fig. 28. *Hemiophrys pleurosigma* (Stokes), left lateral view.

Family Amphileptidae
Genus *Amphileptus*

AMPHILEPTUS CLAPAREDEI Stein (= A. MELEAGRIS Claparède & Lachmann) (Fig. 29)

Morphology (Kahl, 1931)

Length 120–150 μm; laterally compressed, neck-like anterior end bent towards the dorsal side; mouth is on the convex (= ventral) side, slit-like, clearly visible only when the ciliate is feeding (this is a characteristic feature of all members of the family Amphileptidae (cf., *Litonotus lamella*, p. 40); ciliation uniform and nearly complete but ciliary rows of the left side of the body are not distinct and somewhat reduced by comparison with those on the right side; numerous contractile vacuoles irregularly distributed along the ventral and dorsal margins; 2 macronuclei and a single micronucleus; fission takes place within cysts.

Taxonomy

Canella (1960) suggests transferring *A. claparedei* to the genus *Hemiophrys*, if indeed one does not prefer to place all *Hemiophrys* species in Ehrenberg's old genus *Amphileptus*. Specific studies on the morphology and taxonomy of *A. claparedei* are much needed.

Food

Carnivorous, feeding only on peritrichs (*Carchesium polypinum*, *Opercularia coarctata*, *Vorticella convallaria*, and others). Characteristic feeding habits; after capturing the zooid of its peritrich prey, *Amphileptus* encysts. The cyst itself remains hanging for some time on the stalk of the ingested zooid; after digestion is complete, the ciliate divides within its cyst (1 or 2 fissions).

Occurrence and ecology

Recorded from Europe and North America, all through the year in still and flowing waters. From its food requirements, *A. claparedei* appears to be restricted to zones where colonies of peritrichs are able to live. High abundance only under alpha-mesosaprobic conditions that are favourable for the peritrichs mentioned above.

Ecological characteristics (from Noland, 1925 and Gajewskaja, 1933)

	Extreme tolerances
temperature (°C)	3.5–22.5
pH	6.5–8.4
dissolved O_2 (mg/l)	1.0–7.0

Saprobiology

According to Liebmann (1962), this is an alpha-mesosaprobic indicator organism with a high indicator value.

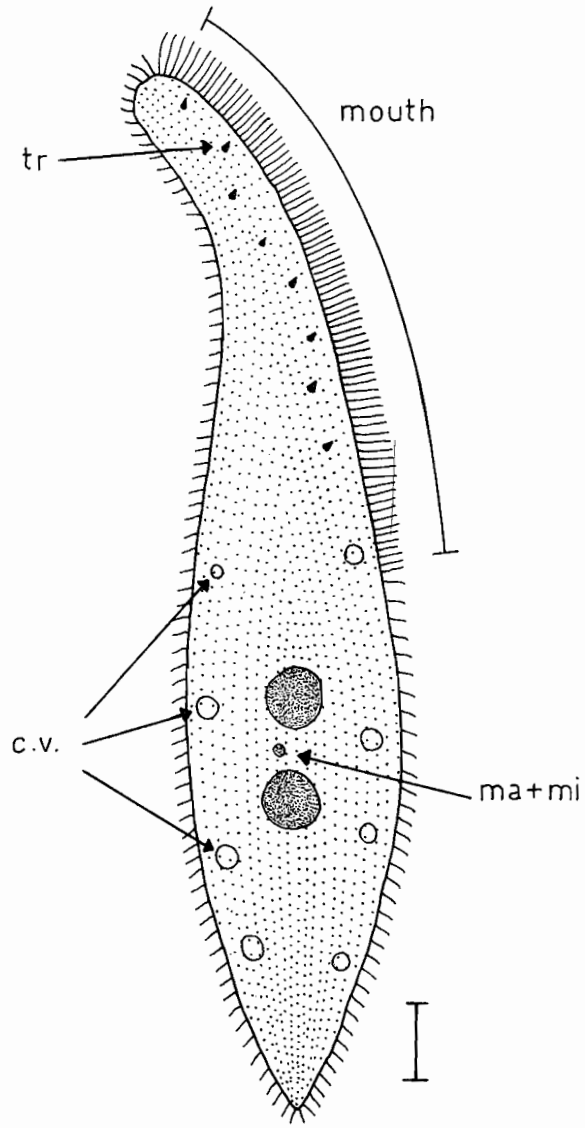

Fig. 29. *Amphileptus claparedei* Stein, right lateral view; redrawn from Canella (1960).

Family Amphileptidae
Genus *Acineria*

ACINERIA INCURVATA Dujardin (Fig. 30)

Morphology

Length 50–150 μm; body laterally compressed, outline more or less long and ellipsoid; rather polymorphic; right side with about 12 rows of cilia; left side with only 4 rows in the dorsal part, ventral part of the left side without cilia; mouth slit-like in the ventral part of the anterior region, trichocysts at the edge of the mouth slit; the left ventral region just behind the mouth is somewhat concave and hyaline; 2 macronuclei, and a single micronucleus between them; 1 contractile vacuole at the posterior pole.

Food

Carnivorous, feeding on small ciliates like *Cyclidium*, *Colpidium*, and *Glaucoma* (Kahl, 1931).

Occurrence and ecology

Widely distributed in fresh and brackish water; all types of stagnant and slowly-flowing water. *A. incurvata* is a true member of the "Colpidietum colpodae" association as described by Šrámek-Hušek (1958), that is, an association composed of *Colpidium colpoda*, *C. campylum*, *Glaucoma scintillans*, *Paramecium caudatum*, *P. trichium*, and *Hemiophrys bivacuolata* form *polysaprobica*.

Saprobiology

According to Šrámek-Hušek (1956), this is a polysaprobic indicator organism, having a high tolerance to lack of oxygen and high concentrations of NH_4^+.

Saprobiological classification

bos	aos	bms	ams	ps	i
—	—	—	3	7	4

Not described :

Family Actinobolinidae
e.g., *Actinobolina* and *Enchelyomorpha* (p. 22; Fig. 12C, 12D).

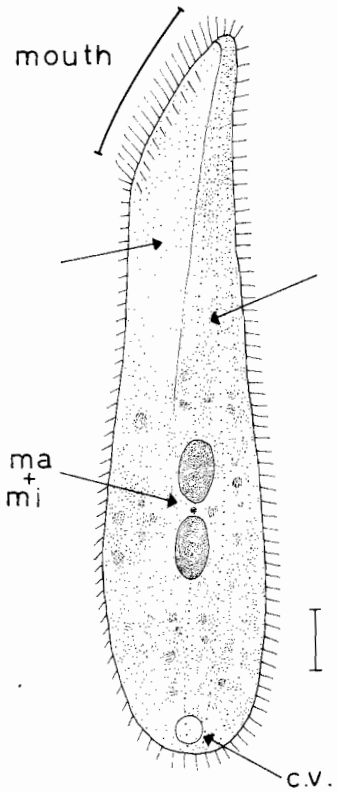

Fig. 30. *Acineria incurvata* Dujardin, left lateral view; redrawn from Kahl (1931). Arrows indicate the main features used for identification.

Family Didinidae
Genus *Didinium*

DIDINIUM NASUTUM (O. F. Müller) (Fig. 31)

Morphology

Length 80–170 μm; barrel-shaped; highly granulated endoplasm (sometimes nearly black); 2 girdles of special cilia (" pectinellae ") that are used only for very rapid locomotion; a group of short bristles is located behind each girdle of cilia (" sensory bristles " consisting of about 4–6 short rows of modified cilia). For further information see Dragesco (1966).

The mouth at the tip of a conspicuous proboscis is highly protrusible and supported by long trichites; macronucleus horseshoe-shaped; contractile vacuole terminal.

Food

Carnivorous, feeding on *Paramecium* and other ciliates.

Occurrence and ecology

Cosmopolitan in distribution; very common; found in still waters in temporary pools as well as lakes, reservoirs and oxidation ponds; sometimes planktonic.

Ecological characteristics (Bick, 1960)

	Extreme tolerances
temperature (°C)	5–25
pH	6–8
dissolved O_2 (mg/l)	3.5–7.5
NH_4^+ (mg/l)	0–1.8

Saprobiology

According to Liebmann (1962), this organism is beta-mesosaprobic.

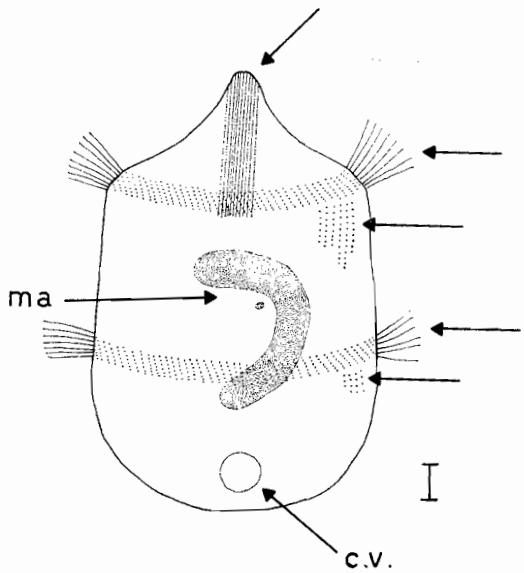

Fig. 31. *Didinium nasutum* (O. F. Müller). Arrows indicate the main features used for identification.

Family Tracheliidae
Genus *Trachelius*

TRACHELIUS OVUM Ehrenberg (Fig. 32)

Morphology (Kahl, 1931; Kudo, 1966)

Length 200–400 μm; more or less spheroidal with a distinct short proboscis; right side flattened, often somewhat concave; left side strongly convex; body ciliation uniform, rows of slightly longer cilia on the ventral face of the proboscis, the circular cytostome is located at the base of the proboscis; cytopharynx exhibiting long trichites; numerous contractile vacuoles; macronucleus sausage-shaped; a single micronucleus; endoplasm vacuolated, brown granules often concentrated in the posterior region.

Food

Carnivorous, feeding on flagellates and ciliates.

Occurrence and ecology

Reported from Europe and America, widely distributed in all types of standing and flowing waters; sometimes occurring among the *Aufwuchs* (periphyton) of artificial substrates (Hentschel, 1916).

Saprobiology

According to Kolkwitz (1950), this is a beta-mesosaprobic indicator organism; single specimens may occur under alpha-mesosaprobic conditions.

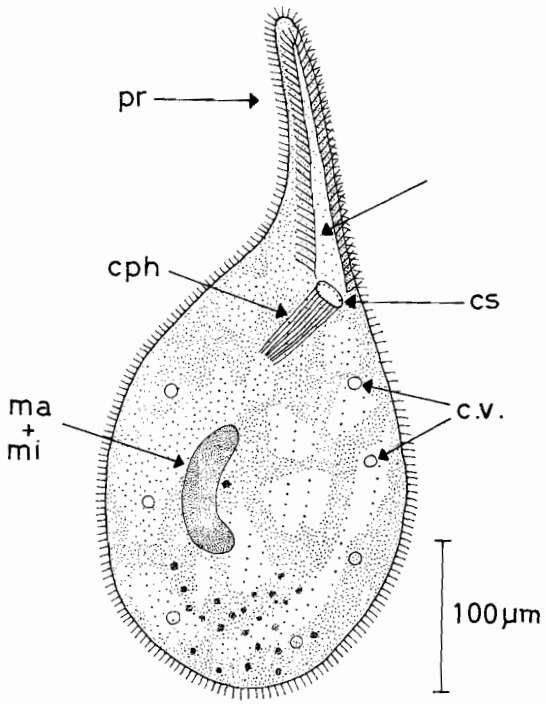

Fig. 32. *Trachelius ovum* Ehrenberg, right lateral view. Arrows indicate further features used for identification.

Family Tracheliidae
Genus *Dileptus*

DILEPTUS ANSER (O. F. Müller) (Fig. 33)

Morphology

Length 250–600 μm, average about 350 μm; slender with neck-like elongated proboscis at the anterior end which is slightly flattened and highly contractile; posterior end drawn out into a tail; the circular cytostome is located at the base of the proboscis; cytopharynx exhibiting long trichocysts; uniform ciliation all over the body, 2 rows of strong cilia and 3 rows of trichocysts along the ventral side of the proboscis; macronucleus divided into 200–500 small bodies; about 20 micronuclei (Dragesco, 1963); numerous contractile vacuoles along the dorsal side. For further morphological details, see Dragesco (1963).

Food

Carnivorous; feeding on ciliates, rotifers, small planarians, and oligochaetes.

Occurrence and ecology

Probably cosmopolitan in distribution, found in still and slowly flowing water at all times of the year.

Ecological characteristics (Wilbert, personal communication)

	Extreme tolerances
temperature (°C)	4–18
pH	7.8–8.6
dissolved O_2	2.5–18
free CO_2 (mg/l)	0–16
NH_4^+ (mg/l)	0–0.2

Saprobiology

According to Liebmann (1962), this is an oligosaprobic indicator organism.

Not described :

Family Loxodidae
e.g., *Loxodes* (p. 24; Fig. 15C).
Family Spathidiidae
e.g., *Spathidium* (p. 24; Fig. 15A).
Family Metacystidae
e.g., *Metacystis*, *Vasicola* (p. 22; Fig. 12A, 12B).

Suborder Cyrtophorina (= Hypostomatina)
Family Dysteriidae
e.g., *Trochilia* (p. 22; Fig. 11B).

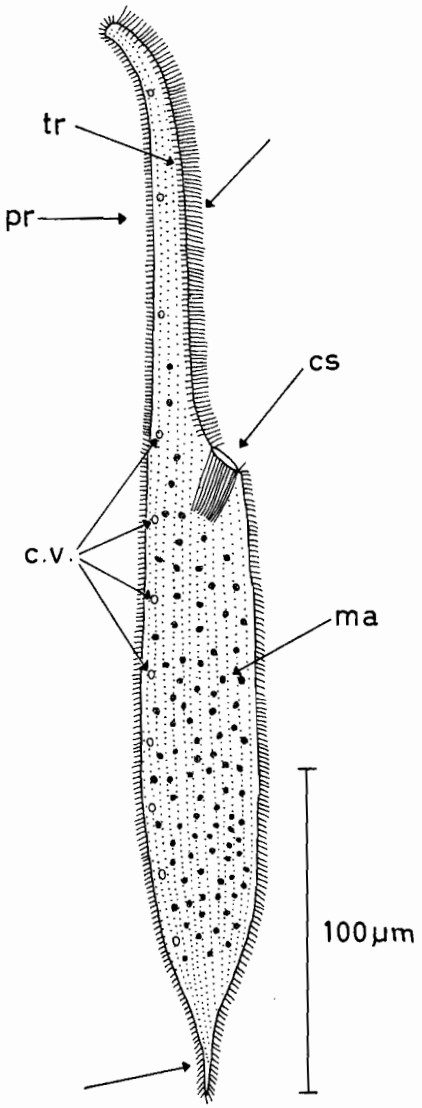

Fig. 33. *Dileptus anser* (O. F. Müller), right lateral view. Arrows indicate the main features used for identification.

Suborder CYRTOPHORINA (=HYPOSTOMATINA)

Family Chlamydodontidae (= Chilodonellidae)
Genus *Chilodonella*

CHILODONELLA CUCULLULUS (O. F. Müller) (Fig. 34)

Morphology

Length 75–300 μm, usually about 150 μm; body dorsoventrally flattened; ventral surface flat with about 20 ciliary rows, the anterior part of the dorsal surface flattened with only 1 transverse row of cilia (" dorsal bristles "), the posterior part more or less convex and lacking cilia; mouth opening round, about 12 cytopharyngeal trichites forming a tube, macronucleus oval with a characteristic concentric structure; 1 small micronucleus, about 6–8 contractile vacuoles. For details on morphology, division, etc., see Radzikowski (1966).

Food

Diatoms, blue-green algae, bacteria.

Occurrence and ecology

Cosmopolitan in distribution, found throughout the year in still and flowing waters (e.g., activated sludge, trickling filters, sewage drains, oxidation ponds) (Liebmann, 1962).

Ecological characteristics (Bick, 1968)

	Extreme tolerances
temperature (°C)	0–30
pH	6.3–8.5
dissolved O_2 (mg/l)	0–12
free CO_2 (mg/l)	0–72
NH_4^+ (mg/l)	0.1–100
free NH_3 (mg/l)	0–20
NO_2^- (mg/l)	0–22
H_2S	0
brackish water (seawater type)	up to 7 g of total salt content per litre
athalassogenic natron lake water	up to 7 g of total salt content per litre
bacteria (plate counts on peptone agar)	140 000–10 000 000/ml

Saprobiology

This is an alpha-mesosaprobic indicator organism (Liebmann, 1962). *C. cucullulus* is able to tolerate a wide range of environmental conditions; single specimens may occur in all zones of self-purification. Only its occurrence in great numbers or its mass-development are significant to the monitoring of water quality.

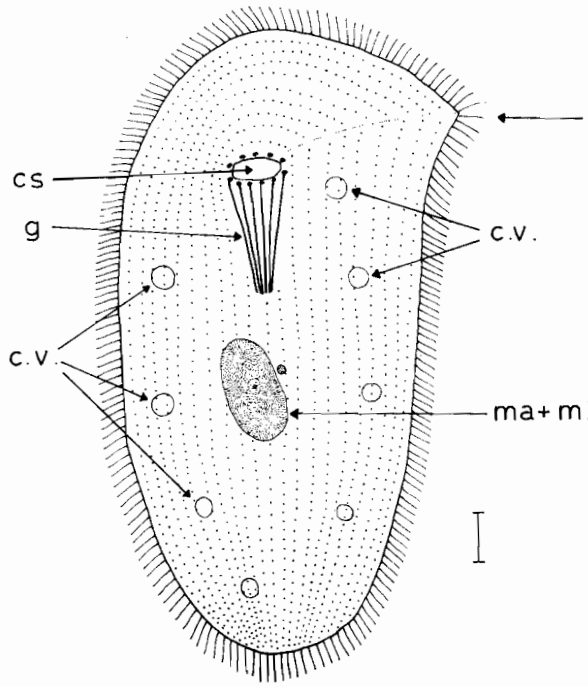

Fig. 34. *Chilodonella cucullulus* (O. F. Müller), ventral view. Arrows indicate the main features used for identification. Cilia are partly omitted but are marked by dots.

Family Chlamydodontidae (=Chilodonellidae)
Genus *Chilodonella*

CHILODONELLA UNCINATA Ehrenberg (Fig. 35)

Morphology (Kahl, 1931)

Length 50–90 μm; body dorsoventrally flattened (cf., *C. cucullulus*); about 11 ventral ciliary rows; dorsally a transverse row of about 7 dorsal cilia or bristles (see Fig. 35B); cytostome round, cytopharyngeal trichites form a cornucopia; macronucleus oval; a single small micronucleus; the 2 contractile vacuoles are located in the anterior right quadrant and the posterior left quadrant, respectively. *Chilodonella dentata* Fouque is generally held to be a synonym of *C. uncinata*.

Food

Bacteria, diatoms, small green algae.

Occurrence and ecology

Cosmopolitan in distribution, found throughout the year in still and flowing waters (e.g., trickling filters, oxidation ponds). Often numerous in bacterial layers, e.g., at the surface of polluted waters.

Ecological characteristics (Bick, 1968; Münch, 1969)

	Extreme tolerances	*Optimal ranges*
temperature (°C)	0–50	30–35
pH	4.0–9.5	6.5–7.5
dissolved O_2 (mg/l)	0–14	0.1–1
free CO_2 (mg/l)	0–200	10–25
NH_4^+ (mg/l)	0–150	0–2
free NH_3 (mg/l)	approx. 0–20	0–0.5
NO_2^- (mg/l)	0–36	—
H_2S (mg/l)	0–2.0	0
brackish water (seawater type)	up to 28 g of total salt content per litre	fresh water
athalassogenic natron lake water	up to 15 g of total salt content per litre	—
bacteria (plate counts on peptone agar)	300–17 000 000/ml	more than 10^6/ml

Saprobiology

According to Liebmann (1962), this is an alpha-mesosaprobic indicator organism; the ecological valencies cited above support Liebmann's view.

Not described:

Family Nassulidae
e.g., *Nassula* (p. 22; Fig. 11A).

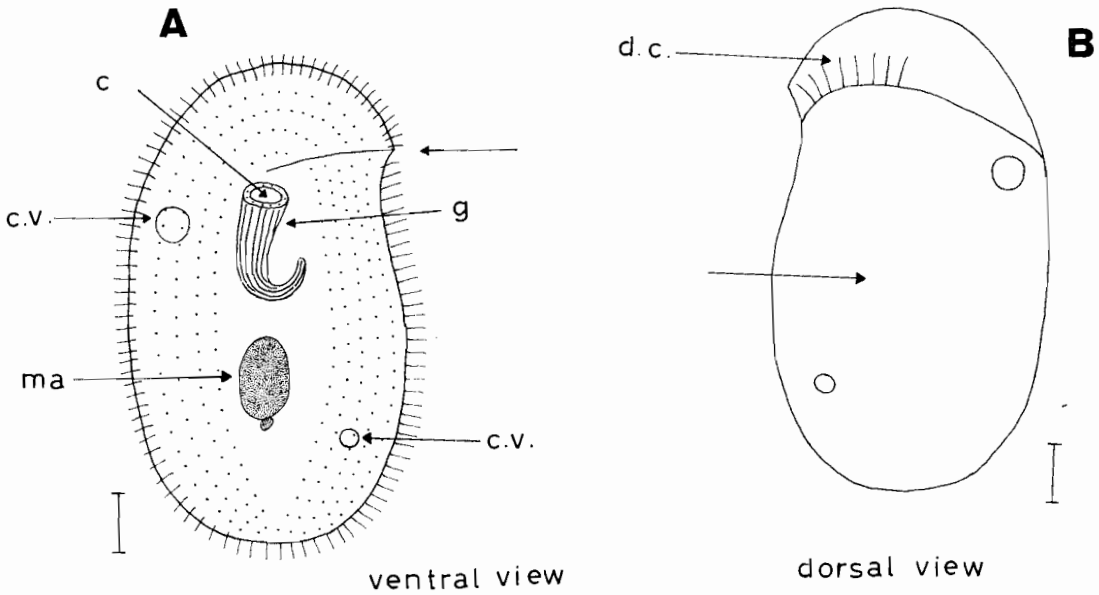

Fig. 35. *Chilodonella uncinata* Ehrenberg. A, Ventral view; B, Dorsal view. Arrows indicate the main features used for identification. The posterior part (marked by an arrow) is free from cilia.

Order TRICHOSTOMATIDA

Family Colpodidae
Genus *Colpoda*

COLPODA STEINI Maupas (Fig. 36)

Morphology

Length 15–60 μm; body more or less kidney-shaped; mouth near lateral margin, cytostome at the bottom of a ciliated vestibulum which bears a " beard " of cilia; the margin anterior to the mouth is indented by about 5 rows of cilia forming the so-called " keel "; ciliation uniform except for 2 longer caudal cilia; contractile vacuole near posterior end; fission only within reproductive cysts.

Food

Bacteria.

Occurrence and ecology

Cosmopolitan in distribution, occurring in all types of water containing decaying plant and animal material.

Ecological characteristics (Bick, 1968)

	Extreme tolerances
temperature (°C)	10–40
pH	4–9.5
dissolved O_2 (mg/l)	0–10
free CO_2(mg/l)	0–200
NH_4^+ (mg/l)	0–120
free NH_3 (mg/l)	approx. 0–30
brackish water (seawater type)	up to 14 g of total salt content per litre
athalassogenic natron lake water	up to 10 g of total salt content per litre
bacteria (direct counts)	2 500 000–135 000 000/ml

Saprobiology

So far, this species has not been used as an indicator organism but it may be useful in the definition of polysaprobic conditions because of its preference for high bacterial numbers and its toleration of oxygen deficiency and high levels of NH_4^+. Mass development occurs under environmental conditions harmful to other ciliates; the resulting lack of competition for food is favourable to *C. steini* (Bick, 1964; Maguire, 1963).

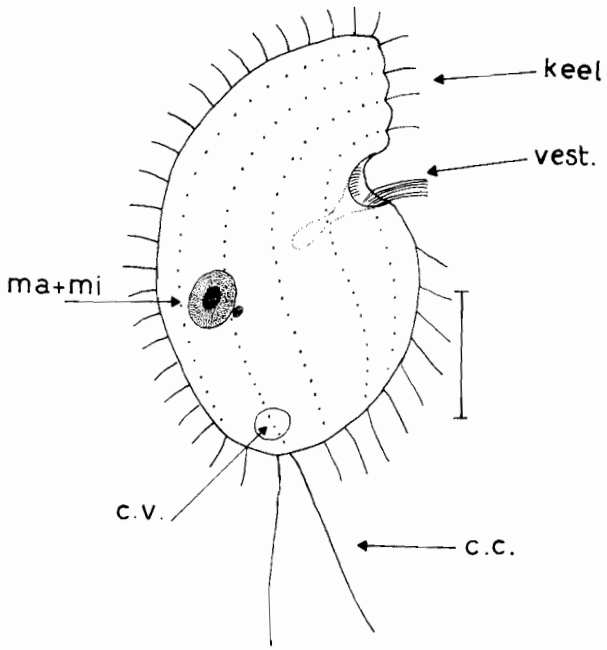

Fig. 36. *Colpoda steini* Maupas (Enriques). Ciliation partly marked by dots.

Family Colpodidae
Genus *Colpoda*

COLPODA CUCULLUS O. F. Müller (Fig. 37)

Morphology

Length 40–120 μm, average about 80 μm; broadly reniform, anterior keel with 8–10 indentations; uniform ciliation; buccal cavity with a deep oral funnel starting at a groove near the left side of the body, the buccal cavity leads to a diagonal groove on the dorsal surface (not evident in the figure), buccal cavity ciliated but without membranes or membranelles; 1 spherical macronucleus, exhibiting a stellate endosome; 1 micronucleus; a single terminal contractile vacuole; in the presence of a good food supply, the body is packed with food inclusions and appears very dark; fission only takes place within reproductive cysts. For further details see Kahl (1931).

Food

Bacteria, small flagellates, and algae.

Occurrence and ecology

Cosmopolitan in distribution, frequently abundant in waters containing putrescible plant material and sewage; polluted streams, oxidation ponds.

Ecological characteristics (Bick, 1968)

	Extreme tolerances
temperature (°C)	5–30
pH	4.4–8.6
dissolved O_2 (mg/l)	0.4–8.0
free CO_2 (mg/l)	18–136
NH_4^+ (mg/l)	0.2–25
NO_2^- (mg/l)	0–25
brackish water (seawater type)	up to 3.5 g of total salt content per litre
bacteria (plate counts on peptone agar)	1 200 000–4 500 000/ml

Saprobiology

According to Liebmann (1962), this is an alpha-mesosaprobic indicator organism; the ecological characteristics given above support Liebmann's view.

Not described:

Family Microthoracidae
e.g., *Microthorax*, *Leptopharynx* (p. 32; Fig. 21).

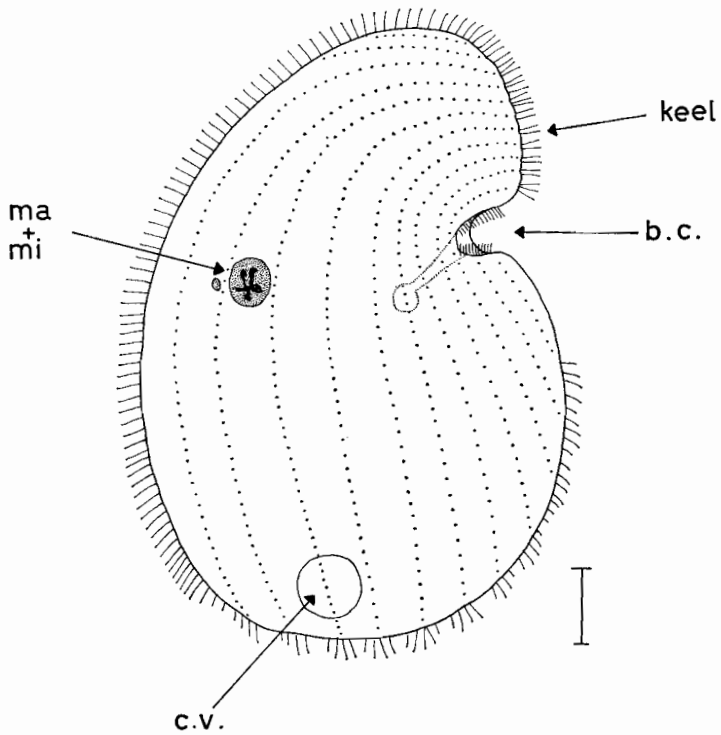

Fig. 37. *Colpoda cucullus* O. F. Müller, ventral view. Food vacuoles omitted, ciliation partly omitted and marked by dots.

Family Plagiopylidae
Genus *Plagiopyla*

PLAGIOPYLA NASUTA Stein (Fig. 38)

Morphology

Length 80–180 μm; dorsoventrally flattened; uniform ciliation, sometimes yellowish or beige in colour, oral groove transverse, cytostome on the left end; a so-called " striated structure " (of unknown function) is present on the dorsal side starting from the edge of the mouth groove and turning backwards (see Fig. 38B); trichocysts in large numbers all over the body; macronucleus near the right margin in the middle of the body; contractile vacuole at the posterior end; *P. nasuta* exhibits great morphological variability. For further details see Kahl (1931) and Liebmann (1962).

Food

Bacteria, algae (Liebmann, 1962).

Occurrence and ecology

Reported in Europe and North America, sapropelobiontic; saprobiological classification according to Liebmann (1962): polysaprobic, indicator of hydrogen sulfide, does not occur in raw sewage; frequently associated with *Discomorphella*, *Metopus*, and *Caenomorpha*.

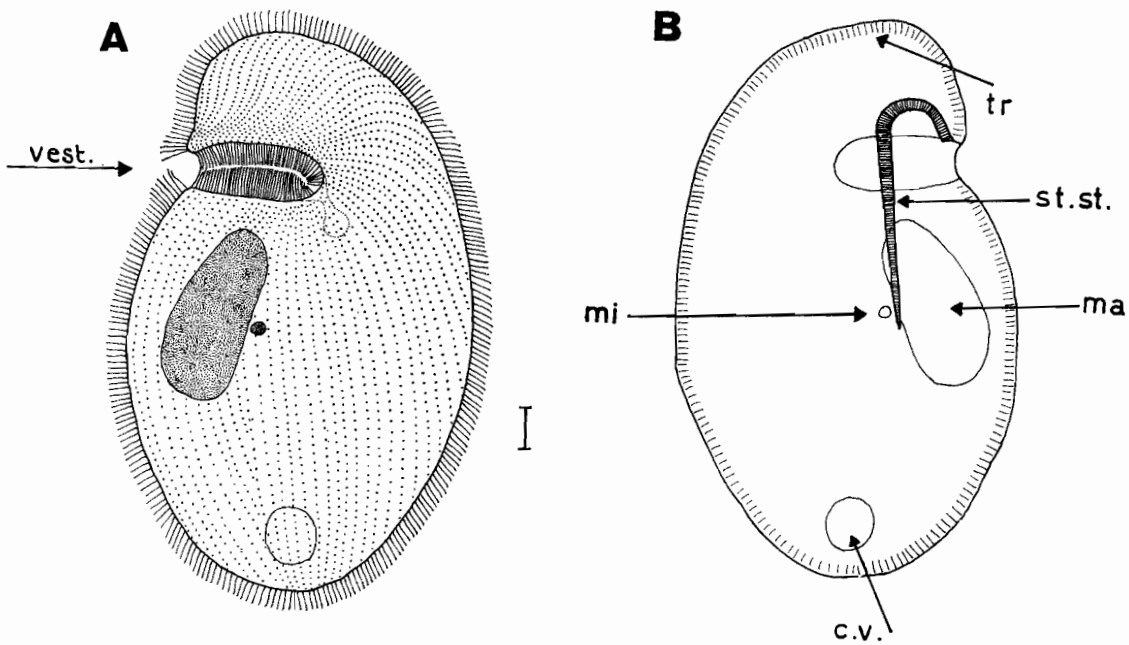

Fig. 38. *Plagiopyla nasuta* Stein. A, Ventral view, after Jankowski (1964a); B, Dorsal view; diagrammatic representation, cilia omitted.

Family Trimyemidae
Genus *Trimyema*

TRIMYEMA COMPRESSUM Lackey (Fig. 39)

Morphology (Kahl, 1931; Liebmann, 1962; Noland, 1959)

Body length 25–50 μm; contour of the cell more or less spindle-shaped, dorsoventrally flattened, the posterior end is more or less acute and bears 1 long caudal cilium; the somatic ciliation is arranged in a spiral surrounding the anterior part of the cell; vestibulum and cytostome near apical end of the body; nuclei in the middle of the cell; contractile vacuole near the equatorial body part too. For details of infraciliation see Jankowski (1964).

Food

Bacteria.

Occurrence and ecology

Cosmopolitan distribution but only in fresh water and athalassogenic natron lake water up to 2 g of total salt content per litre.

Ecological characteristics (Bick, 1968)

	Extreme tolerances
temperature (°C)	0–25
pH	6.8–8.5
dissolved O_2 (mg/l)	0–3
free CO_2 (mg/l)	0–30
NH_4^+ (mg/l)	0–3.0
H_2S (mg/l)	0–6.0

Saprobiology

A polysaprobic indicator organism, according to Liebmann (1962), that occurs in waters receiving fresh manure and sewage, or waste waters containing cellulose material (paper-mill outlets, etc.). From the ecological characteristics given above, the species seems to prefer environmental conditions that are characterized by low ammonia content, i.e., conditions prevailing during the decay of cellulose and other materials poor in nitrogenous compounds.

Not described :

Family Marynidae
e.g., *Maryna* (p. 30; Fig. 20C).

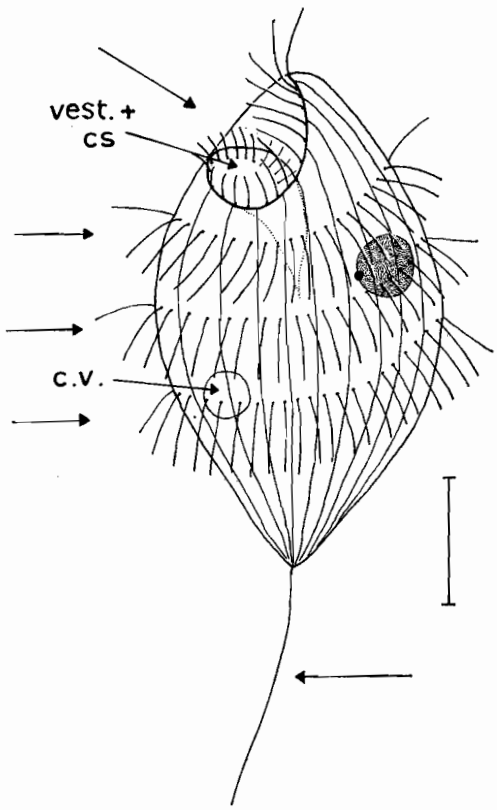

Fig. 39. *Trimyema compressum* Lackey, ventral view; after Kahl (1931). Arrows indicate further features used for identification.

Order HYMENOSTOMATIDA
Suborder TETRAHYMENINA

Unassigned tetrahymenine Hymenostomes *sensu* Corliss (1961)
Genus *Dexiotrichides* (only one species)

DEXIOTRICHIDES CENTRALIS (Stokes) (Fig. 19B)

Morphology (Kahl, 1931)

Length 30–45 μm; reniform, laterally compressed; sparse ciliation of comparatively long cilia, 1 prominent caudal cilium; mouth near middle of the cell within the concave ventral margin; oral ciliation consisting of 2 membranes; 1 spherical macronucleus and 1 micronucleus located anteriorly; contractile vacuole terminal; when resting the cilia are spread wide; movement is very quick.

Food

Bacteria.

Occurrence and ecology

Reported from Europe and America, occurring only in waters with heavy organic pollution, particularly putrefying plant material. Frequently found in purification plants and other localities of this type (Liebmann, 1962); often associated with *Trimyema compressum* (see p. 68).

Saprobiology

According to Liebmann (1962), this is a polysaprobic indicator organism.

Saprobiological classification

bos	aos	bms	ams	ps	i
—	—	—	2	8	4

Unassigned tetrahymenine Hymenostomes *sensu* Corliss (1961)
Genus *Platynematum*

PLATYNEMATUM SOCIALE (Penard) Kahl (= PLATYNEMA SOCIALE Penard) (Fig. 19C)

Morphology (Kahl, 1931; Kudo, 1966)

Length 30–50 μm; body ellipsoid, highly flattened, especially in the anterior part; ventral side concave; small buccal cavity located towards the right side, surrounded by horseshoe-shaped ciliary furrows; smooth and rather short ciliation, 1 predominant caudal cilium originating from a posterior groove; front margin indented by ciliary furrows; macronucleus spherical in posterior half of the body; contractile vacuole located in the right posterior part; plasma yellowish and granulated.

Food

Bacteria.

Occurrence and ecology

Recorded in Europe and America in flowing and standing waters; widely distributed and often abundant in oxidation ponds, sewage irrigation fields, sewage purification plants, often among tufts of *Sphaerotilus* (Liebmann, 1962); the species is associated, for example, with *Cinetochilum margaritaceum* (p. 90) (Lopez-Ochoterena, 1966).

This organism does not tolerate hydrogen sulfide and a dissolved oxygen content below approximately 2 mg/l (Liebmann, 1962). Present in both fresh and brackish water (Kahl, 1931) up to a salt content of 15 g per litre (thalassogenic type).

Saprobiology

According to Liebmann (1962), this is an alpha-mesosaprobic indicator organism.

Saprobiological classification

bos	aos	bms	ams	ps	i
—	—	2	7	1	3

Not described:

Family Ophryoglenidae
e.g., *Ophryoglena* (p. 28; Fig. 18A).

Family Cohnilembidae (= Lembidae)
Genus *Uronema*

URONEMA MARINUM Dujardin (Fig. 19A)

Morphology

Length 30–50 μm; body long, ovoid; anterior pole without cilia and somewhat asymmetrically curved; cilia are arranged in about 15 longitudinal rows; 1 long caudal cilium; the rather short triangular buccal cavity is situated anteriorly and bears 1 small external undulating membrane and 3 adoral membranelles in its depths (these membranelles are not shown in the figure); the total length of the buccal cavity is about 1/6 of the body length; the spherical macronucleus is located in the region of the mouth, a single micronucleus lies close to it; contractile vacuole at the posterior end of the cell. *U. marinum* forms resting cysts in starved cultures; conjugation is by fusion of the anterior ends of the body. Sometimes polymorphic (Jankowski, 1964b).

Food

Bacteria.

Occurrence and ecology

Reported from Europe and North America but is probably cosmopolitan. Found in flowing and standing water containing decaying organic material.

Ecological characteristics (Bick, 1968)

	Extreme tolerances	*Optimal ranges*
temperature (°C)	0–25	?
pH	4.1–7.8	7.0–7.5
dissolved O_2 (mg/l)	0.2–4.5	0.1–1.0
free CO_2 (mg/l)	5–200	10–20
NH_4^+ (mg/l)	0–22	—
H_2S	0–1.2	—
brackish water (seawater type)	up to 35 g of total salt content per litre	?
athalassogenic natron lake water	up to 5 g of total salt content per litre	?
bacteria (plate counts on peptone agar)	2 000–16 000 000/ml	?

Saprobiology

This is an alpha-mesosaprobic indicator organism according to Liebmann (1962).

Family Cohnilembidae (=Lembidae)
Genus *Cohnilembus*

COHNILEMBUS PUSILLUS (Quennerstedt) Kahl (= LEMBUS PUSILLUS Quennerstedt) (Fig. 20A)

Morphology (Kahl, 1931)

Length 30–50 μm; slender and spindle-shaped; uniform complete body ciliation, 1 long caudal cilium; buccal cavity elongated, reaching from anterior pole to one-third or one-half the body length; oral ciliation consisting of 2 long membranes; macronucleus oval, central; contractile vacuole terminal; endoplasm with rod-like, dark bodies; cilia never spread when at rest.

Food

Bacteria.

Occurrence and ecology

Widely distributed in all types of water rich in decaying plant material or receiving manure; probably cosmopolitan in distribution in fresh and brackish waters; associated with *Uronema marinum* (Kahl, 1931) and with *Cyclidium lanuginosum* (Liebmann, 1951).

Ecological characteristics (from Noland, 1925; Dietz, 1964; Wilbert, personal communication)

	Extreme tolerances
temperature (°C)	1–25
pH	7–8.9
dissolved O_2 (mg/l)	0.3–17.0
free CO_2 (mg/l)	0–15.4
brackish water (seawater type)	up to 19.9 g of total salt content per litre

Saprobiology

According to Liebmann (1951), this is an alpha-mesosaprobic indicator organism; subsequently classified (Liebmann, 1962) as polysaprobic.

Saprobiological classification (Bick, unpublished data)

bos	aos	bms	ams	ps	i
—	—	1	6	3	3

Family Tetrahymenidae
Genus *Tetrahymena*

TETRAHYMENA PYRIFORMIS (Ehrenberg) Lwoff (= GLAUCOMA PYRIFORMIS (Ehrenberg) Schewiakoff (Fig. 40)

Morphology

Length 25–90 μm; body ovoid and uniformly ciliated; mouth roughly triangular, longitudinal axis of the buccal cavity parallel to that of the cell itself; buccal cavity containing an undulating membrane on the right side and an adoral zone of 3 membranelles on the left (" tetrahymenal complex "); the spherical macronucleus is situated medially and is usually accompanied by 1 micronucleus (amicronucleate strains occur); 1 contractile vacuole near the posterior end.

Food

Bacteria.

Occurrence and ecology

Cosmopolitan distribution in fresh water, frequently occurring in waters containing plant or animal materials in which bacterial decomposition has commenced, particularly in waters polluted with manure; recorded in trickling filters, oxidation ponds, sewage drains.

Ecological characteristics (Bick, unpublished data)

	Extreme tolerances
temperature (°C)	1–40
pH	7.0–8.9
dissolved O_2 (mg/l)	0–10
free CO_2 (mg/l)	0–200
NH_4^+ (mg/l)	0–250
free NH_3 (mg/l)	0–25
H_2S (mg/l)	0–2

Saprobiology

A polysaprobic indicator organism according to Liebmann (1962).

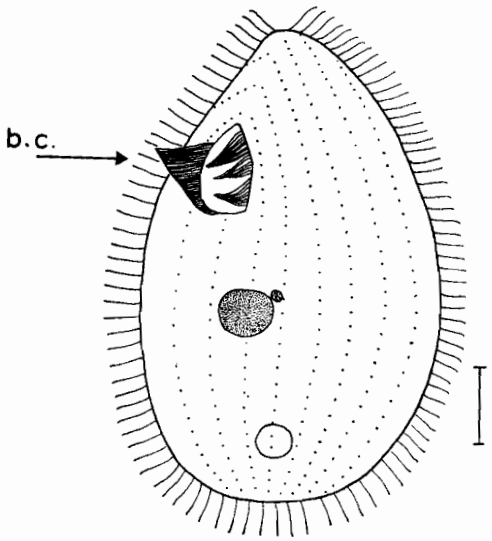

Fig. 40. *Tetrahymena pyriformis* (Ehrenberg) Lwoff, ventral view; after Corliss (1961).

Family Tetrahymenidae
Genus *Glaucoma*

GLAUCOMA SCINTILLANS Ehrenberg (Fig. 41)

Morphology

Length 40–80 μm; body ellipsoid, ventrally flattened, uniformly ciliated; mouth groove oblique to the longitudinal axis of the cell, buccal cavity with 1 large undulating membrane and 3 adoral membranelles; contractile vacuole posteriorly located.

Food

Bacteria.

Occurrence and ecology

Cosmopolitan in distribution; common, for example, in Europe, India, and North America, widely distributed in stagnant and flowing waters rich in organic material just beginning to decompose—trickling filters, sewage drains; in flowing waters frequently in tufts of *Sphaerotilus*.

Ecological characteristics (Bick, 1966, 1968)

	Extreme tolerances	*Optimal ranges*
temperature (°C)	0–35[1]	—
pH	3.8–8.6	7.0–8.0
dissolved O_2 (mg/l)	0–8.9	0–1.0
free CO_2 (mg/l)	5–200	10–25
NH_4^+ (mg/l)	0–300	15–30
free NH_3 (mg/l)	0–10	0–25.
NO_2^- (mg/l)	0–40	0
brackish water (seawater type)	up to 3.5 g of total salt content per litre	fresh water
athalassogenic natron lake water	up to 2 g of total salt content per litre	
bacteria (direct counts)	2 500 000–148 000 000/ml	more than 10 000 000/ml

Saprobiology

This is a polysaprobic indicator organism (Liebmann, 1962) with remarkably high tolerances to oxygen deficiency and septic substances; eurypotent with regard to nearly all environmental factors listed above, but preferring habitats rich in bacteria.

Saprobiological classification

According to Sládeček (1964):

bos	aos	bms	ams	ps	i
—	—	+	2	8	4

[1] Münch (personal communication).

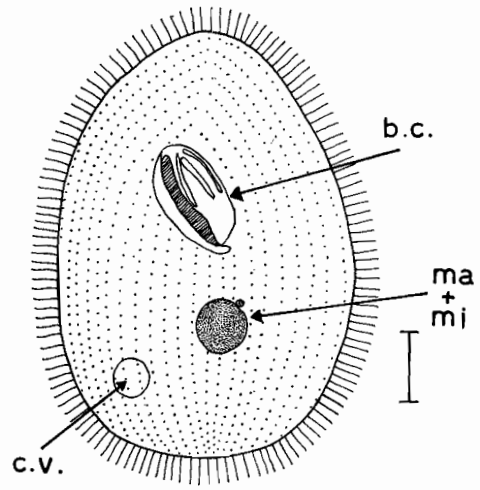

Fig. 41. *Glaucoma scintillans* Ehrenberg, ventral view.

Family Tetrahymenidae
Genus *Colpidium*

COLPIDIUM CAMPYLUM Stokes (Fig. 42)

Morphology

Length 50-120 μm; elongated, reniform, sometimes ovoid; uniform ciliation except for a group of longer cilia at the posterior pole; preoral suture slightly displaced towards the ventral side; suture curved to right; small triangular buccal cavity near the right side of the body at about one-quarter of the body length from the anterior pole; buccal ciliation tetrahymenal; 1 undulating membrane on the right side and 3 adoral membranelles on the left; 1 spherical macronucleus and 1 micronucleus in the central part of the body; 1 contractile vacuole located near the right margin. For special morphological features (silver line system), see Jankowski (1967). It should be mentioned that Jankowski (1967) proposed to put *C. campylum* into a genus of its own (*Dexiostoma* n.g.).

Food

Bacteria, small flagellates.

Occurrence and ecology

Cosmopolitan, occurring in waters rich in bacterial decomposition of organic material, e.g., in tufts of *Sphaerotilus*.

Ecological characteristics (Bick, 1968)

	Extreme tolerances
temperature (°C)	4–30
pH	4.0–8.9
dissolved O_2 (mg/l)	0–11.0
free CO_2 (mg/l)	0–200
NH_4^+ (mg/l)	0.2–160
free NH_3 (mg/l)	0–15
NO_2^- (mg/l)	0–15
brackish water (seawater type)	up to 3.5 g of total salt content per litre

In laboratory experiments, no development occurred in athalassogenic natron lake water.

Bacteria:

(1) plate counts on peptone agar	9 000–4 000 000/ml
(2) direct counts	20 000 000–150 000 000/ml
(3) optimal ranges	above 10^6/ml for (1) or 100×10^6/ml for (2)

Saprobiology

C. campylum was not used as an indicator organism in the *Saprobiensystem* established by Liebmann. Šrámek-Hušek (1956) proposed to use *C. campylum* as a beta-polysaprobic indicator organism (beta-polysaprobic *sensu* Šrámek-Hušek corresponds approximately to the polysaprobic zone of Kolkwitz). Zelinka & Marvan (1961) also classified *C. campylum* as a polysaprobic indicator organism.

According to the ecological characteristics given above, *C. campylum* should be a good polysaprobic indicator organism. It is very tolerant of high concentrations of NH_4^+ or free ammonia, and high population densities are achieved only in the presence of large numbers of bacteria.

Saprobiological classification

According to Zelinka & Marvan (1961):

bos	aos	bms	ams	ps	i
—	—	—	1	9	5

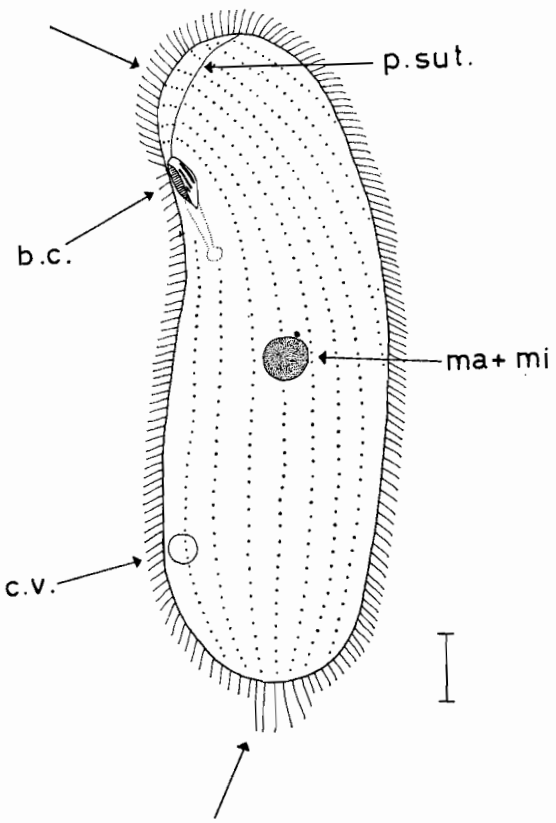

Fig. 42. *Colpidium campylum* Stokes, ventral view. Arrows indicate the main features used for identification.

Family Tetrahymenidae
Genus *Colpidium*

COLPIDIUM COLPODA (Ehrenberg) (Fig. 43)

Morphology (Kahl, 1931)

Length 100–150 μm; ovoid or reniform, elongated; except for a few long caudal cilia, uniform ciliation; about 55 ciliary meridians; preoral suture curved to the left and widely displaced to the ventral side; buccal cavity near the right side of the body at about one-quarter of the body length from the anterior pole; buccal ciliation similar to that of *C. campylum*; 1 spherical macronucleus, a single micronucleus; the contractile vacuole is located in the central part of the body near the dorsal face. For silver line system, see Jankowski (1967).

Food

Bacteria, small flagellates.

Occurrence and ecology

Cosmopolitan in distribution, present throughout the year in waters rich in putrefying organic material; very often occurs on excrement just starting to decompose. Frequently associated with *Cinetochilum margaritaceum*, *Colpidium campylum*, *Glaucoma scintillans*, *Paramecium trichium*, *Tetrahymena pyriformis*, and other forms; this association was called " Colpidietum colpodae " by Šrámek-Hušek (1958), the name being derived from the most characteristic species of the association.

Ecological characteristics (Bick, 1968)

	Extreme tolerances
temperature (°C)	4–30
pH	6.2–8.3
dissolved O_2 (mg/l)	0–7.2
free CO_2 (mg/l)	10–56
NH_4^+ (mg/l)	0.4–25
free NH_3 (according to Stammer, 1953)	up to 25 mg/l
brackish water (seawater type)	up to 3.5 g of total salt content per litre
bacteria (plate counts on peptone agar)	30 000–17 000 000/ml

Saprobiology

C. colpoda was classified as a polysaprobic indicator organism by Liebmann (1962) and as a beta-polysaprobic organism by Šrámek-Hušek (1956). The ecological characteristics given above support these statements. Only mass development should be held to indicate polysaprobic conditions, since single examples may also occur in the alpha-mesosaprobic zone.

Saprobiological classification

According to Zelinka & Marvan (1961) after Sládeček (1964):

bos	aos	bms	ams	ps	i
—	—	—	3	7	4

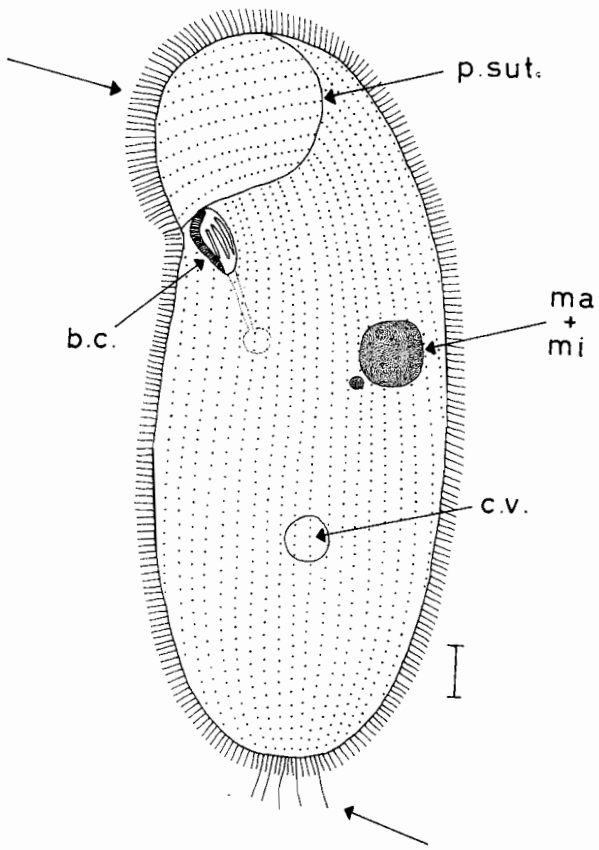

Fig. 43. *Colpidium colpoda* (Ehrenberg). Arrows indicate further features used for identification.

Suborder PENICULINA

Family Parameciidae
Genus *Paramecium*

PARAMECIUM CAUDATUM Ehrenberg (Fig. 44)

Morphology

Length 180–300 μm; cigar-shaped, posterior end bluntly pointed and with a group of long cilia, ciliation otherwise uniform; oral groove (" vestibulum ") long and slightly oblique; buccal cavity with one endoral membrane and 2 peniculi (peniculus = group of specialized cilia characteristic of the " Peniculina "); an ellipsoid macronucleus and *1 compact* micronucleus (the species *P. aurelia*, which is otherwise similar to *P. caudatum*, has *2 vesicular* micronuclei); 2 contractile vacuoles, each with radial canals, near the aboral surface; numerous trichocysts, which may discharge explosively, all over the body.

Food

Bacteria (for feeding habits, see Curds & Vandyke (1966)).

Occurrence and ecology

Cosmopolitan in distribution; abundant throughout the year in stagnant and flowing waters rich in putrescible organic material.

Ecological characteristics (Bick, 1968)

	Extreme tolerances	*Optimal ranges*
temperature (°C)	1–35°	—
pH	4.0–9.4	6.5–7.5
dissolved O_2 (mg/l)	0–12	0–1
free CO_2 (mg/l)	0–200	10–25
NH_4^+ (mg/l)	0–100	0–2
free NH_3 (mg/l)	0–2	below 0.05
NO_2^- (mg/l)	0–32	—
brackish water (seawater type)	up to 21 g of total salt content per litre	fresh water
athalassogenic natron lake water	up to 4 g of total salt content per litre	fresh water
bacteria (plate counts on peptone agar)	600–32 000 000/ml	—

P. caudatum is eurypotent with regard to the ecological factors listed above except to NH_4^+ and NH_3; very common to extremely abundant only in habitats rich in bacterial decomposition of organic matter but with a low content of NH_4^+. Occasional individuals have been recorded in both polysaprobic and beta-mesosaprobic zones; therefore, only high individual counts are of significance in the biological evaluation of water pollution.

Saprobiology

According to Liebmann (1962), this is an alpha-mesosaprobic indicator organism; by Šrámek-Hušek's (1954) classification it is beta-polysaprobic. Ventz (1964), dealing with the saprobiology of *P. caudatum*, found the " ecological maximum " (= highest frequency of occurrence) under alpha-mesosaprobic conditions.

Saprobiological classification

According to Zelinka & Marvan (1961) and Sládeček (1964):

bos	aos	bms	ams	ps	i
—	—	—	5	5	3

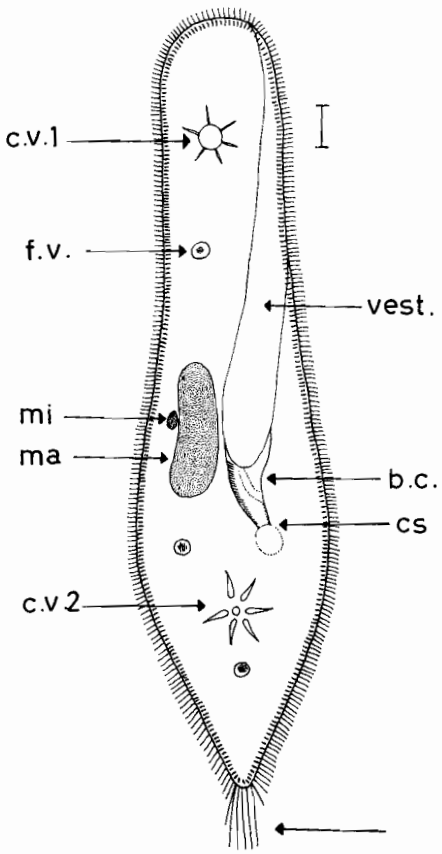

Fig. 44. *Paramecium caudatum* Ehrenberg; semidiagrammatic.

Family Parameciidae
Genus *Paramecium*

PARAMECIUM BURSARIA Ehrenberg (Fig. 45)

Morphology

Length 90–150 μm; foot-shaped, more or less flattened; uniform ciliation except for a group of long caudal cilia; green with symbiotic zoochlorellae; a long broad oral groove (vestibule) leads to the buccal cavity, the buccal ciliary apparatus is characterized by 2 " peniculi "; [1] 1 macronucleus, 1 compact micronucleus; 2 contractile vacuoles; numerous prominent trichocysts.

Food

Bacteria (sometimes purple-coloured sulfur bacteria), flagellates; starving individuals digest their symbionts.

Occurrence and ecology

Cosmopolitan in distribution, e.g., Europe, North America, India, in still waters rich in higher plants and algae, such as ponds or littoral zones of lakes, forest pools rich in decaying leaves, oxidation ponds, polluted streams. Under laboratory conditions this ciliate occurs in cultures rich in peptone, under which conditions it can withstand high ammonium and low oxygen levels.

Ecological characteristics (Bick, 1968)

	Extreme tolerances
temperature (°C)	0–25
pH	6.4–8.2
dissolved O_2 (mg/l)	0.1–11.0
free CO_2 (mg/l)	0–48
NH_4^+ (mg/l)	0–60
free NH_3 (mg/l)	0–3
H_2S (mg/l)	0–1.1
bacteria (direct counts)	3 000 000–140 000 000/ml

Under laboratory conditions no development occurs in thalassogenic brackish waters. The species develops in athalassogenic natron lake water with a total salt content of up to 2 g per litre.

Saprobiology

According to Liebmann (1962), this is a beta-mesosaprobic indicator organism. My results do not support this opinion; I found *P. bursaria* able to tolerate high levels of NH_4^+ and a very low oxygen content; under these conditions the populations increased to about 500 individuals per ml, and were accompanied by *P. trichium*, *Colpidium campylum*, *Glaucoma scintillans*, and other alpha-mesosaprobic or even polysaprobic indicator organisms. These results (cf., Krishnamoorthi & Bick) [2] support the following saprobiological classification of Zelinka & Marvan (1961):

bos	aos	bms	ams	ps	i
—	—	2	6	2	2

[1] See description of *Paramecium caudatum*, p. 82.

[2] Krishnamoorthi, K. P. & Bick, H. (1966) *Laboratory studies on the succession of ciliates during the decomposition of peptone in relation to certain environmental factors*, parts I and II, unpublished WHO working documents WHO/EBL/66/83 and WHO/EBL/66/84.

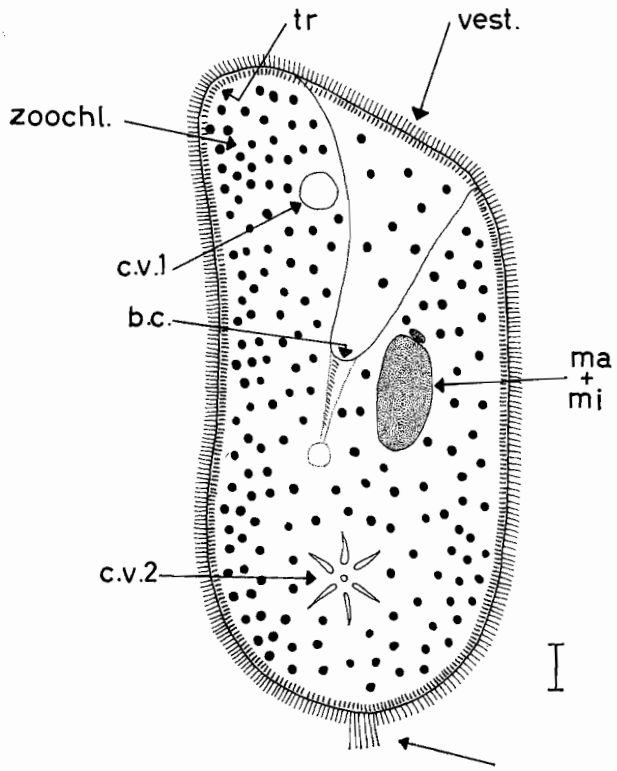

Fig. 45. *Paramecium bursaria* Ehrenberg.

Family Parameciidae
Genus *Paramecium*

PARAMECIUM PUTRINUM Claparède & Lachmann (Fig. 46)

Morphology

About 130 μm long; similar to *P. bursaria* but without zoochlorellae; macronucleus elongated, kidney-shaped; 1 micronucleus; only 1 contractile vacuole; no trichocysts (Lepşi, 1926; Kahl, 1931).

Records of *P. putrinum* are scanty, and it is in fact doubtful whether the species is valid. This problem is of some saprobiological interest since Liebmann (1962) classified *P. putrinum* as a polysaprobic indicator organism. On the other hand, Šrámek-Hušek (1954) failed to find any specimens of *P. putrinum* during his saprobiological studies in Czechoslovakia; all representatives of the genus *Paramecium* that he found in the more heavily polluted zones were referable to *P. trichium*. Therefore, Šrámek-Hušek submitted that the polysaprobic " *P. putrinum* " of earlier authors is really *P. trichium* Stokes (Šrámek-Hušek, 1954, 1956). In my own studies on ciliates I also failed to find *P. putrinum*.

The figure of *P. putrinum* given by Liebmann (1962) differs from the original diagnosis: *P. putrinum sensu* Liebmann has 2 contractile vacuoles, both shown with radial canals; the specimen illustrated thus resembles individuals of *P. caudatum* cultivated under polysaprobic conditions (e.g., oxygen lack, high levels of ammonia). *P. putrinum sensu* Liebmann was recorded from the sludge of polluted reservoirs, dammed rivers, lakes etc., in the upper zone of trickling filters, sewage drains, and in floating tufts of *Sphaerotilus* (Liebmann, 1962). Taxonomic studies of " *P. putrinum* " and *P. trichium* are thus urgently required.

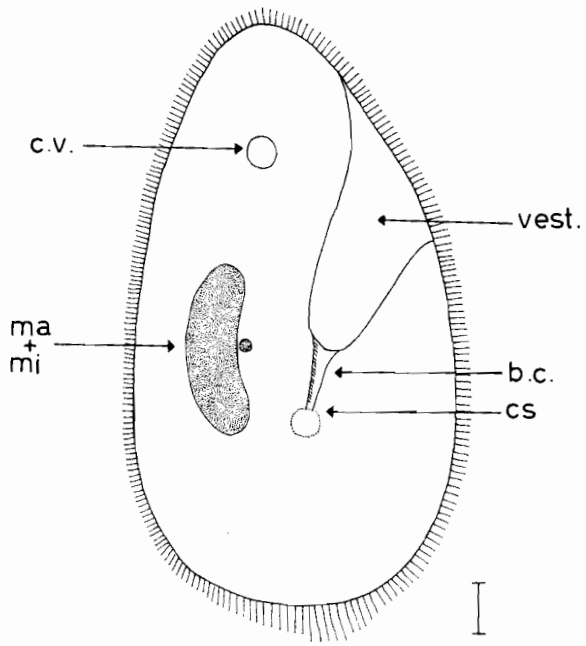

Fig. 46. *Paramecium putrinum* Claparède & Lachmann; redrawn after Kahl (1931) and Lepşi (1926).

Family Parameciidae
Genus *Paramecium*

PARAMECIUM TRICHIUM Stokes (Fig. 47)

Morphology

Length 50–120 μm; body shape highly variable, more or less ellipsoid, somewhat flattened; ciliation uniform except for a group of long caudal cilia; oral groove and buccal equipment similar to those of *P. bursaria*; 1 macronucleus; 1 compact micronucleus; 2 contractile vacuoles, each with a convoluted outlet; unlike other members of its genus, *P. trichium* has a contractile vacuole without radial canals but with tributary vacuoles; numerous trichocysts all over the body; posterior part of the body more or less filled with dark granules. According to Šrámek-Hušek (1954), *P. pseudoputrinum* Baumeister is referable to *P. trichium*.

Food

Bacteria.

Occurrence and ecology

Probably cosmopolitan in distribution in habitats with decaying organic material, both stagnant and flowing waters.

Ecological characteristics (Bick, 1968)

	Extreme tolerances
temperature (°C))	2–25
pH	6.4–8.3
dissolved O_2 (mg/l)	0–7.5
free CO_2 (mg/l)	20–93
NH_4^+ (mg/l)	0–60
free NH_3 (mg/l)	0–3
H_2S (mg/l)	0–1
brackish water (seawater type)	up to 14 g of total salt content per litre
bacteria (direct counts)	1 000 000–165 000 000/ml

Saprobiology

P. trichium is not listed in the *Saprobiensystem* (Liebmann, 1962). Šrámek-Hušek (1954) proposed to use the species as an alpha-mesosaprobic indicator organism. The ecological characteristics given above favour this proposal. However, the range of occurrence extends from the polysaprobic to the beta-mesosaprobic zone, and only a mass development (or at least a high frequency of this species) would indicate an alpha-mesosaprobic condition.

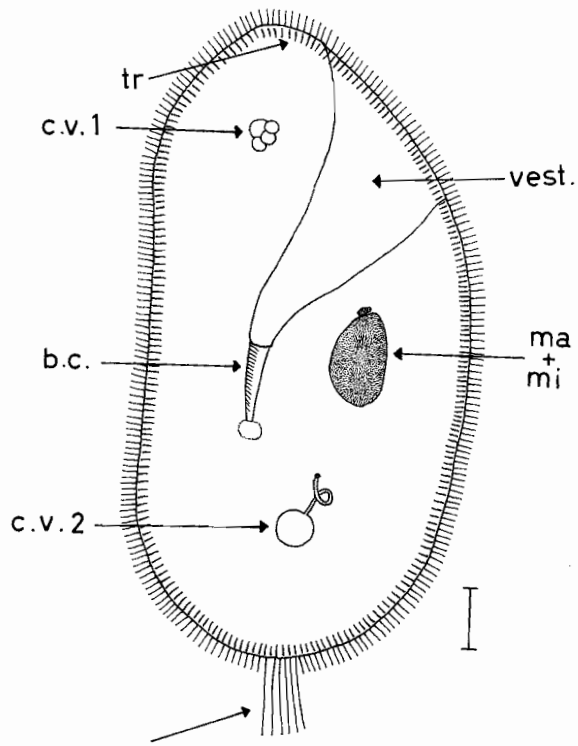

Fig. 47. *Paramecium trichium* Stokes. The convoluted outlet of the second contractile vacuole (c.v.2) is shown.

Family Cinetochilidae
Genus *Cinetochilum*

CINETOCHILUM MARGARITACEUM Perty (Fig. 48)

Morphology

Length 15–45 μm; body shape oval to ellipsoid, flattened; ciliation present only on the ventral surface, 3 or 4 caudal cilia; buccal cavity in the right posterior part of the cell, membranes situated on both edges of the buccal cavity, the right one forming a pocket; 1 spherical macronucleus and 1 micronucleus in the central part of the cell; 1 contractile vacuole near to the left posterior end; trichocysts present all over the body (Kahl, 1931).

Food

Bacteria.

Occurrence and ecology

Reported from Europe, America, India; widely distributed in all types of water containing decaying organic material.

Ecological characteristics (Bick, 1968; Münch, 1969)

	Extreme tolerances	*Optimal ranges*
temperature (°C)	0–45	about 15
pH	6.4–9.7	about 7
dissolved O_2 (mg/l)	0–16	0–6
free CO_2 (mg/l)	0–48	15–30
NH_4^+ (mg/l)	0–80	0–20
free NH_3 (mg/l)	0–0.8	below 0.1
H_2S (mg/l)	0	—
brackish water (seawater type)	up to 7 g of total salt content per litre	fresh water
athalassogenic natron lake water	up to 10 g of total salt content per litre	—
bacteria (plate counts on peptone agar)	300–9 000 000/ml	—

Saprobiology

According to Kolkwitz (1950), this is a beta-mesosaprobic indicator organism. On account of the rather low tolerance to free ammonia, *C. margaritaceum* is not able to live in the upper self-purification zone of water polluted with sewage; under special conditions, however, e.g., pollution with decaying leaves or other materials containing cellulose but only a few nitrogenous compounds, *C. margaritaceum* may occur under alpha-mesosaprobic conditions. The species should therefore be considered as a rather unreliable indicator organism. Mass development should be considered to indicate alpha-mesosaprobic conditions in waters polluted with organic material poor in nitrogenous compounds.

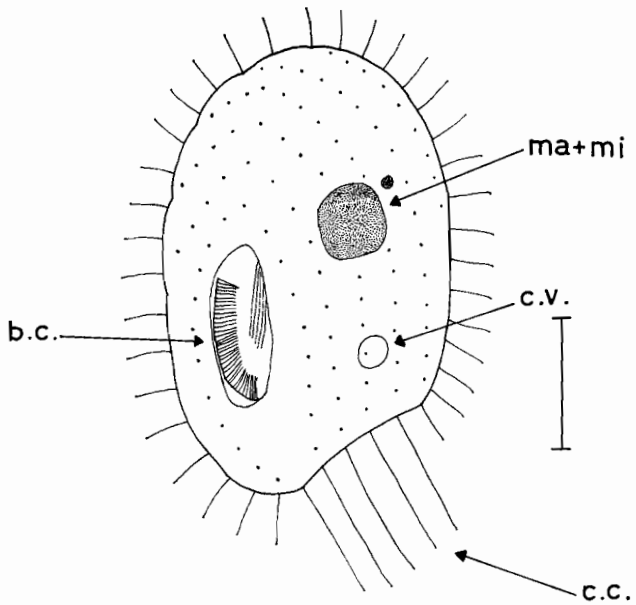

Fig. 48. *Cinetochilum margaritaceum* Perty, ventral view.

Family Urocentridae
Genus *Urocentrum*

UROCENTRUM TURBO (O. F. Müller) (Fig. 49)

Morphology

Length 50–80 μm; body cylindrical and ventrally slightly flattened; constricted at the middle; 2 broad girdles of cilia and 1 eccentric posterior tuft; a zone of short cilia in the constricted area; buccal cavity subequatorial with 1 membrane and 2 short undulating membranelles; in the postoral area, a longitudinal zone with small cilia; macronucleus horseshoe-shaped and posteriorly located; a single micronucleus; contractile vacuole terminal, and with 8 collecting canals; large number of trichocysts all over the body (Kahl, 1931).

Unique movement

Very rapid locomotion with intermittent rotation at one spot fixed by a mucilaginous thread that is secreted by the ciliate itself.

Food

Bacteria.

Occurrence and ecology

Cosmopolitan in distribution, occurring all through the year in lakes, ponds, pools with natural pollution (e.g., decaying leaves), sewage oxidation ponds with low loadings; in fresh water only.

Ecological characteristics (Bick, 1957; 1968)

	Extreme tolerances
temperature (°C)	5–25
pH	6.0–7.6
dissolved O_2 (mg/l)	0–12
free CO_2 (mg/l)	0–36
NH_4^+ (mg/l)	0–18
H_2S (mg/l)	0–0.5
bacteria (plate counts)	2 000–500 000/ml

Saprobiology

An alpha-mesosaprobic indicator organism according to Liebmann (1962).

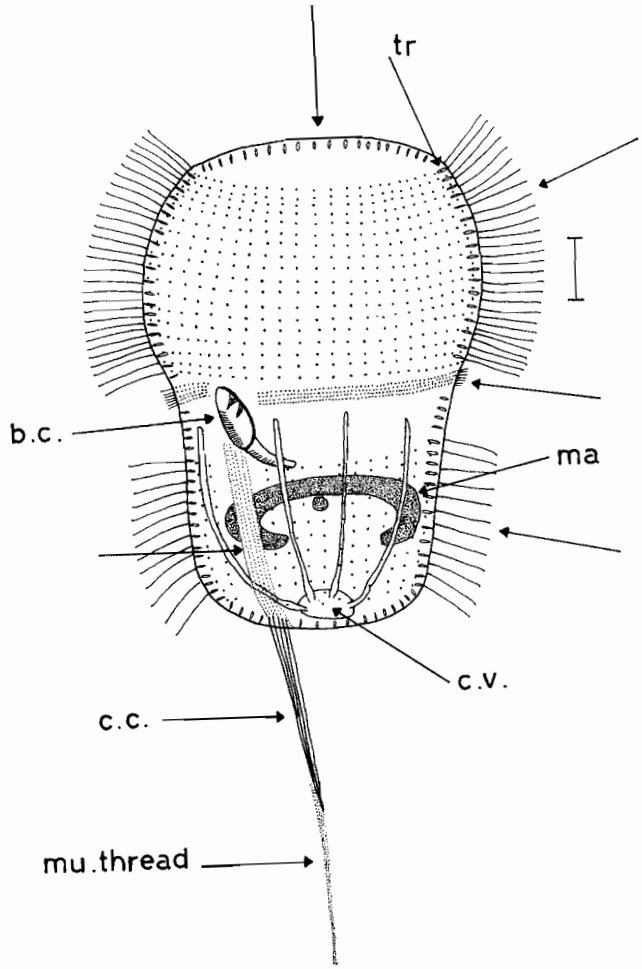

Fig. 49. *Urocentrum turbo* (O. F. Müller). Arrows indicate the main features used for identification.

Family Urocentridae
Genus *Urozona*

UROZONA BUETSCHLI Schewiakoff (Fig. 50)

Taxonomic position according to Jankowski (1964a)

Morphology (Kahl, 1931)

Body length 20–30 μm; cilia in 1 girdle encircling the middle of the body, 1 long caudal cilium, the rest of the cell is bare; buccal cavity situated equatorially within the girdle of cilia, mouth equipment contains 1 undulating membrane and 2 membranelles, which are revealed by impregnation with silver nitrate (Jankowski, 1964a); contractile vacuole and nuclei situated near the posterior end of the cell; body surface free of cilia shows fine longitudinal lines; forward swimming is alternated with periods of quick rotation in one place (Jankowski, 1964a).

Food

Bacteria.

Occurrence and ecology

Cosmopolitan distribution in flowing and standing waters containing decaying plant material, particularly in pools with litter and decaying leaves.

Ecological characteristics

	Extreme tolerances
temperature (°C)	5–25
pH	6.0–7.7
dissolved O_2 (mg/l)	0–5.2
free CO_2 (mg/l)	0–19
NH_4^+ (mg/l)	0–5

Saprobiology

A polysaprobic indicator organism according to Liebmann (1962), a typical inhabitant of sewage, in Europe occurring all through the year. Associated with *Dexiotrichides centralis*, and sometimes with *Trimyema compressum* and *Enchelyomorpha vermicularis*.

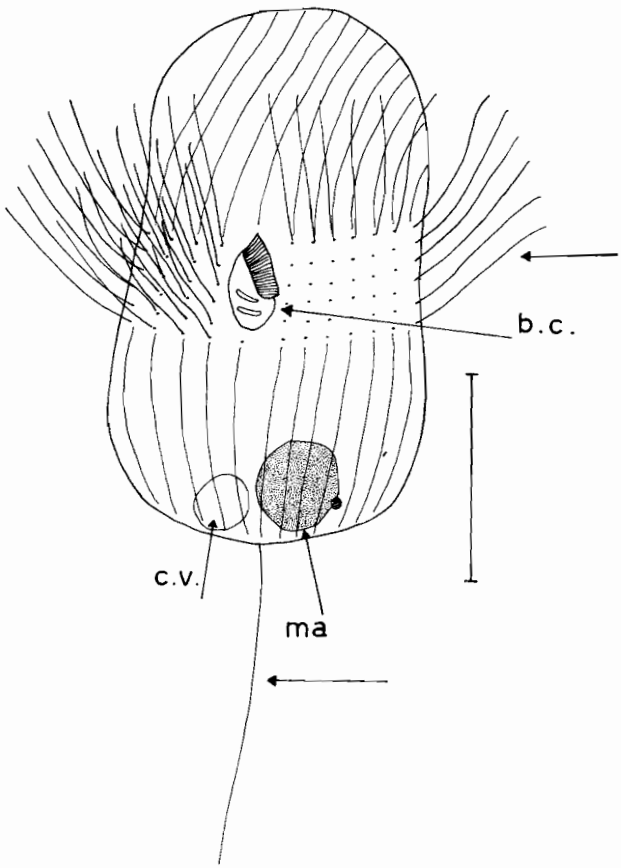

Fig. 50. *Urozona buetschli* Schewiakoff. Arrows indicate the main features used for identification. Cilia partly omitted but marked by dots.

Family Frontoniidae
Genus *Frontonia*

FRONTONIA ACUMINATA Ehrenberg (Fig. 17A)

Morphology

Length 50–150 μm; body ovoid to ellipsoid, dorsoventrally flattened; dorsal side slightly convex, ventral face flat; complete uniform ciliation; buccal cavity lies in anterior right third of the cell; ciliary rows of the right and left ventral surface meet in a preoral suture and a very postoral groove, respectively; postoral groove usually nearly closed; buccal cavity lancet-like with pointed anterior and truncate posterior end, complex buccal ciliation consisting of compound ciliary organelles; single macronucleus ellipsoid in the middle of the body; 1 micronucleus; 1 contractile vacuole near the right margin.

According to Kahl (1931) there are two morphological types to be found:

(1) *F. acuminata* form *typica*; highly flattened with an accumulation of dark granules near the anterior pole.

(2) *F. acuminata* var. *angusta* Kahl; moderately flattened, without granules.

Food

Green algae, diatoms, ciliates.

Occurrence and ecology

F. acuminata typica is reported in America and Europe, widely distributed in all types of slowly flowing and standing waters rich in plants and algae; found also in woodland pools and ponds rich in decaying leaves. *F. acuminata* var. *angusta* has been reported from ponds and pools occurring in the periphyton community (Wilbert, 1969); the highest abundance in Bonn (Federal Republic of Germany) was in spring (February–April), associated with the diatoms *Nitzschia*, *Synedra*, and *Tabellaria* and the ciliates *Cinetochilum margaritaceum* (p. 90), *Coleps nolandi*, *Opercularia nutans* (p. 122), and *Stentor igneus*.

If the periphyton community consists only of heterotrophic organisms, e.g., in deep layers without sufficient sunlight for algal growth, *Frontonia* does not occur at all; sometimes planktonic.

Ecological characteristics (from Noland, 1925; Bick, 1957)

	Extreme tolerances
temperature (°C)	1–22
pH	6.5–8.7
dissolved O_2 (mg/l)	0.8–14.3
NH_4^+ (mg/l)	0–2.2
H_2S (mg/l)	0–1.1

Ecological characteristics of F. acuminata var. **angusta** (Wilbert, personal communication)

temperature (°C)	1.8–20.5
pH	7.4–9.3
dissolved O_2 (mg/l)	0–22.4
O_2 (percentage saturation)	0–207
free CO_2 (mg/l)	1.5–37
NH_4^+ (mg/l)	0–3.1
H_2S (mg/l)	0–1.1
bacteria (direct counts)	800 000–23 000 000/ml

Apparently there are no significant differences between the two morphological types of *F. acuminata* in their ecological tolerance ranges.

Saprobiology

According to Liebmann (1962), the typical *F. acuminata* is an oligosaprobic indicator organism. The ecological data presented above are in contradiction to this statement. By investigations using the glass-slide method, Wilbert (1968) has demonstrated that at least the variety *angusta* is unable to live under oligosaprobic conditions but grows well in beta-mesosaprobic localities. From the data on the ecological characteristics of the two types of *F. acuminata* it is evident that both prefer beta-mesosaprobic conditions favouring mass development of green algae and diatoms.

Saprobiological classification

bos	aos	bms	ams	ps	
—	2	6	2	—	3

Suborder PLEURONEMATINA

Family Pleuronematidae (= Cyclidiidae)
Genus *Cyclidium*

CYCLIDIUM CITRULLUS Cohn (Fig. 51)

Morphology

Length 15–40 μm, mean about 30 μm; body elongate ovoid, ventral surface flattened; anterior pole without cilia (frontal plate), 1 long caudal cilium inserted in a hollow at the posterior end, 15–16 ciliary meridians (Berger, 1959); conspicuous external undulating membrane of approximately two-thirds length of body, forming a pocket around the cytostomal groove; membrane with 2 sinuations; when inactive the membrane is concealed in a groove situated at the posterior part of the cell; 1 spherical macronucleus and a single micronucleus are located anteriorly (amicronucleate strains have been described by Berger (1959)); contractile vacuole at the posterior end of the cell; a very characteristic feature is that the organism remains motionless when feeding, its cilia spread wide and the undulating membrane in action.

Food

Bacteria.

Occurrence and ecology

Cosmopolitan in distribution, e.g., Europe, India, North America. In littoral zones of lakes and rivers polluted with organic material, sometimes planktonic. Freshwater sapropel (Jankowski, 1964b), oxidation ponds and, according to Liebmann (1962), trickling filters, woodland pools with decaying leaves (Bick, 1958).

Saprobiology

An alpha-mesosaprobic indicator organism according to Liebmann (1962); according to Bick (1968), only its presence in great abundance points to alpha-mesosaprobic conditions; scattered individuals may occur under other ecological circumstances.

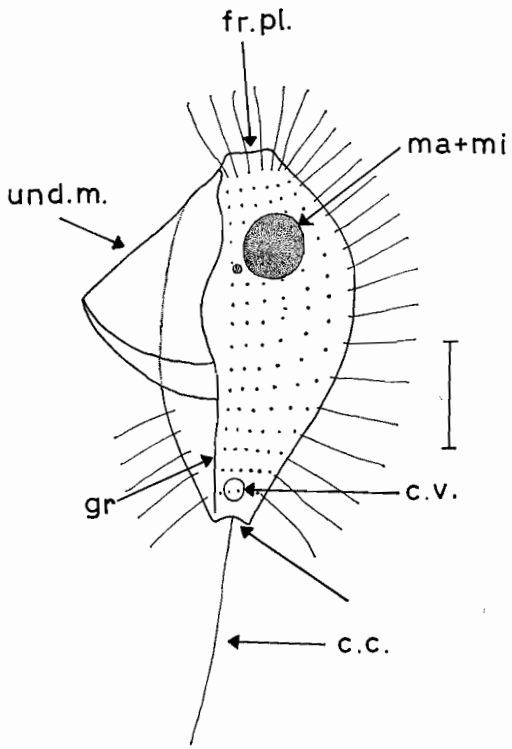

Fig. 51. *Cyclidium citrullus* Cohn. Arrows indicate the main features used for identification.

Family Pleuronematidae (=Cyclidiidae)
Genus *Cyclidium*

CYCLIDIUM GLAUCOMA (O. F. Müller) (Fig. 52)

Morphology

Length 15–30 μm, mean about 20 μm; body ovoid with cilia-free anterior end; 1 long caudal cilium; 10 (rarely 11) ciliary meridians (Berger, 1960); the large undulating membrane is free of sinuations and approximately one-half the length of body; a full description of the buccal organelles is given by Berger & Thompson (1960); in addition to the undulating membrane, there are 3 definitive membranelles that are difficult to observe in the living condition; unlike *C. citrullus*, this species lacks a postoral longitudinal groove; 1 spherical macronucleus and a single micronucleus are located near the anterior end of the body; the contractile vacuole is posteriorly situated.

Food

Bacteria; during feeding periods the ciliate remains in one position with spread cilia and beating membranelles.

Occurrence and ecology

Reported from Europe, North America, New Zealand; widely distributed, inhabiting the polysaprobic zone of freshwater ponds; " one of the most common ciliates recorded from the tens of natural sources " (Jankowski, 1964b).

According to Kolkwitz (1950), it is an alpha-mesosaprobic indicator organism.

Saprobiological classification

According to Sládeček (1969):

bos	aos	bms	ams	ps	i
—	—	—	9	1	5

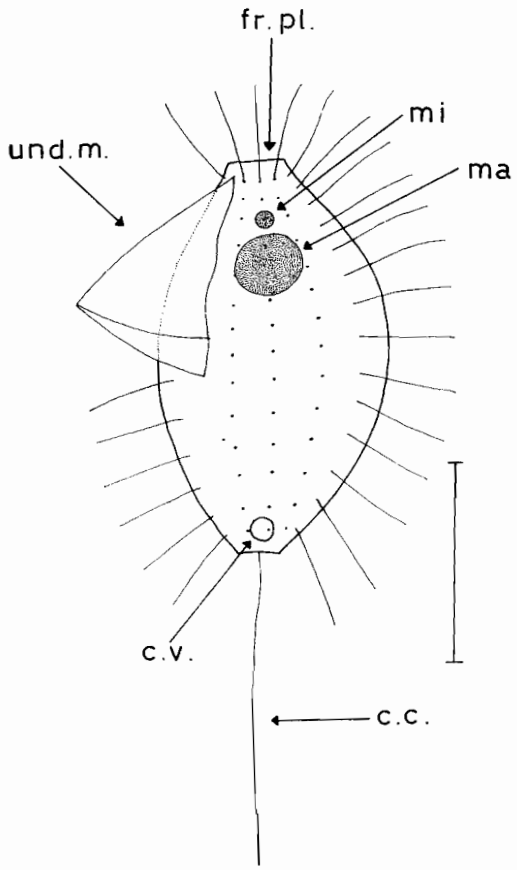

Fig. 52. *Cyclidium glaucoma* (O. F. Müller); after Berger et al. (1960).

Family Pleuronematidae (=Cyclidiidae)
Genus *Cyclidium*

CYCLIDIUM LANUGINOSUM Penard (Fig. 53)

Morphology

Length 35–40 μm; body elongate-ovoid, dorsally flattened in contrast to the other species of the genus, which are ventrally flattened (cf., Kahl, 1931); 2 long frontal cilia are inserted close to the anterior pole; 1 long caudal cilium; about 22 longitudinal rows of rather short cilia; undulating membranelle approximately three-quarters of the body length; macronucleus in the anterior region; contractile vacuole dorsally positioned and close to the posterior end; according to Wilbert (1969) this species lives within a thin tube-shaped shell or case that is secreted by the organism itself and is attached to the substrate (plant material or artificial surfaces such as glass slides); the ciliate is attached to the wall of its case by the flattened dorsal part of the body. The shell is abandoned immediately in the event of any disturbance; perhaps this is the reason why this particular feature of *C. lanuginosum* escaped earlier observation.

Food

Bacteria; food organisms are whirled into the case by the beating of the undulating membranelle.

Occurrence and ecology

Reported in European fresh water and brackish water (Kahl, 1931); eutrophic ponds (Wilbert, 1969), trickling filters, activated sludge, and polluted rivers on tufts of *Sphaerotilus* (Liebmann, 1962).

Ecological characteristics (Wilbert, personal communication)

	Extreme tolerances
temperature (°C)	3–22
pH	7.7–9.2
dissolved O_2 (mg/l)	1.4–24.8
free CO_2 (mg/l)	0–21.6
NH_4^+ (mg/l)	0–2.5
H_2S (mg/l)	0–1.2

Saprobiology

According to Liebmann (1962), it is an alpha-mesosaprobic indicator organism.

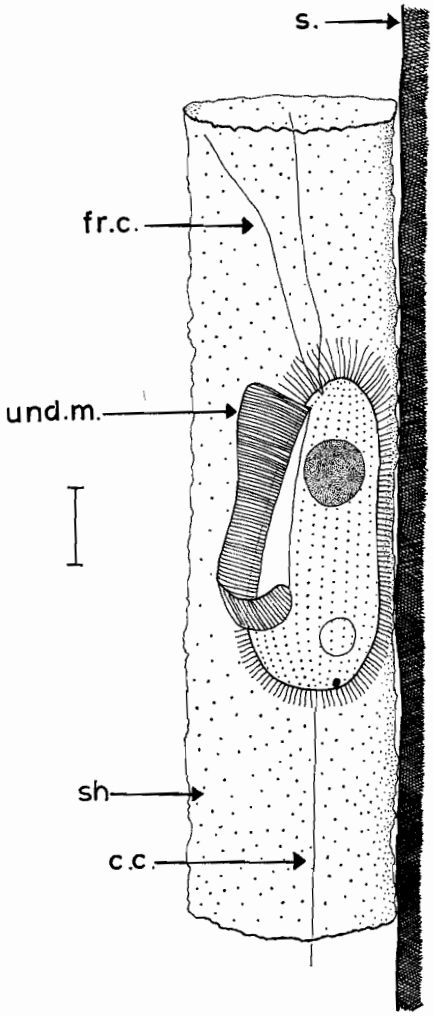

Fig. 53. *Cyclidium lanuginosum* Penard; after Wilbert (1969).

Subclass PERITRICHIA
Order PERITRICHIDA
Suborder SESSILINA

Family Ophrydiidae
Genus *Ophrydium*

OPHRYDIUM VERSATILE (O. F. Müller) (Fig. 54)

Morphology

Individuals 300–600 μm long (fully extended), colonies up to 15 cm; body elongated flask-form, the " neck " (see Fig. 54) is extremely contractile; green in colour on account of symbiotic zoochlorellae; long dichotomous stalk; macronucleus long, band-like, extending along the longitudinal axis of the cell; several strains are amicronucleate; contractile vacuole with a long vacuolar canal that empties into the buccal cavity; individuals are embedded in a large mucilaginous mass that is attached to various substrates (e.g., stones, sticks, shells, plants); colonies are green in colour; small colonies are nearly spherical, larger colonies are of an irregular spherical form, sometimes flattened, often with a central cavity; dispersal by telotrochs (= free-swimming larvae), which are equipped with an aboral locomotory girdle of cilia. For a detailed description of morphology and systematics, see Winkler & Corliss (1965).

Food

Bacteria.

Occurrence and ecology

Reported from Europe and America; widely distributed in still and slowly flowing oligotrophic waters near the shore-line; occurs throughout the year, in Michigan, USA, the largest colonies have been recorded in October (Winkler & Corliss, 1965).

Saprobiology

According to Liebmann (1962), it is an oligotrophic indicator organism; according to Kolkwitz (1950), it also occurs in alpha-mesosaprobic habitats.

OPHRYDIUM SESSILE Kent

Morphology

Individuals up to 300 μm long, colonies 3 mm in diameter; buccal ciliation, contractile vacuole, and macronucleus very similar to *O. versatile* but zoochlorellae are absent (therefore not green) and there is no stalk; colony-forming; mucilaginous loricae colourless or brownish, colonies comparatively small. It is doubtful whether *O. sessile* is an independent species, possibly it is a subspecies of *O. versatile* (cf., Winkler & Corliss, 1965).

Food

Bacteria.

Occurrence and ecology

Reported from European lakes and reservoirs, attached to plants, stones, and artificial substrates (e.g., microscope slides). *O. sessile* was observed in the Sedliče Reservoir, Czechoslovakia, during a period of heavy pollution by wastes from sugar factories (Sládečková & Sládeček, 1963).

Saprobiological classification

According to Sládečková & Sládeček (1964):

bos	aos	bms	ams	ps	i
—	2	3	5	—	2

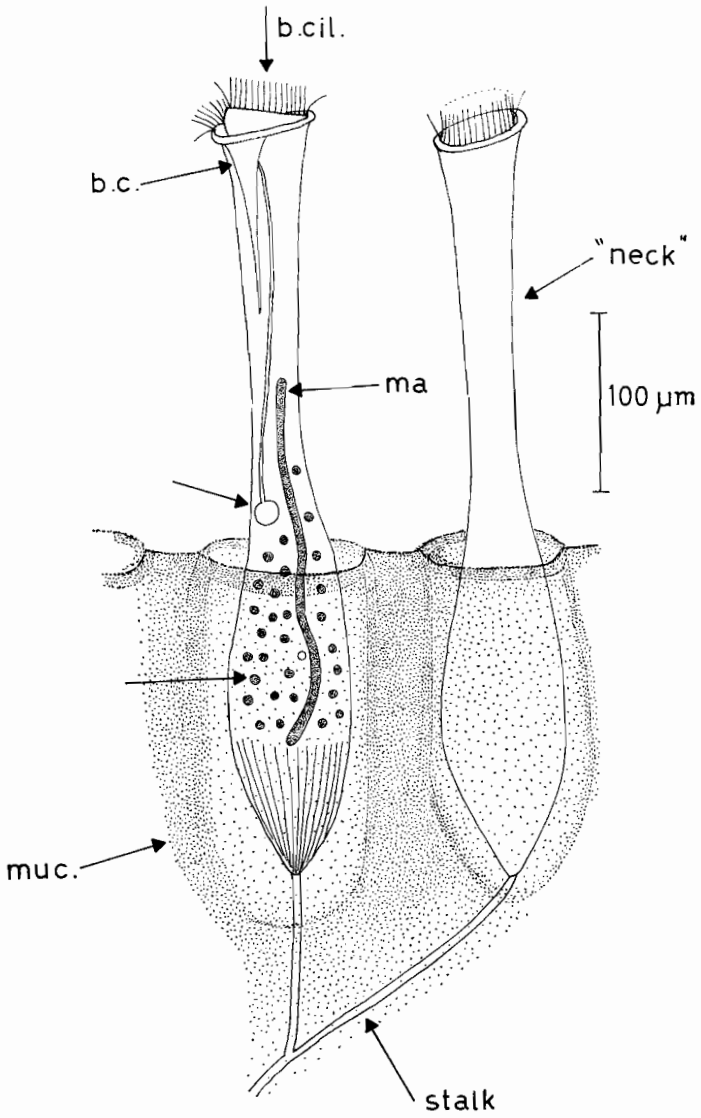

Fig. 54. *Ophrydium versatile* (O. F. Müller).

Family Vorticellidae
Genus *Vorticella*

VORTICELLA MICROSTOMA Ehrenberg (Fig. 55)

Morphology

Body vase-like, length 35–120 μm; long contractile stalk about 20–400 μm; pellicle annulated; cytoplasm slightly yellowish; anterior region (= " peristome ") with buccal ciliation that winds counterclockwise to the buccal cavity; anterior region rather narrow by comparison with other species of the genus; 1 long band-form macronucleus extending more or less along the longitudinal axis of the cell; a single micronucleus; a contractile vacuole is located near the buccal cavity; usually solitary, although sometimes in large groups.

Mature sessile individuals without body ciliation; the sessile individual may develop to the free-swimming " telotroch " stage without a stalk but with a posterior girdle of cilia. Telotroch formation occurs under defined ecological conditions, e.g., lack of oxygen and high carbon dioxide tension (Stout, 1954). Asexual reproduction is by longitudinal binary fission; one daughter cell usually remains on the stalk, while the other is provided with a posterior ciliary girdle (" free-swimming larvae ").

Conjugation by sessile macroconjugants and free-swimming microconjugants with posterior ciliary girdle; the microconjugant is formed by unequal division.

V. microstoma may vary greatly in size, shape, and stalk-length (Stiller, 1954).

Food

Bacteria, small algae.

Occurrence and ecology

Cosmopolitan in distribution, present throughout the year in still and flowing waters containing putrescible organic material.

Ecological characteristics (Bick, 1960; Nusch, 1969)

	Extreme tolerances
temperature (°C)	0–30
pH	6.5–9.5
dissolved O_2 (mg/l)	0–12.0
free CO_2 (mg/l)	0–60.0
NH_4^+ (mg/l)	0–65.0
NH_2^- (mg/l)	0–50.0
H_2S (mg/l)	0–4.0
bacteria (membrane-filter method)	5 000 000–85 000 000/ml

The species occurs in thalassogenic and athalassogenic brackish water (Stiller, 1954). The high variability of *V. microstoma* poses considerable difficulty in identifying the species under conditions of high total salt content; it therefore seems better to disregard specific data on salt tolerance at present.

Saprobiology

V. microstoma was classified as a polysaprobic indicator organism by Liebmann (1962); it should be stressed that only mass development indicates polysaprobic conditions (Liebmann, 1962). Small colonies may occur under mesosaprobic conditions, solitary specimens even being found in the oligosaprobic zone. According to Stiller (1954, 1961) the typical *V. microstoma* is to be found under alpha-mesosaprobic conditions, while specimens living in the polysaprobic zone show much variability with respect to size, colour, shape, and structure of pellicle. It should be added that all varieties change into the typical form if cultivated under appropriate laboratory conditions.

Saprobiological classification

According to Zelinka & Marvan (1961) (1) and Sládeček (1964) (2):

	bos	aos	bms	ams	ps	i
(1)	—	—	—	2	8	4
(2)	—	—	—	1	9	5

This classification seems somewhat too narrow since *V. microstoma* may also occur under beta-mesosaprobic, and even alpha-oligosaprobic, conditions. It is evident from the ecological characteristics given above that *V. microstoma* is able to live within a wide range of environmental factors and does not confine itself to zones with high bacterial activities. Further investigations are necessary to verify the true saprobiological position of the species.

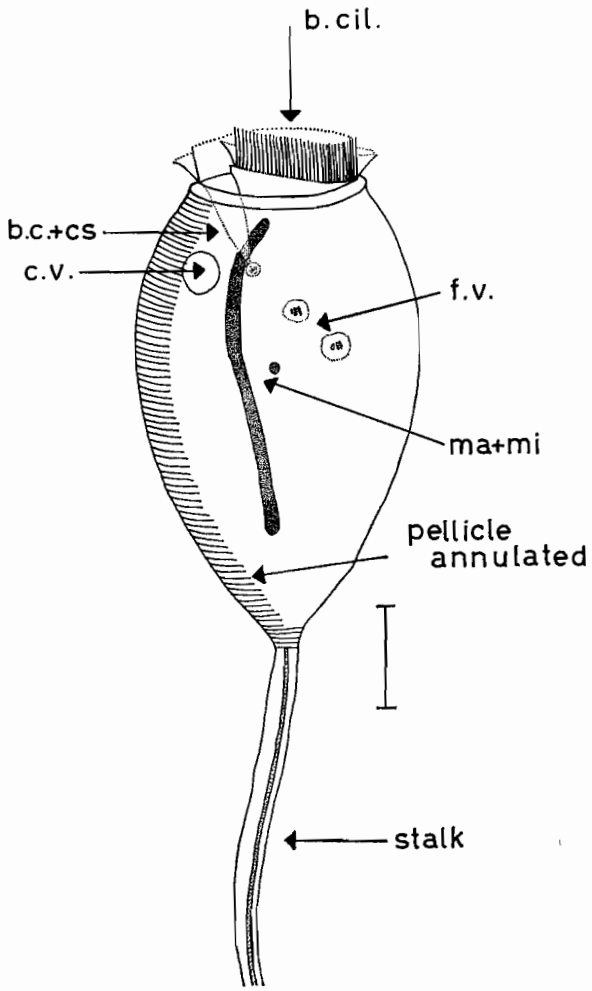

Fig. 55. *Vorticella microstoma* Ehrenberg; specimen from an alpha-mesosaprobic locality.

Family Vorticellidae
Genus *Vorticella*

VORTICELLA CAMPANULA Ehrenberg (Fig. 56)

Morphology

Body 50–160 μm long, 35–100 μm wide; stalk about 250–350 μm long and 6–12 μm wide; bell-shaped, very changeable in outline, sometimes bending back; the central part of the cell is filled with refractile reserve granules, therefore the animals are very conspicuous by their darkish body and they are easy to recognize; the peristome extends considerably outwards; the buccal cavity (" vestibulum ") is very large and equipped with an outer undulating membrane (" pharyngeal membrane "); pellicle faintly annulated; macronucleus extending more or less along the longitudinal axis of the cell; very long, wormlike; a single micronucleus; 1 contractile vacuole near the buccal cavity; the stalk may be somewhat invaginated into the basal portion of the body; sessile (for a full morphological description, see Noland & Finley (1931)); Stiller (1963) described *V. campanula* var. *monilata*, which is characterized by numerous small pellicular tubercles; reproduction and conjugation as described for *V. microstoma* (p. 106).

Food

Bacteria.

Occurrence and ecology

Cosmopolitan in distribution, frequently occurring throughout the year in all types of flowing and standing waters, avoiding foul water conditions; according to Noland & Finley (1931), it is favoured by a certain amount of current in the water; usually found in groups attached to plants (e.g., *Ceratophyllum*, *Lemna*, *Myriophyllum*), insect larvae, crustacea, stones, artificial substrates (slides), and detritus; specimens occurring in athalassogenic brackish waters are covered with pellicular tubercles (cf., morphology).

Ecological characteristics (from Noland, 1925; Nusch, 1969)

	Extreme tolerances
temperature (°C)	0–23
pH	6.9–9.0
dissolved O_2 (mg/l)	4.5–16
free CO_2 (mg/l)	0–12
NH_4^+ (mg/l)	0–7.5
bacteria (membrane-filter method)	1 000 000–9 000 000/ml

Saprobiology

According to Liebmann (1962), this is a beta-mesosaprobic indicator organism but this classification seems too narrow because *V. campanula* is able to tolerate alpha-mesosaprobic conditions also.

Saprobiological classification

According to Sládečková & Sládeček (1966):

bos	aos	bms	ams	pa	i
—	1	6	3	—	3

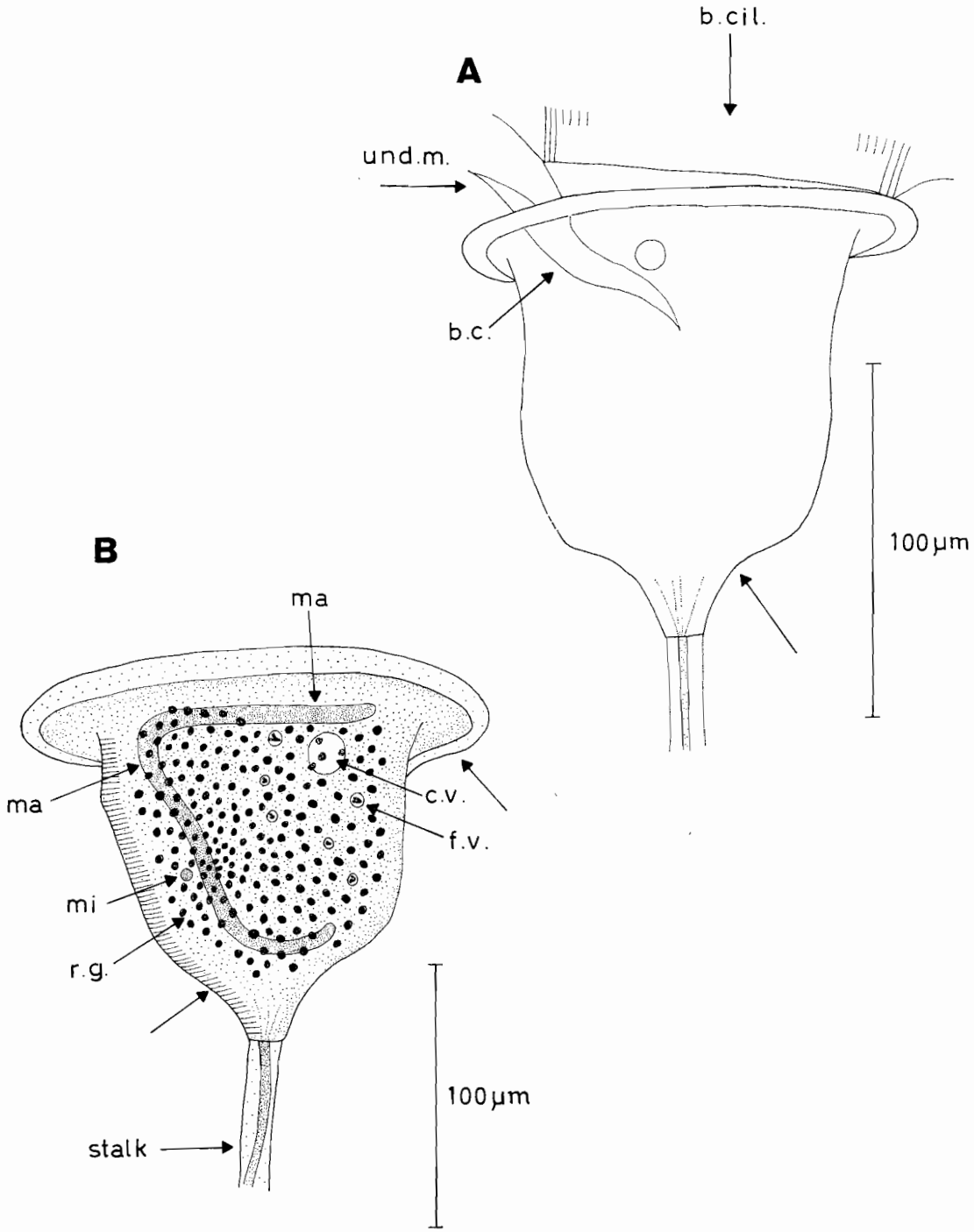

Fig. 56. *Vorticella campanula* Ehrenberg. A, Outline of an expanded individual; B, posterior view of a rather bent individual, redrawn from Nusch (1969). Arrows indicate the main features used for identification.

Family Vorticellidae
Genus *Vorticella*

VORTICELLA CONVALLARIA L. (Fig. 57)

Morphology

Body bell-shaped; length 30–120 μm, width 35–70 μm, peristome width 55–75 μm, stalk length 100–500 μm, width 4–6.5 μm (data from Noland & Finley (1931) and Kralik (1957-58)); the typical shape of *V. convallaria* is shown in Fig. 57A; in contrast to *V. campanula* (p. 108); there are no, or only a few, darkish-looking refractile granules, the animal therefore never looks dark but is very often yellow-tinted; the peristomal area of *V. convallaria* is narrower than in *V. campanula*; the annulation of the pellicle is easily visible; macronucleus and contractile vacuole as in *V. campanula*; food vacuole with oval contour (Noland & Finley, 1931).

Body shape and size, including the ratio of length to peristomal width, may vary greatly in *V. convallaria* (see Fig. 57A–57C; there may be striking morphological similarities between *V. convallaria* described here and the related species *V. nebulifera* O. F. Müller var. *similis* (Stokes) Noland & Finley, 1931 (= *V. similis* Stokes) (cf., p. 112); Kralik (1957-58; 1961b) has shown that it is very often impossible to decide whether specimens in question belong to *V. convallaria* or to *V. similis*. Kahl (1935) assumed that the ratio of body length to peristome width is an identifying feature (for *V. convallaria*, body length : peristome width = 0.8–1.3 : 1; for *V. similis*, 1.5–1.75 : 1) but even this ratio may vary greatly in both species (cf., Kralik, 1961).

Stiller (1962) described a form of *V. convallaria* that is characterized by pellicular tubercles (var. *monilata*); this form is to be found in athalassogenic brackish water (e.g., natron lakes).

Reproduction and conjugation as described for *V. microstoma* (p. 106); sessile, dispersal only by " telotrochs " (= free-swimming stages with a posterior girdle of cilia).

Food

Bacteria.

Occurrence and ecology

Reported from Europe and America, probably cosmopolitan in distribution; found in fresh and brackish water all through the year. In Europe the highest abundance is in autumn and spring; it frequently occurs in all types of flowing and stagnant water attached to crustaceans, insects, molluscs, detritus, stones, slides, and plants; usually found in groups, very often occurring in greyish-white colonies that cover stream banks or other habitats. The species occurs in trickling filters and activated sludge; associated with *Aspidisca costata*, *Euplotes affinis*, *V. campanula*, and other species.

Ecological characteristics (according to Nusch, 1969)

	Extreme tolerances
temperature (°C)	2–23
pH	5.5–9.0
dissolved O_2 (mg/l)	1.0–13.0
free CO_2 (mg/l)	0–15.0
NH_4^+ (mg/l)	0–17.5
NO_2^- (mg/l)	0–30
bacteria (membrane-filter method)	1 000 000–9 000 000/ml

Saprobiology

V. convallaria was classified as an alpha-mesosaprobic indicator organism by Liebmann (1962); it should be stressed here that the very similar *V. nebulifera* var. *similis* has been classified as an oligosaprobic indicator organism (Liebmann, 1962).

Saprobiological classification

bos	aos	bms	ams	ps	i
—	—	3	6	1	3

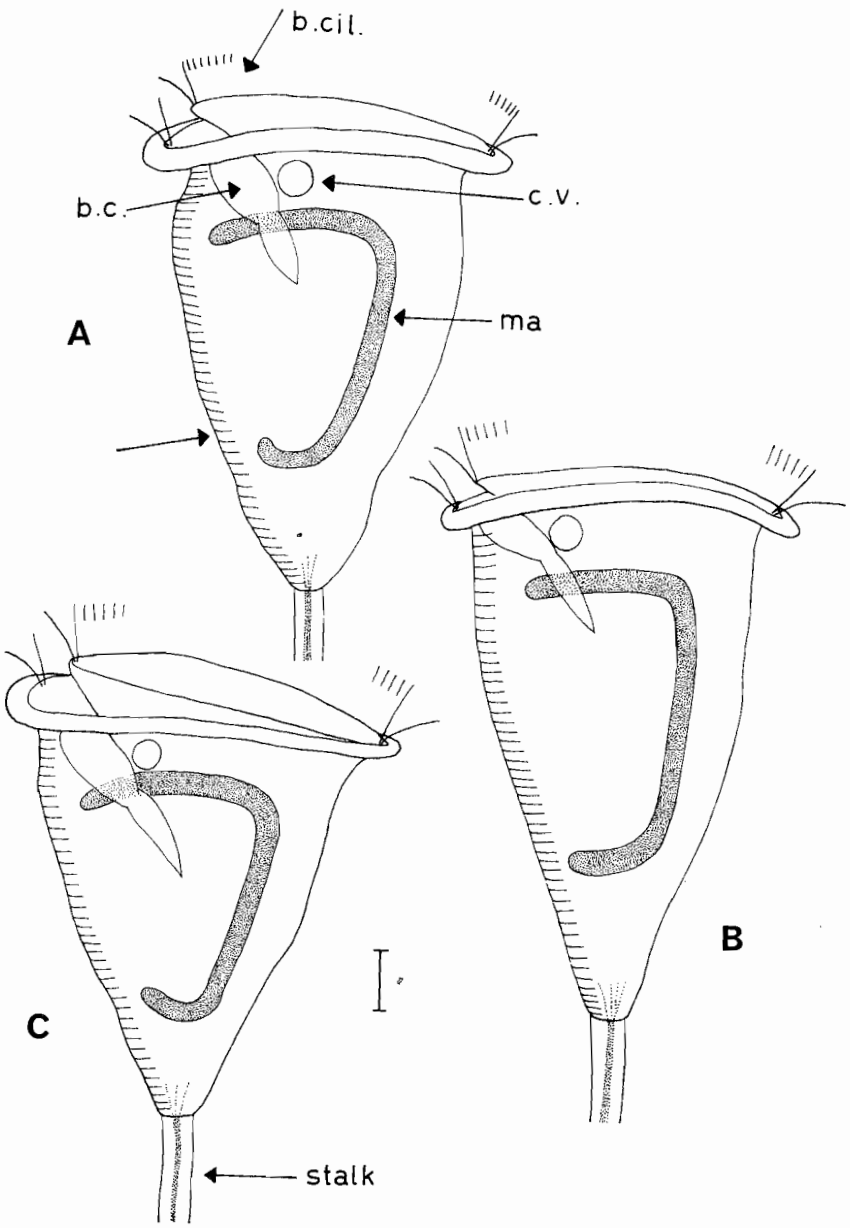

Fig. 57. *Vorticella convallaria* L.; redrawn from Nusch (1969). A, Typical specimen; B and C, specimens showing the variety of shapes, C strongly resembles individuals of *Vorticella nebulifera* var. *similis*. Arrows indicate the main features used for identification.

Family Vorticellidae
Genus *Vorticella*

VORTICELLA NEBULIFERA O. F. Müller var. SIMILIS (Stokes) Noland & Finley (= VORTICELLA SIMILIS Stokes)

Morphology

Body length 40–90 μm, body width 20–50 μm, peristome 30–70 μm, stalk length 50–800 μm; body shape similar to some varieties of *V. convallaria* (cf., *V. convallaria*, Fig. 57C); macronucleus long and band-like, as in *V. convallaria*; the only features distinguishing this species from *V. convallaria* may be as follows (Noland & Finley, 1931): body very translucent, pure misty white or slightly greyish in colour, food vacuoles oblong or spindle-shaped; it seems rather doubtful whether these features are valid taxonomic criteria (for extensive discussion of the morphology and ecology, see Kralik (1957-58) and Nusch (1969)); sessile.

Food

Bacteria.

Occurrence and ecology

Reported from Europe and America in flowing and stagnant fresh water (the typical *V. nebulifera* occurs in marine habitats) singly or in groups attached to plants (including planktonic algae), insect larvae, molluscs, detritus, stones or artificial substrates (e.g., glass slides); according to Noland & Finley (1931), the species " will persist for days in relatively clean laboratory cultures but dies out when bacterial action becomes intensive ".

Ecological characteristics (Noland, 1925)

		Extreme tolerances
temperature (°C)		4–20
dissolved O_2 (mg/l)		0.5–10
O_2 (percentage saturation) . . .		4.5–81.2
free CO_2 (mg/l)	approx.	0–10

The characteristics given here are very similar to those tabulated for *V. convallaria.*

Saprobiology

According to Liebmann (1962), this is an oligosaprobic indicator organism but the ecological characteristics given above are not in agreement with Liebmann's opinion. It should be mentioned that Liebmann's indicator organism is explicitly the same as that described by Noland & Finley (1931).

In view of the rather difficult and confusing taxonomic situation, it is assumed that *V. nebulifera* var. *similis* is a rather bad indicator organism. Probably it is a modification of *V. convallaria* which occurs only in clean waters poor in bacteria as a source of food.

Family Vorticellidae
Genus *Vorticella*

VORTICELLA STRIATA Dujardin 1841 var. OCTAVA (Stokes) Noland & Finley (= VORTICELLA OCTAVA Stokes) (Fig. 58)

Morphology

Body length 20–60 μm, body width 15–40 μm, peristome width 13–40 μm, stalk length 20–300 μm; body shape vase-like, undergoes some variation in size and outline; the body resembles that of *V. microstoma*, but *V. octava* is smaller, the pellicular annulations are very distinct and the macronucleus lies transverse to the longitudinal axis; the peristome border is thicker than in *V. microstoma* but shows much variation (cf., Stiller, 1967).

Cytoplasm translucent or slightly misty white; annulations of pellicle very distinct, about 25–40 striae; surface of body slightly ribbed; macronucleus thick, sausage-like; 1 contractile vacuole near the buccal cavity; reproduction and conjugation as described for *V. microstoma*; sessile.

Food

Bacteria.

Occurrence and ecology

Reported from Europe, America, and India, occurring in all types of flowing and stagnant waters: rivers (Kralik, 1957-58), ponds (Hammann, 1953), pools (Stiller, 1968), reservoirs (Sládečková & Sládeček, 1963), and lakes (Sommer, 1951), fresh water, brackish athalassogenic waters (natron lakes (Stiller, 1967)), and marine habitats (Stiller, 1968); high toleration of changes in salinity; attached to various kinds of substrate (e.g., algae, plants, larvae of insects, stones, glass slides, detritus).

V. striata may live in clean or slightly polluted waters; apparently it prefers high levels of dissolved oxygen (Kralik, 1957-58; Hammann, 1953).

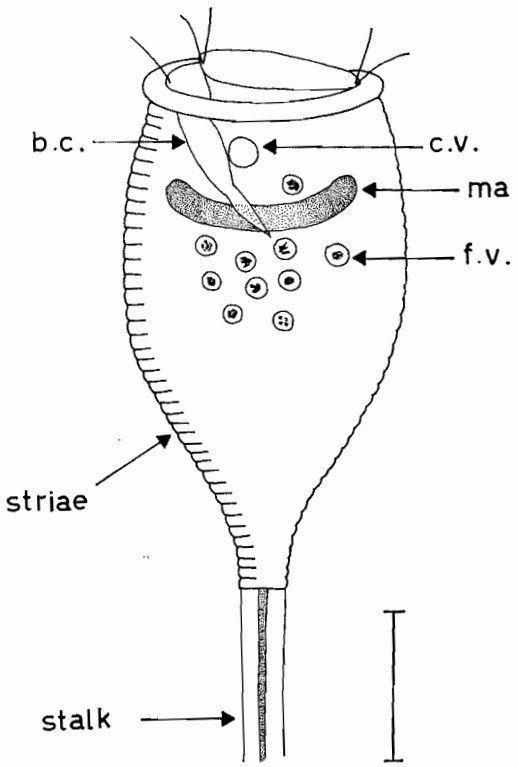

Fig. 58. *Vorticella striata* Dujardin var. *octava* (Stokes) Noland & Finley.

Ecological characteristics (Nusch, 1969)

	Extreme tolerances
temperature (°C) . . .	2–23
pH	5–8
dissolved oxygen (mg/l)	3–12
free CO_2 (mg/l)	0–12
NH_4^+ (mg/l)	0–15
bacteria (membrane-filter method)	1 000 000–9 000 000/ml

Saprobiological classification

According to Sládečková & Sládeček (1963):

bos	aos	bms	ams	ps	i
—	—	8	2	—	4

Family Vorticellidae
Genus *Carchesium*

CARCHESIUM POLYPINUM L. (Fig. 59)

Morphology

Individuals 80–140 μm, colonies up to 3 mm; main stalk up to 1 mm long and 20 μm in diameter; body bell-shaped, very often more or less bent; peristome outwardly extended; 1 long band-like macronucleus extends along the longitudinal axis of the cell; 1 contractile vacuole near the buccal cavity; sessile; colonial; myonemes in stalk not continuous, at branching points the myonemes continue only into one branch, therefore individual stalks contract independently (by contrast, in the genus *Zoothamnium* myonemes of all stalks of the colony are continuous, and therefore all individuals contract simultaneously); young solitary individuals of *C. polypinum* resemble mature stages of the non-colonial *Vorticella convallaria* (cf., p. 110), which may occur in the same habitats.

Food

Bacteria.

Occurrence and ecology

Cosmopolitan in distribution, attached to stones, detritus, plants, and insects, as well as to artificial substrates, e.g., glass slides; in all types of flowing and standing water including oxidation ponds and trickling filters. According to Buck (1968), *C. polypinum* occurs in all purification plants with comparatively low turbulence, e.g., oxidation ditches.

Ecological characteristics (Bick, unpublished data; Nusch, 1969)

	Extreme tolerances	*Optimal ranges*
temperature (°C)	0–25	4–8
pH	6.4–8.3	7.0–7.5
dissolved O_2 (mg/l)	0.2–14	7–12
free CO_2 (mg/l)	0–14	3–7
NH_4^+ (mg/l)	0–18	0–1
H_2S (mg/l)	0	0
bacteria (membrane-filter method)	1 000 000–10 000 000/ml	4 000 000–6 000 000/ml

Saprobiology

According to Liebmann (1962), this is an alpha-mesosaprobic indicator organism.

Saprobiological classification

According to Zelinka & Marvan (1961) (1) and Sládeček (1964) (2):

	bos	aos	bms	ams	ps	i
(1)	—	+	1	7	2	3
(2)	—	+	2	7	1	3

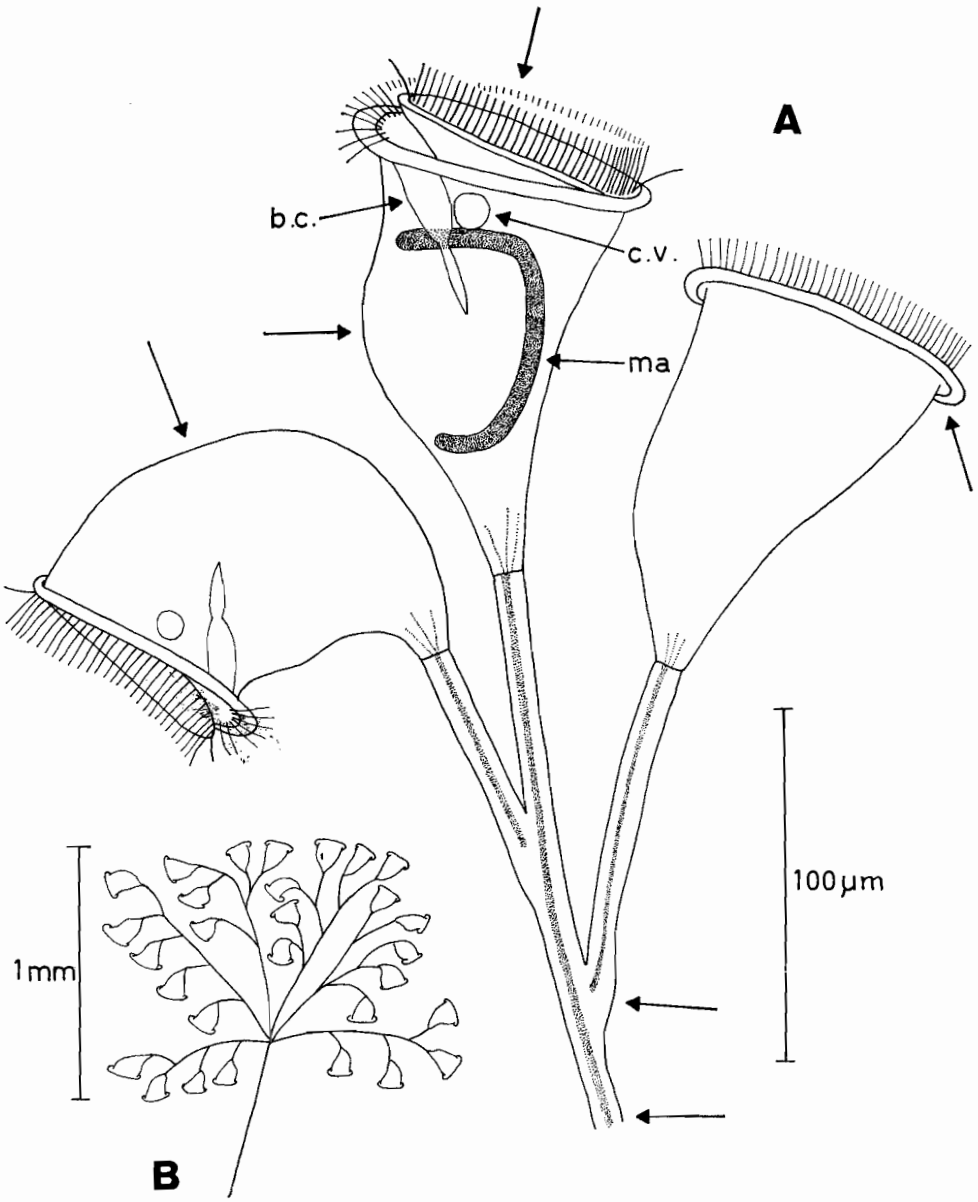

Fig. 59. *Carchesium polypinum* L. A, Three individuals of a colony; B, diagram of a colony. Arrows indicate the main features used for identification.

Family Epistylidae
Genus *Epistylis*

EPISTYLIS PLICATILIS Ehrenberg (Fig. 60)

Morphology

Individuals 70–160 μm, colony up to 3 mm; elongated bell-form, contracted individuals with characteristic folds at posterior end (see Fig. 60); pellicle slightly annulated; macronucleus transverse to longitudinal axis in the anterior part of the cell; stalk without myonemes, therefore not contractile; dichotomously branched; large colonies; sessile.

Food

Bacteria.

Occurrence and ecology

Reported from Europe and America, occurring in flowing and standing waters; in polluted rivers (Kralik, 1957-58), eutrophic lakes (Stiller, 1940), ponds (Nenninger, 1948), trickling filters (Kolkwitz, 1950); attached to all kinds of abiotic substrates and to plants and snails (e.g., *Physa, Lymnaea*) (Lopez-Ochoterena, 1966), sometimes to tadpoles or *Dytiscus* beetles (Nenninger, 1948).

Ecological characteristics (calculated from data presented by Kralik (1957-58) and Nusch (1969)

	Extreme tolerances
temperature (°C)	4–25
pH	6.5–7.5
dissolved O_2 (mg/l)	2–12
free CO_2 (mg/l)	0–8
NH_4^+ (mg/l)	0–10
bacteria (membrane-filter method)	1 000 000–8 000 000/ml

Saprobiology

According to Kolkwitz (1950), this is an alpha-mesosaprobic indicator organism.

Saprobiological classification

bos	aos	bms	ams	ps	i
—	—	5	5	—	3

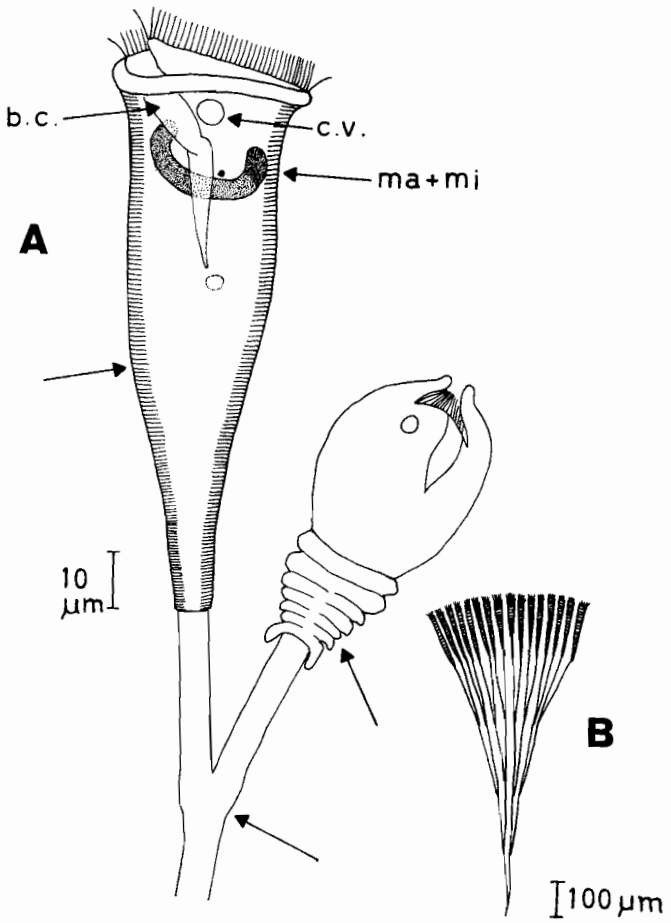

Fig. 60. *Epistylis plicatilis* Ehrenberg. A, Expanded (left) and contracted (right) individuals; redrawn from Nusch (1969); B, diagram of a colony after Kahl (1935). Arrows indicate the main features used for identification.

Family Epistylidae
Genus *Campanella*

CAMPANELLA UMBELLARIA L. (Fig. 61)

Morphology (Kahl, 1935)

Individuals 200–260 μm long, colony up to 4 mm in diameter; main stalk about 3 mm; inverted bell-form; adoral zone turns 4-6 times; pellicle annulated; macronucleus horseshoe-shaped in the anterior part of the cell; a single contractile vacuole is located near the buccal cavity; specimens occurring in eutrophic brackish waters (e.g., athalassogenic natron lakes) may show pellicular tubercles resembling those of *Vorticella monilata* (Stiller, 1962); sessile; dichotomous non-contractile stalk; colonies may consist of about 40–50 individuals (Sommer, 1951); free-swimming stages (" telotrochs ") with a posterior ciliary girdle occur under suboptimal conditions of life.

Food

Bacteria.

Occurrence and ecology

Reported from Europe and America, probably cosmopolitan in distribution, occurring in moderately polluted flowing (Kralik, 1957-58) and standing waters (Hammann, 1953; Nusch, 1969); attached to stones, shells, plants, or artificial substrates, e.g., glass slides.

Saprobiological classification

According to Sládeček (1964):

bos	aos	bms	ams	ps	i
—	—	5	5	—	3

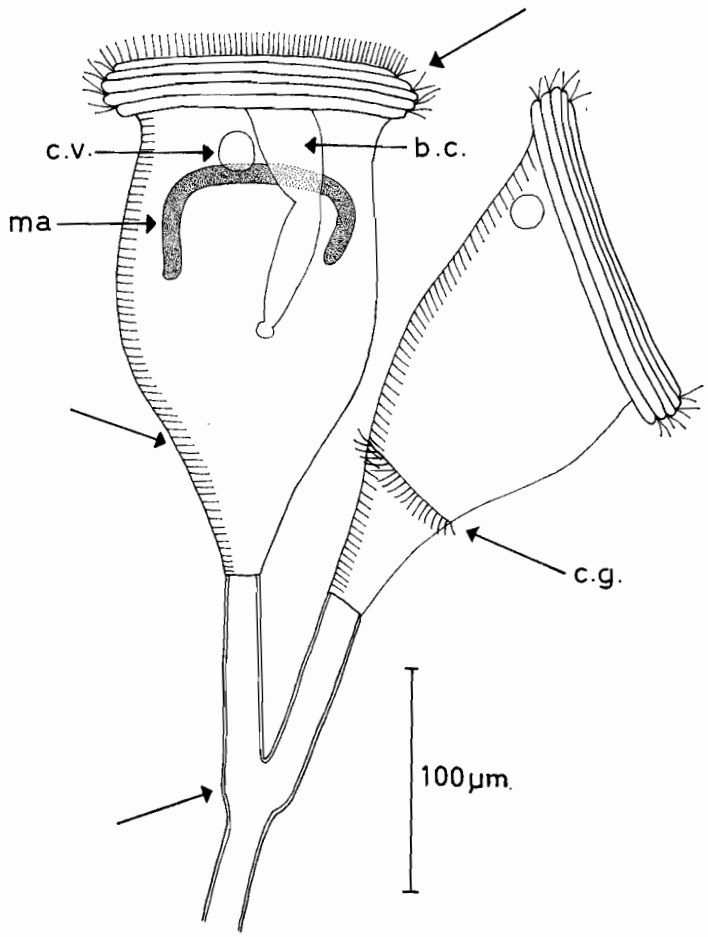

Fig. 61. *Campanella umbellaria* L.; redrawn from Nusch (1969). Arrows indicate the main features used for identification. The individual on the right shows telotroch formation.

Family Epistylidae
Genus *Opercularia*

OPERCULARIA COARCTATA (Claparède & Lachmann) (= EPISTYLIS COARCTATA Claparède & Lachmann) (Fig. 62)

Morphology

Individuals 45–65 μm, stalk about 50–100 μm; colonies small, consisting of 3–6 individuals; body elongate; peristomal area small and not constricted from the body; buccal area with distinct oblique disk which is set off from the border by a deep incision; obvious undulating membrane; macronucleus horseshoe-like, its axis transverse to the longitudinal; stalk without myonemes, dichotomous branching; sessile.

Food

Bacteria.

Occurrence and ecology

Cosmopolitan in distribution, occurring in all types of slowly flowing and standing waters rich in bacteria from the decomposition of organic matter, e.g., polluted streams, oxidation ponds, trickling filters, activated sludge; attached to detritus, shells of molluscs, *Sphaerotilus*; abundant in activated sludge up to 110 000/ml (Buck, 1968) with an average of 8 500/ml. *O. coarctata*, *Vorticella putrina*, and *V. convallaria* (p. 110) are characteristic inhabitants of activated sludge in plants using the diffused air system; in this association *V. putrina* is dominant in " high intensity " plants with comparatively low oxygen content; with decreasing intensity of decomposition and increasing oxygen content the individual counts of *Opercularia* increase first, and those of *V. convallaria* later (Buck, 1968).

Saprobiology

According to Liebmann (1962), *O. coarctata* is an alpha-mesosaprobic indicator organism, Kolkwitz (1950) is of the same opinion but has used the synonym " *Epistylis* " *coarctata*.

Saprobiological classification

bos	aos	bms	ams	ps	i
—	—	2	7	1	3

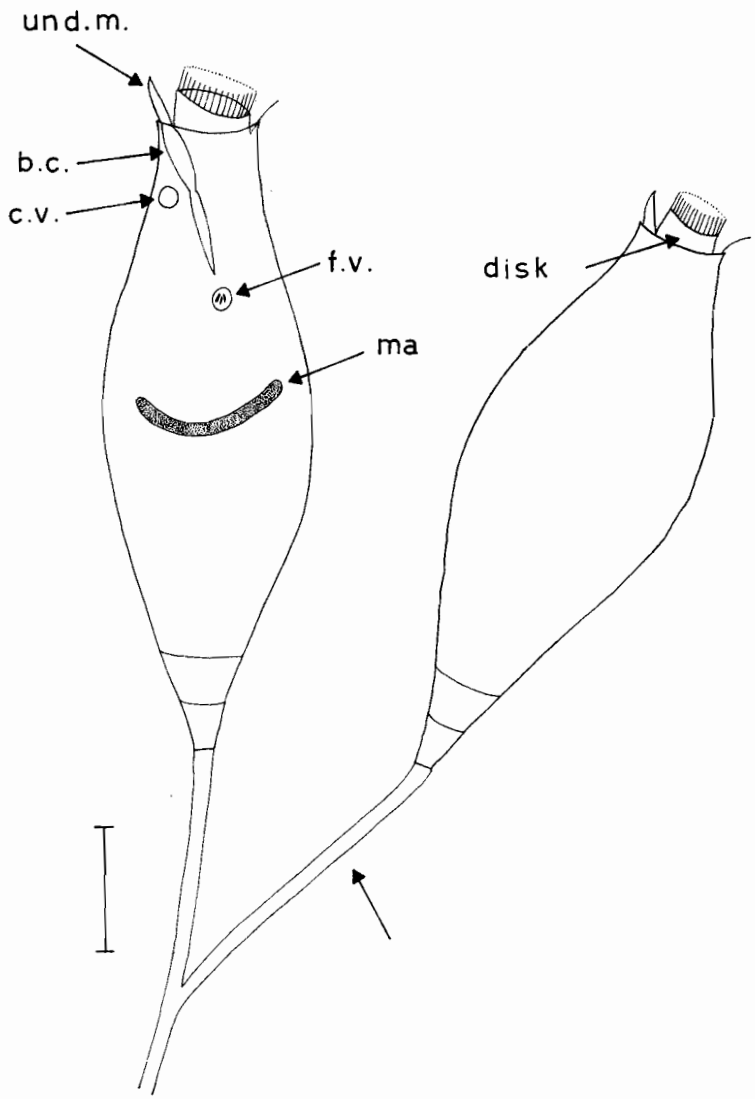

Fig. 62. *Opercularia coarctata* (Claparède & Lachmann). Arrows indicate the main features used for identification.

Family Epistylidae
Genus *Opercularia*

OPERCULARIA NUTANS (Ehrenberg) (Fig. 63)

Morphology

Individuals 60–141 μm, colonies up to 3 mm; generic features as described for *O. coarctata* (see p. 120) but disk comparatively high and stalk more or less annulated (at least in the anterior region); large colonies; sessile.

Food

Bacteria.

Occurrence and ecology

Reported from Europe in standing waters and slowly-flowing rivers (Kralik, 1957-58), lakes (Nenninger, 1948), reservoirs (Sládečková & Sládeček, 1963); attached to plants, algae such as *Enteromorpha*, *Cladophora* (Sommer, 1951), stones, artificial substrates (e.g., glass slides), insects (e.g., larvae of *Caenis* (Sommer, 1951)).

Ecological characteristics (compiled from several authors; preliminary data)

	Extreme tolerances
temperature (°C)	2–25
pH	6.5–8.7
dissolved O_2 (mg/l)	2–21
free CO_2 (mg/l)	0–18.5
NH_4^+ (mg/l)	0–12

Saprobiological classification

According to Sládeček (1964):

bos	aos	bms	ams	ps	i
—	—	7	3	—	4

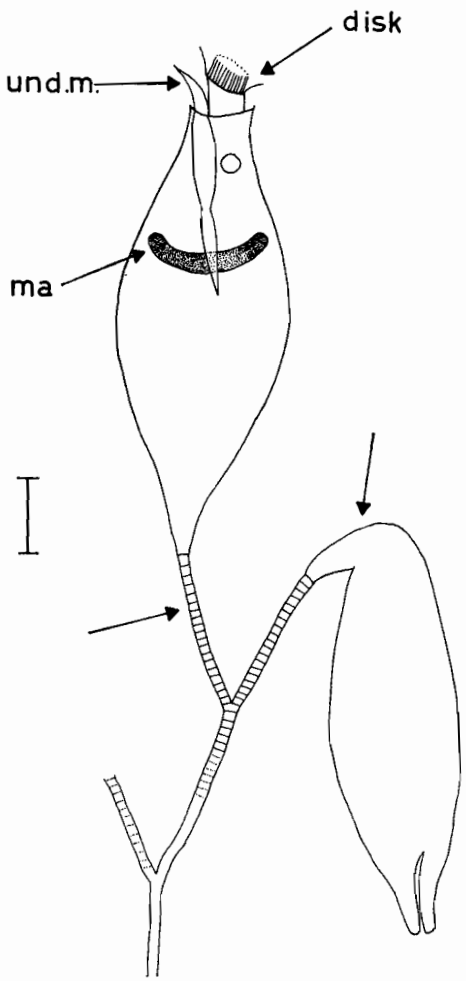

Fig. 63. *Opercularia nutans* (Ehrenberg). Arrows indicate the main features used for identification.

Family Vaginicolidae
Genus *Vaginicola*

VAGINICOLA INGENITA (O. F. Müller) (Fig. 64)

Morphology

Body about 50 μm long: lorica about 40 μm; lorica vase-like; case attached to substrate with its somewhat pointed posterior end; body elongated, the posterior end fixed to the base of the lorica; only the peristomal area extends beyond the lorica; macronucleus band-like; contractile vacuole near the buccal cavity.

Food

Bacteria.

Occurrence and ecology

Reported from Europe in flowing and standing waters, e.g., rivers (Kralik, 1957-58), reservoirs (Sládečková & Sládeček, 1963), lakes (Sommer, 1951); attached to diatoms (*Melosira*, *Fragilaria* (Sommer, 1951)); glass slides (Sládečková & Sládeček, 1963).

Saprobiological classification

According to Sládeček (1964):

bos	aos	bms	ams	ps	i
—	—	6	4	—	3

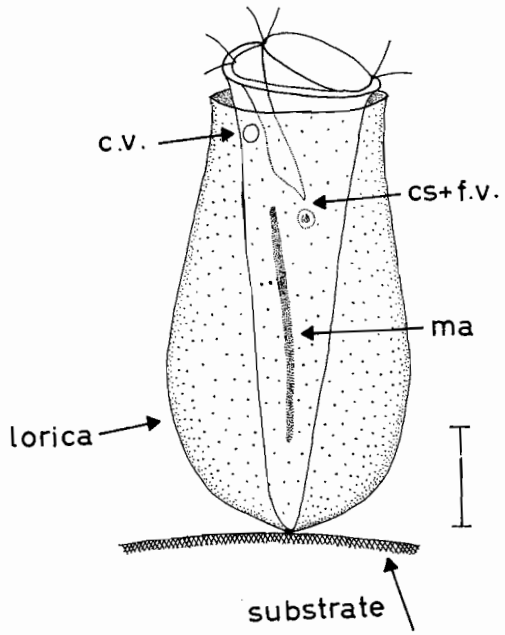

Fig. 64. *Vaginicola ingenita* (O. F. Müller).

Family Vaginicolidae
Genus *Platycola*

PLATYCOLA TRUNCATA Fromentel (Fig. 65)

Morphology

Body 60–170 μm (Kralik, 1961a), lorica 65–145 μm (average 96 μm); loricated, lorica always decumbent and attached by the flat (= " dorsal ") side to the substrate (see Fig. 65B); the lorica shows a small neck-like opening in the anterior region and is fastened to the substrate by a characteristic darkish, cementing edge, which is clearly seen in the ventral view (see Fig. 65A); outline of lorica, shape of neck, etc. may vary greatly (Kralik, 1961a); older loricae are more or less covered by brownish Fe $(OH)_3$.

Body of the ciliate fixed to the posterior end of the lorica; the elongated cylindrical body may be extended beyond the lorica; 1 band-like macronucleus; a single micronucleus; contractile vacuole near the buccal cavity; usually there are 2 individuals in the lorica, often only 1 and sometimes 3 or more; sometimes an empty lorica may be colonized by *Chaetospira muelleri* or *Lacrymaria olor* (Kralik, 1961a).

For morphological and taxonomic details, see Kralik (1961a).

Systematics

Kralik (1961a) is of the opinion that the species *Platycola striata*, *P. decumbens* and others belong to *P. truncata*.

Food

Bacteria, small algae (Hammann, 1953).

Predators

Trachelophyllum chilense (Protozoa, Ciliata); fission stages of the carnivorous ciliate may be found inside the empty lorica of *Platycola* (Kralik, 1961a).

Occurrence and ecology

Reported from Europe and North America, frequently to be found in flowing and standing waters; according to Kralik (1961a), *P. truncata* is the most abundant loricate ciliate in Central Europe. Attached to all kinds of abiotic substrata including glass slides; also attached to colonizing plants (*Lemna*, *Ceratophyllum*), algae and shells of molluscs. In Europe, the highest individual counts of *P. truncata* have been recorded in March–April and July–September (Kralik, 1961a). Colonization of bare substrates occurs by means of free-swimming " larvae " (telotrochs).

Ecological characteristics (preliminary data, compiled from Kralik, 1957-58, 1961a)

	Extreme tolerances	*Optimal ranges*
temperature (°C)	0–20	10–18
pH	6.3–7.4	—
dissolved O_2 (mg/l)	2.0–12.0	—
O_2 (percentage of saturation)	40–100	50–100
BOD_5	4–12	—
NH_4^+	0–16	0–5

Saprobiological classification

According to Sládeček (1964):

bos	aos	bms	ams	ps	i
—	2	4	4	—	2

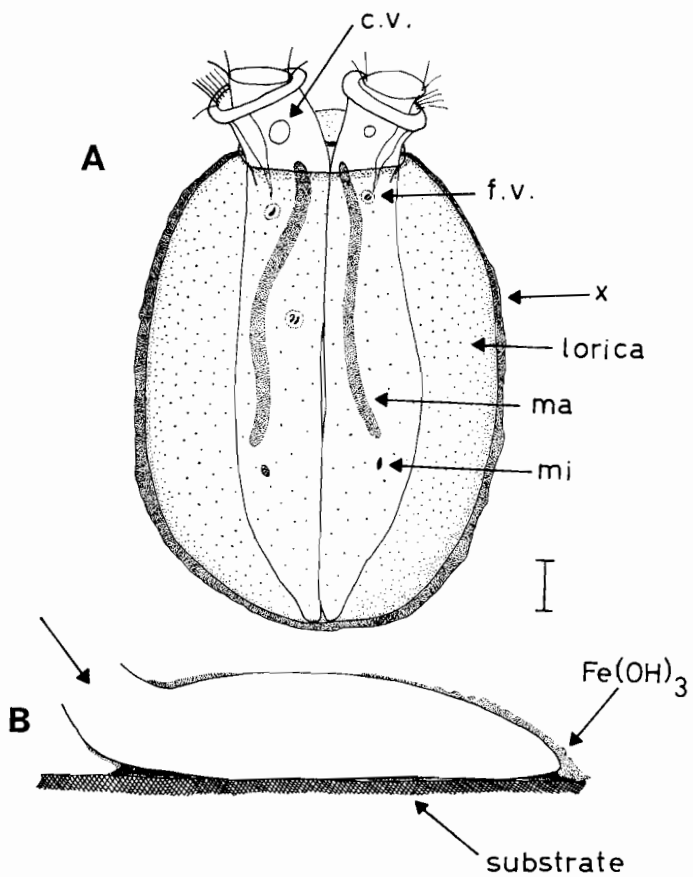

Fig. 65. *Platycola truncata* Fromentel. A, View of the convex ("ventral") face of the lorica; B, diagrammatic longitudinal section through the lorica; redrawn from Kralik (1961a).

Family Vaginicolidae
Genus *Thuricola*

THURICOLA FOLLICULATA (O. F. Müller) (Fig. 66)

Morphology (Kahl, 1935; Kudo, 1966)

Length of lorica 130–300 μm; stalkless, vase-shaped lorica equipped with valve-like apparatus which closes the anterior part of the case obliquely like a trap-door when the cell contracts; body attached to the base of the case by a very short stalk; body elongated, peristomial area extends outwards; pellicle annulated; macronucleus band-like, extending longitudinally nearly the entire length of the cell; contractile vacuole near to the buccal cavity; cytoplasm hyaline, with or without zoochlorellae; the lorica usually contains 2 individuals.

Food

Algae, bacteria.

Occurrence and ecology

Widely distributed in both standing and flowing water; reported from peat-bogs (Liebmann, 1962), attached to plants, algae, e.g., *Enteromorpha* sp. (Sommer, 1951), and artificial substrates (glass slides, etc.); occurring throughout the year with highest abundance in summer; associated with *Platycola truncata* (Nusch, 1969); very sensitive to low oxygen content (Liebmann, 1962).

Ecological characteristics (preliminary data provided by Nusch, 1969)

	Extreme tolerances
temperature (°C)	4–22
pH	7.1–7.9
dissolved O_2 (mg/l)	6.0–12.0
free CO_2 (mg/l)	0–12.0
NH_4^+ (mg/l)	0–2.5
bacteria (membrane-filter technique)	1 000 000–9 000 000/ml

Saprobiology

According to Liebmann (1962), this is an oligosaprobic indicator organism but this characterization seems too narrow.

Saprobiological classification

bos	aos	bms	ams	ps	i
—	2	6	2	—	3

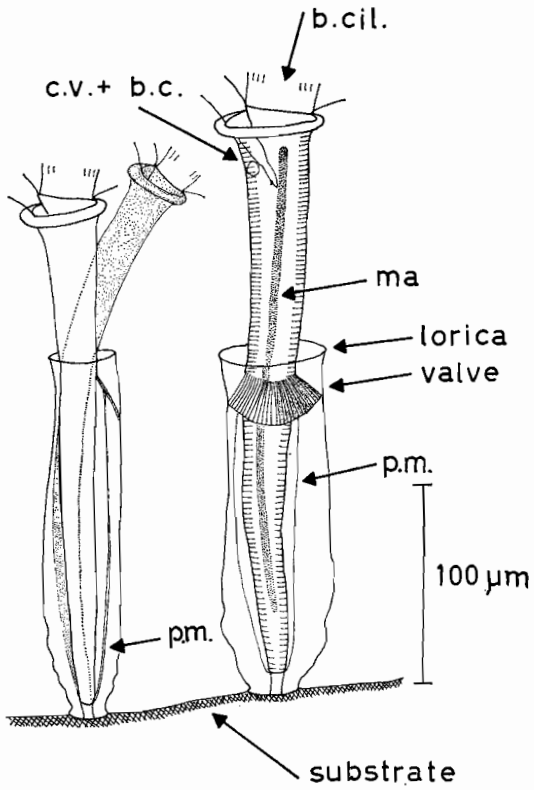

Fig. 66. *Thuricola folliculata* (O. F. Müller); two aspects of the lorica redrawn, with modifications, from Kahl (1935).

Not described:

Family Lagenophryidae
e.g., *Lagenophrys* (p. 14; Fig. 4H).
Family Scyphidiidae
e.g., *Scyphidia* (p. 12; Fig. 3C).
Family Astylozoidae
e.g., *Astylozoon*, *Hastatella* (p. 10; Fig. 2A, 2B).
Suborder Mobilina
Family Urceolariidae
e.g., *Trichodina* (p. 10; Fig. 3A).

Subclass SUCTORIA

Family Podophryidae
Genus *Podophrya*

PODOPHRYA FIXA O. F. Müller (Fig. 67)

Morphology (Kudo, 1966)

Body 10–50 μm in diameter; stalk of various lengths; body spherical; no lorica; mature stage without cilia, but suctorial tentacles distributed all over the body; sessile, stalked, sometimes without stalk and free; macronucleus spherical; 1 contractile vacuole; asexual reproduction by exogenous budding; free-swimming larvae with broad girdle of cilia.

Formation of resting cysts takes place on the stalk; the cyst itself is annulated by about 4–5 latitudinal ridges.

Food

Carnivorous, feeding on ciliates (*Cyclidium*, *Paramecium*, *Stylonychia*, and other genera).

Occurrence and ecology

Cosmopolitan in distribution, found throughout the year in all types of polluted waters, attached to algae, detritus, and stones as well as to artificial substrates, e.g., glass slides; regularly occurring in trickling filters and activated sludge.

Saprobiology

According to Liebmann (1962), it is an alpha-mesosaprobic indicator organism.

Saprobiological classification

According to Zelinka & Marvan (1961) (1) and Sládeček (1964) (2):

	bos	aos	bms	ams	ps	i
(1)	—	—	1	6	3	2
(2)	—	—	1	8	1	4

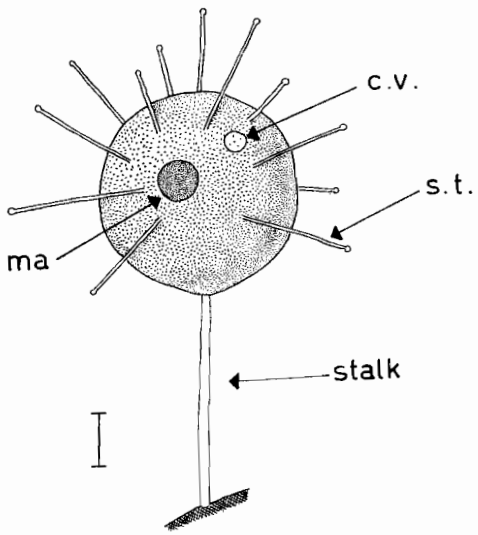

Fig. 67. *Podophrya fixa* O. F. Müller.

Family Podophryidae
Genus *Metacineta*

METACINETA MYSTACINA (Ehrenberg) (Fig. 68)

Morphology

Body about 35–100 μm in diameter, tentacles up to 150 μm, lorica up to 800 μm; mature stage without any cilia but with suctorial tentacles that are arranged in 6 groups at the anterior end (Fig. 68A); no cytostome; food ingestion by means of the tentacles; the stalked lorica (Fig. 68B) is attached to the substrate (stones, plants, artificial substrates, e.g., glass slides); 1 spherical macronucleus; a single contractile vacuole. For details see Kudo (1966).

Asexual reproduction by exogenous budding; the free-swimming ciliated bud (" larva ") undergoes metamosphosis to the sessile mature stage described above.

Food

Carnivorous, feeding on ciliates (*Carchesium, Cyclidium, Halteria, Uronema, Vorticella,* and other genera); the prey is captured by the tentacles.

Occurrence and ecology

Widely distributed in stagnant and flowing waters; in brackish and fresh water (Kahl, 1934), associated with *Coleps hirtus, Cyclidium citrullus, Stentor roeseli, Urotricha farcta* (Bick, unpublished data); in the River Elbe (Hentschel, 1916) a high frequency of *M. mystacina* on artificial substrates mostly coincides with high individual counts of *Epistylis, Vorticella,* or *Zoothamnium*; maximum development in the Elbe occurred in May–September.

Ecological characteristics (preliminary data)

	Extreme tolerances
temperature (°C)	5–25
pH	6.5–7.5
dissolved O_2 (mg/l)	0.3–10
NH_4^+ (mg/l)	0–5

Saprobiological classification

According to Sládečková & Sládeček (1963):

bos	aos	bms	ams	ps	i
—	—	5	5	—	3

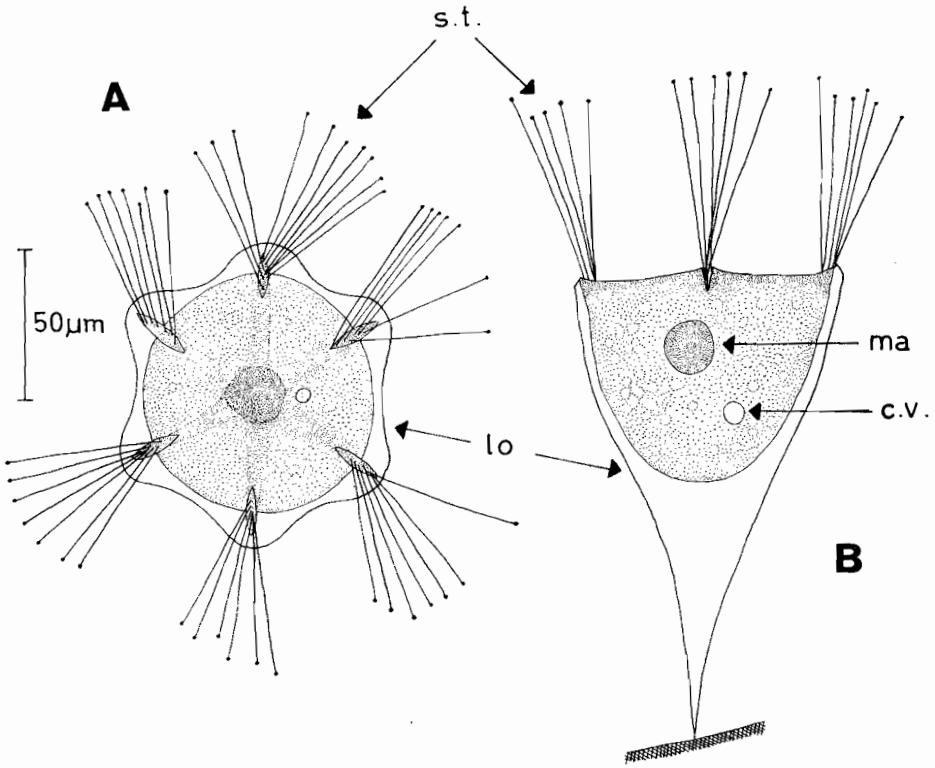

Fig. 68. *Metacineta mystacina* (Ehrenberg). A, Plan of anterior region; B, lateral view.

Family Podophryidae
Genus *Sphaerophrya*

SPHAEROPHRYA SOLIFORMIS Lauterborn (Fig. 69)

Morphology

Diameter about 100 μm; spherical, without stalk; mature stage without cilia; numerous suctorial tentacles all over the body; length of tentacle about 30 μm; macronucleus ellipsoid; a single contractile vacuole. For details see Eyferth & Schoenichen (1927) and Kudo (1966), asexual reproduction by exogenous budding; free-swimming larvae with cilia.

Food

Carnivorous; feeding on ciliates.

Occurrence and ecology

Widely distributed but only in freshwater habitats, occurring mainly in the sapropelic region of waters with decaying plant materials or sewage.

Saprobiological classification

According to Sládeček (1964):

bos	aos	bms	ams	ps	i
—	—	—	1	9	5

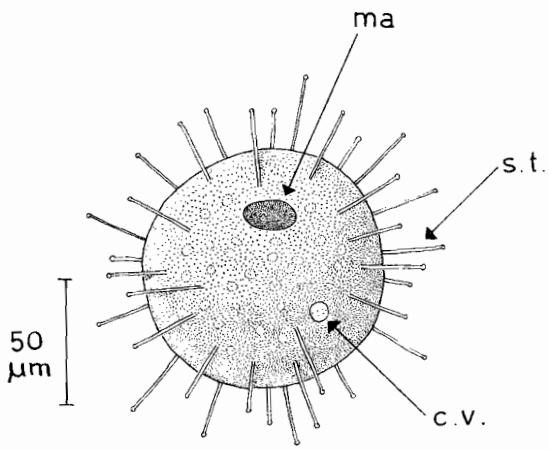

Fig. 69. *Sphaerophrya soliformis* Lauterborn.

Family Dendrosomatidae
Genus *Dendrosoma*

DENDROSOMA RADIANS Ehrenberg (Fig. 70)

Morphology

Body up to 2.5 mm high, branching irregular; adult without cilia but with suctorial tentacles arranged in clusters at the end of the branches; macronucleus long and band-like, branched; numerous contractile vacuoles; sessile; free-swimming larvae with cilia. For morphological details see Gönnert (1935).

Food

Carnivorous, feeding on ciliates.

Occurrence and ecology

Widely distributed, attached to plants, stones, and artificial substrates (e.g., glass slides); in standing and flowing waters, e.g., rivers (Holm, 1928; Hentschel, 1916) and reservoirs (Sládečková & Sládeček, 1963).

Occurring at all times of the year; in the Sedliče Reservoir, Czechoslovakia, conspicuous maxima have been recorded in April, June, and November, partly associated with *Campanella umbellaria*, *Heliophrya rotunda*, *Ophrydium sessile*, and *Stentor roeseli* (Sládečková, 1962, 1963). Hentschel (1916) found the highest abundance during May, June, and July (River Elbe, Hamburg, Federal Republic of Germany); associated predominantly with *Carchesium polypinum*, *Epistylis hentscheli* Kahl, *Metacineta mystacina*, *Vorticella campanula*, and *Zoothamnium hentscheli* Kahl.

Saprobiology

According to Holm (1928), *D. radians* occurs in beta- and alpha-mesosaprobic localities.

Saprobiological classification

According to Sládečková & Sládeček (1966):

bos	aos	bms	ams	ps	i
—	—	5	5	—	3

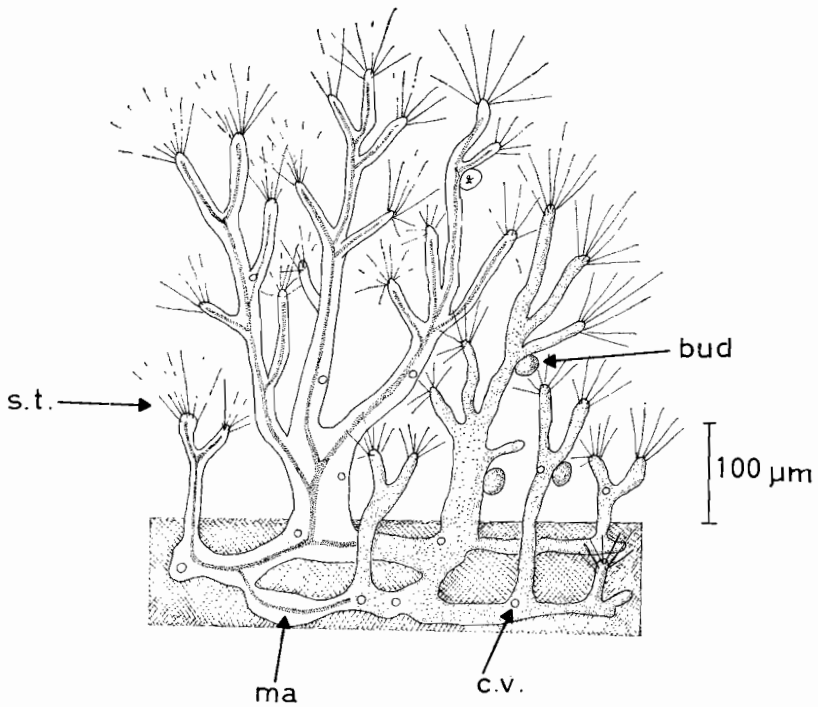

Fig. 70. *Dendrosoma radians* Ehrenberg.

Family Discophryidae
Genus *Heliophrya*

HELIOPHRYA ROTUNDA (Hentschel) Matthes
(= TRICHOPHRYA ROTUNDA Hentschel) (Fig. 71)

Morphology

Body disk-like, 30–85 μm in diameter; outline in anterior view more or less spherical, sometimes irregular; without stalk; fixed to substrate by its lower surface; basal area surrounded by pellicular border; suctorial tentacles up to 15 μm long and arranged in 8–15 clusters borne at the upper margin of the body; tentacles of each group arranged in 2 or 3 short rows; adult without any cilia.

Thick pellicle; ectoplasm hyaline, endoplasm granulated and greyish; macronucleus reniform, located in the central region; a single micronucleus near the concave side of macronucleus; 7–22 contractile vacuoles arranged more or less in a circle.

Reproduction by endogenous budding; free-swimming larvae with cilia. For details see Matthes (1965).

Food

Ciliates.

Occurrence and ecology

Reported in standing and flowing waters, e.g., lakes, ponds, reservoirs, rivers, creeks, attached to stones and artificial substrates (e.g., glass slides). Occurs at all times of the year; highest abundance has been observed in June and September or November (Hentschel, 1916; Sládečková, 1962). In the River Elbe, associated with *Carchesium polypinum*, *Epistylis hentscheli* Kahl, *Metacineta mystacina*, *Vorticella campanula*, *Zoothamnium hentscheli* Kahl, and *Z. procerius* Kahl (Hentschel, 1916). In the Sedliče reservoir, Czechoslovakia associated with *Campanella umbellaria*, *Chaetospira remex*, *Stentor roeseli*, and *Tintinnidium fluviatile* var. *emarginatum* (Sládečková, 1962). According to Rieder (1936), this species occurs under beta-mesosaprobic to oligosaprobic conditions.

Saprobiological classification

According to Sládečková & Sládeček (1966):

bos	aos	bms	ams	ps	i
—	—	5	5	—	3

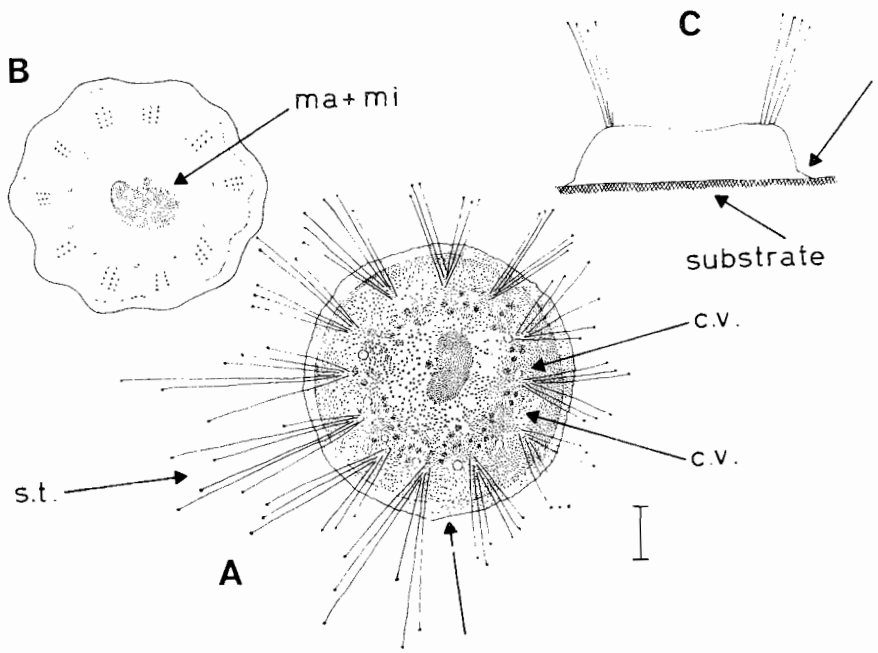

Fig. 71. *Heliophrya rotunda* (Hentschel) Matthes. A, Forma *typica*, anterior view; B, forma *sinuosa* (Rieder) anterior view, the suctorial tentacles are indicated by dots; C, diagrammatic cross-section.

Subclass SPIROTRICHIA
Order HETEROTRICHIDA

Not described :

Family Bursariidae
e.g., *Bursaridium* (p. 20; Fig. 9C).

Family Stentoridae
Genus *Stentor*

STENTOR COERULEUS Ehrenberg (Fig. 72)

Morphology

Length 1–2 mm (fully extended), trumpet-shaped when extended, after contraction more or less spherical; striking blue colour (due to the pigment " stentorin "); uniform ciliation all over the body, a small number of sensory bristles; adoral zone of membranelles extends in a spiral form around the anterior pole of the body; the buccal area itself is equipped with rows of smaller cilia; macronucleus rosary-shaped; contractile vacuole in the anterior part left behind the cytopharynx with long canals directed in posterior and anterior direction.

Food

Flagellates, algae, ciliates.

Occurrence and ecology

S. coeruleus is a sessile organism living attached to stones, roots, or detritus (even on floating material) in a mucilaginous lorica, sometimes free-swimming near the bottom, and often occurring in great colonies. Inhabits still and slowly flowing waters; tolerates free ammonia up to 0.3 mg/l (Stammer, 1953).

Saprobiology

An alpha-mesosaprobic indicator-organism according to Liebmann (1962).

Saprobiological classification

According to Sládeček (1964):

bos	aos	bms	ams	ps	i
—	—	4	6	+	3

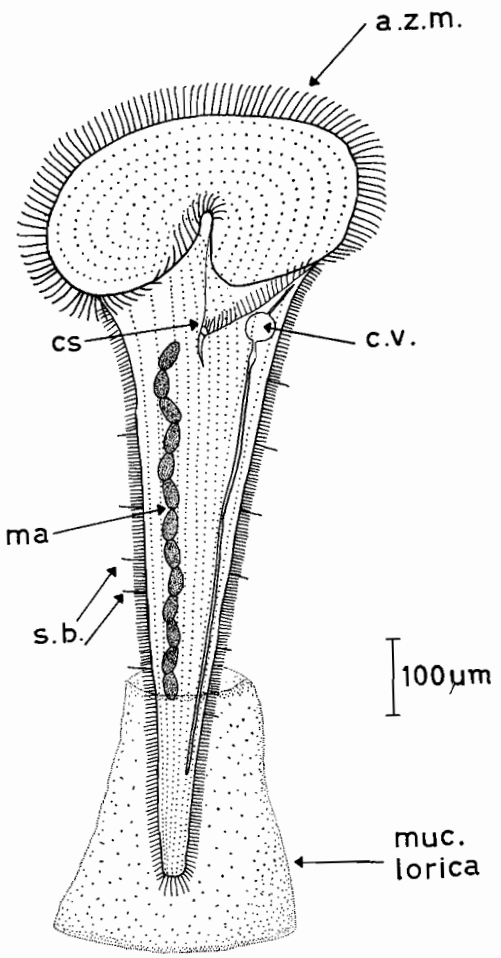

Fig. 72. *Stentor coeruleus* Ehrenberg.

Family Stentoridae
Genus *Stentor*

STENTOR ROESELI Ehrenberg (Fig. 73)

Morphology

Length 0.5—1.0 mm (fully extended); general features similar to those of *S. coeruleus* (p. 140), but colourless or slightly yellowish, and with a long, band-like nucleus; groups of longer cilia (sensory bristles) between the uniform ciliation; posterior portion often housed in a mucilaginous lorica or tube.

Food

Flagellates, algae, ciliates, bacteria.

Occurrence and ecology

Widely distributed; sessile, living attached to detritus, stones, and plants in still and slowly running waters.

Ecological characteristics

		Extreme tolerances
temperature (°C)		0–25
pH		5.9–9.4
dissolved O_2 (mg/l)		0–22.4
free CO_2 (mg/l)		0–52.0
NH_4^+ (mg/l)	approx.	0–5.0
H_2S (mg/l)		0–1.2
bacteria (plate counts on peptone agar)		1 000–5 400 000/ml

Under laboratory conditions, *S. roeseli* does not become established in brackish water and lives only in fresh water.

Saprobiology

According to Kolkwitz (1950), this is an alpha-mesosaprobic indicator organism but *S. roeseli* is not restricted to the alpha-mesosaprobic zone, it also lives under beta-mesosaprobic conditions. The compatibility with NH_4^+ seems to be rather narrow, and therefore the species does not occur in more highly polluted zones.

Saprobiological classification

According to Sládeček (1964):

bos	aos	bms	ams	ps	i
—	—	5	5	—	3

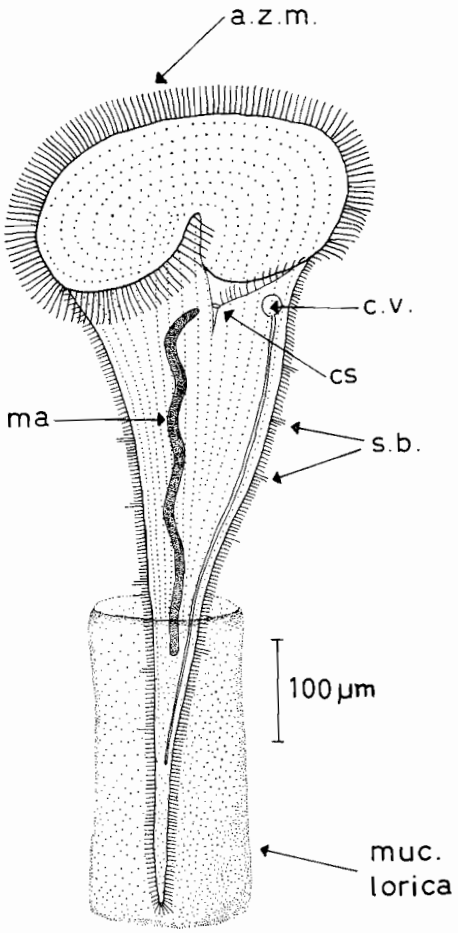

Fig. 73. *Stentor roeseli* Ehrenberg.

Family Stentoridae
Genus *Stentor*

STENTOR POLYMORPHUS (O. F. Müller) (Fig. 74)

Morphology

Length 1–2 mm (fully extended); shape very similar to that of *S. coeruleus* but colourless and the body is filled with symbiontic zoochlorellae; macronucleus rosary-shaped; usually without a lorica.

Food

Flagellates, algae.

Occurrence and ecology

Distribution and ecology similar to those of *S. roeseli*; according to Liebmann (1962), it is a beta-mesosaprobic indicator organism. I believe that it would be more accurate to say beta-mesosaprobic/alpha-mesosaprobic. *S. polymorphus* is able to tolerate dissolved oxygen levels down to 0.5 mg/l and may therefore occur in rather polluted zones.

Ecological characteristics (from various sources)

	Extreme tolerances
temperature (°C)	4–25
pH	6.8–8.8
dissolved O_2 (mg/l)	0.5–22.5
free CO_2 (mg/l)	0–44
NH_4^+ (mg/l)	0–6
H_2S (mg/l)	0–1

Saprobiological classification (calculated from data of Šrámek-Hušek (1956) and unpublished data of Bick)

bos	aos	bms	ams	ps	i
—	—	4	6	—	3

STENTOR MUELLERI (Bory St. Vincent)

Morphology (Kahl, 1932)

When fully extended, 2–3 mm long., very similar to *S. polymorphus* but without zoochlorellae (note: sometimes food vacuoles are filled with ingested algae); macronucleus rosary-shaped; often housed in gelatinous tube; posterior end drawn out into stalk (unlike *S. polymorphus*).

Ecology and saprobiology

Similar to those of *S. polymorphus*.

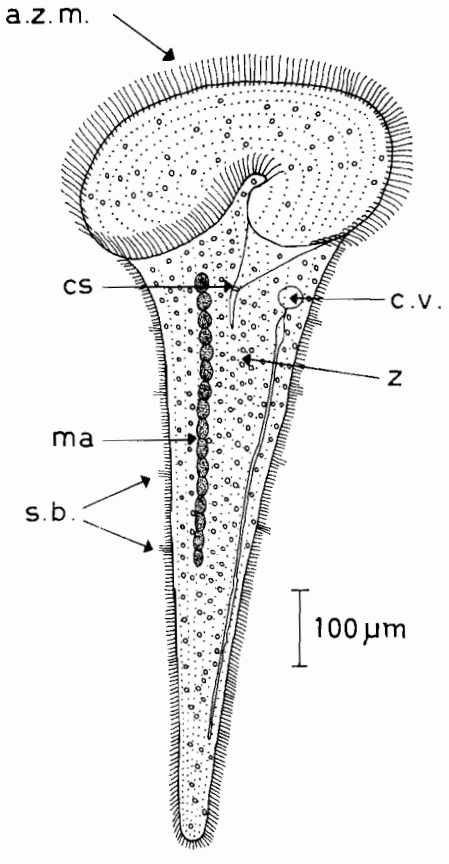

Fig. 74. *Stentor polymorphus* (O. F. Müller).

Family Gyrocorythidae (= Metopidae)
Genus *Metopus*

METOPUS ES (O. F. Müller) Kahl, 1932 (Fig. 75)

Morphology

Length 120–160 μm; body form oblong sigmoid; the slightly spiral diagonal peristome divides the body into anterior and posterior portions; body ciliation uniform; the longitudinal rows of cilia in the posterior part of the body curve into the anterior part on account of the sigmoid torsion; the peristome is surrounded anteriorly by the perizonal ciliary stripe, which includes 5 ciliary rows and is equipped with about 32 membranelles; a small undulating membrane on the right upper side of the cytostome; 1 oval macronucleus and 1 micronucleus near the peristome; 1 terminal contractile vacuole; refractile bodies accumulated near the anterior pole. According to Schulze (1959) the granules contain peroxidase.

Systematics

See Jankowski (1964a).

Food

Colourless sulfur bacteria, sometimes purple-coloured bacteria, saprophytic bacteria, and small flagellates and algae.

Occurrence and ecology

Widely distributed in sapropelic localities rich in hydrogen sulfide. Reported from Europe and North America, probably cosmopolitan in distribution; according to Liebmann (1962), a polysaprobic indicator organism. The occurrence of *M. es* indicates the presence of hydrogen sulfide; it is not found in rough sewage and purification plants but is frequent in putrefying sludge rich in hydrogen sulfide (sapropel), and in reservoirs, lakes, pools (Liebmann, 1962). Occurs in forest pools rich in decaying litter and hydrogen sulfide and poor in oxygen (" natural pollution ") (Bick, 1957, 1958).

This species is associated with *Caenomorpha*, *Epalxella*, *Pelodinium*, *Plagiopyla*, and *Saprodinium*; all these ciliates may be called sapropelobiontic, i.e., living in putrefying sludge containing hydrogen sulfide and blackened by ferrous sulfide. *M. es* and the associated ciliates mentioned above constitute a peculiar and very sharply characterized group among the polysaprobic organisms since they do not occur during the self-purification process itself but where self-purification has been stopped by a lack of oxygen and the presence of high concentrations of hydrogen sulfide. These conditions may persist for shorter or longer periods and self-purification can only start again after the addition of oxygen. From this point of view, the sapropelobiontic ciliates are not true polysaprobic organisms but indicators of self-purification processes arrested by lack of oxygen and high concentrations of hydrogen sulfide (cf., Bick, 1957). According to Liebmann (1962), *M. es* may also occur in oligosaprobic springs containing hydrogen sulfide. In spite of sapropelic habitats in those springs, this species is never associated with *Enchelyomorpha vermicularis*, *Hexotrichia caudatum*, and *Trimyema compressum*.

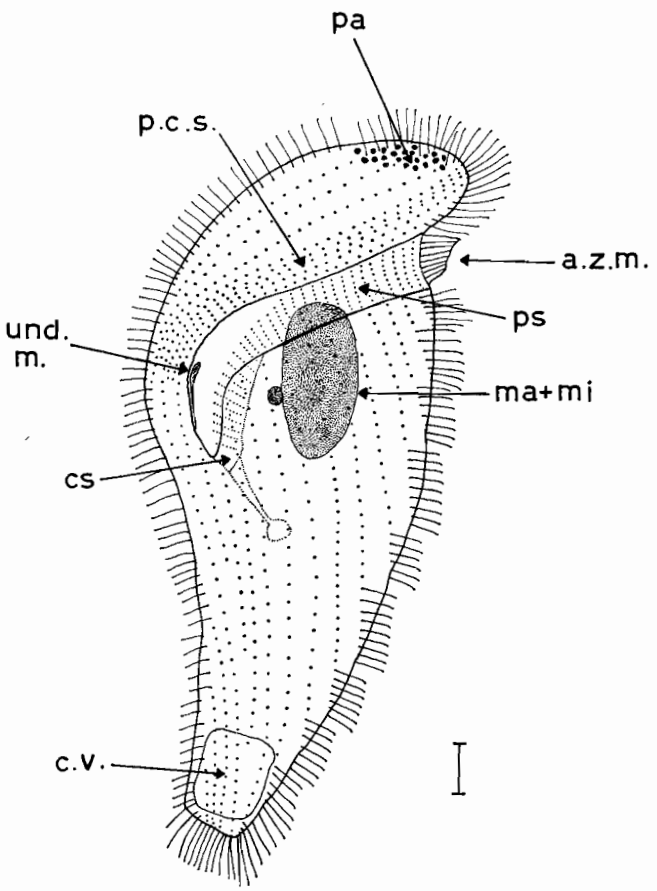

Fig. 75. *Metopus es* (O. F. Müller) Kahl, 1932; ventral view after Jankowski (1964).

Family Gyrocorythidae (=Metopidae)
Genus *Brachonella*

BRACHONELLA SPIRALIS (Smith) Jankowski, 1964a (Fig. 76)
(= METOPUS CONTORTUS Levander; *sic* Liebmann, 1962)

Morphology

Length 80–150 μm; body ovoid, peristome spirally diagonal; cytostome dorsally located, near the posterior end of the cell; body ciliation uniform except for a group of long caudal cilia; brownish in colour; accumulation of refractile granules at the anterior pole; 1 spherical macronucleus and 1 micronucleus located centrally; contractile vacuole near the posterior end; trichocysts present.

Systematics

See Jankowski (1964a).

Food

Purple-coloured and colourless sulfur bacteria; diatoms, flagellates.

Occurrence and ecology

Reported from Europe and North America; sapropelobiontic, associated with *Metopus es*, *Caenomorpha*, *Epalxella*, and other genera.

Saprobiology

According to Liebmann (1962), this is a polysaprobic indicator organism. However, it seems better to regard it as an indicator of hydrogen sulfide. For a discussion of the ecology of the sapropelobiontic ciliates see *Metopus es*.

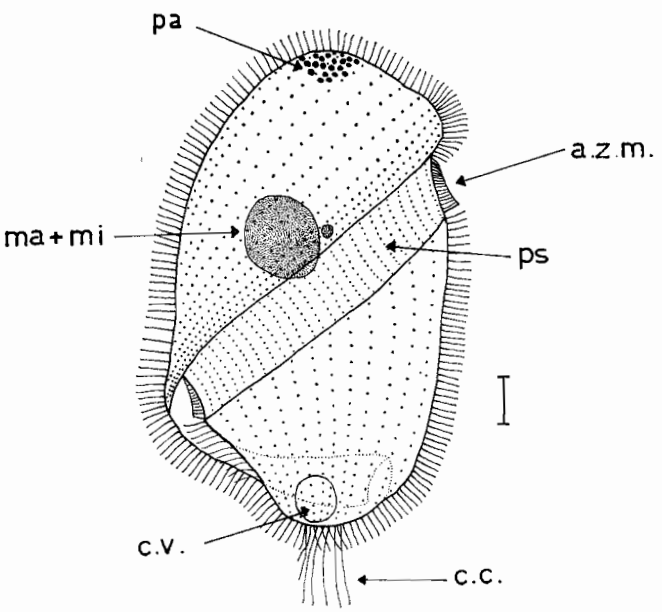

Fig. 76. *Brachonella spiralis* (Smith) Jankowski, 1964; ventral view after Jankowski (1964a).

Family Gyrocorythidae (=Metopidae)
Genus *Caenomorpha*

CAENOMORPHA MEDUSULA Perty (Fig. 77)

Morphology

Length 100–150 μm; body medusoid with a long posterior spine; somatic ciliation restricted to 2 rows of thick flexible cirri (which are highly thigmotactic) and to the perizonal ciliary stripe; buccal cavity with the adoral zone of membranelles forms a long spiral encircling the body; cytostome situated posteriorly, cytopharynx directed anteriorly; a single undulating membrane borders the cytostome; 3 or 4 macronuclei, 1 micronucleus; 1 contractile vacuole located at the posterior extremity (for further details see Jankowski, 1964a).

Food

Bacteria, particularly sulfur bacteria.

Occurrence and ecology

Throughout the year in putrefying sludge with hydrogen sulfide (Liebmann, 1962); pools, lakes, reservoirs, dammed rivers; often associated with *Metopus es* and *Brachonella spiralis*; does not occur in fresh sewage sludge. According to Bick (1957), also present in the oxidized mud of small ponds lacking hydrogen sulfide.

Ecological characteristics (from Noland, 1925, and Wilbert, unpublished data)

	Extreme tolerances
temperature (°C)	4–19
pH	6.2–8.6
dissolved O_2 (mg/l)	0–13
free CO_2 (mg/l)	0–100
NH_4^+ (mg/l)	0–18
H_2S (mg/l)	0–22

Saprobiology

According to Liebmann (1962), this is a polysaprobic indicator organism but this statement should be restricted to the association *Caenomorpha, Epalxella, Pelodinium, Metopus*, etc. Furthermore, it should be stressed that none of these sapropelobiontic ciliates are true polysaprobic organisms; they are simply indicators of hypersaprobic conditions where decomposition is checked or even stopped by a high hydrogen sulfide content and a lack of oxygen.

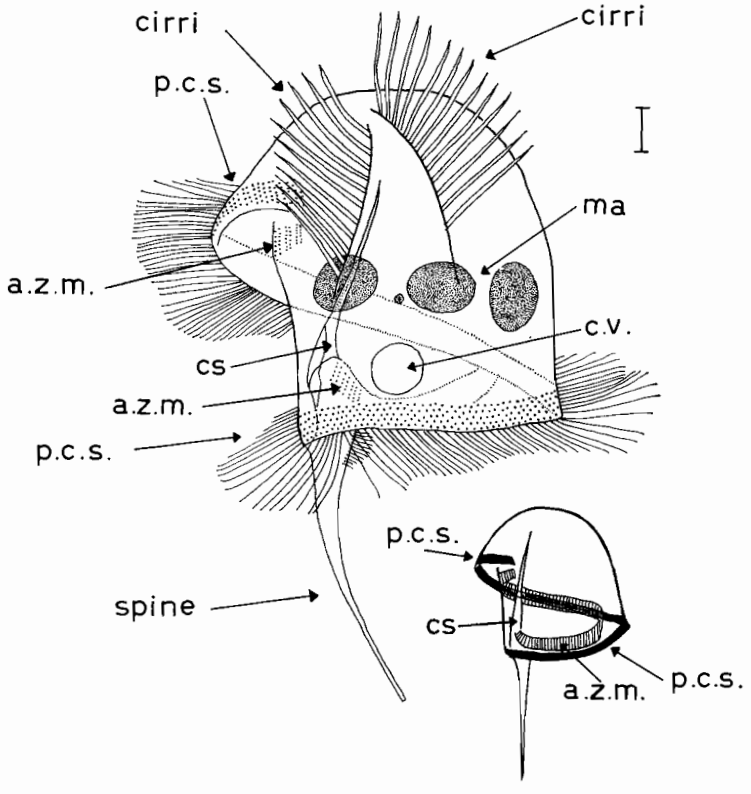

Fig. 77. *Caenomorpha medusula* Perty, left lateral view; after Jankowski (1964). The small inset diagram illustrates the course of the adoral zone of membranelles and the perizonal ciliary stripe.

Family Spirostomatidae
Genus *Spirostomum*

SPIROSTOMUM AMBIGUUM (O. F. Müller) Ehrenberg (Fig. 78)

Morphology

Length 1–3 mm; elongated, cylindrical body, brownish in colour; very large, easily distinguished with the unaided eye; highly contractile on account of longitudinal myonemes; uniform ciliation in longitudinal rows; peristome two-thirds of the body length, closely lined with short membranelles; the long macronucleus appears like a string of beads; many micronuclei; a single large contractile vacuole terminally, with 1 long canal close to the dorsal side.

Food

Bacteria, flagellates, algae.

Occurrence and ecology

Cosmopolitan in distribution, found in lenitic zones of streams and rivers, and still waters; prefers decaying plant material (leaves, etc.) and is therefore a characteristic inhabitant of forest pools and lakes rich in litter (Bick, 1958).

Ecological characteristics (Bick, 1968)

	Extreme tolerances
temperature (°C)	0–25
pH	6.0–7.8
dissolved O_2 (mg/l)	0.1–7.4
NH_4^+ (mg/l)	0–17
H_2S (mg/l)	0–1.3
brackish water (seawater type)	up to 4 g of total salt content per litre
bacteria (plate counts on peptone agar)	2 000–100 000/ml

Saprobiology

An alpha-mesosaprobic indicator organism (Liebmann, 1962).

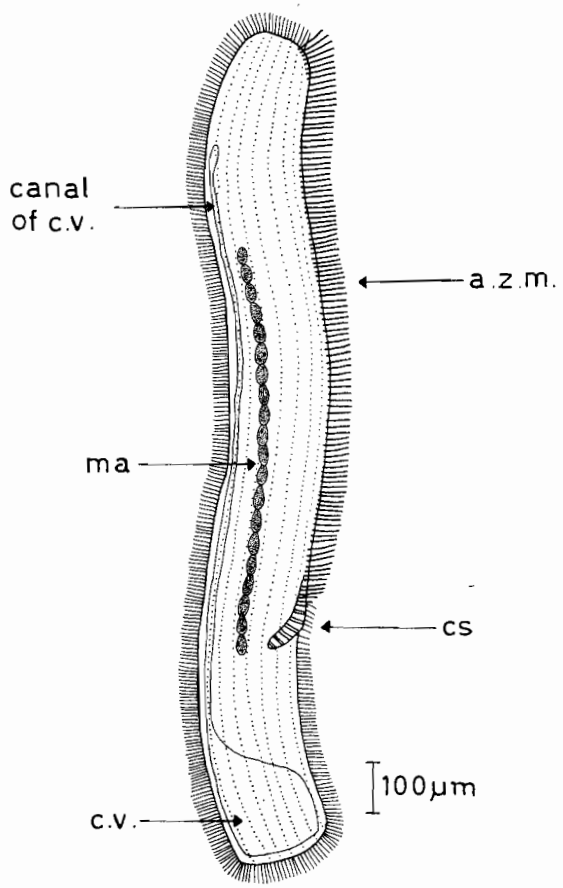

Fig. 78. *Spirostomum ambiguum* (O. F. Müller) Ehrenberg.

Family Spirostomatidae
Genus *Spirostomum*

SPIROSTOMUM TERES Claparède & Lachmann (Fig. 79)

Morphology

Length 150–400 μm; body shape similar to that of *S. ambiguum* but comparatively small; colour yellowish or slightly brown; peristome about one-third of the body length; macronucleus oval; contractile vacuole terminal with long canal. For special features of silver impregnation, see Boggs (1965).

Food

Algae, flagellates.

Occurrence and ecology

Widely distributed in Europe and America. Among decaying plant material; indifferent to oxygen lack, but low tolerance to NH_4^+.

Ecological characteristics (Bick, 1968)

	Extreme tolerances
temperature (°C)	0–25
pH	6.7–8.1
dissolved O_2 (mg/l)	0–8
free CO_2 (mg/l)	0–50
NH_4^+ (mg/l)	0–3.5
H_2S (mg/l)	0–1
brackish water (sea-water type)	up to 7 g of total salt content per litre
athalassogenic natron lake water	up to 2 g of total salt content per litre
bacteria (plate counts on peptone agar)	25 000–16 000 000/ml

Saprobiology

According to Kolkwitz (1950), this is a beta-mesosaprobic indicator organism. On account of its low tolerance to ammonia, it is not found in waters receiving high quantities of sewage but is frequently present in waters with great quantities of decaying plant materials or other material poor in nitrogenous compounds.

Not described:

Family Condylostomatidae
e.g., *Condylostoma* (p. 20; Fig. 10B).
Family Folliculinidae
e.g., *Folliculina* (p. 20; Fig. 10C).

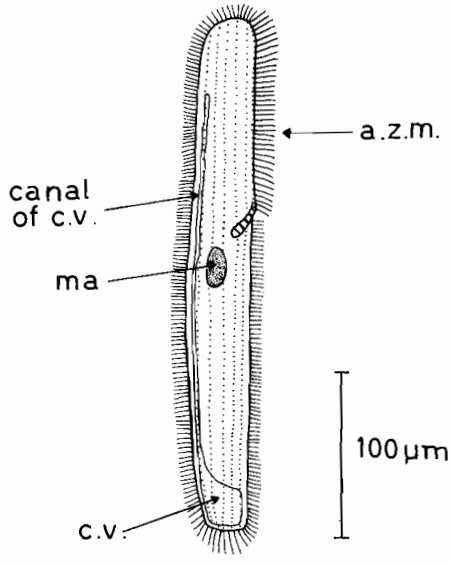

Fig. 79. *Spirostomum teres* Claparède & Lachmann.

Order OLIGOTRICHIDA

Family Halteriidae
Genus *Halteria*

HALTERIA GRANDINELLA (O. F. Müller) Dujardin (Fig. 5C)

Morphology

Length 20–50 μm; body spherical; membranelles in circle anteriorly; cytostome at the end of the zone of the membranelles near the anterior end of the organism; lateral body surface with 7 groups of long tactile cilia (3 cilia per group); locomotion is of two types, slow rotatory movements and swift darts. For details see Kahl (1932) and Tamar (1965).

Food

Bacteria.

Occurrence and ecology

Cosmopolitan, recorded, for example, from Europe, North America, and India in various types of fresh and brackish water; bottom-dwelling among plants or on detritus; sometimes planktonic.

Ecological characteristics (Bick, 1968)

	Extreme tolerances	*Optimal ranges*
temperature (°C)	1–35 [a]	25
pH	6.1–9.4	7–7.5
dissolved O_2 (mg/l)	0–16	0.1–1.0
free CO_2 (mg/l)	0–56	5–30
NH_4^+ (mg/l)	0–25	0–0.5
free NH_3 (mg/l)	0–0.8	0
NO_2^- (mg/l)	0–30	0
brackish water (seawater type)	up to 3.5 g of total salt content per litre	fresh water
bacteria (plate counts on peptone agar)	300–17 000 000/ml	—

[a] From Münch (1969).

The table shows that *H. grandinella* is able to tolerate a low oxygen content and high levels of free carbon dioxide but it prefers low NH_4^+ levels. Thus the species normally occurs in abundance in the beta-mesosaprobic zone of the self-purification process where the NH_4^+ originating from sewage decomposition is mineralized to NO_3^-. Under special conditions, however (e.g., pollution with cellulose and similar materials poor in nitrogenous compounds), *Halteria* may be found in more heavily polluted zones.

Saprobiology

According to Liebmann (1962), it is a beta-mesosaprobic indicator organism.

Saprobiological classification

According to Zelinka & Marvan (1961) (1) and Sládeček (1964) (2):

	bos	aos	bms	ams	ps	i
(1)	—	—	7	3	—	2
(2)	—	2	7	1	—	3

Not described:

Family Strobilidiidae
e.g., *Strobilidium* (p. 14; Fig. 5B).

Order TINTINNIDA

Family Tintinnidiidae
Genus *Tintinnidium*

TINTINNIDIUM FLUVIATILE Stein (Fig. 5A)

Morphology

Lorica elongated, 40–350 μm long, of irregular form, mostly tube-like; posterior end closed; wall mucilaginous with foreign bodies (e.g., shells of diatoms) attached to it; free-swimming (planktonic) or attached to substrate (*T. fluviatile* var. *emarginatum* Maskell); body more or less trumpet-shaped and fixed to the bottom of the case by means of a myoneme-bearing contractile stalk; well-developed adoral zone of membranelles at the anterior pole running clockwise to the mouth; body ciliation restricted to few transverse rows of cilia just behind the buccal area; 1 oval–reniform macronucleus in the anterior half of the body; a single contractile vacuole located somewhat laterally in the anterior region.

Remarks. The very similar *T. semiciliatum* Sterki may occur also in the plankton of lakes and reservoirs; the identification being rather difficult, it has been omitted from this guide. For further information see Kahl (1932) and Kudo (1966).

Food

Flagellates, diatoms, bacteria.

Occurrence and ecology

The planktonic *T. fluviatile* is widely distributed in standing and slowly-flowing waters, and is probably cosmopolitan. The sessile form has been reported in ponds, lakes and reservoirs (e.g., Sládečková & Sládeček, 1963; Nusch, 1969); predominantly occurring in spring (Sládečková & Sládeček, 1963; Nusch, 1969) and autumn (Nusch, 1969) attached to various kinds of substrate, e.g., glass slides. Associated with *Carchesium polypinum*, *Campanella umbellaria*, and other species (Sládečková, 1962).

Ecological characteristics of *T. fluviatile* var. *emarginatum* (preliminary data from Nusch, personal communication)

	Extreme tolerances
temperature (°C)	2–15
pH	6.9–7.7
dissolved O_2 (mg/l)	12–14
free CO_2 (mg/l)	2–5
NH_4^+ (mg/l)	0.1 and below
bacteria (membrane-filter technique)	300 000–2 500 000/ml

Saprobiology

According to Liebmann (1962) the planktonic form of *T. fluviatile* is an oligosaprobic indicator organism; the sessile variety *emarginatum* has also been found under beta-mesosaprobic conditions (Sládečková, 1962).

Saprobiological classification

According to Sládečková & Sládeček (1966):

bos	aos	bms	ams	ps	i
—	3	7	—	—	4

Order ODONTOSTOMATIDA

Family Discomorphellidae
Genus *Discomorphella* (only one species)

DISCOMORPHELLA (= DISCOMORPHA) PECTINATA (Levander) Corliss 1960 (Fig. 80)

Morphology

Length 70–90 μm; oval, flattened, with a dorsal keel and ventral spines; perizonal ciliary stripe runs from right to left sides of the body; short rows of cilia situated in front of and behind the buccal area; 2 or 3 long cirri inserted posteriorly; buccal cavity (with membranelles) opens on to the left side behind the perizonal hoop; 1 oval macronucleus and 1 micronucleus; contractile vacuole located posteriorly. For details see Jankowski (1964a).

Food

Sulfur bacteria.

Occurrence and ecology

Widely distributed, probably cosmopolitan, in putrefying sludge rich in hydrogen sulfide (sapropel): forest pools with natural pollution by litter; ponds, lakes, reservoirs; according to Liebmann (1962), not to be found in raw sewage and purification plants. Associated with *Caenomorpha*, *Epalxella*, *Metopus es*, and other sapropelobionts.

Saprobiology

According to Liebmann (1962), this is a polysaprobic indicator organism, but in my opinion it is better classified as an indicator of arrested self-purification processes (cf., discussion of the saprobiological classification in the section on *Metopus es*, p. 146).

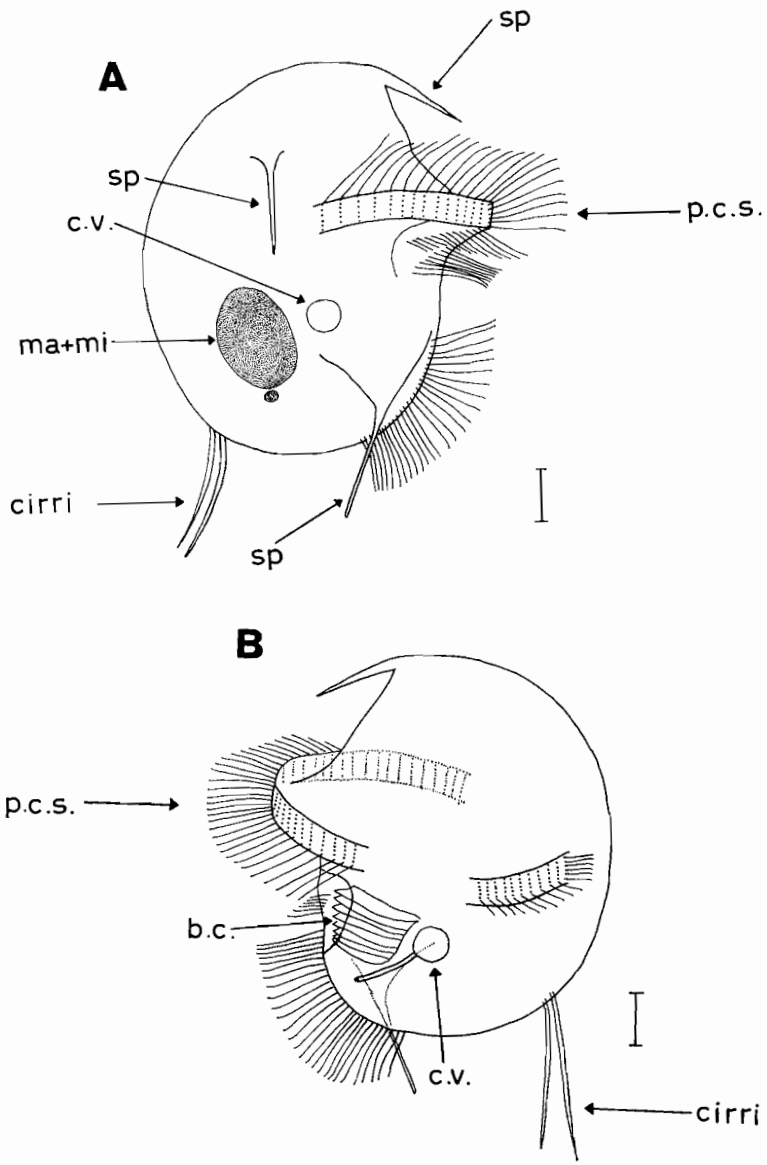

Fig. 80. *Discomorphella pectinata* (Levander) Corliss; after Jankowski (1964a). A, Right lateral view; B, left lateral view.

Family Epalxellidae
Genus *Epalxella*

EPALXELLA STRIATA (Kahl) Corliss 1960 (Fig. 81)

Morphology

Length 20–35 μm; compressed, pellicle carapaced; right side convex, left side flattened; perizonal ciliary stripe consisting of 7 rows of cilia in the anterior part of the body and 4 short rows of cilia in the posterior part; buccal cavity with 8 membranelles, opening to the left side; 1 macronucleus and 1 micronucleus; the single contractile vacuole posteriorly located, near the buccal cavity; numerous refractile granules give this ciliate a greyish appearance; for details see Jankowski (1964a).

Food

Sulfur bacteria.

Occurrence and ecology

Reported from Europe and America; sapropelobiontic, occurring in putrefying sludge rich in hydrogen sulfide; associated with *Caenomorpha*, *Metopus*, *Pelodinium*, *Plagiopyla* (p. 66), and *Saprodinium*. Like the other sapropelobiontic species, it does not occur in raw sewage.

Saprobiology

According to Liebmann (1962), it is a polysaprobic indicator organism (for discussion of this point, see the section on *Metopus es*, p. 146).

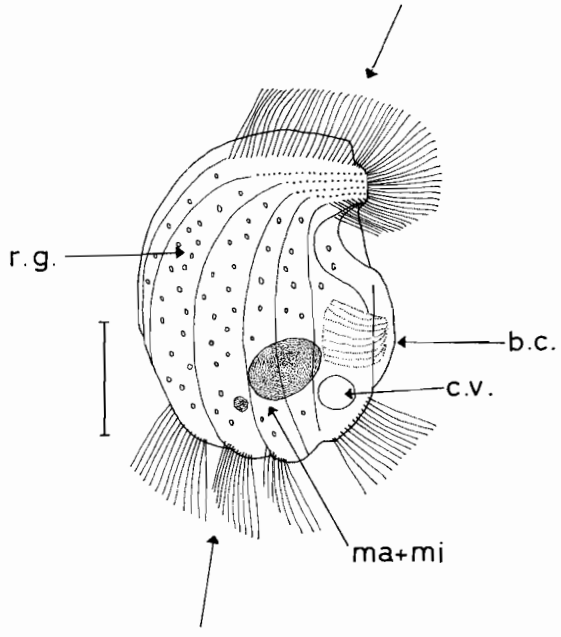

Fig. 81. *Epalxella striata* (Kahl) Corliss, right lateral view; after Jankowski (1964a). Arrows indicate the main features used for identification.

Family Epalxellidae
Genus *Pelodinium* (only one species)

PELODINIUM RENIFORME Lauterborn (Fig. 82)

Morphology

Length 40–50 μm; body reniform, compressed, carapaced; dorsal side convex; 1 spine ventrally in front of the buccal area, and 6 spines surrounding a small hollow at the posterior pole; perizonal ciliary stripe consisting of 7 rows of cilia; 4 shortened longitudinal rows in the posterior half of the cell; buccal cavity opens ventrally to the left side; 2 macronuclei and 1 micronucleus close to the dorsal side; 1 contractile vacuole in the posterior region, refractile granules at the anterior pole. For further details see Wetzel (1928), Kahl (1932), and Jankowski (1964a).

Food

Bacteria, mainly sulfur bacteria.

Occurrence and ecology

Widely distributed in putrefying sludge rich in hydrogen sulfide; in pools, lakes, reservoirs; does not occur in raw sewage (Liebmann, 1962). *Pelodinium* belongs to the sapropelobiontic community (cf., *Epalxella striata* and *Metopus es*); like other sapropelobiontic ciliates, it is classified as a polysaprobic indicator organism (Liebmann, 1962); for a discussion of this classification see section on *Metopus es* (p. 146).

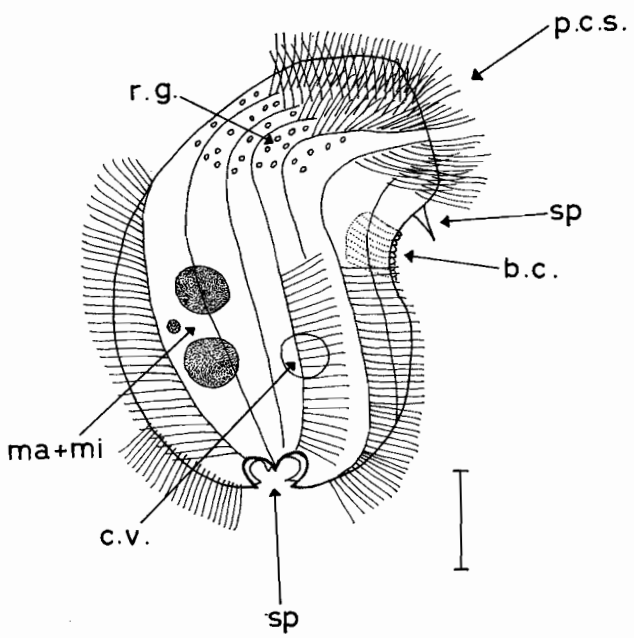

Fig. 82. *Pelodinium reniforme* Lauterborn, right lateral view.

Family Epalxellidae
Genus *Saprodinium*

SAPRODINIUM DENTATUM Lauterborn (Fig. 83)

Morphology

Length 60–80 μm; compressed, carapaced, and ridged; the convex dorsal side forms a distinct keel with an anterior spine; 1 spine situated ventrally, and 8 others surround a hollow at the posterior end; the perizonal ciliary stripe consists of 5 rows of cilia located on a distinct prominence of the carapace; further groups of cilia are located near the anterior margin between the perizonal ciliary stripe and buccal cavity, and in the posterior portion of the body; buccal cavity opens ventrally to the left side; 1–3 macronuclei, 1 micronucleus, 1 contractile vacuole; refractile granules at the anterior pole. For further details see Kahl (1932) and Jankowski (1964a).

Food

Bacteria.

Occurrence and ecology

Widely distributed in putrefying sludge containing hydrogen sulfide, and in pools, lakes, reservoirs, and lenitic zones of flowing waters. According to Liebmann (1962), it is a polysaprobic indicator organism. Associated with the sapropelobiontic ciliates *Caenomorpha*, *Epalxella*, *Metopus*, and *Pelodinium*. For discussion of the saprobiological classification, see *Metopus es* (p. 146).

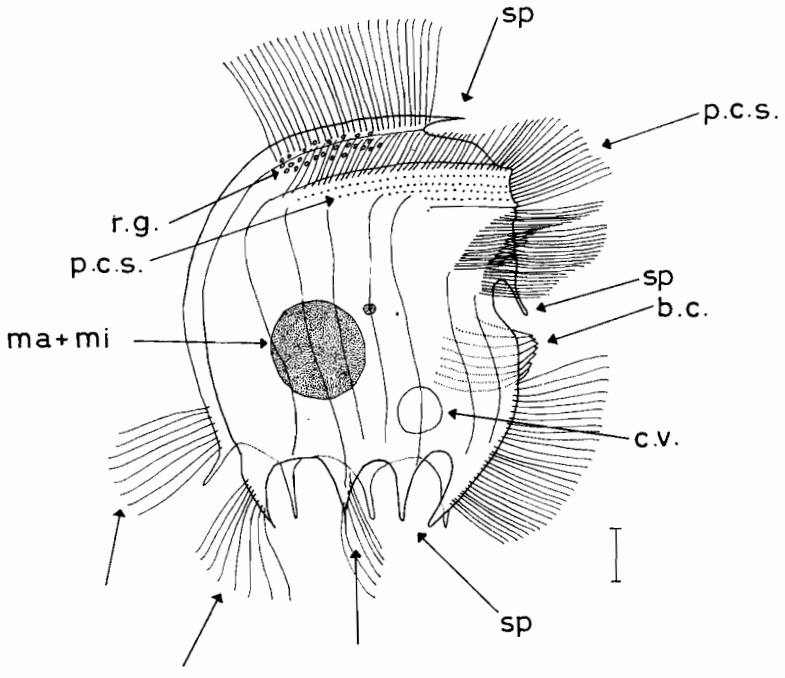

Fig. 83. *Saprodinium dentatum* Lauterborn, right lateral view; after Jankowski (1964a).

Order HYPOTRICHIDA

Family Aspidiscidae
Genus *Aspidisca*

ASPIDISCA COSTATA (Dujardin) (Fig. 84)

Morphology

Length 25–40 μm; small, ovoid; body not plastic because of the armour-like pellicle; ventral side flattened and furnished with 7 frontoventral cirri and 5 transversal, 2 of which are located immediately behind the buccal area; the adoral zone of membranelles is reduced in comparison with *Stylonychia* and other hypotrichs; the buccal area bears a rather small group of membranelles and is located in the left posterior part of the ventral side, its membranelles are covered by a thin transparent fold; on the left anterior part of the ventral side there is a group of 3 small membranelles—a remnant of a greater adoral zone.

Dorsal side convex and conspicuously ridged, the 6 longitudinal ridges vary in size (Fig. 84B) (types according to Hamm, 1964).

Macronucleus horseshoe-shaped; 1 small spherical micronucleus anteriorly; contractile vacuole near the right side in the vicinity of the first transversal cirrus.

Food

Bacteria; the food is taken by " grazing " on layers of bacteria.

Occurrence and ecology

Cosmopolitan in distribution and found throughout the year in various types of water: activated sludge, trickling filters, oxidation ponds. Ecological data referring to activated sludge are given by Hamm (1964).

Ecological characteristics (Bick, 1957, 1968; Hamm, 1964)

	Extreme tolerances
temperature (°C)	0–30
pH	5.4–9.4
dissolved O_2 (mg/l)	0.1–12.0
BOD_5 (mg/l)	1.9–21.0
free CO_2 (mg/l)	0.1–12.0
NH_4^+ (mg/l)	0–31.0
free NH_3 (mg/l)	0–2.3
NO_2^- (mg/l)	0–51.0
H_2S (mg/l)	0
brackish water (seawater type)	up to 3.5 g of total dissolved salts per litre
athalassogenic natron lake water	up to 7.5 g of total dissolved salts per litre
bacteria (plate counts on peptone agar)	200–3 500 000/ml

Saprobiology

According to Liebmann (1962), this is a beta-mesosaprobic indicator organism; however, the present ecological characteristics indicate that *A. costata* can tolerate much higher degrees of pollution without ill effect.

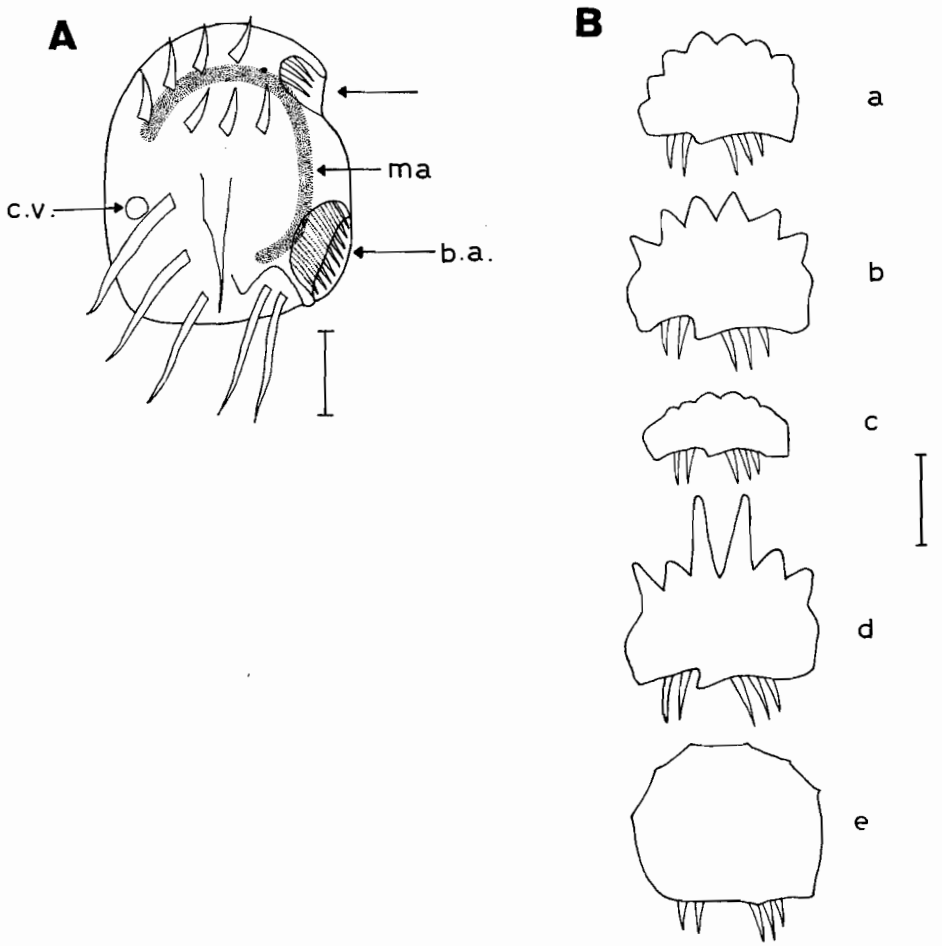

Fig. 84. *Aspidisca costata* (Dujardin). A, Ventral view; the right upper arrow indicates the anterior rudiment of the adoral zone; B, diagrammatic cross-sections of individuals to illustrate the 5 main varieties (according to Hamm (1964)). (a) Normal type; (b) overfed form with 6 strong ribs; (c) starved specimen; (d) specimen with extremely high ribs; (e) specimen damaged by adverse environmental conditions.

Family Aspidiscidae
Genus *Aspidisca*

ASPIDISCA LYNCEUS Ehrenberg (Fig. 85)

Morphology

Length 30–50 μm; generic features as described for *A. costata*. For details see Kahl (1932).

Special features

Dorsal side smooth and without ribs, a short distinct spine between the two left transverse cirri.

Food

Bacteria.

Occurrence and ecology

Cosmopolitan in distribution, occurring in all types of stagnant and flowing waters where decomposition of organic materials takes place; frequently in activated sludge, trickling filters (lower part), oxidation ponds, and inside tufts of *Sphaerotilus* (Liebmann, 1962); also in pools containing decaying leaves.

Ecological characteristics (from Noland, 1925, and Bick, unpublished data)

	Extreme tolerances
temperature (°C)	0–25
pH	6.5–9.8
dissolved O_2 (mg/l)	1–12

Saprobiology

According to Liebmann (1962), *A. lynceus* is an alpha-mesosaprobic indicator organism.

Saprobiological classification (calculated from data given by Beer, 1964)

bos	aos	bms	ams	ps	i
—	—	2	7	1	3

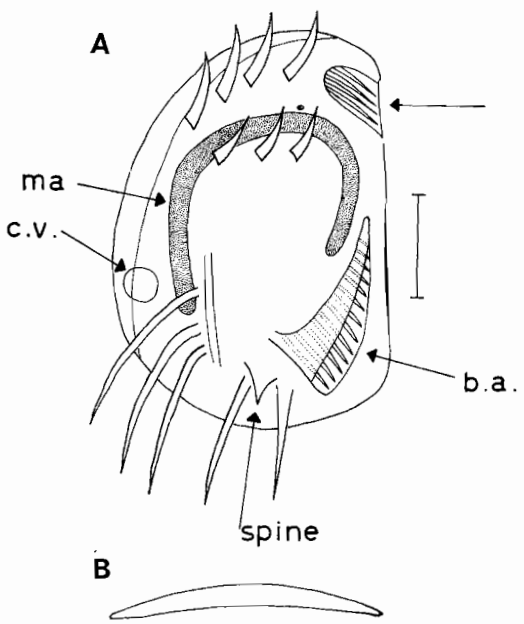

Fig. 85. *Aspidisca lynceus* Ehrenberg. A, Ventral view; B, diagrammatic cross-section. The right upper arrow indicates the anterior rudiment of the adoral zone.

Family Euplotidae
Genus *Euplotes*

EUPLOTES PATELLA (O. F. Müller) Ehrenberg (Fig. 86)

Morphology

Length 80–150 μm; body flattened dorsoventrally; ventral side shows characteristic sets of cirri: somatic cirri (9 frontoventrals, 5 transversal, 4 caudals) and buccal cirri (= adoral zone of membranelles); the dorsal side bears small sensory bristles the base of which is marked by small granules forming asterisks (see Fig. 86), otherwise the dorsal side is bare but very often exhibits 5–7 ribs or keels of varying height, the height of the ribs as well as the contour of the whole body varies greatly; symbiotic zoochlorellae are sometimes present; anterior part of the buccal area covered by a rigid plate; macronucleus is C-shaped; 1 small micronucleus in the anterior part of the cell above the buccal cavity; 1 contractile vacuole on the right side near the transverse cirri (for details of infraciliation and silver line system, see Tuffrau (1960)).

Food

Flagellates, algae, ciliates, bacterial colonies.

Occurrence and ecology

Cosmopolitan in distribution, among plants and decaying plant materials in pools, ponds and other freshwater habitats.

Ecological characteristics (Bick, 1968)

	Extreme tolerances	*Optimal ranges*
temperature (°C)	0–25	—
pH	5.7–8.2	6.5–7.0
dissolved O_2 (mg/l)	0–12	0.1–1.0
free CO_2 (mg/l)	0–66	—
NH_4^+ (mg/l)	0–10	0–0.5
H_2S (mg/l)	0–1	0
brackish water (seawater type)	up to 3.5 g of total salt content per litre	fresh water
bacteria:		
(1) plate counts on peptone agar	8 000–16 000 000/ml	—
(2) direct counts	1 200 000–60 000 000/ml	—

Saprobiology

E. patella is a beta-mesosaprobic indicator organism according to Kolkwitz (1950); this classification is presumably conservative since *E. patella* is able to tolerate environmental conditions that are characteristic of much more polluted zones. Specimens possessing symbiotic algae may occur in habitats with a high degree of bacterial decomposition and oxygen deficiency.

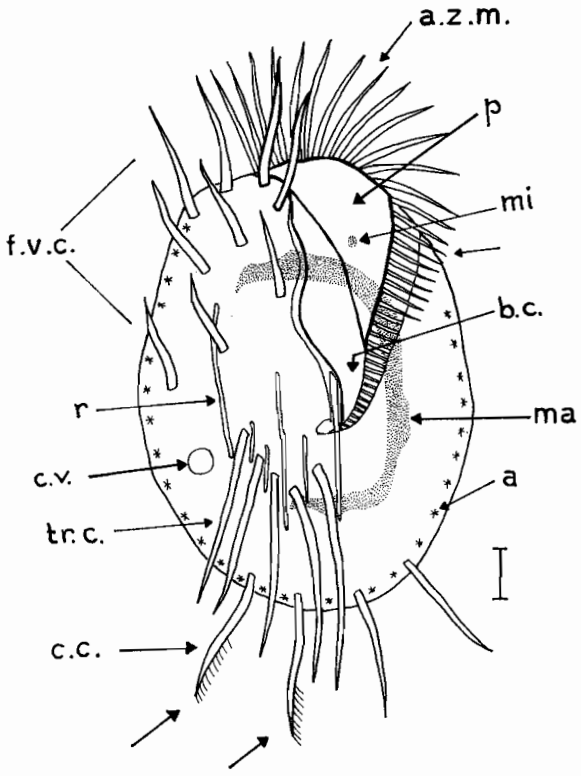

Fig. 86. *Euplotes patella* (O. F. Müller) Ehrenberg, ventral view; after Kahl (1932). Arrows indicate the main features used for identification.

Family Euplotidae
Genus *Euplotes*

EUPLOTES AFFINIS Dujardin (Fig. 87)

According to Tuffrau (1960), *E. affinis* is a synonym of *E. charon* (O. F. Müller) Stein

Morphology

Length 40–70 μm; body dorsoventrally flattened; 9 frontoventral cirri, 5 transverse cirri, and 4 caudal cirri (for nomenclature of cirri see section on *E. patella*); dorsal side with 5–6 ribs or keels; buccal cavity without frontal plate covering the anterior part (contrary to *E. patella*); macronucleus C-shaped; 1 micronucleus near the anterior end of the cell; contractile vacuole on the right side near the transverse cirri.

There are some taxonomic difficulties with this organism; Tuffrau (1960) stated that *E. charon* and *E. affinis* are conspecific. However, *E. affinis* as understood here shows constantly 9 frontoventral cirri, while the typical *E. charon* has 10 (Borror, 1968). As it was not possible to find specimens possessing 10 frontoventral cirri within the populations studied by the author, it was decided to regard *E. affinis* Dujardin (*sensu* Kahl 1932, p. 637) as a valid species. It should be mentioned that sometimes specimens with only 3 caudal cirri occur—i.e., the so-called *E. affinis* forma *tricirratus* Kahl 1932.

Food

Small flagellates, bacteria.

Occurrence and ecology

The geographical distribution of the species is not yet quite clear; present in Central Europe at least.

Ecological characteristics (Bick, 1968)

	Extreme tolerances	*Optimal ranges*
temperature (°C)	0–25	—
pH	6.2–7.9	7.0–7.5
dissolved O_2 (mg/l)	0.1–7.1	0.1–1
free CO_2 (mg/l)	0–64	10–20
NH_4^+ (mg/l)	0–18	0–0.5
free NH_3	0–0.2	0
NO_2^- (mg/l)	0–40	0
H_2S (mg/l)	0–1	0
brackish water (seawater type)	up to 35 g of total salt content per litre	1–3.5 g of total salt content per litre
bacteria (plate counts on peptone agar)	5 000–12 000 000/ml	—

Saprobiology

E. affinis itself has not been listed in the saprobity system but *E. charon* is assumed to be a beta-mesosaprobic indicator organism (Liebmann, 1962).

This species is able to tolerate environmental conditions that characterize the whole range of mesosaprobic conditions; its tolerance of low oxygen concentrations enables it to develop in habitats with intensive bacterial decomposition of plant materials, but its comparatively low tolerance of ammonia prevents it from entering zones with higher rates of sewage decomposition. Further taxonomic and ecological investigations seem to be required.

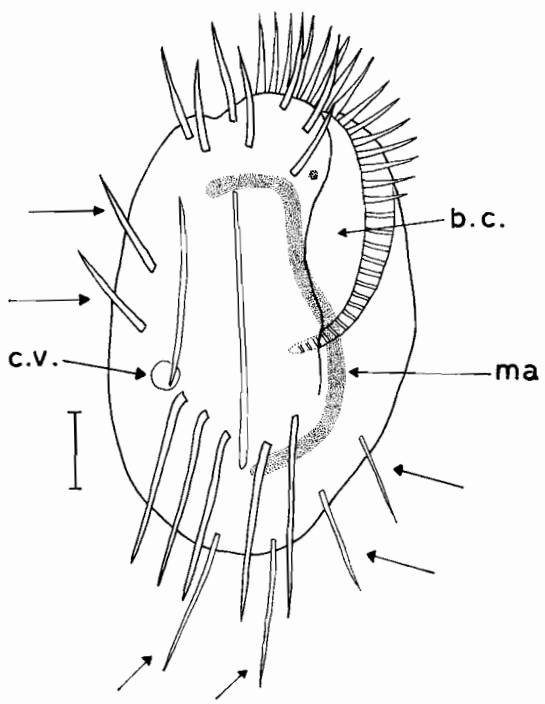

Fig. 87. *Euplotes affinis* Dujardin, ventral view; after Kahl (1932). Arrows indicate the main features used for identification.

Family Oxytrichidae
Genus *Stylonychia*

STYLONYCHIA MYTILUS Ehrenberg (Fig. 88)

Morphology

Length 100–300 μm; body flattened dorsoventrally; the dorsal side bears only small cilia (sensory bristles); the ventral side is furnished with strong cilia or cirri arranged in characteristic rows and groups; rows of cirri near both right and left margins, interrupted posteriorly; 8 strong frontal cirri, 5 ventral ones behind the buccal area, 5 transverse cirri, and 3 caudal ones; the caudals show fringes at the end; for a more detailed description, see Dragesco (1966b).

Buccal area furnished with conspicuous adoral membranelles, and 1 long undulating membrane at the right side, the cytostome is located at the posterior end of the buccal area; 2 macronuclei and 2 micronuclei; 1 contractile vacuole near the posterior end of the buccal area.

The size of *Stylonychia* may vary considerably; furthermore, it should be stressed that the family Oxytrichidae as well as the genus *Stylonychia* itself includes a great number of species, some of which may rather closely resemble the one described here. All identification features should thus be checked carefully; in case of doubt see Kahl (1932).

Food

Algae, flagellates, ciliates.

Occurrence and ecology

Probably cosmopolitan in distribution in pools and bottom zones of ponds, lakes, and rivers.

Ecological characteristics (Bick, 1968)

	Extreme tolerances
temperature (°C)	2–25 [a]
pH	4.0–8.4
dissolved O_2 (mg/l)	0–9.2
free CO_2 (mg/l)	0–205
NH_4^+ (mg/l)	0–26
free NH_3 (mg/l)	0–3
brackish water (seawater type)	up to 1.8 g of total salt content per litre
bacteria (plate counts on peptone agar)	6 000–5 000 000/ml

[a] Or up to 47°C (Dingfelder, 1962).

Saprobiology

According to Kolkwitz (1950), this is an indicator organism of the alpha-mesosaprobic/beta-mesosaprobic zone; the ecological tolerances cited above are in favour of Kolkwitz's statement.

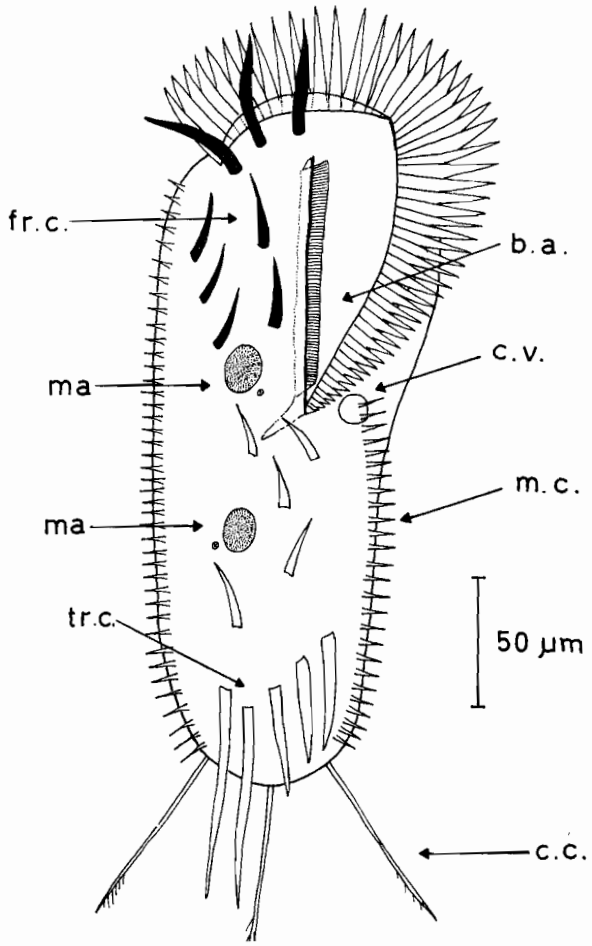

Fig. 88. *Stylonychia mytilus* Ehrenberg. Frontal cirri (fr.c.) shaded black.

Family Oxytrichidae
Genus *Stylonychia*

STYLONYCHIA PUTRINA (Stokes) (Fig. 89)

Morphology

Length 125–145 μm; similar to *S. mytilus* but smaller, and right and left sides are more or less parallel; caudal cirri unfringed, 2–4 transverse cirri protruding slightly beyond the posterior end.

Food

Flagellates, bacteria.

Occurrence and ecology

Freshwater habitats with plant material undergoing decomposition; recorded in Europe and North America.

Ecological characteristics (Bick, 1968)

	Extreme tolerances	*Optimal ranges*
temperature (°C)	2–25	—
pH	5.8–9.4	6.5–7.0
dissolved O_2 (mg/l)	0–12.6	0.1–1.0
free CO_2 (mg/l)	0–56	10–30
NH_4^+ (mg/l)	0–22	—
free NH_3 (mg/l)	0–2	—
brackish water (seawater type)	up to 14 g of total salt content per litre	fresh water
athalassogenic natron lake water	up to 2 g of total salt content per litre	—
bacteria (plate counts on peptone agar)	1 000–20 000/ml	—

Saprobiology

According to the saprobiological classification of Kolkwitz; this species inhabits the alpha-mesosaprobic to beta-mesosaprobic zones; this statement agrees well with the ecological characteristics given above.

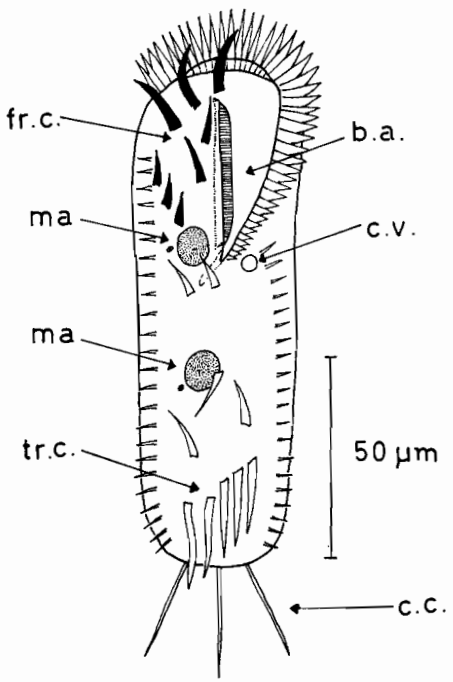

Fig. 89. *Stylonychia putrina* (Stokes); after Kahl (1932).

Family Oxytrichidae
Genus *Urostyla*

UROSTYLA WEISSEI Stein (Fig. 90)

Morphology

Length 220–300 μm; ellipsoid, flexible, dorsoventrally flattened; sensory bristles on the dorsal side only; ventral side furnished with cirri as follows: right and left marginal cirri meet as a continuous row posteriorly; 3 long rows of ventral cirri (see Fig. 90) and 1 (or 2) short rows of about 5–8 ventral cirri just behind the buccal area; 4 strong frontal cirri near the anterior pole and 4 smaller ones close to the ventral rows; the number of ventral rows and of frontal cirri may vary with the individual (Dragesco, 1966b); 8 transverse cirri; macronucleus in two parts; 1 contractile vacuole; for further details, see Dragesco (1966b).

Since there are about 15 species of *Urostyla*, taxonomic difficulties may occur; in case of doubt, see Kahl (1932).

Food

Bacteria, flagellates, algae.

Occurrence and ecology

Reported from Europe; according to Liebmann (1962) the species is found all through the year in stagnant waters with dissolved oxygen levels higher than 3 mg per litre, also in trickling filters.

Saprobiology

An alpha-mesosaprobic indicator organism (Liebmann, 1962).

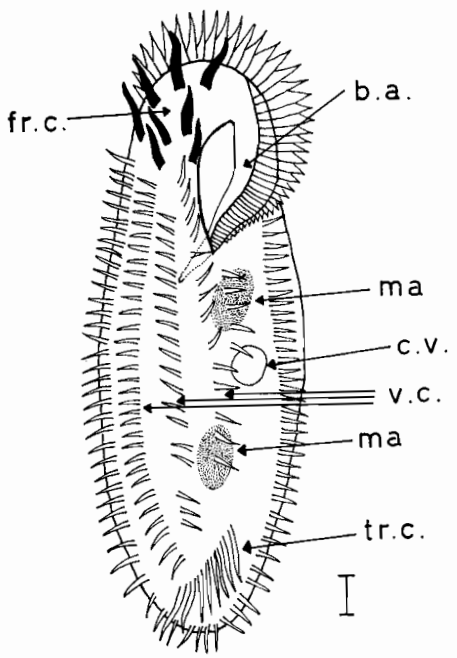

Fig. 90. *Urostyla weissei* (Stein); after Dragesco (1966b).

Family Oxytrichidae
Genus *Oxytricha*

OXYTRICHA FALLAX Stein (Fig. 91)

Morphology

Length about 150 μm; body outline ellipsoid, posterior region broadly rounded; flexible; dorsal surface convex; ventral side flattened and equipped with cirri: 8 frontals; 5 ventrals, 5 transversals; right and left marginal cirri meet as a continuous row posteriorly (note *Stylonychia*, with marginal cirri interrupted at posterior end, and with long caudal cirri); buccal area with well-developed adoral zone of membranelles and a long undulating membrane at the right side; cytostome located at the posterior end of the buccal area; 2 macronuclei and 2 micronuclei; 1 contractile vacuole near to the left margin in the vicinity of the posterior end of the buccal area.

Food

Bacteria, algae, flagellates.

Occurrence and ecology

Widely distributed in stagnant and flowing waters including trickling filters and activated sludge, not to be found in waters receiving manure. Optimal range of environmental factors about pH 6.8–7.5 and 3–5 mg of dissolved oxygen per ml (Liebmann, 1962).

Saprobiology

Classified as an alpha-mesosaprobic indicator organism by Liebmann (1962).

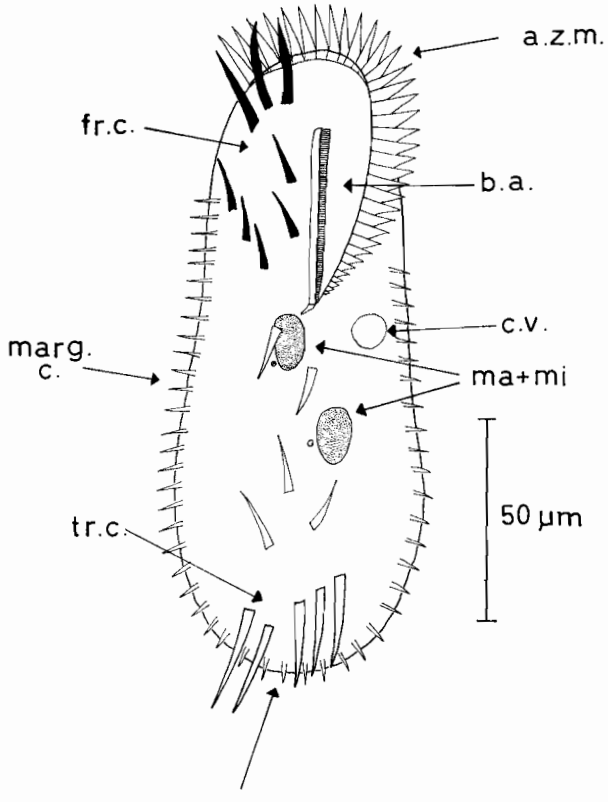

Fig. 91. *Oxytricha fallax* Stein; ventral view. Frontal cirri (fr.c.) shaded black.

Family Oxytrichidae
Genus *Tachysoma*

TACHYSOMA PELLIONELLA (O. F. Müller) (= OXYTRICHA PELLIONELLA O. F. Müller) (Fig. 92)

Morphology

Length about 80 μm; body outline elongate ellipsoid, flexible; ventrally flattened and equipped with 8 frontals, 5 ventrals, 5 strong transversals; right and left rows of marginals interrupted posteriorly (cf., *Oxytricha fallax*, p. 180, with marginals continuous along posterior border); buccal area with adoral zone of membranelles usual for the family Oxytrichidae; dorsal side convex with 3 rows of long tactile bristles; 2 macronuclei, a single micronucleus; 1 contractile vacuole near the left margin just behind the buccal area.

Food

Diatoms, green algae, flagellates, bacteria.

Occurrence and ecology

Reported from Europe, America, and New Zealand in stagnant and running waters; frequently in layers of naviculid diatoms.

Ecological characteristics (Bick, 1957; Noland, 1925; Stout, 1956)

	Extreme tolerances
temperature (°C)	0–25
pH	4.4–8.4
dissolved O_2 (mg/l)	0.4–15.0
free CO_2 (mg/l)	0–17
NH_4^+ (mg/l)	0–5
H_2S (mg/l)	0–0.5

Saprobiology

According to Kolkwitz (1950), this is an alpha-mesosaprobic indicator organism; however, it may occur also under beta-mesosaprobic conditions.

Saprobiological classification

bos	aos	bms	ams	ps	i
—	—	5	5	—	3

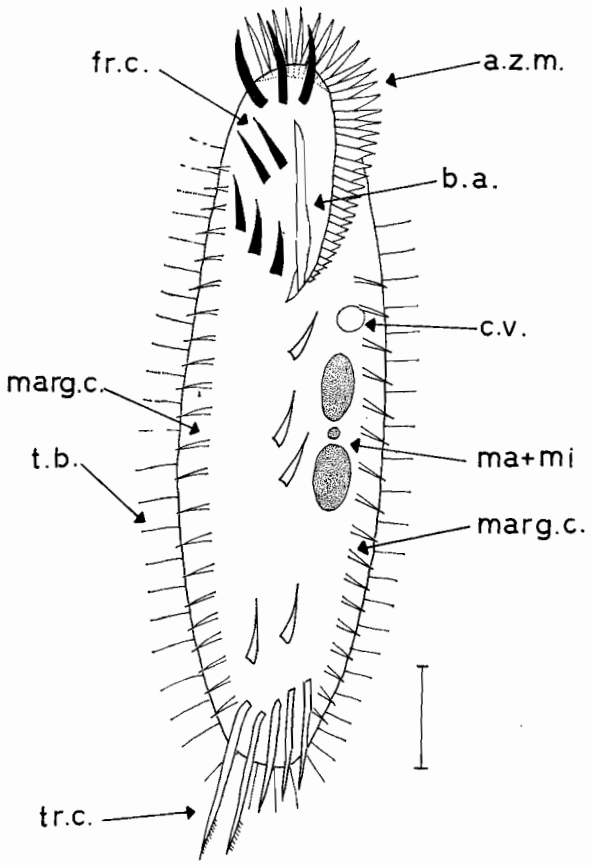

Fig. 92. *Tachysoma pellionella* (O. F. Müller); ventral view. Frontal cirri (fr.c.) shaded black.

Family Oxytrichidae
Genus *Gastrostyla*

GASTROSTYLA STEINI Engelmann (Fig. 93)

Morphology

Length 150–320 μm; body outline ellipsoid; dorsal surface convex; ventral side flattened; 6 frontal cirri, 5 transversals, right and left marginals meet as a continuous row posteriorly, ventrals form an oblique row; 4 macronuclei and 4 micronuclei; a single contractile vacuole close to the left side in the posterior vicinity of the buccal area.

Food

Ciliates (e.g., *Glaucoma, Colpidium*), flagellates.

Occurrence and ecology

Widely distributed in stagnant and flowing waters.

Ecological characteristics (Bick, 1968)

temperature (°C)	5–25
pH	6.5–9.5
dissolved O_2 (mg/l)	0–9
free CO_2 (mg/l)	0–72
NH_4^+ (mg/l)	0.1–55
athalassogenic natron lake-water	up to 10 g of total salt content per litre
bacteria (plate counts on peptone agar)	60 000–8 000 000/ml
freshwater only	

Saprobiological classification

bos	aos	bms	ams	ps	i
—	—	2	7	1	3

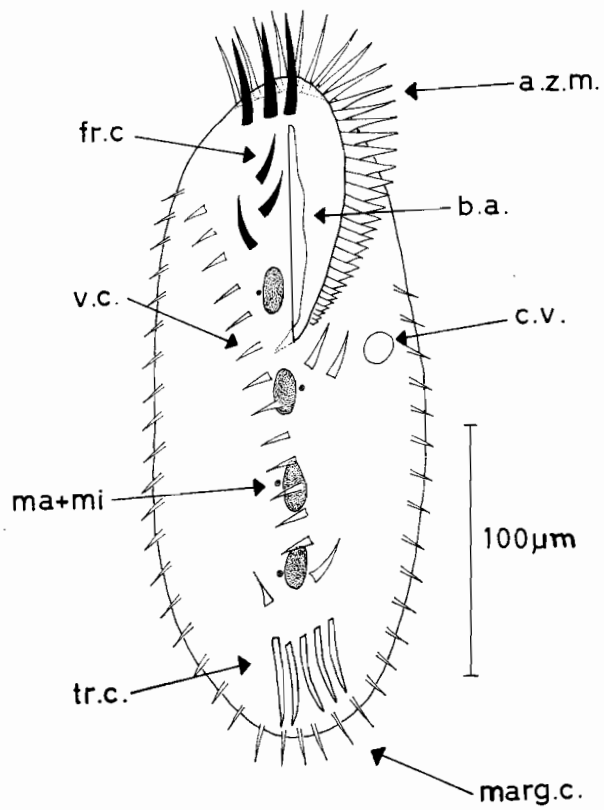

Fig. 93. *Gastrostyla steini* Engelmann. Frontal cirri (fr.c.) shaded black.

Family Oxytrichidae
Genus *Chaetospira*

CHAETOSPIRA MUELLERI Lachmann (Fig. 7B)

Morphology

Length 60–250 μm; housed in lorica attached to substrate; peristome-bearing anterior part of the body narrowed (" proboscis "), extensile and contractile; narrowed part extending more than one-quarter of body length; mouth located at the base of the proboscis at the end of the elongated adoral zone of membranelles; somatic ciliation reduced to 3 short rows of cirri just behind the mouth, and few posterior cirri; proboscis with conspicuous tactile bristles; 2–8 macronuclei; 1 or more micronuclei; 1 contractile vacuole at the base of the proboscis.

Food

Diatoms, flagellates.

Occurrence and ecology

Reported from America and Europe, occurring in ponds (Wilbert, 1969), lakes, and reservoirs attached to detritus plants (above all, decaying plants) and artificial substrates (e.g., glass slides).

Ecological characteristics (Wilbert, personal communication)

	Extreme tolerances
temperature (°C)	12–19
pH	7.6–9.0
dissolved O_2 (mg/l)	5.1–14.0
free CO_2 (mg/l)	0–11
NH_4^+ (mg/l)	0–0.5

Saprobiological classification

According to Sládečková & Sládeček (1966):

bos	aos	bms	ams	ps	i
—	1	8	1	—	4

Family Oxytrichidae
Genus *Chaetospira*

CHAETOSPIRA REMEX Hudson (= STICHOTRICHA MUELLERI Entz = CHAETOSPIRA ENTZI Kahl) (Fig. 94)

Morphology

Body elongated, very contractile; length 150–560 μm when extended (Nusch); housed in tube-like smooth lorica (300–1 250 μm long), more or less incrusted with detritus; with long flexible anterior proboscis more than one-quarter of body length when extended; somatic ciliation spirally in 3 rows (very similar to the genus *Stichotricha* but this is characterized by a comparatively short proboscis of less than one-quarter the length of the body—see Fig. 7C); adoral zone of membranelles very elongated, running along the proboscis; 2 macronuclei; contractile vacuole located in the posterior vicinity of the buccal area.

Food

Flagellates, diatoms (Nusch, personal communication).

Occurrence and ecology

Reported from America and Europe attached to plants, stones, detritus and artificial substrates (e.g., glass slides) in standing and slowly flowing waters; often in reservoirs (Sládečková & Sládeček, 1963; Nusch, 1969). Highest abundance in Central Europe in summer (Nusch, 1969).

Ecological characteristics (preliminary data, Nusch, personal communication)

	Extreme tolerances
temperature (°C) . . .	15–22°
pH	7.1–8.0
dissolved O_2 (mg/l) . .	10–12
free CO_2 (mg/l)	0–6
NH_4^+ (mg/l)	0–0.1
bacteria (membrane-filter method)	500 000–3 000 000/ml

Saprobiological classification

According to Sládečková & Sládeček (1966):

bos	aos	bms	ams	ps	i
—	—	3	7	—	4

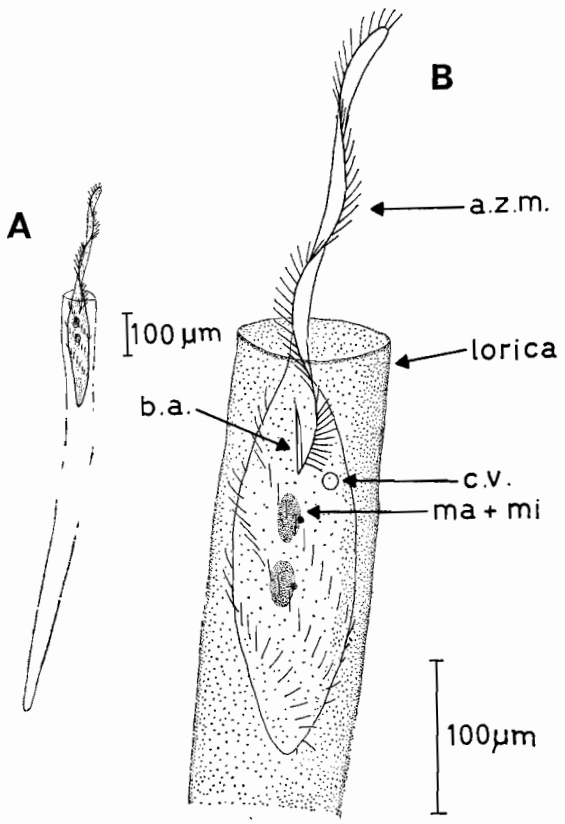

Fig. 94. *Chaetospira remex* Hudson; redrawn, with modifications, from Kahl (1932). A, *Chaetospira* within its mucilaginous tube; B, anterior part of the tube and ciliate at higher magnification.

ACKNOWLEDGEMENTS

The author expresses his gratitude to members of the staff of the World Health Organization for valuable advice in the preparation of this guide and for revising the English text. Special thanks must be expressed to Dr Marshall Laird, Memorial University, Newfoundland, Canada, for his encouragement. The guide was prepared with support from the World Health Organization, and facilities were provided by the Zoological Institute, University of Bonn, Federal Republic of Germany.

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Annex 1

GLOSSARY

(protozoological terms after Noland (1959) and Kudo (1966))

adoral zone of membranelles	short double or triple rows of cilia fused into pennant-like blades, occurring in series, and leading to the mouth
alpha-mesosaprobic (ams)	*see* saprobity system
alpha-oligosaprobic (aos)	*see* saprobity system
athalassogenic brackish water	inland saline waters with inorganic components other than those in seawater
beta-mesosaprobic (bms)	*see* saprobity system
beta-oligosaprobic (bos)	*see* saprobity system
buccal cavity	a food-conducting space or tube, commonly ciliated, open to the outside, and communicating with the cytostome which is located in the depth of the buccal cavity
buccal ciliation	specialized kind of ciliation located in the vicinity of the mouth and associated with feeding
cirrus (plural: cirri)	group or groups of cilia fused into a single organelle; the cirri on the ventral surface of the order Hypotrichida are called, according to their location, frontals, ventrals, marginals, transversals, and caudals
contractile vacuole (cv)	organelle of osmoregulation; it enlarges itself continuously until it reaches a maximum size (" diastole ") and suddenly bursts through the surrounding cytoplasmic layer (" systole "), discharging its content to the outside; 1 or many contractile vacuoles may occur; the number and position of contractile vacuoles in any species is constant under normal conditions
cytopharynx (gullet)	an unciliated passage leading from the cytostome into the cytoplasm
cytostome	the true mouth (cf., buccal cavity)
eurypotent	living within a wide range of a particular ecological factor (in contrast, stenopotent means living only within a very narrow range)
food vacuole	space in the cytoplasm containing fluid medium in which the food matter is suspended
indicator value (=i)	*see* 10-points method
macronucleus	the larger nucleus; it controls the trophic activities and regeneration processes
membrane	*see* undulating membrane
micronucleus	the smaller nucleus; it is concerned with reproductive activities
microscope slide	small glass plates used in microscopy; often used as artificial substrates for evaluating the periphyton community (*Aufwuchs*)
oligosaprobic (os)	*see* saprobity system
pectinellae (pectinelles)	short rows of strong unfused cilia occurring in series
peniculus	group of specialized cilia in the buccal cavity of the suborder Peniculina
periphyton community (*Aufwuchs*)	organisms living on submerged substrates (stones, plants, microscope slides, etc.)
peristome	a differentiated external area adjacent to the mouth, associated with feeding
polysaprobic (ps)	*see* saprobity system
saprobity system	the saprobity system is based on the observation that in the course of the self-purification process a body of water shows distinct zones of decreasing pollution (or improved water quality); these zones are termed polysaprobic (gross pollution), alpha-mesosaprobic, beta-mesosaprobic, and oligosaprobic; the latter may be divided into alpha- and beta-oligosaprobic. Each zone is characterized by a particular content of oxygen, organic matter, products of septic decay, and products of mineralization. Biologically, each zone affords optimal conditions for certain species and communities of organisms, the so-called " indicator " organisms (for full details see Kolkwitz (1950) and Liebmann (1962). The particular saprobity zones may be characterized as follows:

polysaprobic zone—heavy pollution with sewage or other organic materials, mass development of bacteria that are involved in decomposition processes, a high rate of oxygen consumption, and a high production of ammonia and hydrogen sulfide

alpha-mesosaprobic zone—vigorous oxidation processes, increased dissolved oxygen though oxygen consumption is still high, no hydrogen sulfide production, oxidation of ammonia starts

beta-mesosaprobic zone—much dissolved oxygen, low oxygen consumption, mineralization of organic materials, and large amounts of the end-products of mineralization, e.g., nitrates

oligosaprobic zone—all mineralization processes have been completed, the dissolved oxygen content is high and oxygen consumption nearly zero; the beta-oligosaprobic level is characterized by rather moderate variety of species and low bioactivity, while the alpha-oligosaprobic level is characterized by a comparatively large variety of species and high bioactivity (for details of demarcation, see Caspers & Karbe (1966).) [1]

sapropel — putrefying sludge rich in hydrogen sulfide

sapropelobiontic — occurrence limited to the sapropel

slide — *see* microscope slide

stenopotent — *see* eurypotent

suctorial tentacle — tubular tentacle of subclass Suctoria concerned with food-capturing

10-points method — method for the biological assessment of water quality according to Zelinka & Marvan (1961). The evaluation is based on the saprobic valencies of organisms listed by Zelinka & Marvan (1961) and Sládeček (1964); further original data are given in the present paper.

The saprobic valency depends upon the relative frequency of the species as distributed between the 5 graded zones of saprobity. The index numbers (1–10) are so assigned that these valencies in the different saprobic zones add up to 10 for each species. In addition, the indicator value (i) of each species is expressed numerically, 1–5 (1 = very low indicator value, 5 = very high indicator value). The saprobiological classification of *Glaucoma scintillans*, for example, is:

saprobic zones					indicator value
bos	aos	bms	ams	ps	i
–	–	+	2	8	3

The symbol " — " means " not occurring at all ", " + " means " very rare ". For the evaluation of " i " see Sládeček (1964).

Other symbols: bos = beta-oligosaprobic, aos = alpha-oligosaprobic, bms = beta-mesosaprobic, ams = alpha-mesosaprobic, ps = polysaprobic (for explanation, see " saprobity system ").

By means of the saprobic valencies and the indicator value, an index characterizing the degree of pollution of a particular water body may be computed using a special formula (for details, see Zelinka & Marvan (1961)).

thalassogenic — brackish water originating from seawater diluted with fresh water

trichocyst — tiny rod-like body that can shoot out slender threads into the surrounding water when mechanically or chemically stimulated

vestibulum (vestibule) — depressed part of the body (" oral groove ") in the surroundings of the mouth, containing more-or-less modified somatic ciliation associated with feeding

zoochlorellae — algae living symbiotically within the cell of a ciliated protozoon

[1] See also Caspers, H. & Karbe, L. (1966) *Proposals for a saprobiological classification of waters*, unpublished WHO working document WHO/EBL/66.80.

Annex 2

KEY TO ABBREVIATIONS USED IN FIG. 1–94

Unless otherwise indicated, all scale lines on the figures represent 10 μm

a = " asterisk "
a.z.m. = adoral zone of membranelles
b.a. = buccal area
b.c. = buccal cavity (peristome)
b. cil = buccal ciliation
c.c. = caudal cirri or cilia
c.g. = ciliary girdle
cph = cytopharynx with trichites
cs = cytostome
c. sp. = caudal spines
c.v. = contractile vacuole
c.v.1 = first contractile vacuole
c.v.2 = second contractile vacuole
d.c. = dorsal cilia
fr.c. = frontal cirri
fr. pl. = frontal plate without cilia
f.v. = food vacuole
f.v.c. = frontoventral cirri
g = cytopharynx
gr = groove
lo = lorica
m = mouth (cytostome)
ma = macronucleus
mi = micronucleus
ma + mi = macronucleus and micronucleus
marg. c. = marginal cirri
mu. thread = mucilaginous thread
muc. lorica = mucilaginous lorica
p = " plate "
pa = refractile bodies
p.c.s. = perizonal ciliary stripe
p.m. = mechanism that closes the valve (trap-door) when the animal contracts
pr = proboscis
p.s. = peristome
p.sut. = preoral suture
r = ventral longitudinal rib
r.g. = refractile granules
s = substrate (to which the shell is attached)
s.b. = sensory bristles
sh = shell or case
sp = spines
s.t. = suctorial tentacles
st.st. = striated structure
t.b. = tactile bristle
tr = trichocysts
tr.c. = transverse cirri
und.m. = undulating membrane
v.c. = ventral cirri
vest. = vestibulum
x = cementing edge
z, zoochl. } zoochlorellae

INDEX OF GENERA AND SPECIES

When a species characterization is given, the page number is printed in bold-faced type; illustrations are indicated by an asterisk (*)

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