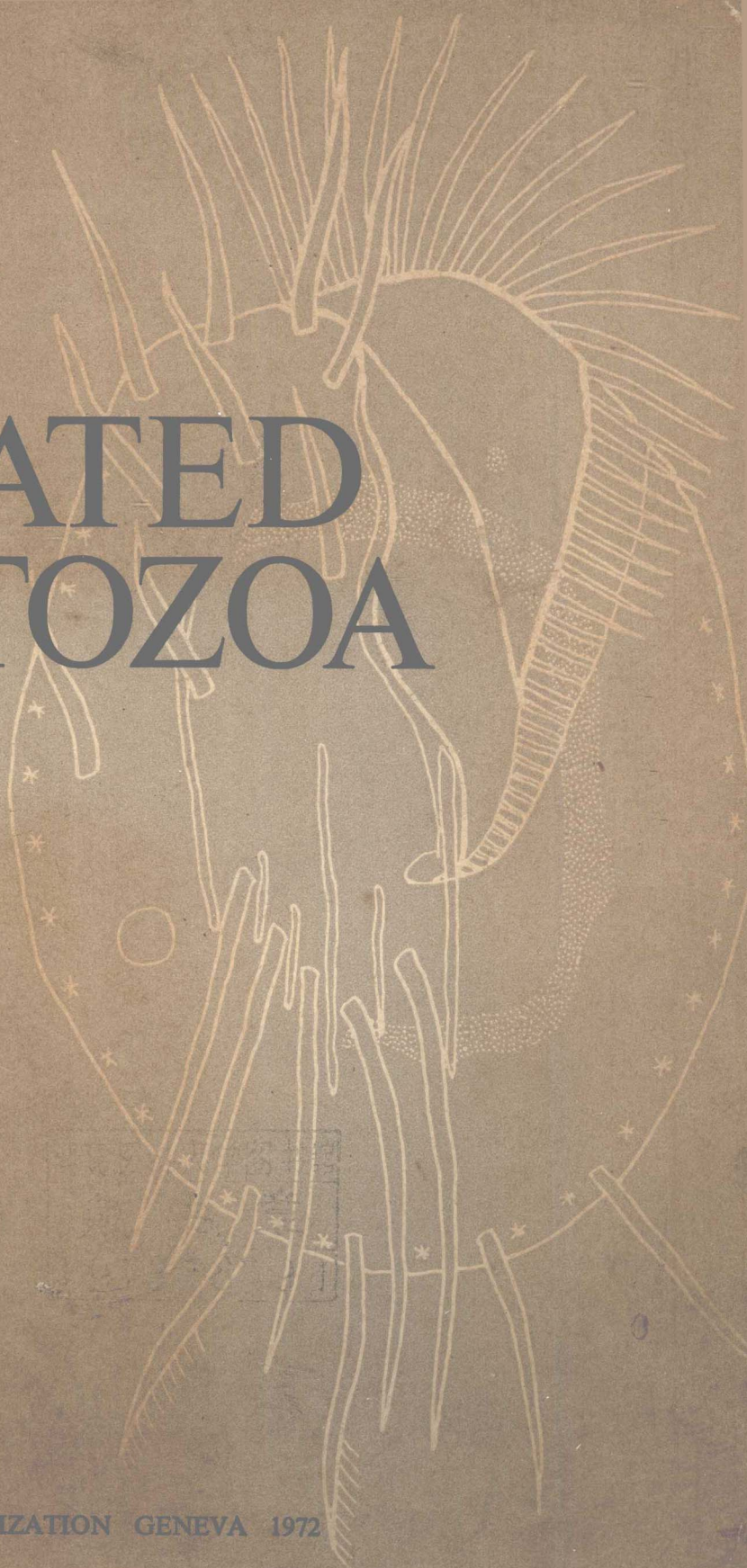
CILIATED PROTOZOA

HARTMUT BICK



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

HARTMUT BICK

Professor and Head, Institute of Agricultural Zoology, University of Bonn, Federal Republic of Germany

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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

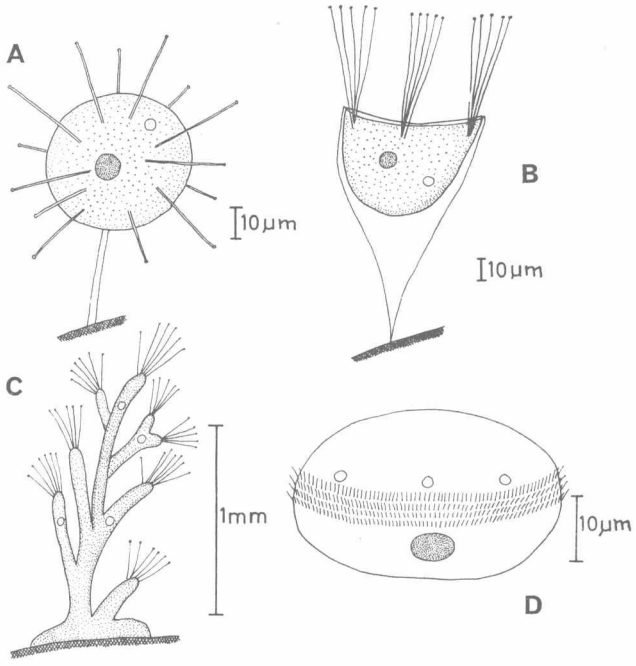

Fig. 1. Suctoria, diagrammatic representations:
A, *Podophrya fixa* O. F. Müller;
B, *Metacineta* Bütschli;
C, *Dendrosoma* Ehrenberg;
D, migratory larva of *Trichophrya* Claparède & Lachmann (Dendrosomatidae).

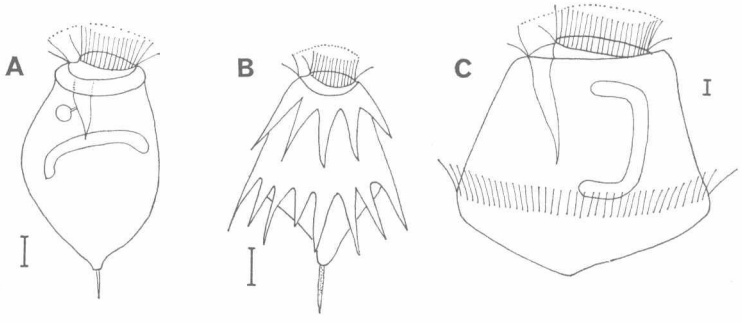

Fig. 2. Peritrichia, diagrammatic representations:
A, *Astylozoon* Engelmann (Astylozoidae);
B, *Hastatella* Erlanger (Astylozoidae);
C, *Telotrochidium* Kent (Epistylidae).

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)

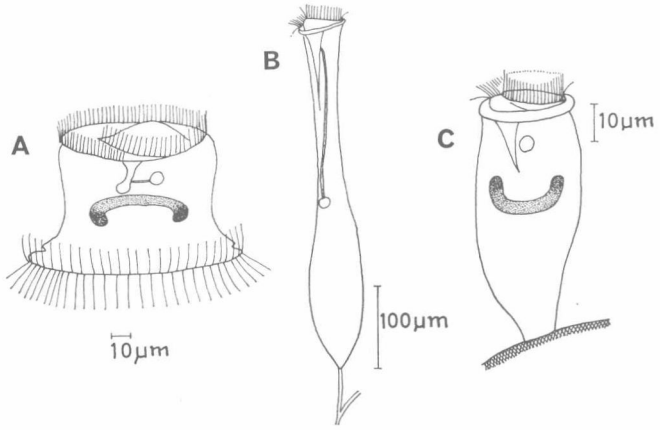

Fig. 3. Peritrichia *(continued)*:
A, *Trichodina pediculus* (O. F. Müller) Ehrenberg (Urceolariidae);
B, *Ophrydium* Bory St. Vincent (Ophrydiidae), diagrammatic representation;
C, *Scyphidia* Dujardin (Scyphidiidae), diagrammatic representation.

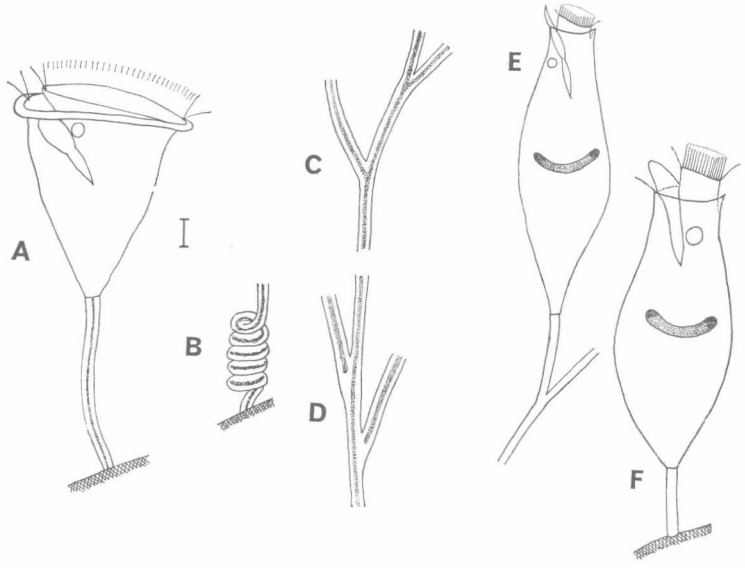

Fig. 4A–4F. Peritrichia *(continued)*, diagrammatic representations:
A, *Vorticella* L. (Vorticellidae);
B, contracted stalk of *Vorticella*;
C, stalk of *Zoothamnium* Bory St. Vincent, branching point;
D, stalk of *Carchesium* Ehrenberg, branching point;
E, *Opercularia* Stein (Epistylidae);
F, *Pyxidiella*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