Ber. nat.-med. Ver. Salzburg	Band 12	S. 25-76	Salzburg 1998

TAXONOMY OF SOME FRESHWATER CILIATES (PROTOZOA: CILIOPHORA) FROM GERMANY

WILHELM FOISSNER AND KARIN GSCHWIND

Universität Salzburg, Institut für Zoologie, Hellbrunnerstrasse 34, A-5020 Salzburg, Austria

Zusammenfassung

Es werden die Morphologie und die Infraciliatur (orales und somatisches Wimpernmuster) einiger limnischer Ciliaten aus Deutschland beschrieben. Die folgenden Arten wurden lebend beobachtet, silberimprägniert, vermessen und gezeichnet: *Ovalorhabdos sapropelicus* FOISSNER, 1984; *Benthontophrys fluviatilis* nov. gen., nov. spec., *Spirostomum minus viride* nov. sspec., *Oxytricha setigera* STOKES, 1891, *Notohymena australis* (FOISSNER & O'DONOGHUE, 1990); *Stylonychia pustulata* (MÜLLER, 1786); *Histriculus histrio* (MÜLLER, 1773); *Onychodromus grandis* STEIN, 1859. Die neue Gattung *Benthontophrys* gehört zu den Prostomatida und zeichnet sich aus durch eine urotrichide orale und holophryide somatische Infraciliatur. Die limnischen Populationen von *O. setigera* sind morphologisch ununterscheidbar von den terricolen Populationen. *Notohymena australis*, ein hypotriches Ciliat, das bisher nur von Australien bekannt war, wurde in der Amper, einem kleinen Fluß in Bayern gefunden. Die bayrische Population ist morphologisch sehr ähnlich der australischen. *Oxytricha setigera* und *Histriculus histrio* werden neotypifiziert.

Keywords: Biodiversität, Ökologie, Infraciliatur, neue Arten, Fließgewässer-Ciliaten.

Abstract

The morphology and infraciliature of some freshwater ciliates from Germany were investigated using live observation, silver impregnation, and morphometry. The following species are described and depicted: *Ovalorhabdos sapropelicus* FOISSNER, 1984; *Benthontophrys fluviatilis* nov. gen., nov. spec., *Spirostomum minus viride* nov. sspec.; *Oxytricha setigera* STOKES, 1891, *Notohymena australis* (FOISSNER & O'DONOGHUE, 1990); *Stylonychia pustulata* (MÜLLER, 1786); *Histriculus histrio*

(MÜLLER, 1773); *Onychodromus grandis* STEIN, 1859. The new genus *Benthontophrys* belongs to the Prostomatida and is characterized by a urotrichid oral and holophryid somatic infraciliature. The freshwater populations of *O. setigera* do not differ significantly from soil populations. Likewise, the Bavarian river population of *N. australis*, a hypotrichous ciliate formerly known only from Australia, is very similar to the Australian pond population. *Oxytricha setigera* and*Histriculus histrio* are neotypified.

Keywords: biodiversity, ecology, infraciliature, new species, river ciliates.

1 Introduction

Protozoans are poorly explored, even in Europe, as evident from the continuous flow of descriptions of new species, genera, and families (FOISSNER 1993, 1997a, OLMO *et al.* 1998); the present paper may also serve as an example. Free-living protozoans from more remote regions, for instance South America, are almost unexplored. Thus, it is not surprising that FOISSNER (1997b) discovered 21 new species in only two soil samples from the Amazon floodplain at Manaus in Brazil. However, not only new species have to be described but many of the older species, which were founded on live observations only, need to be reinvestigated with modern methods and redescribed. Most of these species can now be neotypified due to the new techniques available, to fix their taxonomic status more properly. For this, our paper may also serve as an example.

2 Materials and Methods

2.1 Materials

Ovalorhabdos sapropelicus was collected on 8.3.1989 in the Amper river (stream km 95.2) near the village of Schöngeising in Bavaria. Water quality was beta- to alphamesosaprobic, and moderate numbers of *O. sapropelicus* occurred in the periphyton of the river bed.

Benthontophrys fluviatilis was collected on 8.3.1989 in the Windach stream, a small tributary to the Amper river, about 100m downstream from the effluent of the sewage plant of the village of Eching in Bavaria. High numbers of *B. fluviatilis* occurred in the mud and periphyton of the stream bed, together with a typical alphamesosaprobic ciliate community (*Carchesium polypinum*, *Trithigmostoma cucullulus*, *Spirostomum teres*).

Spirostomum minus viride was obtained on 26.8.1987 from Prof. A. HAUCK, who collected it in the bottom region of a pond near Horb am Neckar, Germany.

Oxytricha setigera was collected on 7.9.1989 in the Windach stream, a small tributary to the Amper river, close upstream of the effluent of the sewage plant of the village of Eching in Bavaria. Water quality was beta- to alphamesosaprobic. It was cultivated by transferring a few specimens in a Petri dish containing Eau de Volvic

(French Table Water) and some cracked wheat grains to stimulate growth of indigenous bacteria and small protists, mainly heterotrophic flagellates.

Notohymena australis was collected on 3.8.1989 in the Amper river (stream km 75.7), close upstream of the effluent of the sewage plant of the village of Geiselbullach in Bavaria. Water quality was alphamesosaprobic. It was cultivated as described for *Oxytricha setigera*.

Stylonychia pustulata was collected in June 1981 in a lake of Lower Austria (Lunzer Untersee) and cultivated as described for *Oxytricha setigera*.

Histriculus histrio was collected on 2.8.1986 in a small lake (Teufelssee) in the surroundings of Berlin, Germany. It reproduced in the sampling jar containing some filamentous algae and water plants.

Onychodromus grandis was obtained from Prof. Dr. W. SCHLEGEL in October 1986, who collected it in a pond near Tübingen. It was cultivated as described for *Oxytricha setigera*.

2.2 Methods

The species described were studied in vivo using a high-power oil immersion objective and bright field and/or differential interference contrast. The ciliary pattern (infraciliature) was revealed by various silver impregnation techniques, preferably protargol, all described in detail by FOISSNER (1991). The descriptions are based either on fresh field material or on specimens from raw cultures set up in Petri dishes with some cracked wheat grains to stimulate growth of bacteria and other natural food organisms.

Counts and measurements on silvered specimens were performed at a magnification of 40 – 1000 x. Although these provide only rough estimates, it is worth giving such data as specimens may shrink in preparations or contract during fixation. Standard deviation and coefficient of variation were calculated according to statistics textbooks. Illustrations of live specimens are based on free-hand sketches, those of impregnated cells were made with a camera lucida. All figures are slightly schematized and orientated with the anterior end of the organism directed to the top of the page.

3 Results and Discussion

Ovalorhabdos sapropelicus FOISSNER, 1984 (Fig. 1 11, Table 1)

Material: Two voucher slides with protargol-impregnated (protocol A in FOISSNER 1991) specimens from the Amper river in Bavaria have been deposited in the Oberösterreichische Landesmuseum in Linz (LI), Austria. The slides contain several morphostatic specimens, with those figured here marked by a black ink circle on the cover glass.

Supplementary observations: *Ovalorhabdos sapropelicus* is difficult to

impregnate. Thus, FOISSNER (1984) noted that he possibly could not recognize all details of the infraciliature in the silver nitrate preparations. Fortunately, we found this species again and obtained good protargol impregnations, which show that FOISSNER's description has to be supplemented by only one, but important detail, namely, the dorsal brush. It occupies almost one (dorsal) half of the cell, but is inconspicuous because it does not consist of dikinetids, as is usual, but of many minute, "condensed" areas within the ciliary rows, each composed of up to 10 narrowly spaced basal bodies having, very likely, bristle-like cilia. Thus, the ciliature looks irregular on the dorsal half of the cell (Fig. 1 – 6, 9 – 11). The ciliary rows of the present specimens extend meridionally to slightly spirally, those

Table 1 Morphometric data from *Ovalorhabdos sapropelicus*. Upper line: Bavarian population described in this paper; lower line: type population from Austria (from FOISSNER 1984).

Character1)	$\bar{x}$	M	SD	CV	Min	Max	n
Body, length	103.3	99.0	16.2	15.7	80	144	22
	68.8	70.0	6.2	9.0	58	78	10
Body, maximum width	55.1	52.0	9.6	17.5	38	70	22
	56.8	57.0	5.5	9.7	48	65	10
Circumoral kinety, length of long axis	21.8	22.0	2.7	12.6	18	30	22
	15.3	15.0	1.5	9.8	14	17	4
Circumoral kinety, length of short axis	4,7	5.0	0.7	15.5	3	6	18
	5.2	5.0	0.5	9.5	5	6	4
Macronuclei, number	1.0	1.0	0.0	0.0	1	1	20
	1.0	1.0	0.0	0.0	1	1	20
Macronucleus, length	42.7	40.0	11.5	26.9	20	63	21
	36.6	35.5	4.7	12.7	28	42	8
Macronucleus, width	15.1	15.0	2.0	13.1	11	18	21
	10.7	10.0	1.6	14.7	9	14	8
Somatic kineties, number	47.9	46.5	7.4	15.5	37	73	18
	59.0				58	60	3
Basal bodies in a normal somatic kinety, number	96.2	95.5	24.6	25.7	55	150	16
	60.0				50	70	2

[1] Data based on protargol-impregnated (Bavarian population; protocol A in FOISSNER 1991) and silver nitrate-impregnated (Austrian population; Chatton-Lwoff method as described in FOISSNER 1991), mounted specimens from field. Measurements in µm. CV – coefficient of variation in %, M – median, Max – maximum, Min – minimum, n – number of individuals investigated, SD – standard deviation, $\bar{x}$ - arithmetic mean.

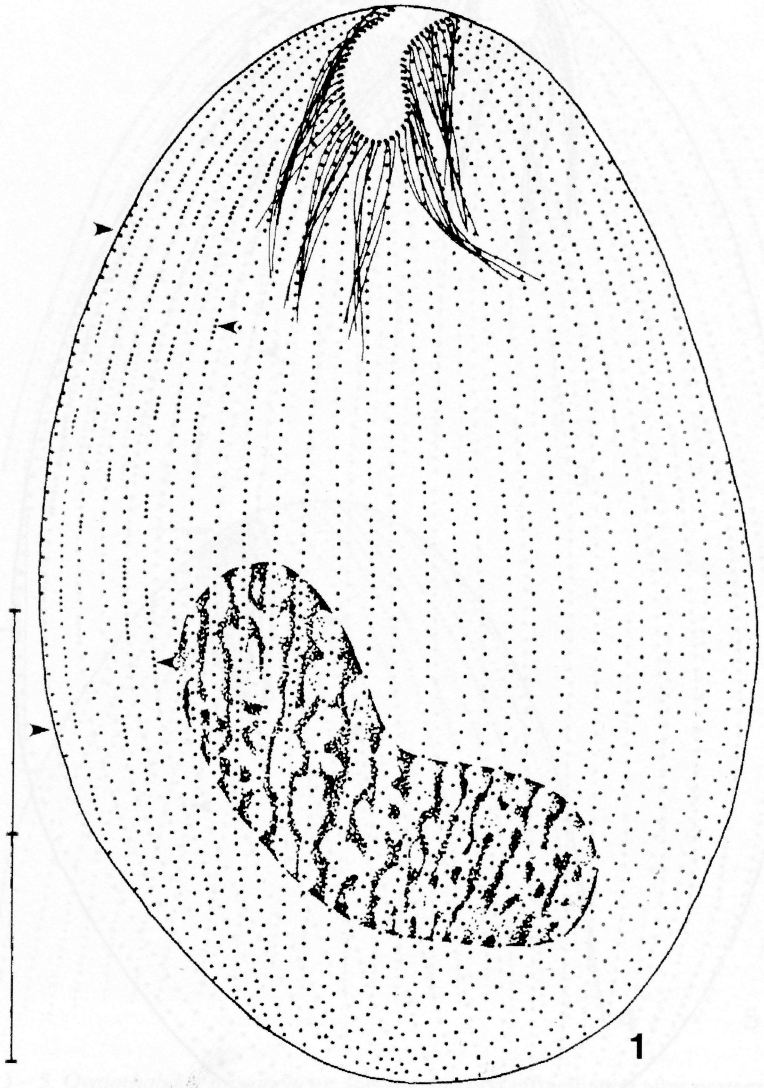


Fig. 1. *Ovalorhabdos sapropelicus*, somatic and oral infraciliature after protargol impregnation. Arrowheads border brush kineties, which continue on the other side of the cell (Fig. 2). Scale bar division 20 µm.

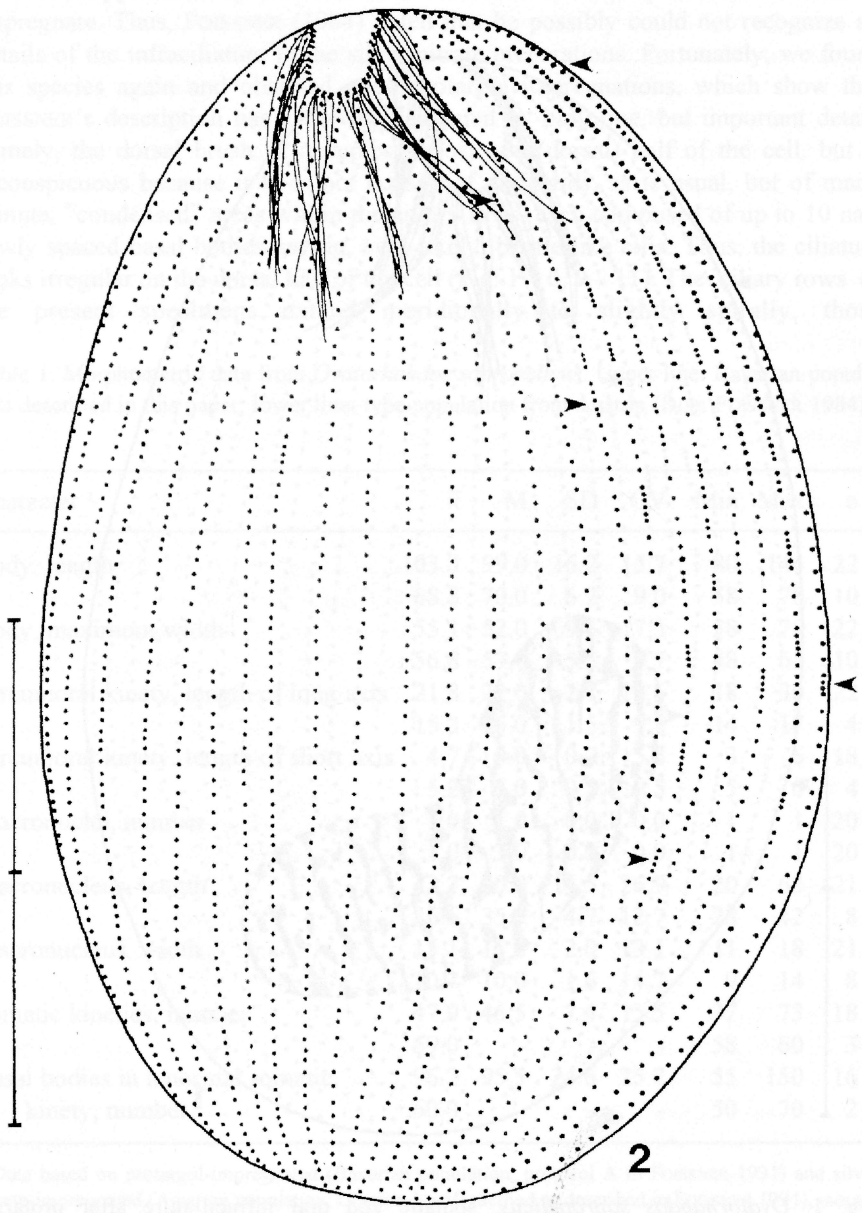


Fig. 2. *Ovalorhabdos sapropelicus*. As Figure 1, but other side of cell, showing dorsal brush (arrowheads) occupying one half of cell. Scale bar division 20 μm.

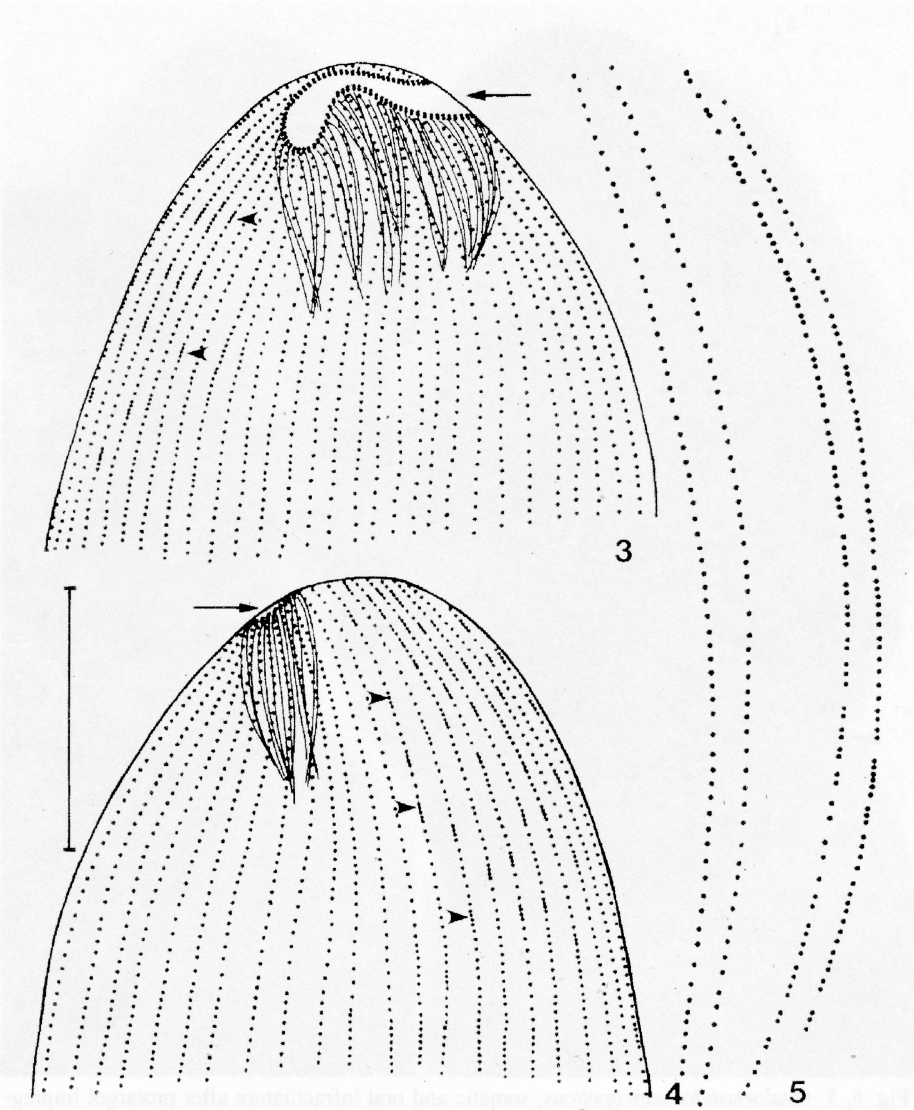


Fig. 3 – 5. *Ovalorhabdos sapropelicus*, somatic and oral infraciliature after protargol impregnation. **3, 4:** Anterior region of same specimen shown from two sides. Note oblong oral opening (arrows) and brush kineties (arrowheads) occupying one half of the cell. **5:** Normal and brush ciliary rows at same magnification. The brush rows differ from normal ciliary rows in that they contain small areas with very narrowly spaced basal bodies, which, very likely, have short, bristle-like cilia. Scale bar 20 μm.

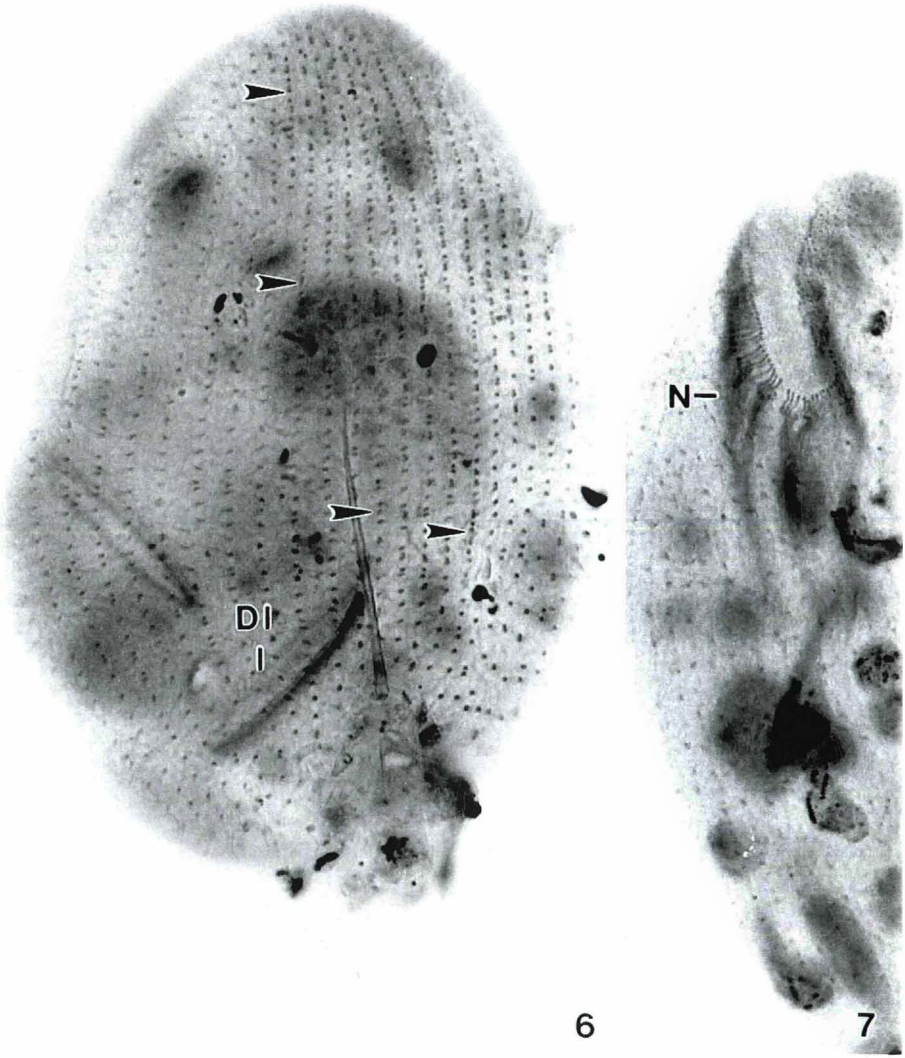


Fig. 6, 7 *Ovalorhabdos sapropelicus*, somatic and oral infraciliature after protargol impregnation. **6:** Dorsolateral view showing dorsal brush occupying right half of cell in the micrograph (cp. Fig. 1, 2). The brush, an important genus character, consists of regions of narrowly spaced basal bodies (some marked by arrowheads) within the ciliary rows, which thus appear much more densely ciliated in the right than in the left half of the micrograph. Note food inclusions, diatoms (DI), possibly from prey (*Trithigmostoma* sp.). **7:** The narrow-elliptical oral opening is an important genus character of *Ovalorhabdos*; it is surrounded by a very likely dikinetidal circumoral kinety, from which bundles of nematodesmata (N) originate.

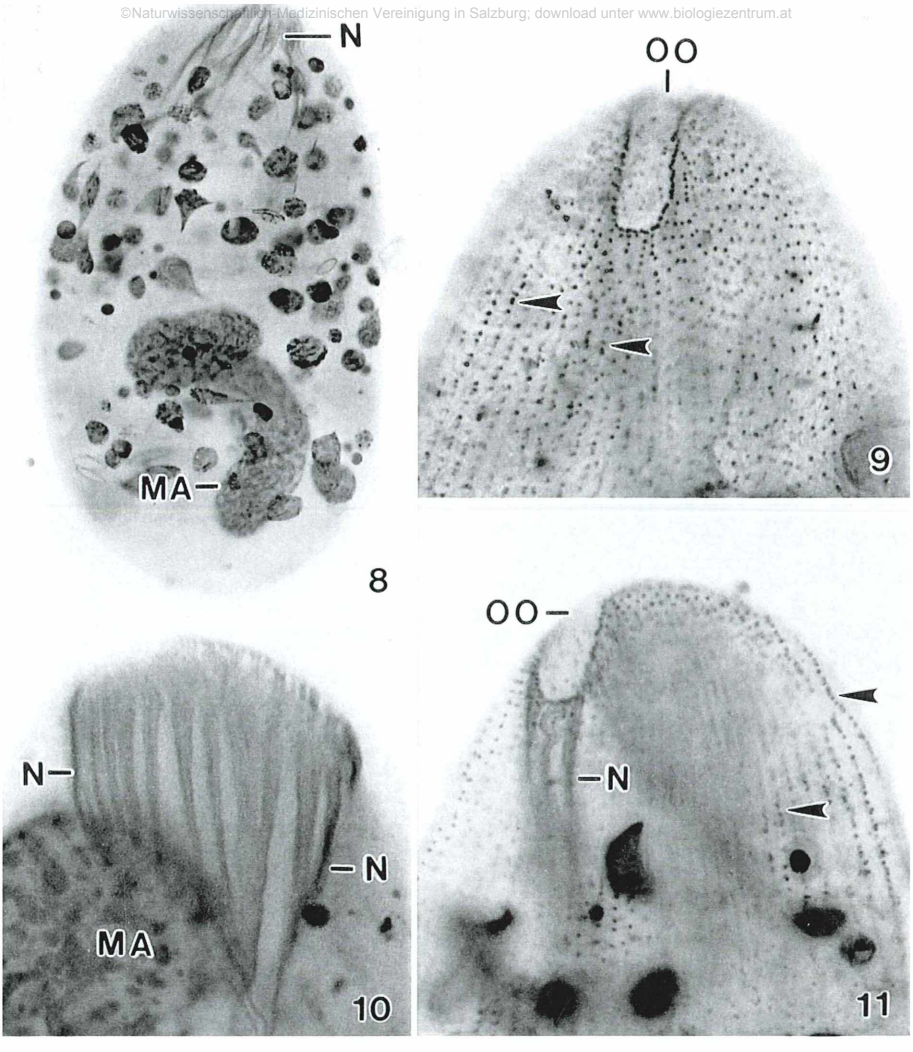


Fig. 8 – 11 *Ovalorhabdos sapropelicus* after protargol impregnation. **8:** General view showing the semicircular macronucleus, the oral basket, and many conical inclusions, that is, oral baskets of preyed cyrtophorids. **9 – 11:** Infraciliature of oral region. The oral opening is narrow-elliptical (genus character, name!) and surrounded by a dikinetidal kinety, from which bundles of nematodesmata originate, which form a rhabdos type oral basket. Note dorsal brush, that is, small regions of narrowly spaced basal bodies (arrowheads) within dorsal side ciliary rows. MA – macronucleus, N – nematodesmata, OO – oral opening.

of the type specimens are more spirally arranged. The main character of *Ovalorhabdos*, the narrow-elliptical, almost linear oral opening is well recognizable also in the Bavarian population (Fig. 1 – 4, 7 – 11).

Systematic position: The brush pattern of *O. sapropelicus* is very constant and more or less distinctly different from that of other gymnostomes. It resembles that of *Prorodon armatides* FOISSNER, 1997a, *Paraenchelys* ssp. FOISSNER, 1984, *Pseudoholophrya* BERGER *et al.*, 1984 (a reinvestigation of *P. terricola* showed that it has a brush very similar to that of *Ovalorhabdos*; Fig. 11a, b), and *Prorodon emmae* (BERGH, 1896) FOISSNER *et al.*, 1994, as redescribed by SONG & WILBERT (1989). In *P. armatides*, which has, like *O. sapropelicus*, an oblong oral opening,

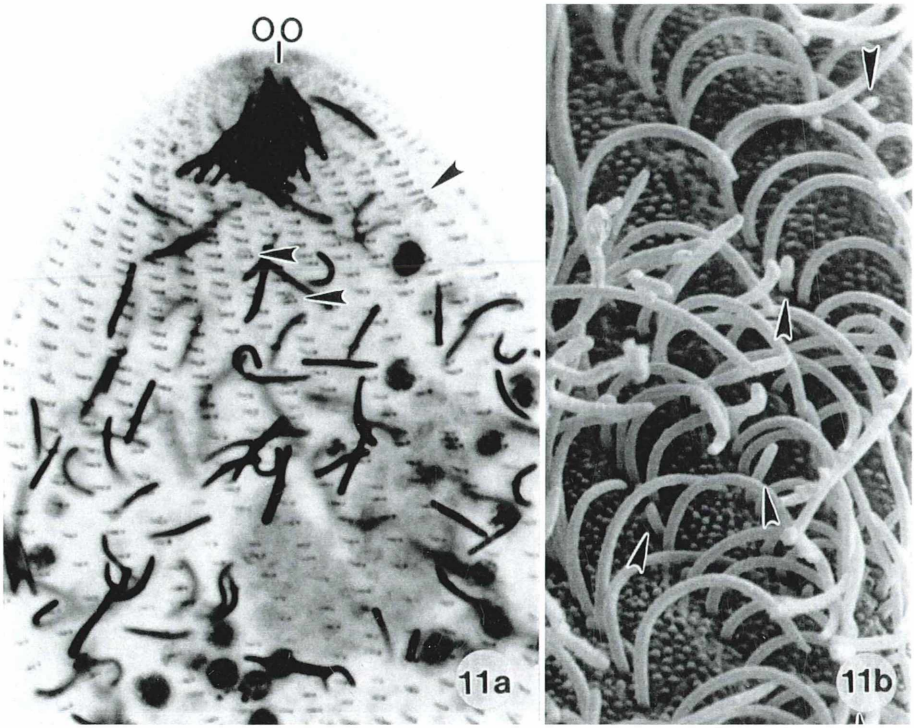


Fig. 11a, b. *Pseudoholophrya terricola*, Venezuelan population, ciliary pattern after silver carbonate impregnation and in the scanning electron microscope. Arrowheads denote some of many slightly condensed regions in the anterior dorsal area, where the basal bodies are closer spaced and bear short (< 3 µm) ciliary bristles (arrowheads), which irregularly alternate with normal (long) cilia. This pattern is highly reminescent of the dorsal brush of *Ovalorhabdos* (Fig. 1 – 6). The minute, circular oral opening (genus character! narrow-elliptical in *Ovalorhabdos*, cp. Figures 9, 11) and the cytoplasm contain many rod- to slightly thorn-shaped toxicysts.

the brush consists of two "normal" dikinetidal kineties plus several rows in which dikinetids and monokinetids irregularly alternate. This pattern is distinctly different from that of *Ovalorhabdos*, *Paraenchelys*, *Pseudoholophrya*, and *Prorodon emmae*, which lack brush dikinetids. These genera (and *Prorodon emmae*, which is very likely distinct at genus level) form a natural assemblage, for which BERGER *et al.* (1984) established the family Pseudoholophryidae. They differ from each other mainly by the shape of the oral opening (circular, except for *Ovalorhabdos*) and the arrangement (in oral opening, except for *P. emmae*, which has also distinct lateral bundles) and shape of the extrusomes (rod- to thorn-shaped in *Pseudoholophrya*, *Ovalorhabdos* and *P. emmae*, clavate in *Paraenchelys*).

***Benthontophrys* nov. gen.**

Diagnosis: Completely ciliated, ellipsoidal Prostomatida with circumoral dikinetids in line with somatic kineties. Brosse (adoral organelles) in distinct subapical pocket, obliquely orientated to main body axis, aklitoloph, composed of several minute, dikinetidal rows. Silverline system reticular.

Type species: *Benthontophrys fluviatilis* nov. spec.

Etymology: Composite of the Greek nouns "tá benthónta" (pertaining to the river bed) and "phrya" (eyebrow, cilium, ciliate sensu lato), meaning a ciliate living in the river bed. Feminine gender.

Comparison with related genera: *Benthontophrys* has a unique combination of holophryid (somatic infraciliature) and urotrichid/colepid (oral infraciliature) features, warranting at least genus level separation [see FOISSNER *et al.* (1994) for a brief review on common prostomatids]. The familial classification is uncertain. However, the reticulate silverline system indicates that it belongs to the *Holophrya* / *Urotricha* group. Unique features of *Benthontophrys* are the brosse pocket and the orientation of the circumoral dikinetids, which are in line with the somatic kineties and thus look like somatic kinetids. In all other prostomatids, the brosse is on or near the cell surface and the circumoral dikinetids are obliquely (e.g., *Holophrya*, *Urotricha*) or even transversely (e.g., *Coleps*, *Plagiocampa*) orientated to the axis of the ciliary rows.

***Benthontophrys fluviatilis* nov. spec.** (Fig. 12 – 21, Table 2)

Diagnosis: In vivo about 60 x 40 µm; broadly ellipsoidal with rather distinct subapical shoulder. Single, globular macronucleus. Extrusomes 5 µm long, rod-shaped. On average 35 somatic ciliary rows, each commencing with a dikinetid. Oral basket circular, campanulate, composed of 20 short (10 µm), thick rods on average. Three brosse kineties: rows 1 and 2 each composed of 3 – 5 dikinetids, row 3 consists of 7 – 10 dikinetids.

Type location: Windach stream in Bavaria, Germany, near the sewage plant of the village of Eching (E 11°/N 48°).

Type slides: 4 slides, that is, 1 holotype (protargol-impregnated, protocol A in FOISSNER (1991) and 3 paratypes (1 protargol-impregnated, 2 Chatton-Lwoff silver nitrate-impregnated) have been deposited in the Oberösterreichische Landesmuseum in Linz (LI), Austria. The slides contain many specimens, with relevant cells marked by a black ink circle on the cover glass.

Etymology: *"fluviatilis"* (living in the river, Latin adjective) refers to the habitat the species was discovered.

Description: Size in vivo 40 – 70 x 25 – 45 µm; unflattened. Overall shape ellipsoidal, especially in prepared cells (Fig. 17), live specimens usually with rather conspicuous subapical shoulder, that is, narrowing anteriorly and posteriorly (Fig. 12); anterior end transverse truncate due to wide oral basket opening, posterior broadly rounded. Macronucleus in or near body centre, globular, with large peripheral nucleoli and, occasionally, a conspicuous central nucleolus (Fig. 12). Micronucleus in indentation of macronucleus, in vivo about 4 µm across and compact, impregnates only lightly with protargol. Contractile vacuole in posterior body end, with some excretory pores in pole area (Fig. 17). Extrusomes, possibly toxicysts, scattered throughout cytoplasm, but not in oral basket, in vivo 5 µm long, slightly curved, fine rods (Fig. 15); in protargol preparations about 3 µm long. Cortex without distinct alveoli and, although rather thick and with distinct ridges

Table 2. Morphometric data from *Benthontophrys fluviatilis*.

Character 1)	$\bar{x}$	M	SD	CV	Min	Max	n
Body, length	50.7	51.0	6.2	12.3	37	63	18
Body, maximum width	36.0	35.0	5.1	14.5	23	42	18
Anterior end to macronucleus, distance	20.6	19.0	6.7	32.5	12	36	17
Macronucleus, length	11 7	12.0	1 4	12.3	9	15	20
Macronucleus, width	11.5	11 1	1.4	25.4	9	13	20
Macronuclei, number	1 0	1.0	0.0	0.0	1	1	20
Somatic kineties, number	35.4	35.5	3.4	9.5	25	39	16
Basal bodies in a somatic kinety, number	33 0	32.0	4.6	14.4	22	38	12
Oral basket, length	8.2	8.5	0.9	11.3	6	9	18
Oral basket, diameter	8.6	9.0	0.9	10.8	7	10	20
Oral basket rods, number	19.9	20.0	1.9	9.7	15	23	18
Brosse kineties, number	3.0	3.0	0.0	0.0	3	3	17
Brosse kinety 1, length	about 1.5 µm					12	
Brosse kinety 2, length	about 1.5 µm					12	
Brosse kinety 3, length	about 3 µm						16

[1] Data based on protargol-impregnated (protocol A in Foissner 1991) and mounted specimens from field. Measurements in µm. CV – coefficient of variation in %, M – median, Max – maximum, Min – minimum, n – number of individuals investigated, SD – standard deviation, $\bar{x}$ – arithmetic mean.

(Fig. 13), fairly fragile because cells soon become globular when removed from sample jar. Cytoplasm colourless, cells, however, usually bright-green due to ingested algae, mainly *Euglena viridis* and green algae 3 – 7 μm across; contains some fat globules 1 – 2 μm across and few to many ellipsoidal structures (4 3 μm) with concave centre, possibly paramylon grains from prey Swims moderately fast by rotation about main body axis.

Somatic cilia about 10 μm long, arranged left of cortical ridges in longitudinal, equidistant rows, two to three of which abut to posterior end of brosse pocket (Fig. 12, 16 – 18). Each row commences subapically with a pair of basal bodies (occasionally, the anterior or posterior basal body is lacking) indistinctly separate from circumoral dikinetids (Fig. 17 – 20). No elongated caudal cilia. Silverline system rarely impregnated, consists of roughly hexagonal meshes (Fig. 14).

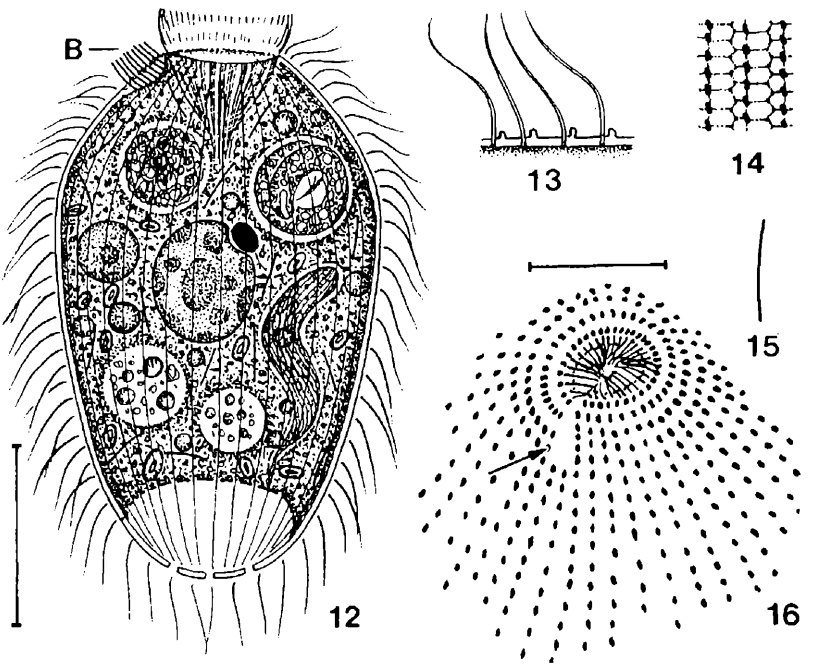


Fig. 12 16. *Benthontophrys fluviatilis* from life (12, 13, 15) and after Chatton-Lwoff silver nitrate impregnation (14, 16). **12:** Left lateral view of a representative specimen with many food vacuoles containing *Euglena viridis*. **13:** Optical section of cortex, which has distinct ridges. **14:** Silverline pattern. **15:** Extrusome, 5 μm. **16:** Oblique anterior polar view showing subapical, triangular, blank area (arrow) at site of brosse, which is in a distinct pocket (cp. Fig. 12) and thus not recognizable when the focal plane is at surface level B brosse. Scale bars 20 μm.

Oral opening at anterior end of cell, circular or, in preparations, occasionally slightly elliptical, surrounded by circumoral kinety and an average of 20 thick, but only about 10 µm long rods forming stout, campanulate basket (Fig. 18, 20), which is often considerably narrower in prepared than in live cells. Circumoral kinety composed of dikinetids having about 7 µm long cilia and being in line with somatic ciliary rows [accordingly, *B. fluviatilis* has about the same number (35, Tab. 3) of circumoral dikinetids as somatic kineties, while only about 20 oral basket rods are present], distinctly indented at brosse site, where basket rods become very fine (Fig. 12, 19, 20). Spatial relationship between circumoral kinetids and basket rods unclear: three patterns were observed (Fig. 21), which possibly depend on the state of contraction of the oral opening. Brosse (adoral organelles) almost apical in 2 – 3 deep cavity, aklitoloph (2 – 3 somatic kineties abut to posterior end of brosse pocket), composed of three minute, dikinetidal rows having about 6 µm long cilia: rows 1and 2 each composed of 3 – 5 dikinetids, row 3 consists of 7 – 10 dikinetids (Fig. 12, 16, 17, 19, 20).

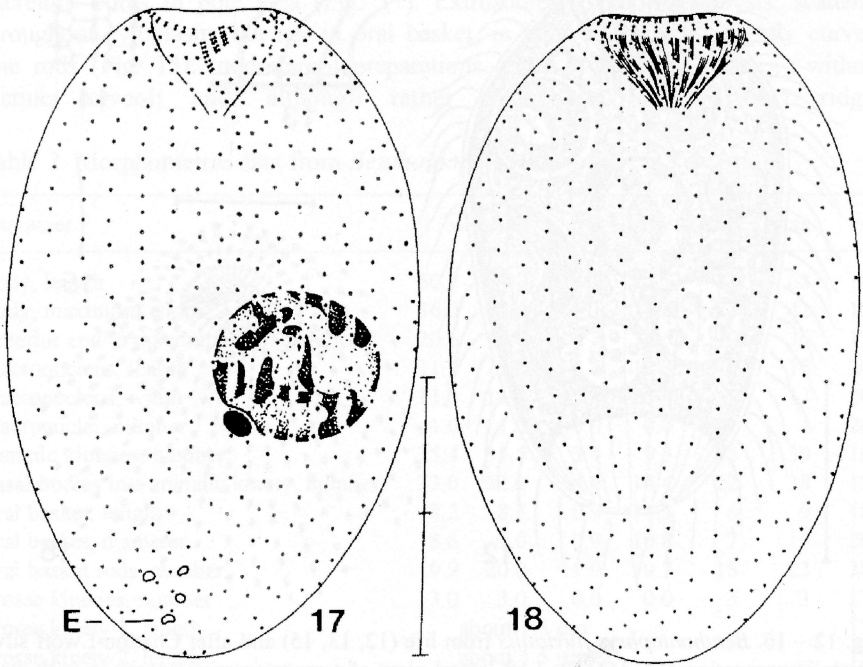


Fig. 17, 18. *Benthontophrys fluviatilis*, infraciliature of ventral (brosse) and dorsal side after protargol impregnation. Note minute brosse (adoral organelles) composed of three rows of dikinetids and short oral basket. See Figure 20 for details on oral apparatus. E – excretory pores of contractile vacuole. Scale bar division 10 µm.

Occurrence and ecology: As yet found only at type location, where it was associated with a typical alphamesosaprobic organism community.

Comparison with related species: There are five holophryids, which have, like *B. fluviatilis*, an aklitoloph brosse: *Prorodon ovalis* DRAGESCO, 1970; *P. pyriformis* GROLIÈRE, 1977; *P. gracilis* GROLIÈRE, 1977; *P. lucens* ALEKPEROV 1985;

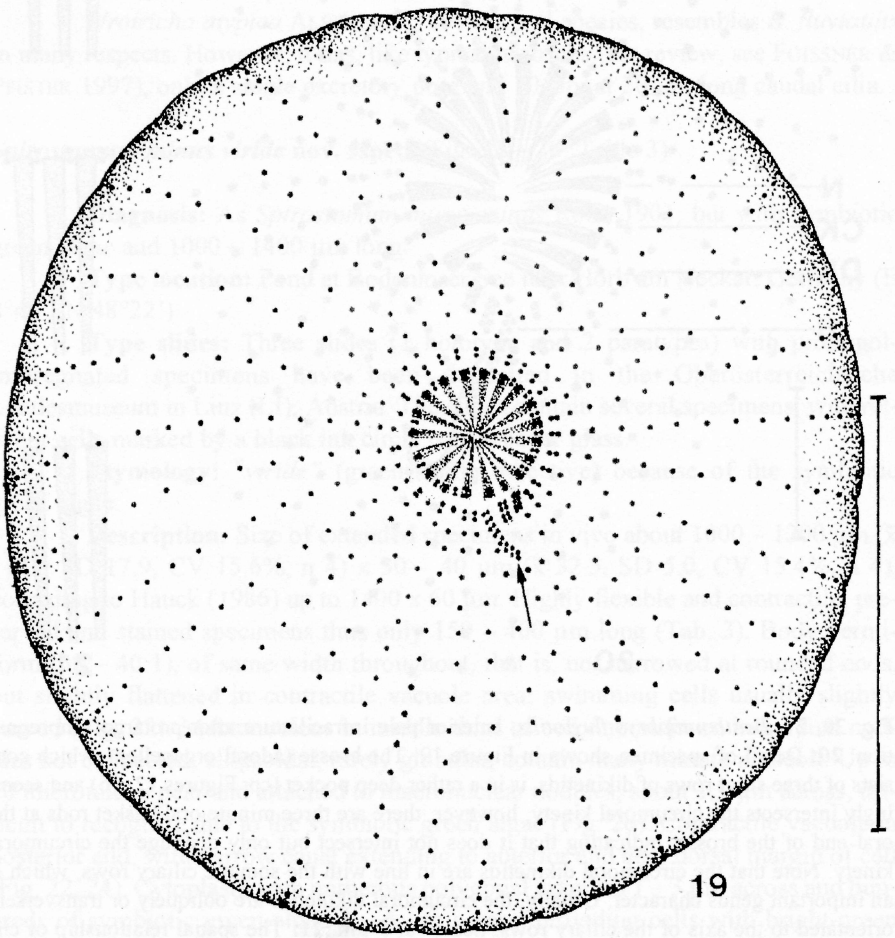


Fig. 19. *Benthontophrys fluviatilis*, anterior polar view after protargol impregnation (rather strongly schematized; for details, see Figure 20). Arrow marks brosse (adoral organelles) composed of three minute rows of dikinetids (paired basal bodies), which bear 6 µm long cilia (Fig. 12). Scale bar 20 µm.

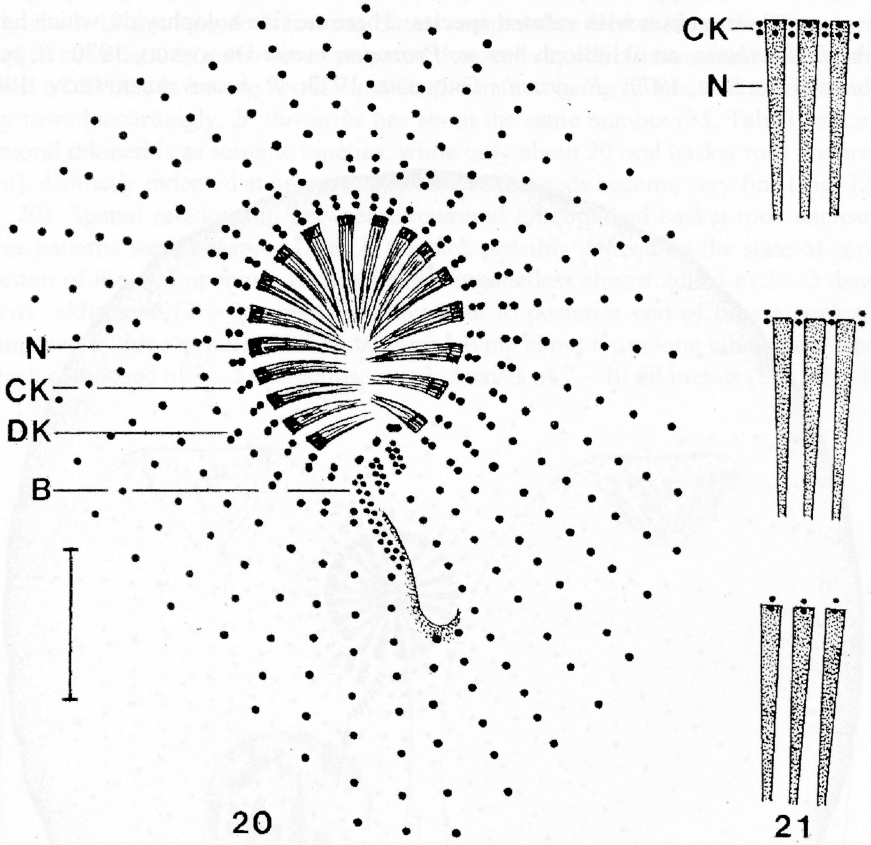


Fig. 20, 21. *Benthontophrys fluviatilis*, anterior pole infraciliature after protargol impregnation. **20:** Detail of specimen shown in Figure 19. The brosse (adoral organelles), which consists of three short rows of dikinetids, is in a rather deep pocket (cp. Figures 12, 16) and seemingly intersects the circumoral kinety; however, there are three minute oral basket rods at the oral end of the brosse, indicating that it does not intersect but only dislodge the circumoral kinety. Note that the circumoral dikinetids are in line with the somatic ciliary rows, which is an important genus character. Usually, the circumoral dikinetids are obliquely or transversely orientated to the axis of the ciliary rows. Scale bar 5 µm. **21:** The spatial relationship of circumoral dikinetids and oral basket rods (nematodesmata) could be not clarified. The figures show the three patterns observed. Possibly, the pattern depends on the state of contraction of the oral opening. B – brosse (adoral organelles), CK – circumoral kinety composed of paired basal bodies (dikinetids), DK – dikinetids at anterior end of ciliary rows (anterior or posterior basal body lacking in some dikinetids), N – nematodesmata (oral basket rods).

1985; and *P. aklitolophon* Hiller & Bardele, 1988. None of these species can be identical with *B. fluviatilis*, although most have a similar size and number of somatic ciliary rows, because their brosse kineties (adoral organelles) are ≥ 10 µm long, while those of *B. fluviatilis* are very minute, that is, less than 4 µm long. However, some of these species might belong to the new genus *Benthontophrys*. Unfortunately, descriptions are too incomplete in most species, especially as concerns the presence/absence of a brosse pocket.

Urotricha atypica Alekperov, 1993, a soil species, resembles *B. fluviatilis* in many respects. However, it has, like typical urotrichs (for review, see Foissner & Pfister 1997), only a single excretory pore and 10, about 20 µm long caudal cilia.

***Spirostomum minus viride* nov. sspec.** (Fig. 22 – 28; Table 3)

Diagnosis: As *Spirostomum minus minus* Roux 1901, but with symbiotic green algae and 1000 – 1400 µm long.

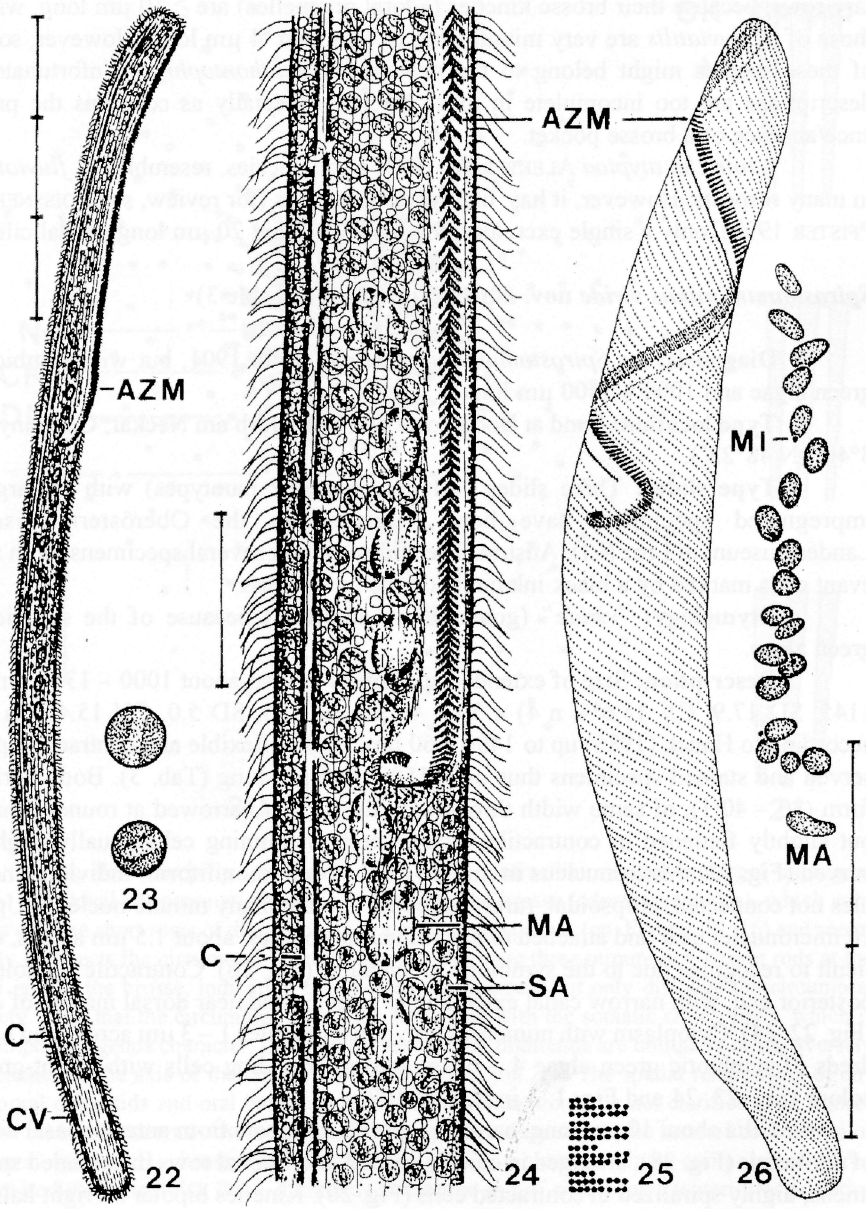
Type location: Pond at Bodenloser See near Horb am Neckar, Germany (E 8∞40'/ N 48∞22').

Type slides: Three slides (1 holotype and 2 paratypes) with protargol-impregnated specimens have been deposited in the Oberösterreichische Landesmuseum in Linz (LI), Austria. The slides contain several specimens, with relevant cells marked by a black ink circle on the cover glass.

Etymology: *"viride"* (green, Latin adjective) because of the symbiotic green algae.

Description: Size of extended specimens in vivo about 1000 – 1300 µm ($\bar{x}$ 1145, SD 17.9, CV 15.6%, n 4) x 30 – 40 µm ($\bar{x}$ 32.5, SD 5.0, CV 15.4%, n 4), according to Hauck (1986) up to 1400 x 60 µm. Highly flexible and contractile, preserved and stained specimens thus only 150 – 400 µm long (Tab. 3). Body vermiform (30 – 40:1), of same width throughout, that is, not narrowed at rounded ends, but slightly flattened in contractile vacuole area; swimming cells usually slightly curved (Fig. 22). Macronucleus in middle third of cell, moniliform; individual nodules not connected, ellipsoidal, rarely globular, contain many minute nucleoli. Up to 10 micronuclei near and attached to macronuclear nodules, about 1.5 µm across, difficult to recognize due to the symbiotic green algae (Fig. 26). Contractile vacuole in posterior end, with narrow canal extending to anterior end near dorsal margin of cell (Fig. 22, 24). Cytoplasm with numerous polygonal granules 1 – 3 µm across and hundreds of symbiotic green algae 4 – 6 µm across, providing cells with bright-green colour (Fig. 23, 24 and Fig. 1, 3 in Hauck 1986).

Cilia about 10 µm long, narrowly spaced, originate from anterior basal body of dikinetids (Fig. 28), arranged in closely spaced, meridional rows in extended specimens, highly spiralized in contracted cells (Fig. 26). Kineties bipolar on right half of cell, successively shortened along adoral zone of membranelles from anterior to posterior.


AZM
C
CV
22
23
AZM
C
MA
SA
24
25
MI
MA
26

Oral apparatus, respectively, adoral zone of membranelles extends from anterior end to second third of cell, proximal portion spirals into inconspicuous pharynx, consists of about 160 – 200 very narrowly spaced membranelles; individual membranelles composed of two about 4 µm long ciliary rows, to which a third, about 2 µm long row is attached distally (Fig. 25). Paroral membrane composed of narrowly spaced, oblique dikinetids, rather distant from adoral zone, commences at anterior end of cell, respectively, adoral zone and terminates at buccal overture, that is, where adoral zone of membranelles enters cytopharynx (Fig. 27). Pharyngeal fibres not recognizable.

Occurrence and ecology: HAUCK (1986) discovered *S. minus viride* in the mud of a pond, where it occurred in great numbers. STEIN (1867) found it several times in peat-holes near Niemegk (Bohemia). These data and the symbiotic green algae indicate that *S. minus viride* is less sapropelic than the congeners (for review, see FOISSNER *et al.* 1992).

Table 3 Morphometric data from *Spirostomum minus viride*

Character 1)	$\bar{x}$	M	SD	CV	Min	Max	n
Body, length 2)	288.2	288.0	66 7	23.2	152	400	21
Body, maximum width 2)	51.3	52.0	8.6	16.7	36	68	21
Anterior end to proximal end of adoral zone, distance 2)	93.9	96.0	24 7	26.3	52	130	21
Somatic ciliary rows, number	26.6	26.0	1.2	4.6	24	28	22
Macronuclear nodules, number	17.0	16.0	2.7	15.9	13	22	22
Macronuclear nodules, length	12.6	12.0	2.3	18.2	10	18	22
Macronuclear nodules, width	7.3	7 5	1.3	18 1	6	10	22

[1]Data based on protargol-impregnated, mounted specimens from field (protocol A in FOISSNER 1991). Measurements in µm. CV – coefficient of variation in %, M – median, Max – maximum, Min – minimum, n – number of individuals investigated, SD – standard deviation, $\bar{x}$ – arithmetic mean.

Specimens are highly contractile. Thus, values are very different from those of living specimens.

Fig. 22 26. *Spirostomum minus viride* from life (22 – 24) and after protargol impregnation (25, 26). **22:** Right lateral view of a representative specimen. Scale bar division 100 µm. **23:** Symbiotic algae 4 – 6 µm across. **24:** Ventrolateral view of proximal oral area. The cell is packed with symbiotic green algae. Scale bar 30 µm. **25:** Adoral membranelles. **26:** Total view of infraciliature and nuclear apparatus of a contracted specimen (for details, see Figures 25, 27, 28). Scale bar division 50 µm. AZM – adoral zone of membranelles, C canal of contractile vacuole extending to anterior end of cell, CV – contractile vacuole, MA macronucleus, MI – micronucleus, SA symbiotic algae.

Comparison with related species: *Spirostomum minus viride* differs from *S. minus minus* ROUX, 1901 (for review, see FOISSNER *et al.* 1992) by the symbiotic green algae (present vs. absent), body size [1000 – 1400 30 – 60 µm vs. 300 – 800 (rarely up to 1140 µm) 30 – 40 µm], length:width ratio (30 – 40:1 vs. 10 – 20:1), and length of adoral zone of membranelles (about 30 – 35% vs. 35 – 50% of body length). On the other hand, important characters, such as the number of ciliary rows (24 – 28, respectively, 20 – 30), the macronucleus type (moniliform), and the number of macronuclear nodules (13 – 22, respectively, 8 – 50, usually 15– 20) are very similar in both taxa. Thus, we assign only subspecies rank to the green variety.

Green *Spirostomum* populations were mentioned by several authors, especially in the older literature. PERTY (1852) described such a population as new species, *Spirostomum semivirescens* (Fig. 29), which STEIN (1867) considered a variety of *S. minus* However, PERTY's poorly described organism is only about 260 µm long and acontractile (PERTY, at least, did not mention any contractility but noted that the organism can bend the hyaline tail; Fig. 29), indicating that it is not a *Spirostomum*, as also mentioned by CLAPARÈDE & LACHMANN (1858). STEIN (1867), however, very likely saw *S. minus viride*: "I found green spirostomums in peat-holes near Niemegk several times between 1854 and 1863. They matched *S. minus* exactly, especially in the relative length of the peristome, but were considerably thinner than this species and the body was of same width throughout. The contractile vacuole was in the posterior end, and the macronucleus consisted of 22 – 30 nodules connected by fine strands. Most specimens were green, but some were colourless" CLAPARÈDE & LACHMANN (1858) also observed green spirostomums. *Spirostomum virens* EHRENBERG, which is now type of the genus *Climacostomum*, as described by FROMENTEL (1876), might also have been *S. minus viride*, although the figures show a much stouter organism with an adoral zone of membranelles extending slightly beyond mid-body. In the recent literature, only REPAK & ISQUITH (1974) mentioned zoochlorellae in *S. ambiguum*. Unfortunately, details were not provided.

Nomenclature: We obtained this species from Arthur HAUCK in 1986, who named it "*Spirostomum viridis*" in the title of a preliminary note (HAUCK 1986). Unfortunately, a full paper never appeared, and in 1986 HAUCK neither indicated whether he wanted to describe a new taxon, nor did he provide any indication that *viride* is a new taxon name. Thus, he can hardly be considered as author of the species, although he mentioned the main (sub)species characters, namely the symbiotic green algae and the slender shape.

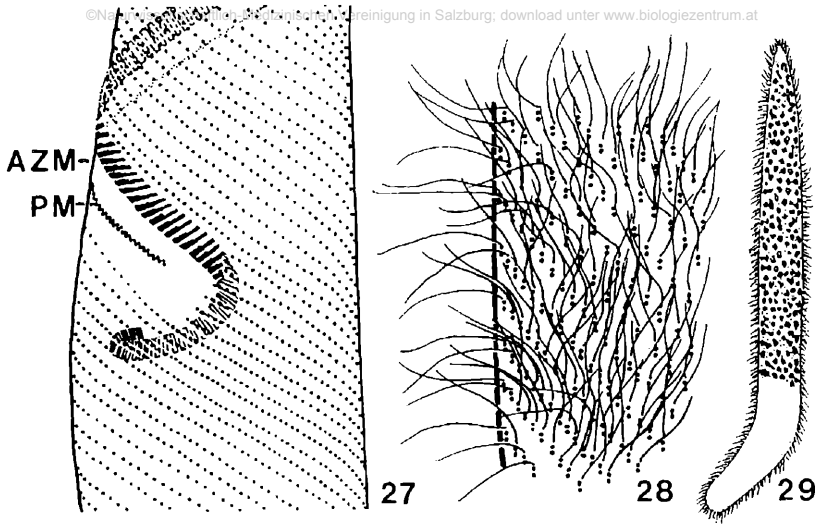


Fig. 27 – 29. *Spirostomum minus viride* (27, 28) and *S. semivirescens* (29; from PERTY 1852) from life (29) and after protargol impregnation (27, 28). **27:** Proximal oral region of specimen shown in Figure 26 at higher magnification. Note that the paroral membrane terminates distinctly above the proximal end of the adoral zone of membranelles. **28:** The ciliary rows consist of paired basal bodies (dikinetids), which have only the anterior basal body ciliated. **29:** PERTY's *S. semivirescens* is only 260 µm long, stout and acontractile, and thus cannot be identical with *S. minus viride*, which is 1000 – 1400 µm long, very slender, and highly contractile (Fig. 22).

Oxytricha setigera STOKES, 1891 (Fig. 30 – 40; Table 4)

Although this species is well-known, we redescribe it again because a very detailed knowledge is necessary to separate it from several similar taxa, which are easily confused and probably not even congeneric (FOISSNER 1998b). Thus, it is necessary to select a neotype. We choose the present population because it is from a limnetic habitat, like STOKES' original population, and morphogenetic data are available (manuscript in preparation).

Neotype material: One neotype slide and five voucher slides with protargol-impregnated specimens (protocol A in FOISSNER 1991) have been deposited in the Oberösterreichische Landesmuseum in Linz (LI), Austria. The slides contain many morphostatic and dividing cells, with relevant specimens marked by a black ink circle on the cover glass.

Description of Bavarian river population: Size in vivo 35 50 15 20 µm, length:width ratio thus about 2.5:1, only slightly flattened, lateral view thus

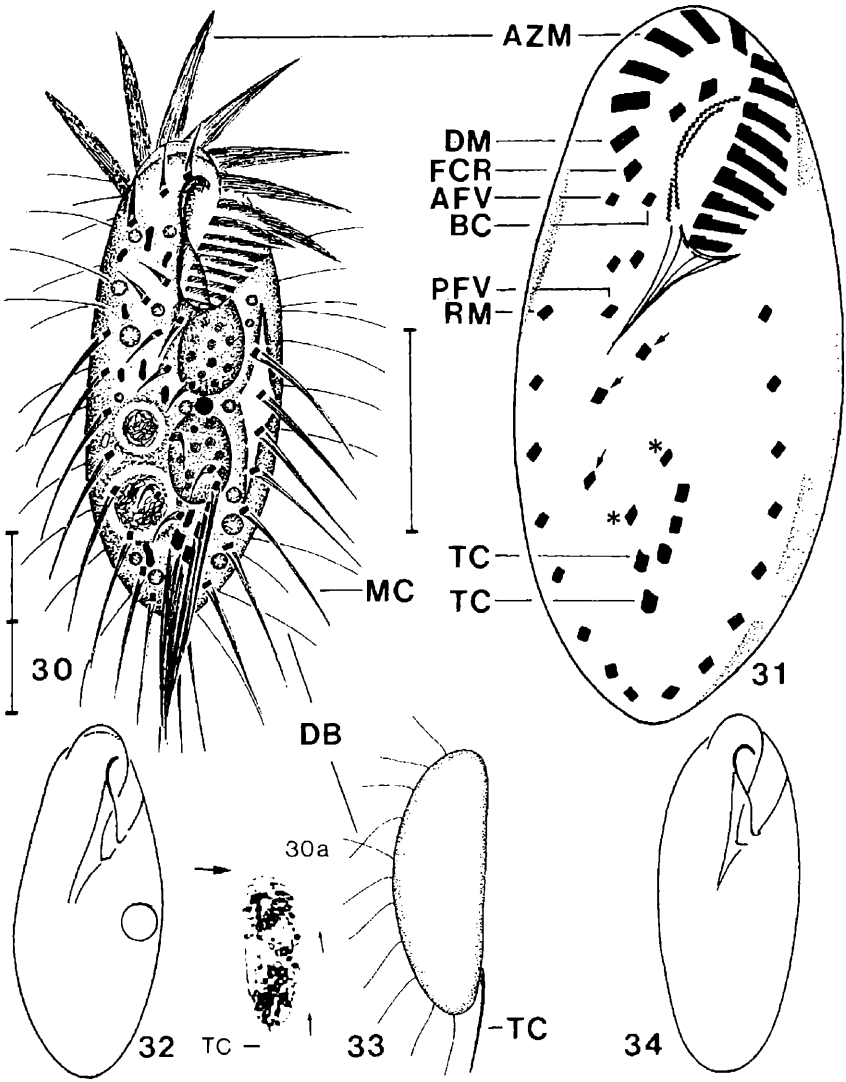


Fig. 30 – 34. *Oxytricha setigera* from life (30, 32 – 34) and after protargol impregnation (31). **30, 30a:** Ventral views of representative specimens. Large arrow marks adoral zone of membranelles, small arrows denote dorsal bristles. **31:** Infraciliature of ventral side. Arrows mark postoral ventral cirri, asterisks denote pretransverse cirri. **32, 34:** Shape variants. **33:** Lateral view. AFV – anteriormost frontoventral cirrus, AZM – adoral zone of membranelles, BC – buccal cirrus, DB – dorsal bristles, DM – distalmost adoral membranelle, FCR – rightmost frontal cirrus, MC – marginal cirrus, PFV – posteriormost frontoventral cirrus, RM – right marginal row, TC – transverse cirri. Scale bar division 10 µm.

loaf-like (Fig. 33). Usually slightly fusiform (Fig. 32), occasionally elongate ellipsoidal (Fig. 30a, 34), both ends narrowly rounded. Body soft, flexible, and colourless. Macronuclear nodules close together in middle third of cell left of midline, ellipsoidal (about 2:1), with many globular nucleoli. Micronucleus spherical to slightly ellipsoidal, invariably between macronuclear nodules (Fig. 30, 36). Contractile vacuole slightly underneath mid-body at very left margin of cell, with inconspicuous collecting canals. Cortex very flexible, without specific granules. Cytoplasm packed with some colourless crystals, fat globules 1 – 3 µm across, and many 5 8 µm sized food vacuoles containing bacterial remnants. Movement rather conspicuous, that is, periods of fast gliding interrupted by jerky jumps and short breaks, where cells are almost motionless.

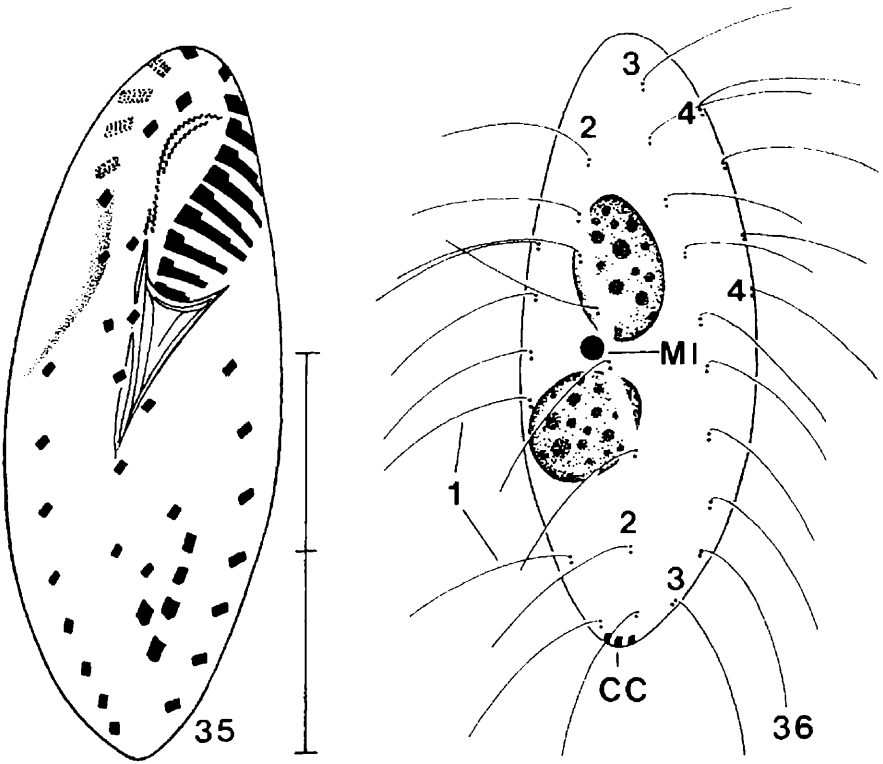


Fig. 35, 36. *Oxytricha setigera*, ventrolateral and dorsolateral view of the infraciliature of same specimen after protargol impregnation. Numbers denote dorsal ciliary rows. Note that one bristle is lacking in subequatorial portion of row 1 CC – caudal cirri, MI micronucleus between macronuclear nodules. Scale bar division 10 µm.

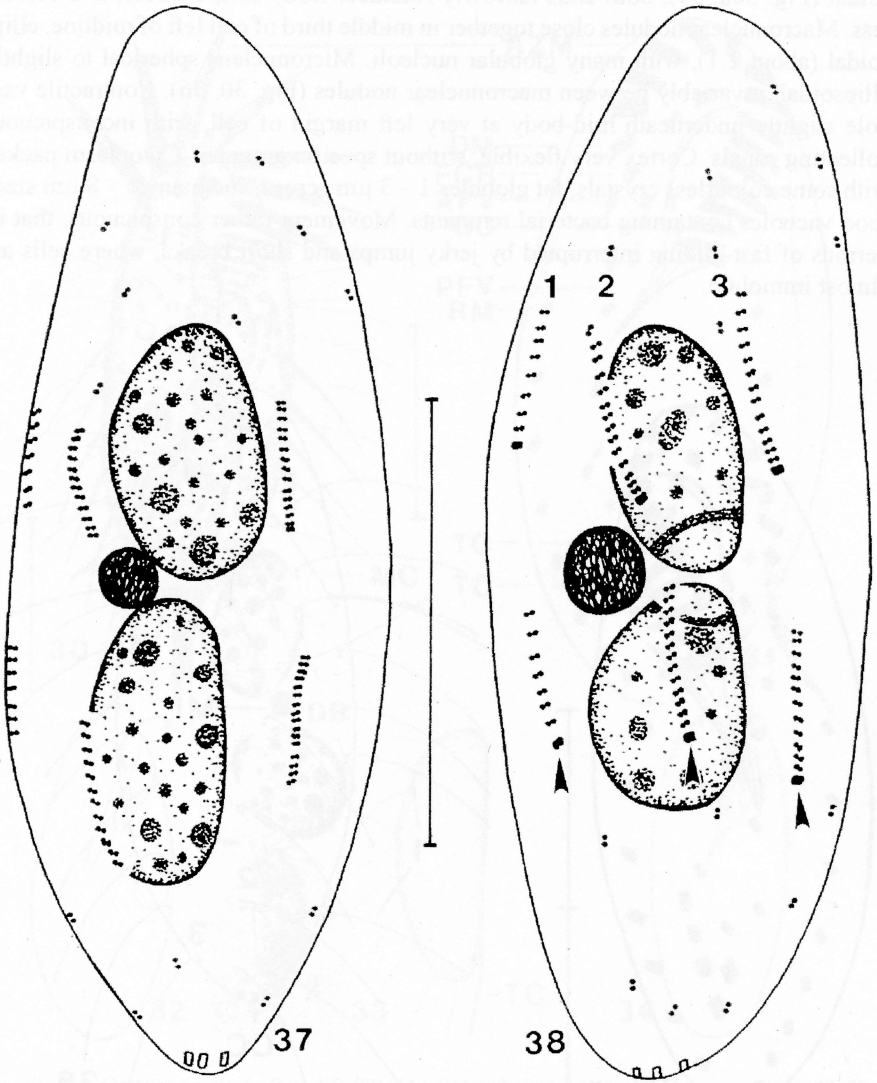


Fig. 37, 38. *Oxytricha setigera*, infraciliature of dorsal side of early dividers. Three new ciliary rows (numbers 1 – 3) originate from within anlagen, each generating a caudal cirrus at the posterior end (arrowheads). Note that row 3 does not fragment posteriorly, in contrast to many other oxytrichids, indicating that this species is not congeneric with *Oxytricha*. Most of the parental infraciliature is still present. Scale bar 20 µm.

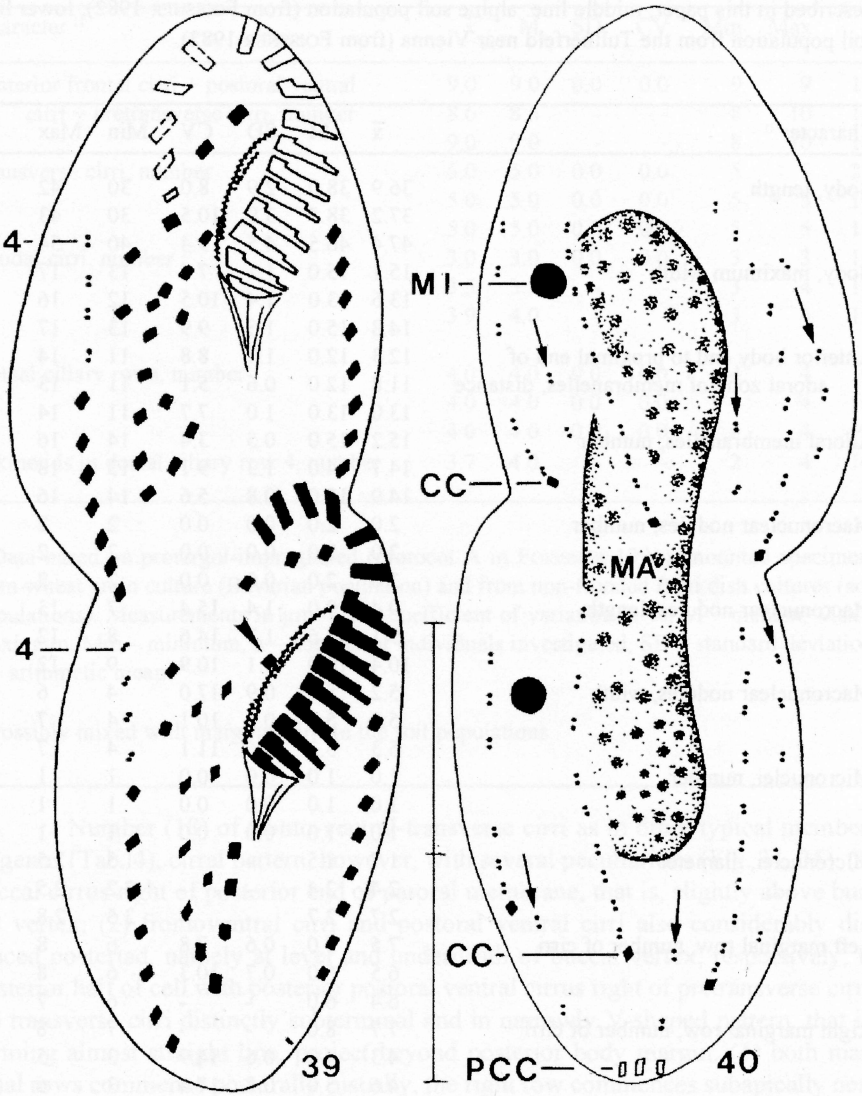


Fig. 39, 40. *Oxytricha setigera*, infraciliature of ventral and dorsal side of a late divider. Note that the new dorsal ciliary row 4 originates at the anterior end of the new right marginal rows. Arrowhead marks opisthe's buccal cirrus, which not yet migrated to the buccal vertex. Arrows denote remnants of parental bristle rows. CC – new caudal cirri, MA – elongating macronucleus, MI – micronucleus, PCC – parental caudal cirri. Scale bar division 10 μm.

Table 4. Morphometric data from *Oxytricha setigera*. Upper line: Bavarian river population described in this paper; middle line: alpine soil population (from FOISSNER 1982); lower line: soil population from the Tullnerfeld near Vienna (from FOISSNER 1982).

Character 1)	$\bar{x}$	M	SD	CV	Min	Max	n
Body, length	36.9	38.0	2.9	8.0	30	42	21
	37.2	38.5	3.9	10.5	30	43	10
	47.4	46.5	4.5	9.4	40	54	10
Body, maximum width	15.1	15.0	1.1	7.4	13	17	21
	13.6	13.0	1.4	10.5	12	16	10
	14.8	15.0	1.5	9.9	13	17	10
Anterior body end to proximal end of adoral zone of membranelles, distance	12.3	12.0	1 1	8.8	11	14	20
	11.8	12.0	0.6	5.1	11	13	10
	13.0	13.0	1.0	7 7	11	14	20
Adoral membranelles, number	15.2	15.0	0.5	3.4	14	16	18
	14.7	14.0	1.3	9 1	13	18	10
	14.9	15.0	0.8	5.6	14	16	10
Macronuclear nodules, number	2.0	2.0	0.0	0.0	2	2	19
	2.0	2.0	0.0	0.0	2	2	10
	2.0	2.0	0.0	0.0	2	2	10
Macronuclear nodules, length	9.4	9.0	1.4	15.4	7	13	19
	9.1	8.6	1.3	14.6	8	12	10
	10.4	10.0	1 1	10.9	9	12	10
Macronuclear nodules, width	5.2	5.7	0.9	17.0	4	6	19
	5.3	5.3	0.5	10.1	4	7	10
	5.3	5.3	0.6	11 1	4	7	10
Micronuclei, number	1.0	1.0	0.0	0.0	1	1	18
	1 0	1.0	0.0	0.0	1	1	10
	1.0	1 0	0.0	0.0	1	1	10
Micronuclei, diameter	1.7	1.5			1.5	2.5	18
	2.4	2.4			2.2	2.5	10
	2.7	2.7			2.5	2.8	10
Left marginal row, number of cirri	7.5	8.0	0.6	7.8	6	8	25
	6.5	6.0	0.7	10.3	6	8	10
	6.4	6.0			6	7	10
Right marginal row, number of cirri	7 7	8.0			7	8	27
	4.3	4.0	0.6	14.9	3	5	10
	4.6	5.0	0.8	17.4	3	6	10
Enlarged frontal cirri, number	3.0	3.0	0.0	0.0	3	3	19
	3.0	3.0	0.0	0.0	3	3	10
	3.0	3.0	0.0	0.0	3	3	10
Buccal cirri, number	1.0	1.0	0.0	0.0	1	1	20
	1.0	1.0	0.0	0.0	1	1	10
	1.0	1 0	0.0	0.0	1	1	10

(continued)

Table 4 (continued)

Character 1)	$\bar{x}$	M	SD	CV	Min	Max	n
Posterior frontal cirri + postoral ventral	9.0	9.0	0.0	0.0	9	9	15
cirri + pretransverse cirri, number	8.6	8.5			8	10	10
	9.0	9.0			8	10	10
Transverse cirri, number	5 0	5.0	0.0	0.0	5	5	21
	5.0	5.0	0.0	0.0	5	5	10
	5.0	5.0	0.0	0.0	5	5	10
Caudal cirri, number 2)	3 0	3 0	0.0	0.0	3	3	14
	3 5	3.5			3	4	10
	3 9	4 0			3	4	10
Dorsal ciliary rows, number	4.0	4.0	0.0	0.0	4	4	16
	4.0	4.0	0.0	0.0	4	4	10
	4.0	4.0	0.0	0.0	4	4	10
Dikinetids in dorsal ciliary row 4, number	3 7	4.0			2	4	10

1) Data based on protargol-impregnated (protocol A in FOISSNER 1991), mounted specimens from wheat grain culture (Bavarian population) and from non-flooded Petri dish cultures (soil populations). Measurements in µm. CV – coefficient of variation in %, M – median, Max – maximum, Min – minimum, n – number of individuals investigated, SD – standard deviation, $\bar{x}$ – arithmetic mean.

2) Possibly mixed with marginal cirri in the soil populations.

Number (18) of fronto-ventral-transverse cirri as in other typical members of genus (Tab. 4), cirral pattern, however, with several peculiarities (Fig. 31, 35): (1) buccal cirrus right of posterior end of paroral membrane, that is, slightly above buccal vertex; (2) frontoventral cirri and postoral ventral cirri also considerably displaced posteriad, namely at level and underneath of buccal vertex, respectively, in posterior half of cell with posterior postoral ventral cirrus right of pretransverse cirri; (3) transverse cirri distinctly subterminal and in narrowly V-shaped pattern, that is, forming almost straight line, project beyond posterior body margin; (4) both marginal rows commence postorally (usually, the right row commences subapically near the distalmost adoral membranelle!) and are composed of rather widely spaced cirri almost confluent posteriorly, where three caudal cirri, each composed of four cilia, insert in midline of dorsal side; (5) frontal cirri of about same size as marginal cirri, that is, not or only slightly enlarged. Cirri long but not particularly fine compared to size of cell: marginal and frontoventral cirri about 15 µm, transverse and caudal cirri about 20 µm long. Dorsal cilia (bristles) 10 µm long, posteriorly elongated to 12 13 µm, usually slightly convex (curved), form very constant pattern (Fig. 36): row 1

commences at level of buccal vertex and extends to posterior end of cell, one bristle lacking in subequatorial region [also in the alpine soil population studied by FOISSNER (1982); SONG & WILBERT (1989) possibly overlooked this minute gap]; rows 2 and 3 commence subapically and extend to posterior end of cell in slightly curved lines, bristles evenly spaced; row 4 commences subapically and ends in or above mid-body, consists of only 2 – 4 (up to 7 in FOISSNER's population) bristles in the present population and in that studied by SONG & WILBERT (1989). Ontogenesis of dorsal infraciliature as shown in Figures 37 – 40, that is, by intrakinetal proliferation of basal bodies in rows 1 – 3 and by formation of dikinetids, which build row 4, at anterior end of new marginal rows (Fig. 39).

Oral apparatus and adoral zone of membranelles conspicuous, although occupying only 27 – 33% of body length (Tab. 4), because distal membranelles stiffly spread in resting specimens and appearing like spokes of a turning wheal when beating (Fig. 30, 30a). Frontal scutum ("Stirnplatte") lacking or inconspicuous. Individual membranelles widest (bases up to 5 µm in vivo) and of conventional fine structure in ventral portion of zone, whereas frontal membranelles consist of four equally long rows having about 15 µm long cilia. Buccal cavity narrow but rather deep, distinctly curved anteriorly, buccal lip reinforced by an about 2 µm high cortical ridge in anterior third (Fig. 30, 30a). Paroral and endoral membrane distinctly curved, intersect optically in mid-portion of buccal cavity, paroral very likely composed of dikinetids having about 4 µm long cilia. Pharyngeal fibres rather distinct and obliquely extending to body centre.

Occurrence and ecology: *Oxytricha setigera* is a common species, which has been reliably recorded from limnetic and terrestrial biotopes worldwide (FOISSNER 1998a, FOISSNER *et al.* 1991). It is a bacteria feeder indicating mesosaprobity (saprobic index 2.6) in running waters (FOISSNER *et al.* 1991, see this monograph for more detailed data).

Comparison with previous descriptions: The original description of *O. setigera* STOKES, 1891 is rather incomplete, and BORROR (1972) synonymized it with *Tachysoma pellionellum*. However, FOISSNER (1982) suggested identifying STOKES' species with a common soil and freshwater ciliate, previously redescribed and identified as *O. setigera* by BUITKAMP (1977). This was accepted by SONG & WILBERT (1989), who investigated a population from a pond in Germany. Although being from different biogeographical regions (Africa, Europe) and biotopes (freshwater, soil), all populations match each other and that described here surprisingly well, suggesting conspecificity (Tab. 4; FOISSNER *et al.* 1991). Unfortunately, DRAGESCO & DRAGESCO-KERNÉIS (1986) established a new species, *Oxytricha buitkampi*, for the African soil population, using as distinguishing features some small differences in the redescriptions of *O. setigera* by BUITKAMP (1977) and FOISSNER (1982). However, these minute differences are mainly caused by the different impregnation techniques used, which must be taken into account especially in species which have, like *O. setigera*, a very soft and flexible body easily distorted by the preparation pro-

cedures. BUITKAMP used WILBERT's method, where specimens often swell, especially when slightly overbleached, while they usually shrink but maintain shape in my preparations. Furthermore, BUITKAMP (1977) did not study live cells and the oral apparatus in detail. HEMBERGER mentions in his doctoral thesis (Univ. Bonn, Germany) that BUITKAMP's species, which he restudied in the original slides, has a distinctly curved buccal lip, as described by KAHL for *O. balladynula*. SONG & WILBERT (1989) did not provide morphometric data, but their excellent figures match those of FOISSNER (1982) and the river specimens shown here.

Taking together the present data and those from BUITKAMP (1977), FOISSNER (1982) and SONG & WILBERT (1989), *O. setigera* can be well defined by the following combination of characters: (1) in vivo 40 60 15 – 25 µm; slightly fusiform to ellipsoidal; (2) two macronuclear nodules with a single micronucleus in between; (3) buccal cirrus near posterior end of paroral membrane (important difference to *O. opisthomuscorum*, which is similar to *O. setigera* in many respects, but has the buccal cirrus near the anterior end of the paroral and six dorsal kineties; PETZ & FOISSNER 1997); (4) posterior frontoventral cirri underneath buccal vertex; (5) transverse cirri distinctly subterminal; (6) both marginal rows commence postorally; (7) four dorsal kineties with 10 – 15 µm long bristles, row 4 ends above mid-body; (8) distal adoral membranelles form wheel-like pattern when beating; (9) paroral and endoral membrane in *Oxytricha* pattern, as defined by BERGER & FOISSNER (1997); (10) on average 15 adoral membranelles and 5 – 8 cirri each in right and left marginal row.

Notohymena australis (FOISSNER & O'DONOGHUE, 1990) BLATTERER & FOISSNER, 1988 (Fig. 41 – 46; Table 5)

Material: Two voucher slides with protargol-impregnated specimens (protocol B in FOISSNER 1991) have been deposited in the Oberösterreichische Landesmuseum in Linz (LI), Austria. The slides contain many morphostatic and dividing cells, with drawn specimens marked by a black ink circle on the cover glass.

Observations and comparison with type population and related species: FOISSNER & O'DONOGHUE (1990) discovered *N. australis* in a pond in Perth, Australia. Our record from a moderately polluted river in Bavaria (Germany) is the first from the holarctic region and the second worldwide, indicating that *N. australis* is cosmopolitan. Both populations were omnivorous and could be cultivated in Table Water (Eau de Volvic) enriched with some cracked wheat grains to promote growth of indigenous bacteria and small ciliates (*Glaucoma scintillans*, *Dexiostoma campylum*), which were readily ingested by *N. australis*; grains of wheat starch were also ingested and digested.

The German population matches the Australian type specimens well, especially in size [in vivo 110 160 40 – 60 µm, respectively, 80 – 140 30 – 45 µm; prepared specimens, however, of rather different size (Table 5), partially due to the different preparation methods; the numbers of marginal cirri indicate that the German population is slightly larger], distinct body flexibility, cortical

Table 5. Morphometric data from *Notohymena australis*. Upper line: German population described in this paper; lower line: Australian type population (from FOISSNER & O' DONOGHUE 1990).

Character 1)	$\bar{x}$	M	SD	CV	Min	Max	n
Body, length	133.4	131.0	13.8	10.3	108	160	22
	81.0	84.0	8.9	11.5	66	95	12
Body, maximum width	58.1	61.0	9.3	12.7	42	72	21
	31.4	32.0	4.5	14.4	22	29	12
Anterior body end to proximal end of	49.3	50.0	6.6	13.3	38	60	22
adoral zone of membranelles, distance	31.1	31.5	2.7	8.8	27	35	12
Adoral membranelles, number	39.0	39.0	1.9	4.9	35	43	19
	39.0	39.0	3.6	9.3	30	44	12
Macronuclear nodules, number	2.0	2.0	0.0	0.0	2	2	20
	2.0	2.0	0.0	0.0	2	2	12
Macronuclear nodules, distance between	13.2	15.0	3.8	28.8	4	18	23
	10.5	10.5	4.2	40.3	3	18	12
Macronuclear nodules, length	24.9	25.0	4.7	18.7	17	36	23
	11.7	11.0	2.3	19.8	8	17	12
Macronuclear nodules, width	11.3	12.0	2.1	18.5	8	15	23
	8.4	8.0	1.3	15.6	7	11	12
Micronuclei, number	3.3	3.0	1.2	34.3	2	5	21
	3.1	3.5	1.1	35.2	1	4	12
Micronuclei, length	3.6	3.7	0.8	22.5	2	4.5	23
	2.9	2.8	0.2	7.9	2.6	3.5	12
Micronuclei, width	2.4	2.3	0.6	24.7	1.5	3	23
	2.8	2.8	0.3	10.6	2.4	3.5	12
Left marginal row, number of cirri	36.3	36.5	2.9	8.1	31	44	20
	28.2	28.0	2.5	8.8	24	32	12
Right marginal row, number of cirri	36.0	36.0	2.3	6.5	31	40	19
	29.5	29.5	3.9	13.3	24	38	12
Enlarged frontal cirri, number	3.0	3.0	0.0	0.0	3	3	20
	3.0	3.0	0.0	0.0	3	3	12
Buccal cirri, number	1.0	1.0	0.0	0.0	1	1	20
	1.0	1.0	0.0	0.0	1	1	12
Frontoventral cirri, number	4.1	4.0			4	5	20
	4.0	4.0	0.0	0.0	4	4	12
Postoral ventral cirri, number	3.0	3.0			2	4	20
	4.3	4.0	1.6	36.0	3	7	12
Pretransverse ventral cirri, number	2.0	2.0			1	3	19
	1.7	2.0			1	3	12
Transverse cirri, number	5.1	5.0			5	6	19
	5.2	5.0			4	6	12
Caudal cirri, number	9.1	9.0	1.0	11.5	8	11	19
	7.5	8.0	0.6	8.6	6	8	12

(continued)

Table 5 (continued)

Character [1]	$\bar{x}$	M	SD	CV	Min	Max	n
Dorsal ciliary rows, number	6.3	6.0	-	-	6	8	19
	6.3	6.0	-	-	6	7	12

[1] Data based on protargol-impregnated, mounted specimens from wheat grain cultures (German specimens prepared with protocol B in FOISSNER 1991, Australian ones with protocol A). Measurements in µm. CV – coefficient of variation in %, M – median, Max – maximum, Min – minimum, n – number of individuals investigated, SD – standard deviation, $\bar{x}$ – arithmetic mean.

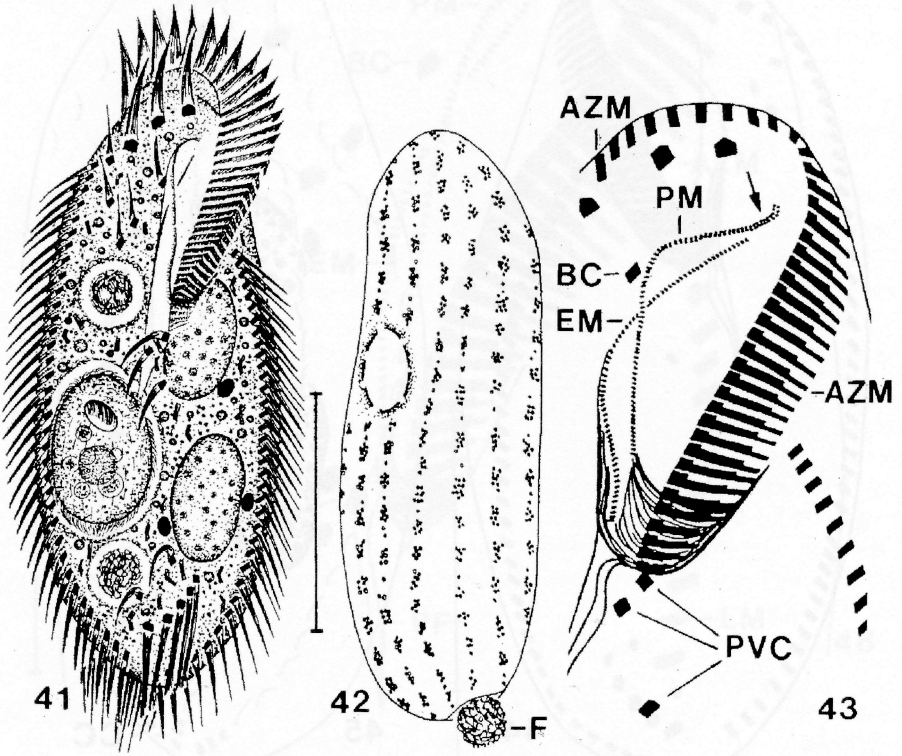


Fig. 41 – 43. *Notohymena australis* from life (1, 2) and after protargol impregnation (3). **41:** Ventral view of a well-fed specimen with a large food vacuole containing a *Glaucoma scintillans*. Scale bar 50 µm. **42:** Dorsal view of a normally fed specimen showing body shape and arrangement of cortical granules, which are bright orange. **43:** Oral infraciliature of specimen shown in Figure 44. Arrow marks the minute, upright curve of the end of the paroral membrane, that is, the genus character of *Notohymena* (cp. Figure 46). AZM – adoral zone of membranelles, BC – buccal cirrus, EM – endoral membrane, F – faecal ball, PM – paroral membrane, PVC – postoral ventral cirri.

granulation (bright orange-yellow in German, yellow-green to orange-green in Australian population), numbers of adoral membranelles (39 on average, Table 5), variability in number of fronto-ventral-transverse cirri, increased number of caudal cirri (Table 5), and the strongly shortened dorsal kinety 4. The caudal cirri originate as in other oxytrichids s.str., that is, at the end of dorsal kineties 1, 2, and 4, each of which generates several cirri one after the other. Kinety 4 originates, also as in typical oxytrichids, by fragmentation from kinety 3. The buccal field is moderately wide and deep and partially covered by a hyaline lip. Its upper portion

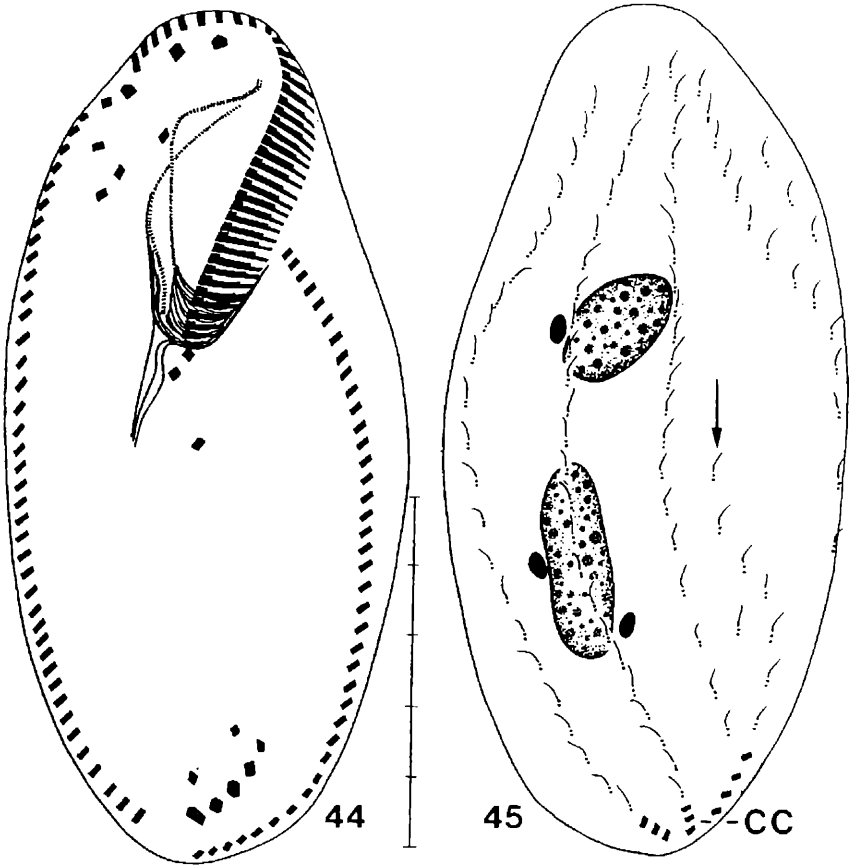


Fig. 44, 45. *Notohymena australis*, infraciliature of ventral and dorsal side after protargol impregnation. Arrow marks strongly shortened dorsal kinety 4. *Notohymena australis* has many caudal cirri (CC), which is a main species character separating it from all known *Cyrtohymena* species, which have only three. For details on oral structures, see Figure 43 Scale bar division 10 µm.

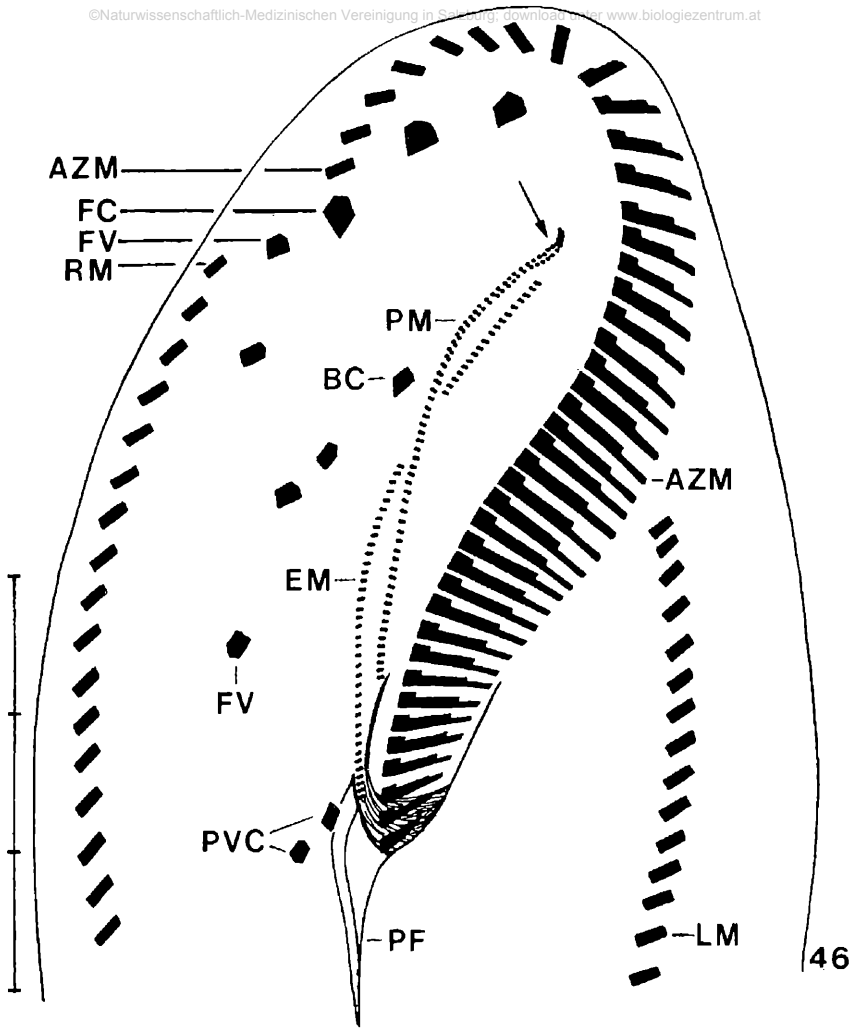


Fig. 46. *Notohymena australis*, infraciliature of anterior ventral side after protargol impregnation. Arrow marks curved anterior end of paroral, that is, the genus character of *Notohymena* (cp. Figures 43, 44). Note that this specimen has six frontoventral cirri, most have five (Fig. 44), as is usual for oxytrichids s.str (Table 5) AZM – adoral zone of membranelles, BC – buccal cirrus, EM – endoral membrane, FC right of the three frontal cirri, FV – frontoventral cirri, LM – left row of marginal cirri, PF pharyngeal fibres, PM – paroral membrane, PVC – postoral ventral cirri, RM right row of marginal cirri.

is distinctly curved to the left (Fig. 41) and follows the curvature of the paroral membrane. The genus-specific structure of the paroral, that is, the minute right turnand the divergence of the basal bodies of the dikinetids at the anterior end, is very distinct in the German population (Fig. 43, 44, 46); however, both characters are recognizable only in excellent protargol slides and were overlooked in the original description (corrected in BLATTERER & FOISSNER 1988 by a reinvestigation of the type slides).

In vivo, *N. australis* is easily confused with *Cyrtohymena citrina* and *C. primicirrata* (described in BERGER & FOISSNER 1987 and FOISSNER 1984), which have a very similar size, general appearance, and cortical granulation. Thus, the number of caudal cirri, which are easily seen with differential interference contrast, must be checked: 6 – 11 (usually 8 – 9) in *N. australis*, only 3 in *C. citrina* and *C. primicirrata*. The genus character of *Notohymena*, that is, the particular structure of the paroral, is clearly recognizable only in silver-impregnated specimens.

Stylonychia pustulata (MÜLLER, 1786) EHRENBERG, 1835 (Fig. 47 – 49; Table 6)

Material: Two voucher slides with protargol-impregnated specimens (protocol A in FOISSNER 1991) have been deposited in the Oberösterreichische Landesmuseum in Linz (LI), Austria. The slides contain many cells, with the drawn specimen marked by a black ink circle on the cover glass.

Observations and comparison with other populations: This species has been reviewed by WIRNSBERGER *et al.* (1985) and FOISSNER *et al.* (1991). Thus, only some supplementary observations will be mentioned: (1) body in vivo stiff and 75 – 100 µm (86.5, SD 9.2, VC 10.6%, n 6) 28 – 35 µm (32.5, SD 3.3, VC 10.2%, n 4) in size, prepared specimens considerably shrunk (Tab. 6); (2) marginal cirri 14 µm, transversal cirri 24 µm, caudal cirri about 25 µm long and rather widely spaced and distinctly spread (Fig. 47); (3) frequently rests for some time with marginal cirri spread in various directions; (4) posterior macronuclear nodule invariably slightly smaller than anterior, as in *Sterkiella cavicola* (BERGER & FOISSNER 1987); (5) in nature feeds on small diatoms, bacteria, and globular green algae; (6) paroral and endoral membrane side by side and distinctly apart (Fig. 48); (7) dorsal ciliary row 4 slightly shortened anteriorly, in contrast to the populations studied by FOISSNER *et al.* (1991) and WIRNSBERGER *et al.* (1985), where this row is as long as row 3 (we rechecked this in WIRNSBERGER's slides). On the whole, the present population is slightly smaller in all characters than the field population investigated by WIRNSBERGER *et al.* (1985). However, the differences are inconspicuous, and thus conspecificity is beyond reasonable doubt, especially also because the cirral pattern matches perfectly.

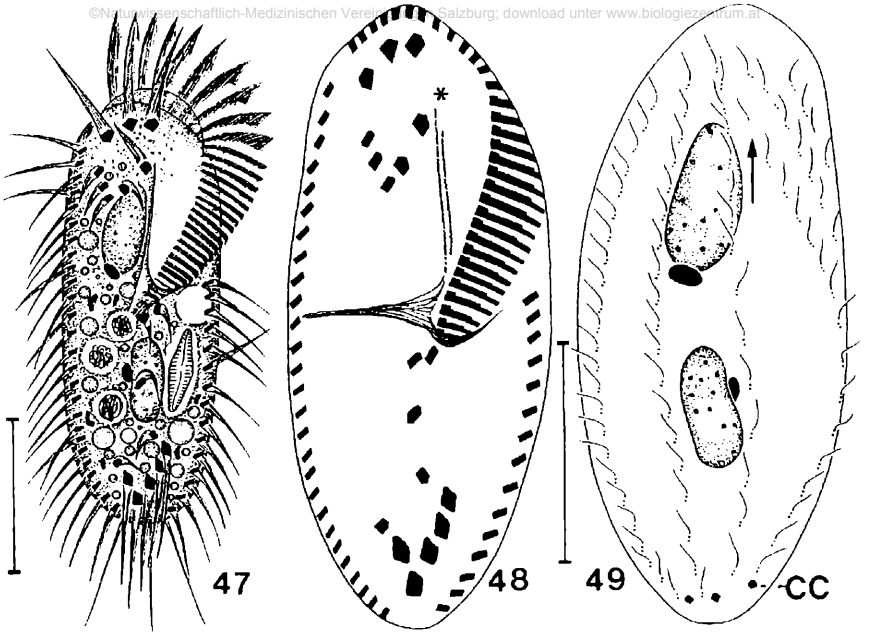


Fig. 47 – 49 *Stylonychia pustulata* from life (47) and after protargol impregnation (48, 49). **47:** Ventral view of a representative, resting specimen with marginal cirri spread in various directions. **48, 49:** Infraciliature of ventral and dorsal side. Asterisk marks the paroral and endoral membrane, which are straight and side by side – a main genus character (BERGER & FOISSNER 1997). The arrow marks the slightly shortened dorsal ciliary row 4, a main difference to the populations studied by WIRNSBERGER et al (1985) and FOISSNER *et al.* (1991). CC – caudal cirri. Scale bars 20 µm

Histriculus histrio (MÜLLER, 1773) CORLISS, 1960 (Fig. 50 – 66; Table 6)

BERGER & FOISSNER (1997) clarified the complex history of the genus *Histriculus* and provided some information about divisional morphogenesis. Thus, we describe and discuss only the type species, *Histriculus histrio*.

Neotype material: One neotype and three voucher slides with protargol-impregnated specimens (protocol A in FOISSNER 1991) have been deposited in the Oberösterreichische Landesmuseum in Linz (LI), Austria. The slides contain many morphostatic and some dividing cells, with relevant specimens marked by a black ink circle on the cover glass. Neotypification is necessary because there is at least one species, *H. erethesticus* STOKES, 1887, which is difficult to distinguish from or even a junior synonym of *H. histrio*.

Table 6. Morphometric data from *Histriculus histrio* (upper line), *Onychodromus grandis* (middle line) and *Stylonychia pustulata* (lower line).

Character 1)	$\bar{x}$	M	SD	CV	Min	Max	n
Body, length	102.2	102.5	10.3	10.0	81	122	21
	161.8	163.5	23.0	14.2	100	218	24
	53.0	52.0	6.2	11.8	44	66	21
Body, maximum width	49.2	49.0	5.0	10.1	40.5	60	21
	96.9	101.0	16.4	16.9	70	115	24
	26.4	26.0	3.0	11.5	21	31	21
Anterior body end to proximal end of adoral zone of membranelles, distance	51.8	51.0	2.9	5.5	47	57	20
	80.1	80.0	7.8	9.7	66	95	24
	29.0	27.5	3.5	12.2	24	37	21
Adoral membranelles, number	47 1	47.0	2.0	4.2	41	50	18
	52.6	53.0	6.0	9 7	41	59	24
	32.1	31.5	2.8	8.6	27	39	21
Macronuclear nodules, number	2.0	2.0	0.0	0.0	2	2	21
	4.5	4.0	1.0	23.4	4	8	39
	2.0	2.0	0.0	0.0	2	2	21
Macronuclear nodules, length	22.5	22.5	2.4	10.7	17.5	27	20
	20.5	21.0	3.5	17 1	14	25	24
	11.5	11.0	1.5	13.3	9	13.5	21
Macronuclear nodules, width	8.4	9.0	1.2	14 4	6	10.5	20
	10.4	10.0	1.7	16.3	7	15	24
	6.1	6.0	0.5	7.3	6	7.5	21
Micronuclei, number	2.0	2.0	0.0	0.0	2	2	20
	3.5	4.0	0.7	20.4	2	6	24
	2.0	2.0	0.0	0.0	2	2	16
Micronuclei, length	5.4	5.3	0.9	16.8	4.5	6.5	20
	4.9	5.0	0.5	10.1	3.5	5.5	24
	2.8	3.0	0.4	13.5	2	3	18
Micronuclei, width	3.3	3.0	0.5	16.4	3.0	4.5	20
	4.2	4.0	0.5	11.6	3.5	5	24
	1.6	1.5	0.2	10.4	1.5	2	18
Left marginal row, number of cirri	29.0	29.0	1.7	5.9	26	33	20
	24.7	25.0	2.1	5.0	21	31	24
	14.9	15.0	1.4	9.5	12	18	21
Right marginal row, number of cirri	42.2	42.0	1.9	4.6	39	46	20
	35.0	35.0	3.0	8.5	28	39	24
	24.2	23.5	2.7	11.0	20	29	21
Enlarged frontal cirri, number	3 0	3.0	0.0	0.0	3	3	20
	3.0	3.0	0.0	0.0	3	3	24
	3.0	3.0	0.0	0.0	3	3	20

(continued)

Table 6 (continued)

Character 1)	$\bar{x}$	M	SD	CV	Min	Max	n
Buccal cirri, number	1.0	1 0	0.0	0.0	1	1	20
	3 1	3 0	0.7	23.7	2	4	24
	1 0	1 0	0.0	0.0	1	1	21
Frontoventral cirri	4.0	4.0	0.0	0.0	4	4	20
	6.2	6.0	0.6	9.2	5	7	24
	4.0	4.0	0.0	0.0	4	4	21
Postoral ventral cirri, number	3 0	3 0	0.0	0.0	3	3	20
	6 3	6.0	0.7	11.8	5	8	24
	3 0	3.0	0.0	0.0	3	3	21
Pretransverse ventral cirri, number	2.0	2.0	0.0	0.0	2	2	20
	1.9	2.0			1	2	24
	2.0	2.0	0.0	0.0	2	2	21
Transverse cirri, number	5.0	5.0	0.0	0.0	5	5	20
	5 0	5.0	0.0	0.0	5	5	24
	5.0	5.0	0.0	0.0	5	5	21
Caudal cirri, number	0.0	0.0	0.0	0.0	0	0	20
	3 0	3 0	0.0	0.0	3	3	24
	3 0	3 0	0.0	0.0	3	3	20
Dorsal ciliary rows	6.0	6.0	0.0	0.0	6	6	20
			see text				
	6.0	6.0	0.0	0.0	6	6	19
Dikinetids in dorsal kinety 1, 2 or 3, number							
	17 5	17.0	1,7	9 6	16	21	16

Data based on protargol-impregnated, mounted specimens. *H. histrio*: field material, protocol A in FOISSNER (1991); *O. grandis*: wheat grain culture, protocol B in FOISSNER (1991); *S. pustulata*: wheat grain culture, protocol A in FOISSNER (1991). Measurements in µm. CV – coefficient of variation in %, M – median, Max – maximum, Min – minimum, n – number of individuals investigated, SD – standard deviation, $\bar{x}$ – arithmetic mean.

Description of German population: Size in vivo 90 – 140 x 40 – 60 µm, laterally flattened 2 – 3 1 Outline elliptical, right margin convex, left straight or slightly concave, anterior end broadly rounded, posterior bluntly pointed (Fig. 50, 51, 60, 65). Body very stiff, specimens thus look like swimming planks. Macronuclear nodules distinctly apart, in middle third near midline of cell, ellipsoidal to narrowly ellipsoidal, contain many tiny nucleoli. Micronuclei conspicuous because large and compact, in vivo about 6 x 4 µm, one each in distinct indentation of macronuclear nodules. Contractile vacuole in mid-body between left margin of cell and proximal end of adoral zone of membranelles.

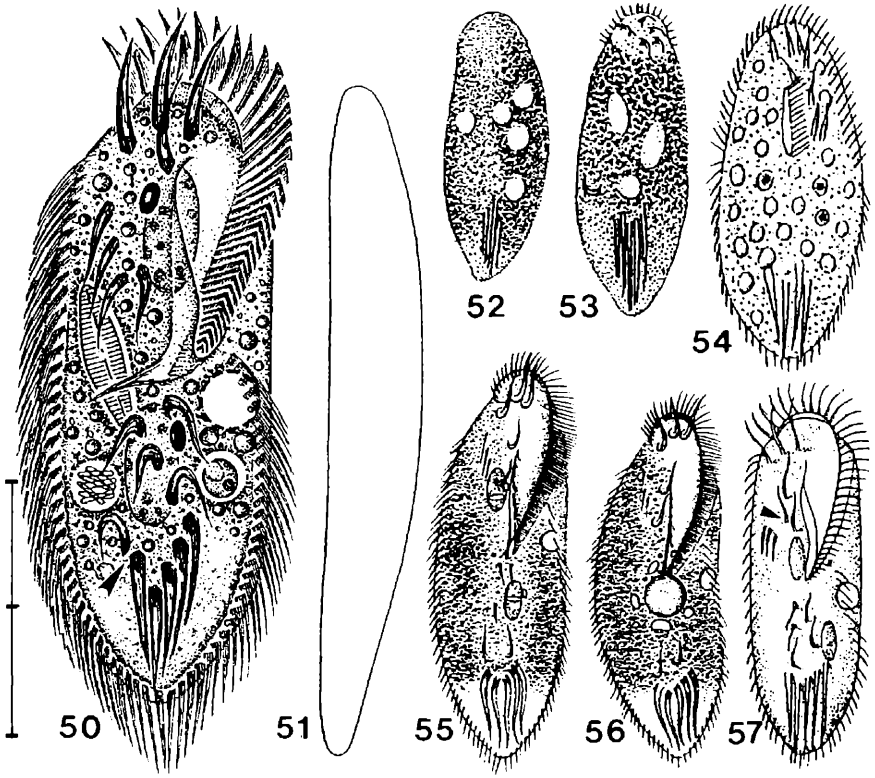


Fig. 50 – 57 *Histriculus histrio* (50 – 56) and *H. erethesticus* (57, from STOKES 1887) from life. **50, 51:** Ventral and lateral view of Berlin population, scale bar division 20 µm (originals). Arrowhead marks uppermost right transverse cirrus, which is close to the posteriormost pretransverse cirrus in all populations (cp. Figures 55, 56). This is one of the many specific features *H. histrio* possesses. Note also the posteriorly confluent marginal rows, an important generic character, recognized already by STEIN (Fig. 55, 56) and STOKES (Fig. 57). **52, 53:** Dorsal and ventral view of Danish type population studied by MÜLLER (1786). Note that MÜLLER recognized the very thick frontal and transverse cirri, an important character of *H. histrio*. **54:** Ventral view of Berlin population studied by EHRENBERG (1838), length 90 – 120 µm. Note that EHRENBERG, like MÜLLER (Fig. 52, 53), recognized the thick frontal and transverse cirri. **55, 56:** Ventral views of the population studied by STEIN (1859), length 140 – 160 µm. STEINS's figures and redescription are considered as authoritative by all revisers and match our data very well (Fig. 50). **57:** Ventral view of *H. erethesticus*, a supposed junior synonym of *H. histrio*. Arrowhead marks a surplus frontoventral cirrus, one of the main characters that distinguish *H. erethesticus* from *H. histrio*. See text for details.

Cortex very rigid, bright, forms distinct ridge along marginal rows (Fig. 60); without particular granules. Cytoplasm with few to many fat globules depending on nutrition conditions, posterior body portion very flat and thus hyaline (Fig. 50), as also noted by MÜLLER (1786; Fig. 52, 53) and STEIN (1859; Fig. 55, 56). Feeds on diatoms, globular green algae, and bacteria. Glides moderately fast, frequently changing direction and suddenly darting backward.

Number (18) of fronto-ventral-transverse cirri as in other typical members of genus (Tab. 6), cirral pattern, however, with several peculiarities, which provide the species with a definitive identity (Fig. 50, 58 – 60, 62 – 66): (1) anterior frontal

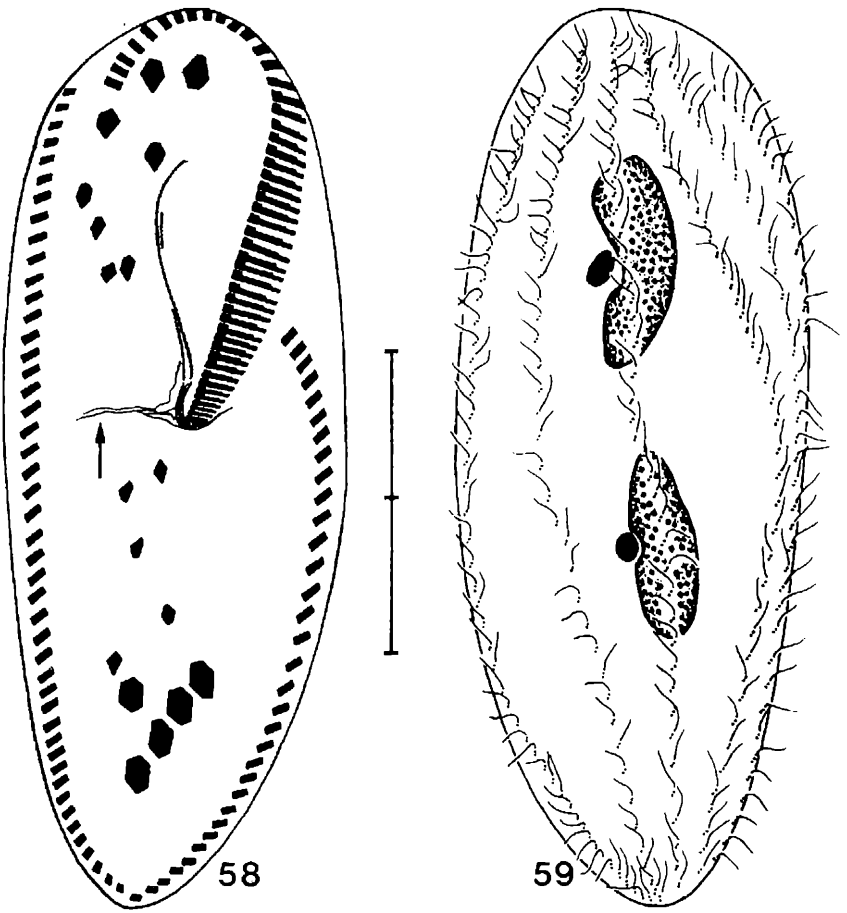


Fig. 58, 59 *Histriculus histrio*, infraciliature of ventral and dorsal side after protargol impregnation. Arrow marks pharyngeal fibres. See following Figures for labelling of structures. Scale bar division 20 µm

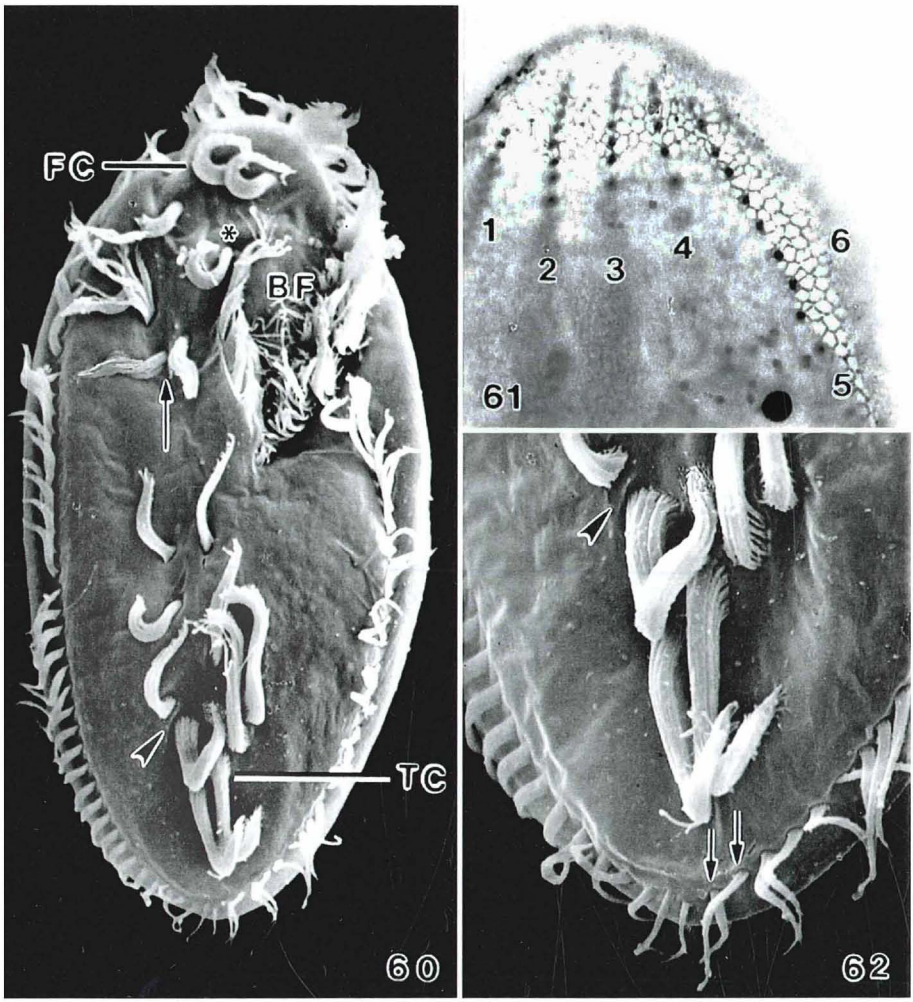


Fig. 60 – 62. *Histriculus histrio* in the scanning electron microscope (60, 62) and after Chatton-Lwoff silver nitrate impregnation (61). **60, 62:** Ventral view showing most of the generic and species characteristics of *H. histrio*: thick frontal (FC) and transverse (TC) cirri, flat buccal field (BC), buccal cirrus (asterisk) at right end of paroral membrane, narrowly spaced frontoventral cirri III/2 and IV/3 (arrow in Fig. 60), posterior pretransverse cirrus close to rightmost transverse cirrus (arrowheads), and posteriorly confluent marginal rows (arrows in Fig. 62 mark ends of right and left row of marginal cirri). Some of the cirri separated in their individual cilia due to the preparation procedures. **61:** Anterior dorsal side. The cortex of *H. histrio* contains a narrowly meshed silverline system. Numbers denote dorsal ciliary rows.

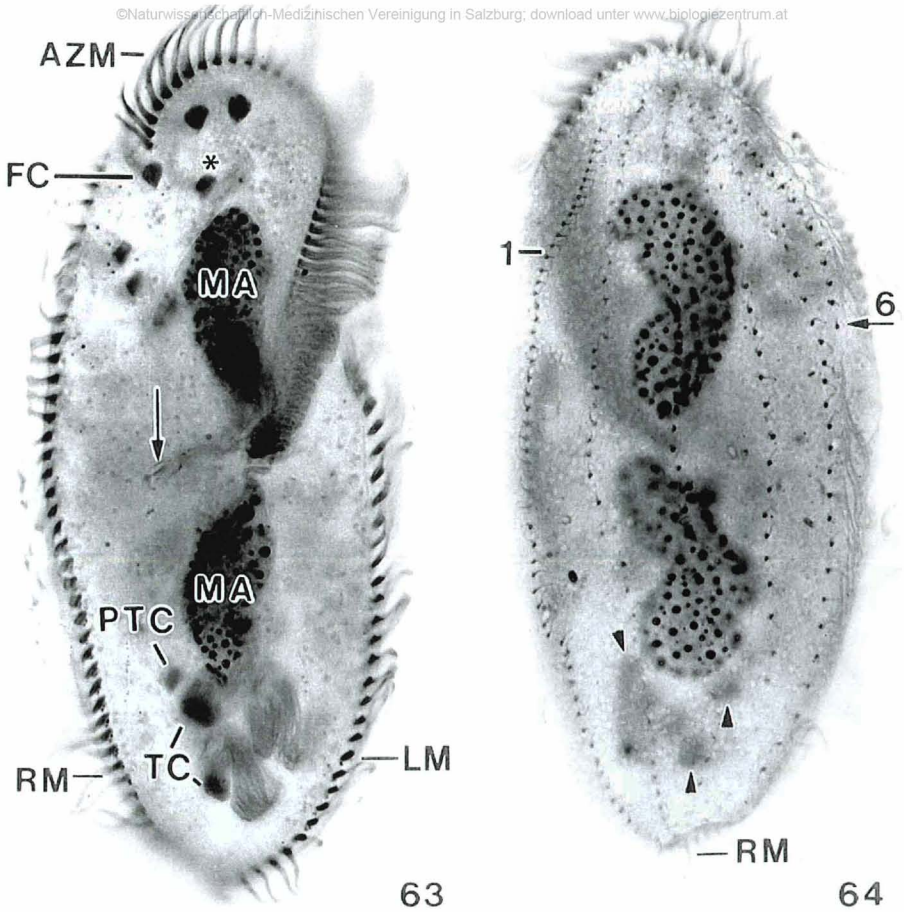


Fig. 63, 64. *Histriculus histrio*, infraciliature of ventral and dorsal side and nuclear apparatus after protargol impregnation. The figures show many of the generic and species characteristics of *H. histrio*, for instance, lack of caudal cirri, distinctly enlarged frontal (FC) and transverse (TC) cirri, buccal cirrus (asterisk) at anterior right end of paroral membrane, posterior pretransverse cirrus (PTC) close to rightmost transverse cirrus (TC), and six dorsal ciliary rows (numbers 1, 6, arrow marks last kinetid of strongly shortened row 6). Arrow in Figure 63 marks pharyngeal fibres at end of conspicuously large adoral zone of membranelles. Note that *H. histrio* is so flat that the contours of the ventral infraciliature, for instance the transverse cirri (arrowheads), are recognizable in dorsal view AZM – adoral zone of membranelles, FC – third frontal cirrus, LM – left marginal row, MA – macronuclear nodules, PTC – posterior pretransverse cirrus, RM – right marginal row, TC – transverse cirri

and transverse cirri extraordinarily thick and thus very prominent in vivo and silverslides; (2) buccal cirrus right of anterior end of paroral membrane; (3) posteriormost frontoventral cirri (cirrus III/2 and IV/3) very close together; (4) posterior pretransverse cirrus invariably very close to transverse cirrus VI/2; (5) rightmost transverse cirrus VI/2 in line with, but distinctly apart from transverse cirrus VI/1, (6) transverse cirri distinctly subterminal, do thus not project, or only very slightly so (in undernourished cells), beyond rear body margin (however, if

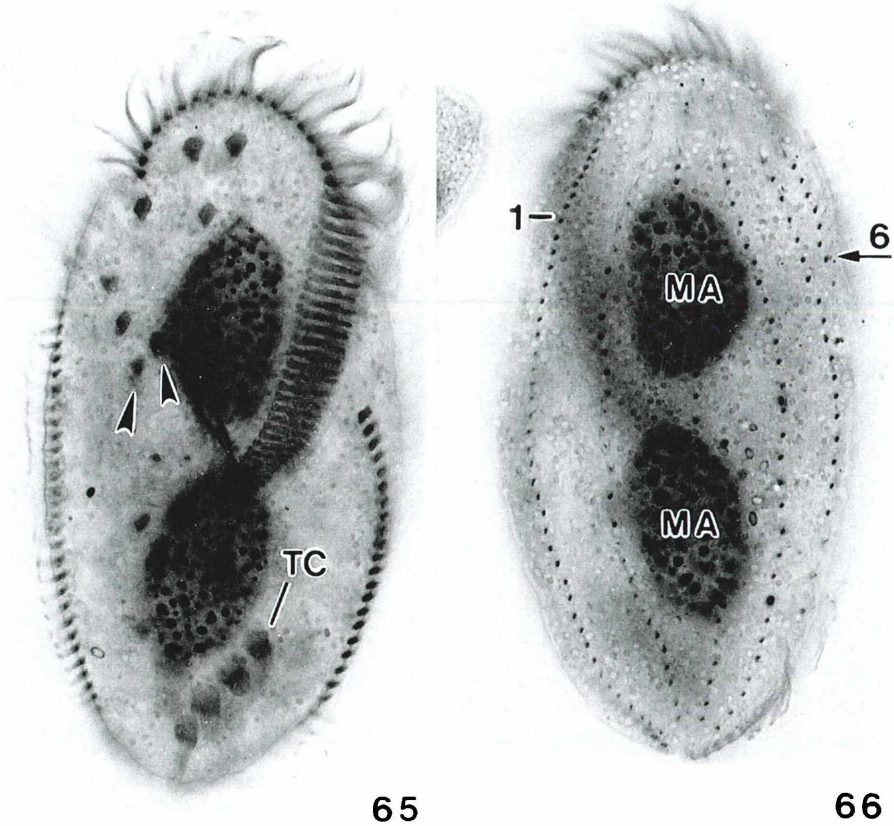


Fig. 65, 66. *Histriculus histrio*, infraciliature of ventral and dorsal side and nuclear apparatus after protargol impregnation. See Figures 63, 64 for detailed labelling. Here, some further species characteristics are shown, namely, the narrowly spaced cirri III/2 and IV/3 (arrowheads), the large bases of the transverse cirri (TC), and the conspicuous adoral zone of membranelles, which extends to body centre. *Histriculus histrio* invariably has two macronuclear nodules (MA) and six (numbers 1, 6) dorsal ciliary rows, of which row 6 is strongly shortened (arrow marks last kinetid).

specimens are slightly squeezed under the cover glass the pointed cell end rounds up causing the transverse cirri to project distinctly!), very stiff, almost immobile and usually held parallel to body surface forming triangular pattern; (7) marginal cirri large, decrease distinctly in size from anterior to posterior end of rows, narrowly spaced throughout, rows confluent posteriorly; (8) caudal cirri lacking (genus character; proved by ontogenesis, see BERGER & FOISSNER 1997). Dorsal cilia (bristles) in vivo about 4 μm long, arranged in five rows as long as cell, plus a single row terminating above mid-body at right margin of cell; row 4 occasionally distinctly curved to right in middle portion, distance between rows 3 and 4 thus increase in mid-body (Fig. 59, 64, 66). Silverline system narrowly meshed (Fig. 61).

Oral apparatus and adoral zone of membranelles conspicuous because occupying 50% of body length (Tab. 6). Frontal scutum ("Stirnplatte") distinct. Buccal cavity rather wide and flat, right third covered by hyaline, posteriorly curved lip (Fig. 50, 60). Paroral membrane longer and more strongly curved than endoral, both intersect optically in mid-portion of buccal cavity (*Oxytricha* pattern, BERGER & FOISSNER 1997), very likely composed of dikinetids. Pharyngeal fibres inconspicuous, extend at right angles from proximal end of buccal cavity to right body margin, as in *Stylonychia*.

Occurrence and ecology: *Histriculus histrio* has been rarely mentioned in the literature, although it is rather common according to our experience and MÜLLER (1786), ROUX (1901), and STEIN (1859). There are probably not more than 50 records, even if the supposed synonym *H. erethesticus* is included (see below). Usually, *H. histrio* is found in clean ponds between filamentous algae and macrophytes. Accordingly, it was classified as oligosaprobic indicator species (MAUCH 1976). We found low numbers of *H. histrio* at four sites in Germany and Austria, namely, in a small lake (Teufelssee) in the surroundings of Berlin, in a mesosaprobic river (Amper) in Bavaria, in a dystrophic forest pond near the Grabensee in Salzburg, and in the eutrophic pond at Salzburg University.

Comparison with previous descriptions and related species: Our observations perfectly match the excellent and authoritative redescription by STEIN (1859), and even MÜLLER (1786) and EHRENBERG (1838) illustrated the conspicuous transverse cirri (Fig. 52 – 54). Thus, our identification is very likely correct.

There is only a single species, *H. erethesticus* STOKES, 1887, which is very similar to *H. histrio*. It has one frontoventral cirrus more than *H. histrio* and two of the five transverse cirri project slightly beyond body margin (Fig. 57). In our opinion, these differences are too inconspicuous for recognizing this population as a distinct species, especially because we cannot be sure about the constancy of the surplus frontoventral cirrus. On the other hand, *H. histrio* might be a complex of sibling species, as indicated by the Chinese population studied by WANG & NIE (1933), which perfectly matches STEINS's and our observations, but has a size of 175 – 217 x 70 – 80 μm (STEIN gives a length of 140 – 160 μm, ROUX 140 – 150 x 60 – 70 μm, and our population measured 90 – 140 40 60 μm).

Onychodromus grandis STEIN, 1859 (Fig. 67 – 76; Table 6)

Material: Four voucher slides with protargol-impregnated specimens (protocol B in FOISSNER 1991) have been deposited in the Oberösterreichische Landesmuseum in Linz (LI), Austria. The slides contain many morphostatic and dividing cells, with drawn specimens marked by a black ink circle on the cover glass. We do not fix this population as neotype because its identity is somewhat doubtful (see Discussion below).

Description of German population: Size in vivo 120 – 235 µm (185.9, SD 36.6, CV 19.7%, n 11) 82.4, SD 15.7, CV 19.1, n 11). Shape also highly variable, narrowly to broadly elliptical or almost parallel-sided, right margin slightly to distinctly convex, left straight to slightly convex, anterior end obliquely truncate from right to left, posterior bluntly pointed to broadly rounded; occasionally like in *Stylonychia mytilus*, that is, widened anteriorly. Laterally flattened 2 – 3:1, depending on nutrition conditions, body margin thin and thus hyaline, ventral side flat to slightly concave, central dorsal area distinctly vaulted and with two lobe-like processes at left margin (Fig. 70); processes often inconspicuous, especially in prepared specimens, as also mentioned by STEIN (1859). Usually four, rarely up to eight ellipsoidal macronuclear nodules one by one slightly left midline; nucleoli globular and minute (Fig. 71, 73). Micronuclei in vivo about 6 µm across, compact and thus easy to recognize, in unfixed position near macronuclear nodules. Contractile vacuole in mid-body at left margin of cell, with two lacunar collecting canals (Fig. 70). Cortex bright, rigid and brittle, like in *S. mytilus*, swimming specimens thus stiff like a board; without particular granules. Cytoplasm colourless, densely granulated by lenticular inclusions 1 – 2 µm across and some up to 5 µm long, colourless crystals. In culture, feeds on bacteria, heterotrophic flagellates (*Astasia*, *Polytomella*), and wheat starch grains; STEIN (1859) observed cannibalism and ingestion of testate amoebae (*Arcella*) and diverse ciliates. Moves jerkily, that is, short periods of rest are interrupted by fast jumps.

Cirral pattern very constant and as shown in Figure 72. Number of frontoventral-transverse cirri slightly variable (Tab. 6): usually 12 in frontal and 13 in postoral region. Frontal cirri enlarged, in vivo about 28 µm long; transverse cirri also distinctly enlarged and with right distal portion frayed, in vivo about 35 µm long and thus projecting beyond posterior cell margin (Fig. 67, 69); caudal cirri in midline of posterior end, well recognizable although thin because about 30 µm long and rather motile. Marginal rows open posteriorly where caudal cirri insert, composed of 18 – 20 µm long cirri, the distances of which decrease from anterior to posterior (uncommon, usually distances increase).

Dorsal cilia in vivo about 3 µm long, arranged in highly characteristic, slightly variable pattern, that is, form two long, rather narrowly spaced rows in midline of cell and several long and short rows at cell margin; thus, a large, bare area occurs right and left of the central rows (Fig. 71, 73).

Oral apparatus conspicuous because occupying about 50% of body length (Tab. 6), largest membranellar bases, however, only about 12 µm wide, membranellar zone thus comparatively narrow (Fig. 72). Paroral and endoral membrane almost straight and side by side, slightly diverging posteriad, very similar to *Stylonychia mytilus*, both very likely composed of dikinetids. Buccal field triangular, wide but flat (Fig. 67, 72). Buccal lip narrow, inconspicuous.

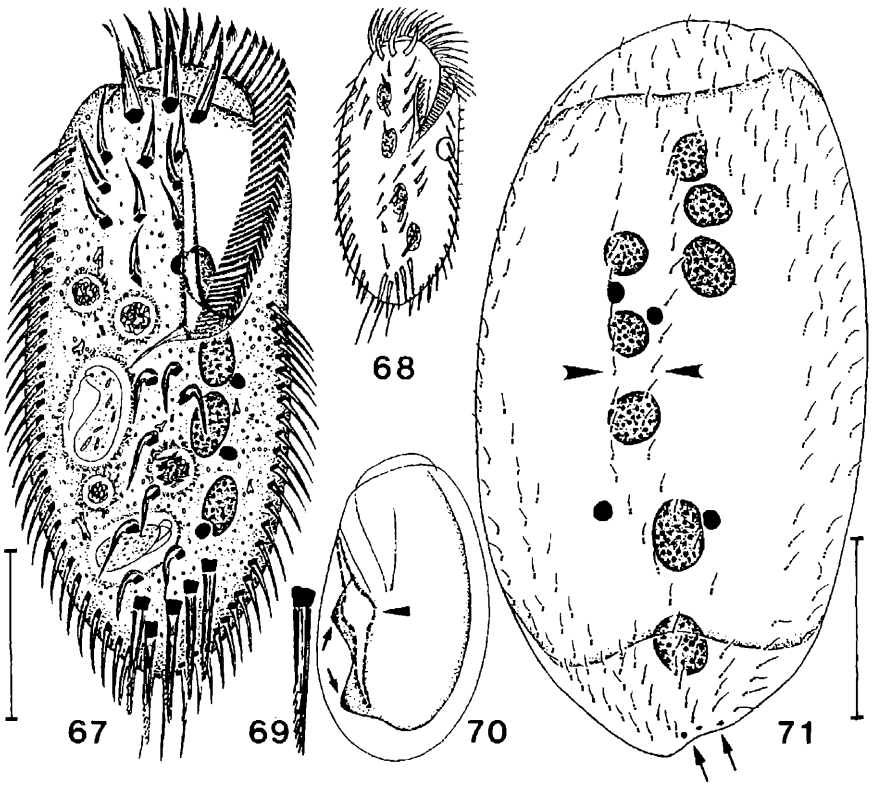


Fig. 67 – 71 *Onychodromus grandis* from life (67 – 70) and after protargol impregnation (71). **67:** Ventral view of a representative specimen from German population. **68:** Ventral view of a specimen from the population observed by KAHL (1932), length 250 µm. **69:** Transverse cirri are frayed in the right posterior half. **70:** Dorsal view of a broad specimen showing the contractile vacuole (arrowhead) and the two species-specific processes (horns, arrows) near the left margin of the cell. **71:** Dorsal view of a specimen with 8 macronuclear nodules. Note the three minute caudal cirri (arrows) and the two central ciliary rows (arrowheads). Scale bars 50 µm

Occurrence and ecology: STEIN (1859a, b) discovered great numbers of *O. grandis* in a marshy trench near Prague in October and November, together with *Stylonychia mytilus*, *Tachysoma pellionellum*, *Paramecium aurelia*, and *Aspidisca lynceus*. Like KAHL (1932), who found a strong population of *O. grandis* in the vicinity of Hamburg, Germany (Fig. 68), STEIN (1859b) mentioned that it is a voracious predator feeding mainly on other ciliates, including individuals of its own species. SZABÓ & WILBERT (1995) found *O. grandis* in some astatic, shallow, slightly alkaline (0.25 – 0.5% salinity, pH 7.1 – 7.8) water bodies with a dense growth of *Glyceria maxima* L. in the Hortobágy National Park, Hungary, where it was associated with *Bryophyllum tegularum*, *Spathidium amphoriforme*,

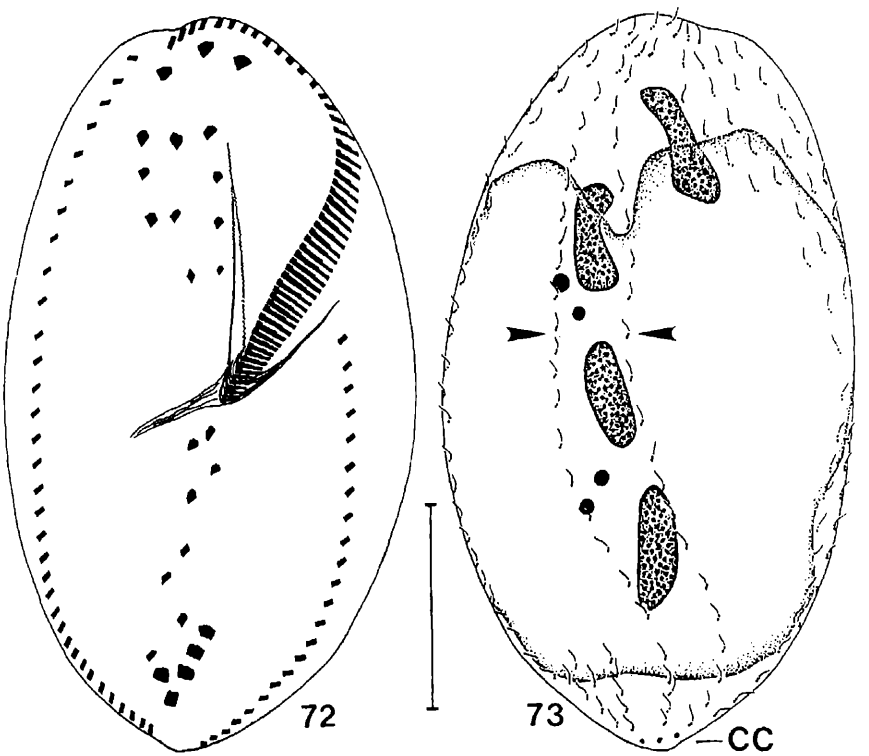


Fig. 72, 73. *Onychodromus grandis*, infraciliature of ventral and dorsal side after protargol impregnation. This is a representative specimen from the German population, having four macronuclear nodules, 26 fronto-ventral-transverse cirri (Tab. 6), and two central dorsal ciliary rows (arrowheads). CC – caudal cirri. Scale bar 50 µm.

Loxophyllum meleagris, *Calyptotricha pleuronemoides*, *Vorticella nebulifera*, *V. convallaria*, and *Balladynopsis sphaericus*. Like our population, which was collected in a pond near Tübingen, it could be cultivated in Table Water (Eau de Volvic) enriched with some cracked wheat or rice grains to stimulate growth of indigenous bacteria and heterotrophic flagellates, which were sufficient for good growth. Still better growth can be obtained with *Chlorogonium elongatum* as food organism. These data indicate that *O. grandis* is omnivorous and prefers environments with a rather high load of organic material. Furthermore, it prefers stagnant waters because reliable records from running waters are lacking.

There are about 50 other records of *O. grandis* in the literature, including reports from plankton and soil. However, none is substantiated by sufficient morphological data; very likely, many are misidentifications, for instance, the soil records. I did not find *O. grandis* in about 1000 soil samples investigated (FOISSNER 1998a).

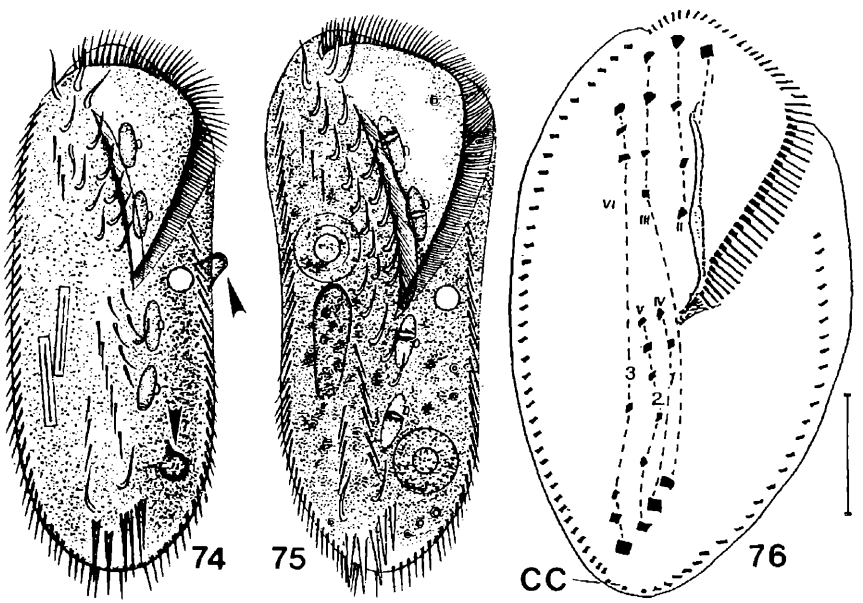


Fig. 74 – 76. *Onychodromus grandis*, ventral views from life (74, 75, from STEIN 1859) and after protargol impregnation (76; from SZABÓ & WILBERT 1995) **74, 75:** Specimens with few and many fronto-ventral-transverse cirri, size 110 – 370 x 180 µm Arrowheads mark the two species-specific dorsal horns. **76:** The infraciliature of the Hungarian population is very similar to that of the German specimens investigated by us (Fig. 72) Hatched lines and Roman

numerals connect cirri originating from the same anlage. Arabic numerals denote ventral cirral rows. CC – caudal cirri. Scale bar 50 µm.

Comparison with previous descriptions: Our specimens are fairly similar to those studied by SZABÓ & WILBERT (1995), except for body size (162 x 97 µm vs. 237 x 146 µm) and number of adoral membranelles (53 vs. 64), which are considerably higher in the Hungarian population. However, such differences might, at least partially, result from slightly different culture conditions. The total number (about 25) and pattern (Fig. 72, 76) of the fronto-ventral-transverse cirri are identical in the German and Hungarian specimens, and thus distinctly different from those of the type population, which usually have about 45 cirri (16 – 28 in frontal and 20 – 30 in postoral region; Fig. 74, 75). This indicates that *O. grandis* could be a species complex. On the other hand, all other characteristics, especially the two dorsal horns, match well in the Czech, German and Hungarian population. Thus, further data, especially gene sequences, should be collected before this species is split. SZABÓ (1992) classified the Hungarian population as "*Onychodromus grandis* STEIN var. *simplex* n. var.", which, however, is an infraspecific rank and thus excluded from the International Code of Zoological Nomenclature.

Acknowledgements

Supported by the Bayerische Landesamt für Wasserwirtschaft (BLWW). The technical assistance of Dr. ANDREAS UNTERWEGER, Dr. EVA HERZOG, Mag. ERIC STROBL and BRIGITTE MOSER is greatly acknowledged. Special thanks to Dr. G. BURKL (BLWW), who organized the investigation, and to Prof. M. SCHLEGEL and Prof. A. HAUCK for providing cultures of *Onychodromus grandis* and *Spirostomum minus viride*.

Literature

ALEKPEROV, I. K. (1985): New free-living ciliates from fresh waters of Azerbaijan. – Zool. Zh., **64:** 1461–1467 (in Russian with English summary).ALEKPEROV, I. K. (1993): Free-living ciliates in the soils of St. Petersburg parks (Protozoa). – Zoosyst. Rossica, **2:** 13–18.

BERGER, H. & FOISSNER W. (1987): Morphology and biometry of some soil hypotrichs (Protozoa: Ciliophora). – Zool. Jb. Syst., **114:** 193–239.

BERGER, H. & FOISSNER, W. (1997): Cladistic relationships and generic characterization of oxytrichid hypotrichs (Protozoa, Ciliophora). – Arch. Protistenk., **148:** 125–155.

BERGER, H., FOISSNER, W. & ADAM, H. (1984): Taxonomie, Biometrie und Morphogenese einiger terricoler Ciliaten (Protozoa, Ciliophora). – Zool. Jb. Syst., **111:** 339–367

BERGH, R. S. (1896): Über Stützfasern in der Zellsubstanz einiger Infusorien. – Arb.

anat. Inst., Wiesbaden, Heft **21** (7. Bd., H. 1): 103–113.

BLATTERER, H. & FOISSNER, W. (1988): Beitrag zur terricolen Ciliatenfauna (Protozoa, Ciliophora) Australiens. – Stapfia (Linz), **17:** 1–84.

BORROR, A. C. (1972): Revision of the order Hypotrichida (Ciliophora, Protozoa). – J. Protozool., **19:** 1–23.

BUITKAMP, U. (1977): Die Ciliatenfauna der Savanne von Lamto (Elfenbeinküste). Acta Protozool., **16:** 249–276.

CLAPARÈDE, É. & LACHMANN, J. (1858): Études sur les infusoires et les rhizopodes. – Mém. Inst. natn. génev., **5** (year 1857)**:** 1–260.

CORLISS, J. O. (1960): The problem of homonyms among generic names of ciliated protozoa, with proposal of several new names. – J. Protozool., **7:** 269–278.

DRAGESCO, J. (1970): Ciliés libres du Cameroun. – AnnlsFac. Sci. Univ. féd. Cameroun (Numéro hors-série): 1–141

DRAGESCO, J. & DRAGESCO-KERNÉIS, A. (1986): Ciliés libres de l'Afrique intertropicale. Introduction à la connaissance et à l'étude des ciliés. Faune tropicale (Éditions de l'ORSTOM, Paris), **26:** 1–559.

EHRENBERG, C. G. (1835): Zusätze zur Erkenntniß großer organischer Ausbildung in den kleinsten thierischen Organismen. Abh. dt. Akad. Wiss., Berl. year 1835: 151–180.

EHRENBERG, C. G. (1838): Die Infusionsthierchen als vollkommene Organismen. Ein Blick in das tiefere organische Leben der Natur. L. Voss, Leipzig. 548 pp.

FOISSNER, W. (1982): Ökologie und Taxonomie der Hypotrichida (Protozoa: Ciliophora) einiger österreichischer Böden. Arch. Protistenk., **126:** 19–143.

FOISSNER, W. (1984): Infraciliatur, Silberliniensystem und Biometrie einiger neuer und wenig bekannter terrestrischer, limnischer und mariner Ciliaten (Protozoa: Ciliophora) aus den Klassen Kinetofragminophora, Colpodea und Polyhymenophora. – Stapfia (Linz), **12:** 1–165.

FOISSNER, W. (1991): Basic light and scanning electron microscopic methods for taxonomic studies of ciliated protozoa. – Europ. J. Protistol., **27:** 313–330.

FOISSNER, W. (1993): Colpodea (Ciliophora). – Protozoenfauna, **4/1:** I–X + 1–798.

FOISSNER, W. (1997a): Faunistic and taxonomic studies on ciliates (Protozoa, Ciliophora) from clean rivers in Bavaria (Germany), with descriptions of new species and ecological notes. – Limnologica (Berlin), **27:** 179–238.

FOISSNER, W (1997b): Soil ciliates (Protozoa: Ciliophora) from evergreen rain forests of Australia, South America and Costa Rica: diversity and description of new species. – Biol. Fertil. Soils, **25:** 317–339.

FOISSNER, W. (1998a): An updated compilation of world soil ciliates (Protozoa, Ciliophora), with ecological notes, new records, and descriptions of new species. – Europ. J. Protistol., **34:** 195–235.

FOISSNER, W. (1998b): Notes on the soil ciliate biota (Protozoa, Ciliophora) from the Shimba Hills in Kenya (Africa): diversity and description of three new genera

and ten new species. – Biodiv. Conserv., **7:** (in press).

FOISSNER, W. & O' DONOGHUE, P. J. (1990): Morphology and infraciliature of some freshwater ciliates (Protozoa: Ciliophora) from Western and South Australia. – Invert. Taxon., **3:** 661–696.

FOISSNER, W. & PFISTER, G. (1997): Taxonomic and ecologic revision of urotrichs (Ciliophora, Prostomatida) with three or more caudal cilia, including a user-friendly key. – Limnologica (Berlin), **27:** 311–347

FOISSNER, W., BLATTERER, H., BERGER, H. & KOHMANN, F. (1991): Taxonomische und ökologische Revision der Ciliaten des Saprobiensystems – Band I: Cyrtophorida, Oligotrichida, Hypotrichia, Colpodea. – Informationsberichte des Bayer. Landesamtes für Wasserwirtschaft, **1/91:** 1–478.

FOISSNER, W., BERGER, H. & KOHMANN, F. (1992): Taxonomische und ökologische Revision der Ciliaten des Saprobiensystems – Band II: Peritrichia, Heterotrichida, Odontostomatida. – Informationsberichte des Bayer. Landesamtes für Wasserwirtschaft, **5/92:** 1–502.

FOISSNER, W., BERGER, H. & KOHMANN, F. (1994): Taxonomische und ökologische Revision der Ciliaten des Saprobiensystems – Band III: Hymenostomata, Prostomatida, Nassulida. – Informationsberichte des Bayer. Landesamtes für Wasserwirtschaft, **1/94:** 1–548.

FROMENTEL, E. DE (1874–1876): Études sur les microzoaires du infusoires proprement dits comprenant de nouvelles recherches sur leur organisation, leur classification et la description des espèces nouvelles ou peu connus. G. Masson, Paris. 364 pp.

GROLIÈRE, C.-A. (1977): Contribution a l'etude des cilies des sphaignes et des etendues d'eau acides. I – Description de quelques especes de gymnostomes, hypostomes, hymenostomes et heterotriches. – Annls Stn limnol. Besse, **10** (years 1975/1976)**:** 265–297

HAUCK, A. (1986): *Spirostomum viridis*: Ein *Spirostomum* mit endosymbiontischen Grünalgen. – Mikrokosmos, **75** (Heft 7): 198–199.

HILLER, S. A. & BARDELE C. F. (1988): *Prorodon aklitolophon* n. spec. and the "dorsal brush" as a character to identify certain subgroups in the genus *Prorodon*. – Arch. Protistenk., **136:** 213–236.

KAHL, A. (1932): Urtiere oder Protozoa I: Wimpertiere oder Ciliata (Infusoria) 3. Spirotricha. – Tierwelt Dtl., **25:** 399–650.

MAUCH, E. (1976): Leitformen der Saprobität für die biologische Gewässeranalyse. Teil 4. – Cour. Forsch.-Inst. Senckenberg, **21:** 339–563.

MÜLLER, O. F. (1773): Vermium Terrestrium et Fluviatilium, seu Animalium Infusorium, Helminthicorum et Testaceorum, non Marinorum, Succincta Historia. Heineck & Faber, Havniae & Lipsiae. 135 pp.

MÜLLER, O. F. (1786): Animalcula Infusoria Fluviatilia et Marina, quae Detexit, Systematice Descripsit et ad Vivum Delineari Curavit. N. Mölleri, Hauniae. 367 pp.

OLMO, J. L., TÉLLEZ, C. & ESTEBAN, G. F. (1998): *Cinetozona pyriformis* n. g., n. sp..

a relative of the ciliate genera *Urozona* and *Cinetochilum* (Ciliophora, Scuticociliatida). – J. Euk. Microbiol., **45:** 448–451.

PERTY, M. (1852): Zur Kenntniss kleinster Lebensformen nach Bau, Funktion, Systematik, mit Specialverzeichniss der in der Schweiz beobachteten. Jent & Reinert, Bern. 228 pp.

PETZ, W. & FOISSNER, W. (1997): Morphology and infraciliature of some soil ciliates (Protozoa, Ciliophora) from continental Antarctica, with notes on the morphogenesis of *Sterkiella histriomuscorum*. – Polar Record, **33**: 307–326.

REPAK, A. J. & ISQUITH, I. R. (1974): The systematics of the genus *Spirostomum* EHRENBERG, 1838. – Acta Protozool., **12:** 325–333.

ROUX, J. (1901): Faune infusorienne des eaux stagnantes des environs de Genève. Mém. Inst. natn. génev., **19:** 1–148.

SONG, W. & WILBERT, N. (1989): Taxonomische Untersuchungen an Aufwuchsciliaten (Protozoa, Ciliophora) im Poppelsdorfer Weiher, Bonn. Lauterbornia, **3:** 2–221.

STEIN, F (1859a): Characteristik neuer Infusorien-Gattungen. – Lotos, **9:** 2–5, 57–60.

STEIN, F. (1859b): Der Organismus der Infusionsthiere nach eigenen Forschungen in systematischer Reihenfolge bearbeitet. I. Abtheilung. Allgemeiner Theil und Naturgeschichte der hypotrichen Infusionsthiere. W. Engelmann, Leipzig. 206 pp.

STEIN, F. (1867): Der Organismus der Infusionsthiere nach eigenen Forschungen in systematischer Reihenfolge bearbeitet. II. Abtheilung. 1) Darstellung der neuesten Forschungsergebnisse über Bau, Fortpflanzung und Entwickelung der Infusionsthiere. 2) Naturgeschichte der heterotrichen Infusorien. W Engelmann, Leipzig. 355 pp.

STOKES, A. C. (1887): Notices of new fresh-water infusoria. Proc. Am. phil. Soc., **24:** 244–255.

STOKES, A. C. (1891): Notes of new infusoria from the fresh waters of the United States. – Jl R. microsc. Soc., year 1891. 697–704.

SZABO, A. (1992): The morphology, morphogenesis and ecology of a new Hypotrichida (Ciliophora) *Onychodromus grandis* STEIN var *simplex* n. var. – Europ. J. Protistol., **28:** 358 (Abstract 127).

SZABÓ, A. & WILBERT, N. (1995): A redescription of the morphology of *Onychodromus grandis* STEIN 1859 and the systematic implications of its morphogenesis. – J. Euk. Microbiol., **42:** 50–60.

WANG, C. C. & NIE, D. (1933): Report on the rare and new species of fresh-water infusoria, part I. – Contr. biol. Lab. Sci. Soc. China, Zoological Series, **10:** 1–99.

WIRNSBERGER, E., FOISSNER, W & ADAM, H. (1985): Morphological, biometric, and morphogenetic comparison of two closely related species, *Stylonychia vorax* and *S. pustulata* (Ciliophora: Oxytrichidae). – J. Protozool., **32:** 261–268.