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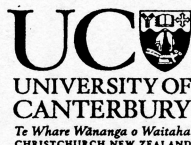
VOLUME THREE **KINGDOMS**

Bacteria, Protozoa, Chromista, Plantae, Fungi

Edited by
DENNIS P. GORDON



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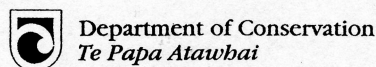
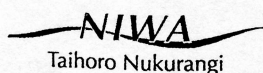
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Cover: The silver fern *Cyathea dealbata* (Plantae:Tracheophyta) on a shaded bank in the Wellington Botanic Gardens and (inset) the dog-vomit slime mould *Fuligo septica* (Protozoa:Amoebozoa).
Dennis Gordon and Clive Shirley

Endpapers: Bull kelp *Durvillaea antarctica* on the south coast of Otago Peninsula (Chromista:Ochrophyta).
Dennis P. Gordon, NIWA

Half-title page: Average sea-surface temperature derived from AVHRR satellite. Warmest temperatures (around New Guinea) are ~30°C; coolest temperatures (around Antarctica) are ~-1.5°C.

Title page: Male inflorescences of the kiekie *Freycinetia banksii* (Plantae:Tracheophyta).
Dennis P. Gordon, NIWA

FOURTEEN

Phylum CILIOPHORA

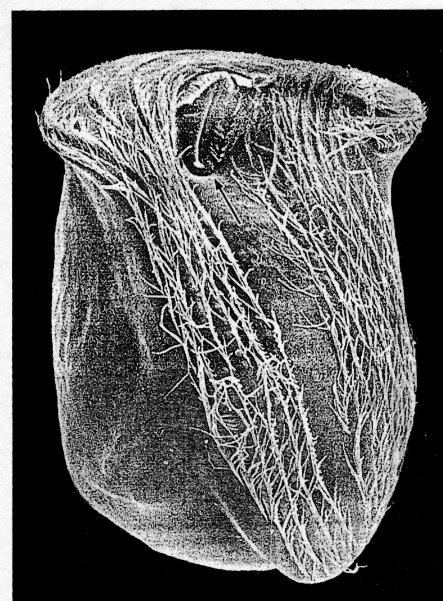
ciliates

WILHELM FOISSNER, TONY CHARLESTON,
MARTIN KREUTZ, DENNIS P. GORDON

Ciliates are among the most complex unicellular organisms. Far from being simple, the bodies of ciliates are analogous to those of metazoans, with highly specialised organelles performing functions of movement, ingestion, digestion, water balance, excretion, reproduction, sensing the environment, and defence. The diversity of size and morphology among ciliates is remarkable. The largest species (funnel-like *Stentor* can reach two millimetres high and worm-like *Spirostomum ambiguum* may be four millimetres long) can exceed the smallest (*Nivaliella plana*, a 20-micrometre-long soil inhabitant) by several orders of magnitude of cell volume. Although most of the approximately 10,000 described species are free-living, some are parasitic, such as *Balantidium coli*, which can cause human disease. Other ciliates induce diseases in fish and are a problem for aquaculturists. Ciliates of cloven-hoofed animals stabilise the huge numbers of bacteria in the rumen and gut. Ciliate feeding strategies include herbivory, fungivory, and predation. Some ciliates, like *Paramecium bursaria*, have symbiotic bacteria and algae ('zoochlorellae'). The products of photosynthesis are beneficial to the protozoan host, which can bring the algae to optimal light conditions and supply carbon dioxide and shelter. A number of ciliates are sessile. They may be stalked or unstalked and some build a protective case (lorica) around the cell.

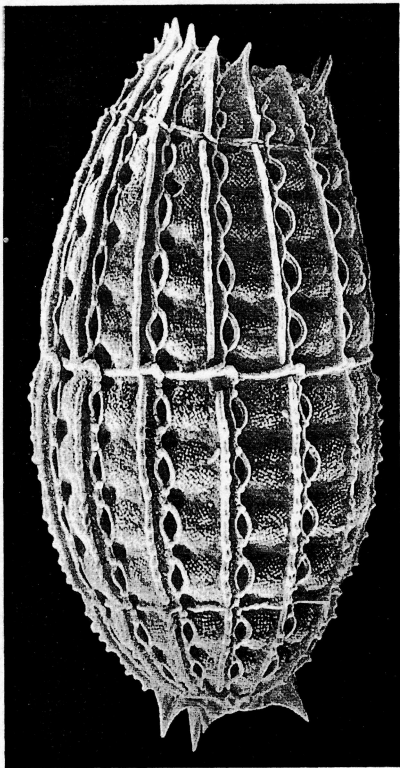
Among eukaryotes, ciliates are distinctive in having a macronucleus and a micronucleus (sometimes more than one of each kind) of very different size and function within the same cytoplasm – a condition termed heterokaryotic and elsewhere known only among a few foraminifera at certain stages of their life-history. The macronucleus, which is usually highly polyploid (having several or multiple sets of chromosomes), divides during asexual reproduction and controls mainly somatic functions (e.g. RNA synthesis). The diploid micronucleus is active mainly during sexual reproduction, when mating pairs exchange genetic material during conjugation.

Ciliates are evolutionarily related to dinoflagellates and apicomplexans (previous chapter) in having membranous sacs (alveoli) in their cell cortex (lacking or reduced in size, however, in a number of groups). The cortex is essentially the outer body layer, which, in ciliates, is extraordinarily complex. The cell membrane is internally supported by the alveoli, except in several specialised regions of the surface. The basic component of the cortex is the kinetid, a complex composed of the basal body (kinetosome) of a cilium and its associated fibrils. The fibrils link kinetids of the same and adjacent kineties (rows of cilia) as an organised system. The arrangement of cilia (which can be fused into larger organelles called cirri and adoral membranelles) on the body and in the oral region is significant in taxonomy. The reader is urged to consult general works like those of Corliss (1979) and Lynn and Small (2000) for details of cellular construction and function in these remarkable organisms.



Phascolodon vorticella (Phyllopharyngea).
It has only two small ciliary fields leading to
the anterior mouth (arrow), and feeds on
planktonic lake microalgae (70 µm).

Wilhelm Foissner



Coleps hirtus (Prostomatea), an armoured ciliate with calcified plates that have elliptical openings through which the cilia (not shown) emerge; benthoplanktonic, feeding on other ciliates (60 µm).
Wilhelm Foissner

Ciliates have long been recognised to be a monophyletic group, but a definitive classification has not yet been achieved. In the 1960s, identification of major lineages was based on cell morphology and details of the cortex (especially arrangement of ciliary rows) and oral structures as revealed by silver staining. In the 1970s, electron-microscope studies revealed details of cell ultrastructure, especially of kinetids and their fibrillar associates. With the advent of gene-sequencing techniques, ribosomal RNA genes have been used to test the reliability of classifications arrived at using previous evidence. The two ciliophoran subphyla, Postciliodesmatophora and Intramacronucleata, and six out of eleven classes (Karyorelictea, Heterotrichea, Litostomatea, Phyllopharyngea, Nassophorea, and Colpodea) are well supported by both molecules and morphology; the remaining five classes (Spirotrichea, Armophorea, Plagiopylea, Prostomatea, Oligohymenophorea) are not (Lynn 2003a).

Ciliates may be found almost anywhere there is liquid water, but different forms predominate in various habitats. On the other hand, some species are such environmental generalists as to be found in marine, freshwater, and terrestrial habitats. Generally, ciliates in soils tend to be small forms that can generate resistant cysts in order to survive periods of dryness. Ciliates abound in freshwater environments, especially those that have been organically enriched, like sewage and oxidation ponds. 'Infusoria' is a term that was used historically for ciliates (and some other protozoans) of nutrient-rich organic (e.g. hay) infusions. Marine plankton, also, can have a diverse ciliate fauna, especially the loricate forms known as tintinnids.

The New Zealand ciliate fauna

Ciliates of New Zealand are relatively little studied and therefore poorly known. The few illustrated accounts focused on freshwater forms in the 1890s (Kirk 1886, 1887; Maskell 1886, 1887; Schewiakoff 1892, 1893) and the 1950s (Bary 1950a,b; Barwick et al. 1955) and unillustrated work was published on soil ciliates during the 1950s through 1980s (e.g. Stout 1952, 1955a,b, 1958, 1960a, 1961, 1962, 1978, 1984). A study of parasites in the gut of the common green and golden bell frog (*Litoria aurea*) yielded the ciliate *Nyctotherus cordiformis* (Brace et al. 1953) and rumen and gut ciliates of New Zealand introduced mammals were reported by Clarke (1964, 1968), Clarke et al. (1982), and Fairley (1996). A study was made on the marine planktonic tintinnids in the 1980s (Burns 1983) and the ciliate parasites of fishes have attracted some attention (Laird 1953; Diggles et al. 2002).

Taken together, these data and some soil samples recently studied by W. Foissner (see below), reveal about 347 ciliate species, of which 50 may be endemic to New Zealand. Unfortunately, few ciliate catalogues are available worldwide to show faunal comparisons. European catalogues, for example, show 696 ciliate species in Austria (Foissner & Foissner 1988), 585 species in Slovakia (Matiset al. 1996), 188 species in Italy (Dini et al. 1995), and about 500 species in Bulgaria (Detcheva 1992). Even these compilations do not show the real number of species likely to be present, demonstrating our ignorance about this exceptional

Summary of New Zealand ciliate diversity

Taxon	Described species + subspecies*	Known undet. species	Estimated unknown species	Adventive species	Endemic species	Endemic genera
Postciliodesmatophora	14+1	2	>100	0	4?	0
Intramacronucleata	326+3	5	>1,000	37	46?+1?	0
Totals	340+4	7	>1,100	37	50?+1?	0

* Not including forms (f).

group of minute but important organisms (see Foissner 1997a, 2000, for more detailed discussion). The known New Zealand fauna is thus only a small fraction of that likely to exist.

Freshwater ciliates

The first accounts of freshwater ciliates in New Zealand were published in the late 19th century when Kirk (1886), Maskell (1886, 1887), and Schewiakoff (1892, 1893) described and illustrated known and new taxa. However, most samples were taken from a small area of New Zealand, viz the Wellington District. More than half a century elapsed before there were any further studies. Bary (1950a,b), working in the Wellington region, added many new records to the fauna and also summarised the earlier accounts. Kirk had briefly reported 13 species of the stalked ciliate *Vorticella*, describing and illustrating two as new – *V. zealandica* (freshwater) and *V. oblonga* (marine). Maskell's lists and descriptions covered about 70 species, 25 of which were regarded as new, together with five new varieties and one new genus, *Thurophora* (= *Lembadion*). Schewiakoff described 11 new species and five new genera. Thus, among them, these three authors reported almost 100 species, of which 38 were described for the first time.

Underscoring the scientific inadequacy of the earlier works, Bary remarkably found none of Maskell's purported new species or any of those described by Kirk and Schewiakoff, even though he made collections from several of the streams sampled by Maskell (1886, 1887). Bary (1950b) himself reported 28 species, none of which was new, and he regarded the fauna as being essentially cosmopolitan. However, 28 species is a very low number, which suggests that his sampling and/or identifications were insufficient. Reporting on a graduate class project carried out at Victoria University (College), Barwick et al. (1953) illustrated 21 taxa, 11 of which were new records for New Zealand, giving locality details and methods of infusion-culture.

It is clear that, in spite of the paucity of studies in New Zealand, freshwater ciliates are common, diverse, and grossly understudied, especially outside the Wellington area.

Marine ciliates

In an annotated index of the known marine protozoa of New Zealand, Dawson (1992) listed 66 named species and five of uncertain identity, 42 of which were tintinnids. Tintinnids are common loricate microplankton organisms of coastal and oceanic waters. The lorica (made of protein, polysaccharide, or both) cements silica grains, diatom frustules, or coccoliths to its matrix, making it hard and resistant. As the living tintinnid cell is frequently destroyed during collection, it is the lorica that has historically formed the basis of classification.

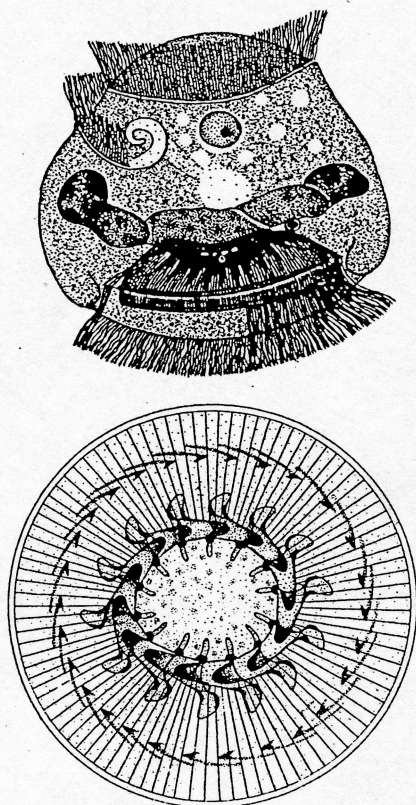
Pelagic tintinnids are primary feeders of nanoplankton, including bacteria, small flagellates, coccolithophorids (Haptophyta), and dinoflagellates (Myzozoa). Cassie (1961) reported several species from New Zealand waters, but the most detailed study was that of Burns (1983), who illustrated loricas by scanning

Summary of New Zealand ciliate diversity by environment

Taxon	Marine/ brackish	Terrestrial	Freshwater
Postciliodesmatophora	3	5	12+1
Intramacronucleata	75	144+1	163+3
Totals	78	149+1	175+4

* Several species occur in more than one environment hence the total across all environments will exceed total diversity of 346 species and four subspecies.

Parasitic ciliates are accorded the major habitat of their hosts.



Trichodina parabranchicola
(Oligohymenophorea). Upper, lateral view of whole organism from a gill of the olive rockfish (*Acanthoclinus fuscus*, drawn from stained specimen). Lower, aboral view of the internal skeletal complex.

From Laird 1953

electron microscopy and gave distributional data on each species in relation to hydrological features of the marine environment in which they were found. Other common planktonic ciliates are *Cyclotrichium meunieri* and *Myrionecta rubra* (*Mesodinium rubrum* in older literature), which cause seasonal red-water blooms in harbours and coastal waters (Bary & Stuckey 1950; Bary 1951, 1953a,b; Taylor 1973; MacKenzie & Gillespie 1986; Chang 1994).

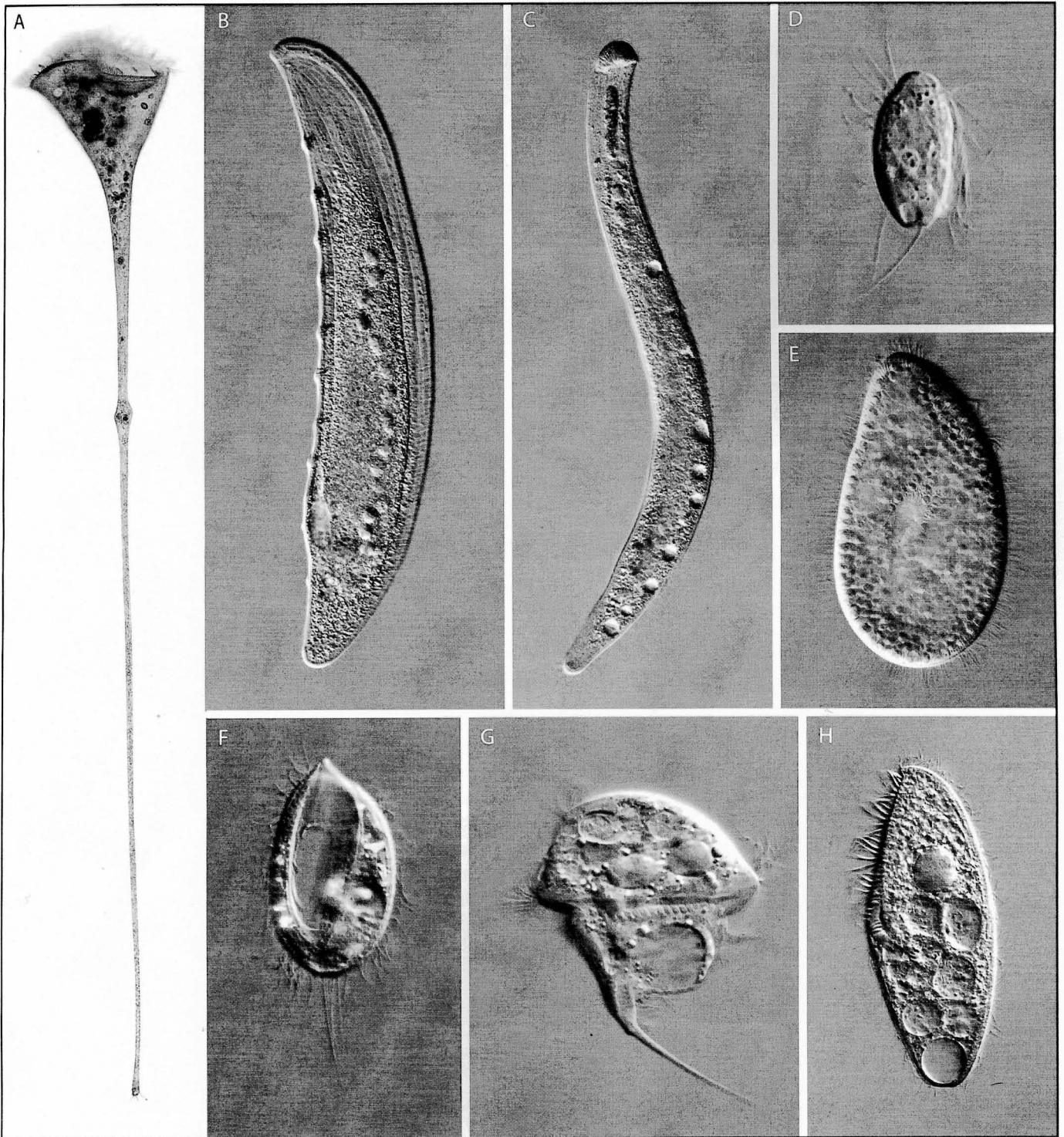
Marine benthic ciliates have scarcely been noted in New Zealand, especially free-living forms, about which nothing is known. On the other hand, some commensal and parasitic forms have been reported, giving evidence of the fascinating range of ciliate microhabitats and hosts, e.g. *Haematophagus megapterae* on baleen plates of the humpback whale (Woodcock & Lodge 1921); *Endosphaera engelmanni*, hyperparasitic in the ciliate *Trichodina multidentis* from gills of the twister *Bellapiscis medius* (Laird 1953); and *Paranophrys elongata*, an endocommensal in the gut of the sea urchin *Evechinus chloroticus* (McRae 1959).

The most problematic forms are those that cause actual diseases in fishes. In reviewing all known parasites of New Zealand marine fishes, and latterly of economic marine invertebrates, Boustead (1982), Hine et al. (2000), and Diggles et al. (2002) reported several species of parasitic ciliates. *Ichthyophthirius multifiliis*, which occurs globally in wild and ornamental freshwater fishes, causes white spot disease. This is the only known parasite to cause significant losses in eel culture in New Zealand (Boustead 1982), despite being easily controlled. Another type of white spot disease affects wild and cultured marine fishes. This is caused by *Cryptocaryon irritans*. In New Zealand it has been observed in captive snapper (*Pagrus auratus*) and probably occurs in wild fish along the northeast coast of the North Island. It may also be present in imported marine ornamental fish (Hine 1982). Ciliates of the genus *Trichodina*, easily recognised by their distinctive ring of 'denticles' and their 'flying-saucer' shape, cause trichodiniasis, which can affect most species of wild and cultured marine fish including snapper (*Pagrus auratus*) and turbot (*Colistium nudipinnis*). Although wild fish may harbour heavy infestations of trichodinids, these usually do not cause disease (Laird 1953). However, ciliate numbers can build up quickly in confined fish, especially at higher temperatures, and skin and gill lesions can develop that may become infected by bacteria and fungi (Diggles 2000).

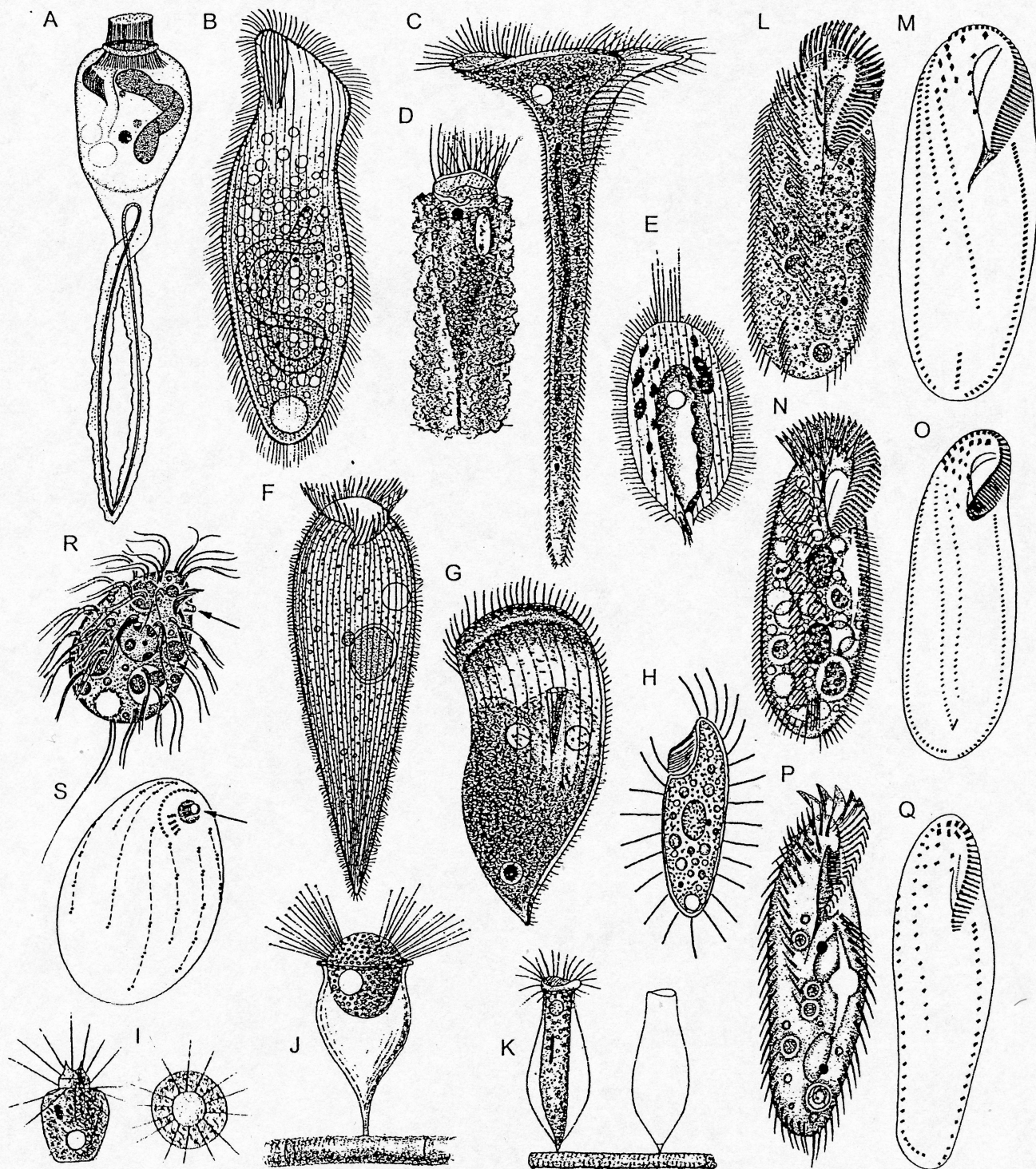
Soil ciliates

Diversity of ciliates is high in terrestrial habitats, with about 1000 species known worldwide (Foissner 1997a, 1998; Foissner et al. 2002). Ecologically, most soil ciliates live in the fresh and slightly decomposed litter layer, where abundances of up to 10,000 individuals per gram of dry mass of litter are reached. Ciliates are thus important primary decomposers and humus producers. In the humus horizon and in mineral soil where testate amoebae dominate, active ciliates are rare, although many cysts (dormant stages) are present. Most soil ciliates feed on bacteria (39%) or are predatory (34%) or omnivorous (20%). Some, however, are strictly mycophagous (fungal-feeding) and highly characteristic for terrestrial habitats; a few are anaerobic, providing a simple tool to assess the soil-oxygen regime (Foissner 1998, 1999). About 70% of soil ciliates are cosmopolitan, while others have a more or less restricted distribution (Foissner 2000).

In New Zealand, soil protozoa were studied mainly by John D. Stout, who worked through the 1950s–1980s in the New Zealand Soil Bureau of the former DSIR and was one of the leading soil protozoologists of this period, publishing important still-cited reviews (Stout & Heal 1967; Stout 1980; Stout et al. 1982). He was interested mainly in ecology, and thus his species lists are not as complete as taxonomists might wish. However, he was a careful worker and most of his identifications appear sound. Stout's species lists contain many unidentified taxa because he recognised – outstanding for that time – that soil and freshwater habitats have few species in common (Stout 1952) and many of the species he



Some conspicuous freshwater ciliates occurring both in New Zealand and in *Sphagnum* ponds in Germany. A: *Stentor coeruleus*. Bluish in life owing to minute cortical granules (see Checklist footnote [h]) (4 mm fully extended). B: *Loxophyllum meleagris*. Flattened and leaflike, it glides on the surface of organic debris and feeds on other protists. The macronucleus comprises a chain of nodules in the body midline (ca. 400 μm long). C: *Homalozoon vermiculare*, a vermiform, strongly contractile ciliate with the mouth at the convex anterior end, opening widely to ingest other ciliates. The macronucleus is composed of a chain of nodules in the body midline, with many contractile vacuoles along the body margin (1 mm when fully extended). D: *Cyclidium glaucoma*, a minute ciliate with comparatively long cilia. It feeds on bacteria digested in globular food vacuoles (30 μm). E: *Paramecium bursaria*, green in life owing to symbiotic green algae ('zoochlorellae') (100 μm). F: *Lembadion lucens*, with a large mouth occupying most of the ventral side (60 μm). G: *Caenomorpha medusula*, anaerobic, with a well-developed caudal spine (150 μm). H: *Blepharisma steinii*, red in life owing to cortical granules (150 μm).



Some remarkable marine (A), freshwater (B–K), and soil (L–S) ciliates originally described from New Zealand (lengths in micrometres). The pairs L–M, N–O, P–Q, R–S are shown before (left) and after silver impregnation, in ventral view except S (lateral). A: *Calipera longipes*, from gills of the striped clingfish *Tracheloschismus melobesia* (140 µm). B: *Cranotheridium taeniatum* (170 µm). C: *Stentor gracilis* (830 µm). D: *Tintinnidium emarginatum* (100 µm). E: *Lembadion lucens* (62 µm). F: *Meseres stentor* (130 µm). G: *Phascolodon elongatus* (130 µm). H: *Cyrtolophosis elongata* (30 µm). I: *Mesodinium phialinum*, lateral and apical views (18 µm). J: *Acineta elegans* on alga (100 µm). K: *Cothurina amphorella* on alga (70 µm). L, M: *Pseudouroleptus buitkampii*, a conspicuous hypotrichous ciliate with a unique cirral pattern, previously known only from an alpine pasture soil in Austria, later found at New Zealand site 8 (150 µm). N, O: *Orthoamphisiella grelli*, an inconspicuous hypotrichous ciliate previously known only from a soil in Antarctica, later found at New Zealand site 10 (80 µm). P, Q: *Keronopsis tasmaniensis*, a conspicuous hypotrichous ciliate with a unique cirral pattern, previously known only from soil in a Tasmanian hop field, later found at New Zealand site 9 (180 µm). R, S: *Pseudoplatyophrya saltans*, an inconspicuous cosmopolitan colpodide ciliate that feeds exclusively on fungal hyphae and spores, which are penetrated by a minute, highly complex feeding tube (arrows), as described by Foissner (1993) (15 µm).

From Laird 1953 (A); Schewiakoff 1892, 1893 (B, F, H); Maskell 1887, 1888 (C, E, G, I, K); Foissner 1982 (L, M); Eigner & Foissner 1993 (N, O); Blatterer & Foissner 1988 (P, Q); Foissner 1988 (R, S).

observed were probably undescribed. It was only 30 years later that this was fully acknowledged (Foissner 1987).

More recently, only Yeates et al. (1991), Yeates and Foissner (1995), and Foissner (1987, 1994) have worked on New Zealand soil protozoans.

Diversity and ecology of New Zealand soil ciliates

A total of 106 soil ciliate species, including one possibly undescribed species and five suctorians identified to genus level only, are presently recognised to occur in New Zealand. Most of them were recorded by J. D. Stout; 34 were new records from three samples W. Foissner investigated in 1987 and 1994 (site descriptions, see below). A diversity of 112 species is pretty low compared with the total number of described soil ciliates globally (almost 1000; Foissner 1998; Foissner et al. 2002) and their estimated actual diversity (up to 2000 species – Foissner 1997b). It is also low when compared with the rather high number of samples investigated by Stout (about 70 as calculated from Stout's papers; see References) because, for instance, two samples from the Murray River floodplain in Australia contained 110 species (Foissner 2000). Stout, being mainly an ecologist, left many species unidentified and used a rather ineffective culture method. Hence, the finding of 34 new records in only three samples indicates that further investigations will undoubtedly reveal many more species, described and undescribed.

None of the known New Zealand soil ciliates is endemic or was originally described from the region. However, some probably have a restricted Gondwanan distribution, namely *Keronopsis tasmaniensis*, discovered by Blatterer and Foissner (1988) in Tasmania, and *Orthoamphisiella grelli*, discovered by Eigner and Foissner (1993) on Gough Island, Antarctica. On the other hand, some species previously known only from the Holarctic (Foissner 1998) were rediscovered in the few samples studied from New Zealand, viz *Amphisiella quadrinucleata* and *Pseudouroleptus buitkampii*.

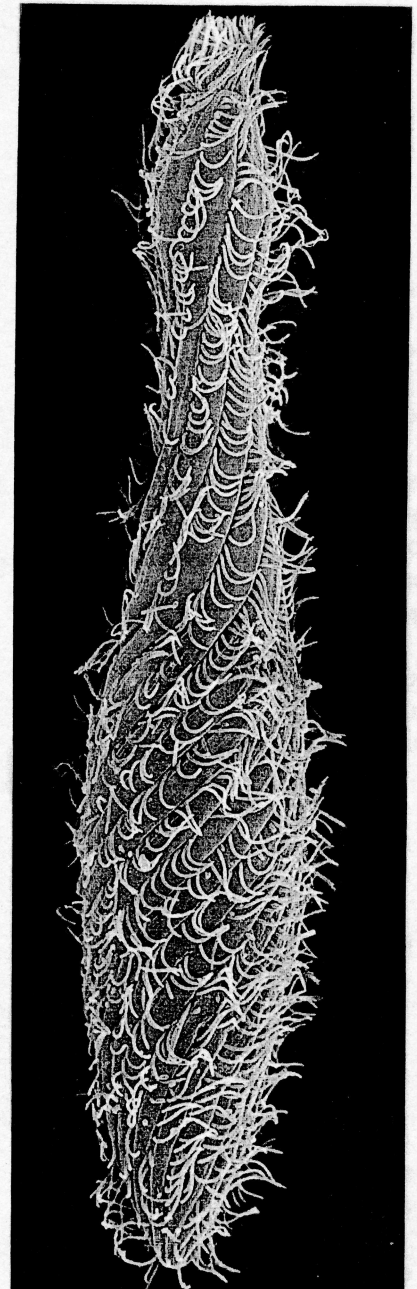
Knowledge about the ecology of New Zealand's soil ciliates is rather limited, although Stout's papers provide valuable insights. However, all data were obtained with highly selective culture methods. Thus, for instance, Stout never recognised the abundance of mycophagous ciliates in New Zealand soils (*Grossglockneria acuta*, *Mykophagophrys terricola*, *Pseudoplatyophrya nana*, and *P. saltans*). Generally, the community structure is very similar to that from other regions of the world (Foissner 1987, 1998), i.e. hypotrichous and colpodid species dominate. Species number per sample is also in the usual range (Foissner 1997a). However, a very humous sample from site 10 (see below), which contained many and rare testate amoebae (Meisterfeld pers. comm.), harboured only 32 ciliate species. Possibly many did not survive prolonged air-drying, as is the case with rain-forest species (Foissner 1997b).

Description of historical sampling sites and methods

The numbers accorded to sites sampled by J. D. Stout and W. Foissner refer to those given in the end-chapter checklist. Descriptions are brief, providing only the most important features. Unfortunately, Stout gave few details in some of his papers.

Site 1 (Stout 1958) comprised three tussock-grassland soils – Omarama soil near Alexandra, a fine sandy loam high in exchangeable bases and with a very high base saturation with reduced and senile tussock cover; Tekoa soil near Bealey, a silt loam of medium base status formerly covered by beech forest but now under tussock and introduced grasses; and Taupo soil near Waiouru, a sand silt of medium base status and with a vigorous plant cover of tussock and other grasses.

Site 2 (Stout 1960a) comprised litter and topsoil samples from the Wairouru and Broken River area – tussock grassland and an adjoining 18-year-old pasture; tussock grassland and an adjoining field which had been under crop cultivation



Lacrymaria olor (Litostomatea) is highly contractile, up to 1.2 millimetres long when fully extended, with the ciliary rows running meridionally. It lives in the organic mud of stagnant and running waters, feeding on

for two years; undisturbed native tussock grassland; an adjoining year-old pasture; and an adjoining crop field in its first year of cultivation.

Site 3 (Stout 1961) comprised litter and topsoil samples from lightly and heavily burnt areas of gorse (*Ulex europaeus*) and manuka (*Leptospermum scoparium*) on the Taita Experimental Station of the former New Zealand Soil Bureau that was at Lower Hutt, North Island.

Site 4 (Stout 1984), 4.5 kilometres southwest of Castlepoint, southeast North Island, was in hill country and received an annual rainfall of 1200 millimetres. The grassland area sampled was at the foot of a slope formed on colluvium dissected by a tributary of Ngakauau Stream. For most of the spring, summer and autumn the site is well drained and may become very dry during the summer and early autumn, but during winter the run-off from the adjacent slope is ponded, and water to a depth of several centimetres tends to lie over much of the site. Nine topsoil (up to 25 millimetres) samples from four adjacent pasture areas (*Lolium perenne*, *Trifolium repens*) were investigated.

Site 5 (Stout 1956a) protozoa from a 'flourishing beech litter culture' were cultivated in various media. Stout's paper also described experiments with freshwater protozoan communities.

Site 6 (Stout 1978; Cairns et al. 1978) comprised 0–10-centimetre topsoil samples from experimental soil cores of 10 very different (pH 4.7–6.6, percentage carbon 2.7–34.5) pastures in North Island. The test plots were irrigated with either tapwater or effluent from a biological sewage-treatment plant.

Site 7 pertains to the species mentioned in the papers by Stout (1955a) – an experimental study with three *Colpoda* species from soil of unknown origin); Stout (1955b) – greenhouse soil at Cawthron Institute; Stout (1962) – grassland soils and forest litter; and Yeates et al. (1991) – pasture at Silverstream (Lower Hutt), forest at Taita (Lower Hutt), and pasture and forest at Kaitoke (Upper Hutt). None of these papers contains full species lists.

Site 8 was at Mt Herbert, Banks Peninsula, about 900 metres above sea-level, comprising litter and topsoil (0–5 centimetres) from a tussock grassland, pH 6.0. A sample was collected on 23 December 1986 by Dr Wolfgang Petz (Salzburg University) and investigated by W. Foissner on 19 August 1987.

Site 9 was at Birdlings Flat, Gemstone Beach, Banks Peninsula, about 100 metres inland from the shore. The sample, which comprised roots and soil from grass tufts, pH 5.3, was collected on 28 December 1986 by Dr Wolfgang Petz (Salzburg University) and investigated by W. Foissner on 19 August 1987.

Site 10 was at the Orongorongo Vally research site (south Wairarapa, North Island). The three samples comprised humus litter (fresh and partially decayed with many fine roots) and topsoil (0–7 centimetres, pH 5.5) from a forest dominated by silver beech (*Nothofagus menziensis*) at about 800 metres above sea-level. They were collected in August 1994 by Peter Berben (Landcare Research) and investigated by W. Foissner on 13 October 1994.

Most such protozoa are not easily recognised among the innumerable soil particles and many are probably in a dormant (cyst) stage most of their lives. Thus, culture methods are required to make them visible. Stout used a simple technique for most of his investigations (Stout et al. 1982): 'The most convenient medium is a firm agar (2% of a good commercial agar) in a 10-cm petri dish. Add 10 g (wet wt) of soil to the surface of the agar on one side of the dish. Add 20 ml of sterile distilled water carefully to the other side. By keeping the soil to one side, the protozoa are able to migrate to the clear translucent part of the dish and can be observed directly under the microscope with a dry or water immersion lens. Distilled water enhances excystment [hatching], and the soil supplies the nutrients necessary for the bacteria, which grow as a film over the agar surface. Incubation temperature can be varied within limits. The most suitable temperature is from 15 to 20°C.'

Obviously, this is some kind of soil infusion and might explain why Stout, and others who used similar methods, never recognised the abundance of

mycophagous ciliates, because most soil fungi do not readily grow under submerged conditions.

Another technique was thus developed – the so-called ‘non-flooded petri dish method’ (Foissner 1987). Briefly, this simple method involves placing 10–50 grams of terrestrial material in a petri dish (10–15 centimetres in diameter) and saturating but not flooding it with distilled water. Such cultures are analysed for ciliates by inspecting about two millilitres of the run-off on days 2, 7, 14, 21, and 28. The non-flooded petri-dish method is selective, i.e. probably only a small proportion of the resting cysts present in a sample are reactivated and undescribed species or species with specialised demands are very likely undersampled (Foissner 1997a). Thus, the real number of species, described and undescribed, in the samples investigated is probably much higher. Unfortunately, a better method for broad analysis of soil ciliates is not known. However, about 800 new ciliate species have been discovered during the past 20 years using this simple technique (Foissner 1998).

Rumen and gut ciliates

An astonishing diversity of ciliate species inhabit the guts of herbivores. They live in a mutualistic relationship with their hosts and play an important role in the digestion of plant matter. Best known and most studied are those inhabiting the rumen and reticulum of ruminants. Ciliates are also found in the alimentary tract of a wide range of non-ruminant herbivores and omnivores including, for example, the stomach of camelids (pseudo-ruminants), hippopotamuses, capybara, and macropodid marsupials, and the colon of hindgut fermenters such as horses, tapirs, rhinoceroses, chimpanzees, gorillas, and elephants.

Reviews of the biology of rumen ciliates and their role in ruminant digestion have been provided by Clarke (1977), Williams and Coleman (1992), and Dehority (1993). Taxonomically, rumen ciliates fall into two groups, viz the orders Entodiniomorphida and Vestibuliferida (Lynn & Small 2000). Fourteen to eighteen genera and more than 250 entodiniomorph species have been described on morphological grounds, most of them from the rumen of various animals. Similarly, more than 100 species of vestibuliferids in about 18 genera have been recorded. Molecular techniques will undoubtedly affect the status and numbers of species. Recently, many endemic genera and species have been described from the alimentary tract of Australian marsupial herbivores (Cameron & O’Donoghue 2004).

Rumen ciliates live in highly complex relationships with each other, rumen bacteria, and their hosts. Although some are predatory on other ciliates, most are directly involved in the digestion of the same plant materials as the rumen bacteria with which they compete and which they also ingest. The ciliates can make up a large proportion of the microbial biomass in the rumen and contribute 50% or more of total microbial fermentation products. Nevertheless, defaunation experiments involving chemical removal of the ciliate fauna have shown that they are not essential for the survival and normal functioning of the host. Nor does their removal have a marked effect on animal growth and production because of compensatory increases in bacterial populations and activity in the rumen and increased hindgut digestion.

A substantial amount of research on the role of rumen ciliates in digestion, factors affecting their population dynamics, and their relationship to bloat in cattle has been carried out in New Zealand, notably between the mid-1960s and early 1980s. In the process, ciliates encountered were identified to genus or species level (see checklist). Thirty-five species belonging to eight entodiniomorph and four vestibuliferid genera were described from cattle (Clarke 1964), nine entodiniomorph species (but no vestibuliferids) were recorded from wild red deer (*Cervus elaphus*) (Clarke 1968), and four entodiniomorph genera were recorded from sheep (Clarke et al. 1982). Three of the species found in deer had also been found in cattle in New Zealand. Since that time little has been published on this subject and much remains to be discovered about the ciliate fauna of both

farmed and feral ruminants. However, with current concerns about the potential for rumen gases, particularly methane, to contribute to global warming, there is renewed interest in the role of rumen bacteria and ciliates in their production. The complexity and intimacy of the relationship between methanogenic bacteria (particularly archaeobacteria) and rumen ciliates has become increasingly evident in recent years. That a substantial proportion of the methane generated in the rumen is attributable to methanogenic bacteria living on the surface of or within rumen ciliates has been known for some time (Newbold et al. 1995; Tokura et al. 1999) and information is emerging on which particular bacterial-ciliate associations are most involved (e.g. Chagan et al. 2004; Ranilla et al. 2007). To add further to the complexity of these associations, there is also evidence for the horizontal transfer of genes, particularly those involved in metabolism, from rumen eubacteria and archaeobacteria to rumen ciliates (Ricard et al. 2006).

Much less has been published worldwide about the ciliates inhabiting the large intestine of herbivores or their significance to digestion. Some species found in the large intestine of ruminants have also been found in the rumen, while others have not. Those present in the large intestine of ruminants in New Zealand do not appear to have been identified. The ciliates of hindgut fermenters such as equids and elephants are generally distinct from those found in ruminants. Most of those described from horses, for example, belong to genera different from those found in ruminants. Nothing is known of those present in equids in New Zealand. There have been very few studies of the role of ciliates in digestion in equids or their interactions with hindgut bacterial and fungal populations. In one it was found that defaunation of ponies resulted in a small decrease in dry matter (but not cellulose) digestibility and an increase in fungal populations in the colon (but not the caecum); there was no effect on bacterial populations (Moore & Dehority 1993).

Balantidium coli is a common inhabitant of the large intestine of pigs worldwide. *Balantidium* organisms have also been recorded from a wide variety of other hosts including humans, other primates, horses, rodents, reptiles, birds, and some invertebrates. While some of these have been given species names, their relationships are not fully understood and many may prove to be synonyms (Levine 1985; Zaman 1993). It is widely considered that human infections are caused by *B. coli* and, in most cases, can be ascribed to direct or indirect contact with pigs. However, comparisons of the antigenicity and *in vitro* cultural characteristics of isolates from humans and other sources, and some epidemiological evidence, suggest this is an oversimplification (see review by Zaman 1993). The organisms are transmitted by means of the relatively resistant cyst stage which is passed in the faeces. Most infections are asymptomatic and the organisms remain within the gut lumen although they may be deep in the crypts of the mucosa. In some circumstances, most often in association with the high carbohydrate diet that encourages the build-up of *Balantidium* populations, organisms penetrate the mucosa and invade the submucosal tissues, causing damage and inflammation. Ulceration of the gut and clinical enteritis may result (Zaman 1993).

Balantidium coli is common in pigs in New Zealand, and sporadic disease cases occur (Anon 1980; Fairley 1996). Infections of calves have also been reported (Dewes 1959), although Levine (1985) suggests that *Balantidium* organisms recorded in ruminants may actually be *Buxtonella sulcata*. It appears that no *Balantidium* infections of humans have been recorded in New Zealand (Fairley 1996). Suspected *Balantidium* organisms have been observed histologically in ostriches (Hooper et al. 1999).

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Checklist of New Zealand Ciliophora

The list contains 308 ciliate species from the literature plus 34 new records of soil ciliates (marked by asterisks) from three samples (sites 8–10) investigated by W. Foissner in 1987 and 1994. Classification is based on Lynn and Small (2000) and Lynn (2003a,b). Abbreviations are as follows: E, endemic; F, freshwater; M, marine; T, terrestrial. Marine species (including parasitic species) are mainly those listed by Dawson (1992) for the Exclusive Economic Zone (EEZ).

For soil ciliates (T), the site number from where samples were collected [see Description of historical sampling sites and methods (in text)] is given after each entry; † signifies a doubtful record, i.e. a typical freshwater species not yet found by W. Foissner in terrestrial habitats; * signifies a new record for New Zealand from sites 8, 9, 10; • signifies a species described in detail by Stout (1954a,b, 1956a,b, 1960a).

Basically the checklist is non-annotated, that is, species are listed as given in the original publications and synonyms have been only partially removed, mainly in those groups for which detailed revisions are available. See Berger (1999), Foissner and Foissner (1988), Foissner (1993, 1998), Foissner and Leipe (1995), Foissner et al. (1991, 1992, 1994, 1995, 2002), Kahl (1930, 1931, 1932, 1935), and Kofoid and Campbell (1929) for names and dates of combining authors and literature. Nomenclature has also been adapted to these reviews. Usually, only taxa identified to species level have been included. Note also:

- (a) A junior synonym of *S. minus* Roux (1901) according to Foissner et al. (1992). Found by Stout (1978) in sewage-irrigated soil.
- (b) Very likely a senior synonym of *Acineria uncinata* Tuculesco according to Foissner et al. (1995).
- (c) The author of this species is not readily discoverable.
- (d) Likely misidentified *V. astyliiformis* [see Foissner et al. (1992) for detailed revision of this type of peritrich].
- (e) A misidentified species of the *Vorticella infusionum* complex (see Foissner et al. 1992), as evident from the figures in Stout (1954a), which show a horseshoe shaped macronucleus in the transverse axis of the cell.
- (f) Status uncertain.
- (g) Likely a misidentification as this is a freshwater species.
- (h) Kahl (1932) suggested synonymy with *S. coeruleus* (Pallas), but the large size (up to 3.125 mm) and the filiform posterior body half indicates that it could be a distinct, probably endemic, species because many observations have shown that *S. coeruleus* is smaller (up to 2.0 mm) and stouter (Foissner et al. 1992). However, Kreutz and Foissner (2006) have shown that the European *S. coeruleus* is indeed very similar to Maskell's species when observed under optimal conditions).

NEW ZEALAND INVENTORY OF BIODIVERSITY

KINGDOM CHROMISTA

SUBKINGDOM HAROSA

INFRAKINGDOM ALVEOLATA

PHYLUM CILIOPHORA

SUBPHYLUM POSTCILIODESMATOPHORA

Class KARYORELICTEA

Order LOXODIDA

LOXODIDAE

Loxodes rostrum (Müller, 1773) F

Class HETEROTRICHEA

Order HETEROTRICHIDA

BLEPHARISMIDAE

Blepharisma hyalinum Perty, 1849 F/T 1,3,9

Blepharisma lateritium (Ehrenberg, 1831) F/T 4

Blepharisma steini Kahl, 1932 F/T 1,3,5,6

FOLLICULINIDAE

?*Ascobius* sp. Gordon 1972 M

Echinofolliculina mortensenii Dons, 1935 M E?

cf. *Lagotia expansa* (Levinson, 1893) M

SPIROSTOMIDAE

Spirostomum ambiguum ambiguum (Müller, 1786) F

Spirostomum a. major Roux, 1909 F (f)

Spirostomum intermedium Kahl, 1932 F/T 6 (a)

STENTORIDAE

Stentor attenuatus Maskell, 1887 F (h)

Stentor gracilis Maskell, 1886 (? *S. roeseli*) F E?

Stentor multiformis (Müller, 1786)† F/T 3

Stentor polymorphus (Müller, 1773) F

Stentor roeseli Ehrenberg, 1835 F

Stentor striatus Maskell, 1886 (? *S. coerules*) F E?

Order LICNOPHORIDA

LICNOPHORIDAE

Licnophora setifera Maskell, 1886 F E? (very curious species)

SUBPHYLUM INTRAMACRONUCLEATA

Class SPIROTRICHEA

Subclass PHACODINIIDA

Order PHACODINIIDA

PHACODINIIDAE

Phacodinium metchnikoffi (Certes, 1891) T 3,5

Subclass HYPOTRICHIA

Order EUPLOTIDA

ASPIDISCIDAE

Aspidisca cicada (Müller, 1786) F (formerly *A. costata*)

Aspidisca lynceus (Müller, 1773) F

Aspidisca turrita (Ehrenberg, 1831) F

EUPLOTIDAE

Euplotes aedicularis (Pierson, 1943) F

Euplotes charon (Müller, 1786) F/M

Euplotes muscicola Kahl, 1932 F/T 3

Euplotes patella (Müller, 1773) F

Subclass CHOREOTRICHIA

Order TINTINNIDA

ASCAMPBELLIELLIDAE

Acanthostomella gracilis (Brandt, 1896) M

Acanthostomella minutissima Kofoid & Campbell, 1929 M

CODONELLIDAE

Codonella elongata Kofoid & Campbell, 1929 M

Codonella robusta Kofoid & Campbell, 1929 M

Tintinnopsis cylindrica Daday, 1887 M

Tintinnopsis laevigata Kofoid & Campbell, 1929 M

Tintinnopsis minuta Wailes, 1925 M

Tintinnopsis parvula Jörgensen, 1912 M

Tintinnopsis radix (Imhof, 1886) M

Tintinnopsis rapa Meunier, 1910 M

Tintinnopsis rotundata Jörgensen, 1899 M

Tintinnopsis sacculus Brandt, 1896 M

CODONELLOPSIDAE

Codonellopsis morchella Cleve, 1899 M

Luminella pacifica (Kofoid & Campbell, 1929) M

Stenosemella nivalis (Meunier, 1910) M

CYTAROCYLIDIDAE

Cyttarocyclus euecryphalus (Haeckel, 1887) M

Cyttarocyclus magna (Brandt, 1906) M

DICTYOCYSTIDAE

Dictyocysta dilatata (Brandt, 1906) M

Dictyocysta fenestrata Kofoid & Campbell, 1929 M

Dictyocysta lata Kofoid & Campbell, 1929 M

Dictyocysta reticulata Kofoid & Campbell, 1929 M

Dictyocysta tiara Haeckel, 1873 M

EPILOCYLIDIDAE

Epiplocyclus acuminata (Daday, 1887) M

Epiplocyclus blanda Jörgensen, 1924 M

Epiplocyclus inflata Kofoid & Campbell, 1929 M

Epiplocyclus lata Kofoid & Campbell, 1929 M

METACYCLIDIDAE

Climacocyclus scalaria (Brandt, 1906) M

Coxiella fasciata (Kofoid, 1905) M

Helicostomella kiliensis (Laackmann, 1906) M

PETALOTRICHIDAE

Petalotricha ampulla (Fol, 1881) M

Petalotricha serrata Kofoid & Campbell, 1929 M

RHABDONELLIDAE

Protorhabdonella curta (Cleve, 1901) M

Rhabdonella amor (Cleve, 1899) M

Rhabdonella torta Kofoid & Campbell, 1929) M

TINTINNIDAE

Amphorides brandtii (Jörgensen, 1924) M

Dadayiella ganymedes (Entz, 1884) M

Eutintinnus macilentus (Jörgensen, 1924) M

Eutintinnus rugosus (Kofoid & Campbell, 1929) M

Tintinnidium fluviatile (Stein, 1863) F

Tintinnidium emarginatum Maskell, 1888 F (? *T. semiciliatum* Sterki, 1879)

UNDELLIDAE

Proplectella fastigata (Jörgensen, 1924) M

XYSTONELLIDAE

Favella ehrenbergii (Claparède & Lachmann, 1858) M

Xystonella clavata Jörgensen, 1924 M

Xystonella treforti (Daday, 1887) M

Subclass STICHOTRICHIA

Order SPORADOTRICHIDA

AMPHISIELLIDAE

Amphisiella quadrinucleata Berger & Foissner, 1989* T 8

Orthoamphisiella grelli Eigner & Foissner, 1993* T 10

Pseudouroleptus buitkampii (Foissner, 1982)* T 8

Tetrastyla oblonga Schewiakoff, 1892 F E?

SPIROFILIDAE

Stichotricha remex (Hudson, 1875) F

Stichotricha secunda Perty, 1849 F

KAHLIELLIDAE

Engelmanniella mobilis (Engelmann, 1862) T 1,2,6

Kahliella simplex (Horvath, 1934) F/T

Psilotricha acuminata Stein, 1859 F

KERONIDAE

Kerona pediculus (Müller, 1773) F

Keronopsis tasmaniensis Blatterer & Foissner, 1988*

T 9

Keronopsis sp. (n. sp.?)* T 10

Paraholosticha lichenicola Gellért, 1955 T 2

Order SPORADOTRICHIDA

OXYTRICHIDAE

Cyrtohymena quadrinucleata (Dragesco & Njiné, 1971)* F/T 9

Gastrostyla steinii Engelmann, 1862 F/T

Histrio acuminatus Maskell, 1886 F E? (doubtful)

Onychodromus grandis Stein, 1859† F/T 5

Oxytricha fallax Stein, 1859† F/T 3,4,6,7

Oxytricha granulifera Foissner & Adam, 1983* T 9,10

Oxytricha minor (Maskell, 1887) F (as *Opisthotricha parallela* var. *minor*)

Oxytricha parallela Engelmann, 1862 F

Oxytricha setigera Stokes, 1891 F/T 1,3–6,9

Steinia platystoma (Ehrenberg, 1831) F

Sterkiella histriomuscorum-complex Foissner & Berger, 1999* F/T 9,10

Stylonychia mytilus (Müller, 1773) F/T 4

Stylonychia notophora Stokes, 1888 F

Stylonychia putrina Stokes, 1885 F

Tachysoma pelliellum (Müller, 1773)† F/T 1–5,7

Urosoma acuminata (Stokes, 1887)* F/T 8

Urosomoida agilisformis Foissner, 1982* F/T 9

TRACHELOSTYLIDAE

Gonostomum affine (Stein, 1859) F/T 1–6,8–10

Hemiscirra inquieta Hemberger, 1985* T 8

Order UROSTYLIDA

UROSTYLIDAE

Holosticha muscorum (Kahl, 1932) T 1–4,7

Uroleptus musculus (Kahl, 1932) F/T 2,3,6

Uroleptus piscis (Müller, 1773)† F/T 4,6

Subclass OLIGOTRICHIA

Order HALTERIIDA

HALTERIIDAE

Halteria chlorelligera Kahl, 1932 F

Halteria grandinella (Müller, 1773) F/T 1,3–6

Meseres cordiformis Schewiakoff, 1892 F E?

Meseres stentor Schewiakoff, 1892 F E?

STROBILIDIIDAE

Strobilidium adhaerens Schewiakoff, 1892 F

(? *S. gyrans*)

Order STROMBIDIIDA

STROMBIDIIDAE

Strombidium clapedi Kent, 1882 F (? *Strobilidium gyrans*)

Strombidium intermedium Maskell, 1887 F E?

(? *Strobilidium gyrans*)

Strombidium sulcatum Claparède & Lachmann, 1859 M

Order ODONTOSTOMATIDA

EPALXELLIDAE

Epalxella mirabilis (Roux, 1901) F

Class ARMOPHOREA

Order ARMOPHORIDA

METOPIDAE

Metopus es (Müller, 1776) F

Brachonella spiralis (Smith, 1897) F

CAENOMORPHIDAE

Caenomorpha medusula Perty, 1852 F

Order CLEVELANDELLIDA

NYCTOTHERIDAE

Nyctotherus cordiformis (Ehrenberg, 1838) F

Class LITOSTOMATEA

Subclass HAPTORIA

Order CYCLOTRICHIDA

MESODINIIDAE

Mesodinium phialinum Maskell, 1887 F E?

Myrionecta rubra (Lohmann, 1908) M

Order HAPTORIDA

DIDINIIDAE

Cyclotrichium meunieri Powers, 1932 M

ENCHELYIDAE

Haematophagus megapterae Woodcock & Lodge, 1920 M

HOMALOOZONIDAE

Homalozoon vermiculare (Stokes, 1887) F

LACRYMARIIDAE

Chueneca crassa Maskell, 1887 F E?
Lacrymaria olor (Müller, 1786)† F/T 1,3
Lacrymaria filiformis Maskell, 1886 F E? (as
Trachelocerca)
PSEUDOHOLOPHYRIDAE
Pseudoholophrya terricola Berger, Foissner & Adam,
 1984* T 9
SPATHIDIIDAE
Arcuospathidium atypicum (Wenzel, 1953)* T 10
Arcuospathidium muscorum (Dragesco & Dragesco-
 Kernéis, 1979)* T 8,9
Bryophyllum loxophylliforme Kahl, 1931 T 3
Cranotheridium taeniatum Schewiakoff, 1892 F E?
Epispathidium amphoriforme (Greeff, 1888) T 3
Epispathidium ascendens (Wenzel, 1955)* T 9
Epispathidium papilliferum (Kahl, 1930) T 3
Spathidium spathula (Müller, 1773) T 4
TRACHELIIDAE
Dileptus americanus Kahl, 1931 T 1
Dimacrocaryon amphileptoides (Kahl, 1931) T 3
Dileptus anguillula Kahl, 1931 T 1–3
Dileptus anser (Müller, 1773) F
Dileptus binucleatus Kahl, 1931 T 3
Dileptus conspicuus Kahl, 1931 T 3
Dileptus irregularis (Maskell, 1887) F E? (as
Amphileptus)
Dileptus margaritifer (Ehrenberg, 1838) F/T 4
Trachelius tracheloides (Maskell, 1887) F E? (as
Amphileptus)
Trachelius ovum (Ehrenberg, 1831) F (probably incl.
Amphileptus rotundus Maskell, 1887)
TRACHELOPHYLLIDAE
Trachelophyllum pusillum (Perty, 1852) F/T 4 (b)

Order **PLEUROSOTOMATIDA**
LITONOTIDAE
Acineria incurvata Dujardin, 1841 F
Amphileptus irregularis (Maskell, 1888) F E? (see
Trachelius ovum)
Litonotus fasciola (Müller, 1773) F
Litonotus muscorum (Kahl, 1931) T 3
Loxophyllum meleagris (Müller, 1773) F
Siroloxophyllum utriculariae (Penard, 1922)† F/T 1,2

Subclass **TRICHOSTOMATIA**
 Order **VESTIBULIFERIDA**
BALANTIDIIDAE
Balantidium coli (Malmsten, 1857) A T P
ISOTRICHIDAE
Dasytricha ruminantium Schuberg, 1888 A T P
Dasytricha sp. indet. Clarke et al. 1982 A T P
Isotricha intestinalis Stein, 1859 A T P
Isotricha prostoma Stein, 1859 A T P

Order **ENTODINIOMORPHIDA**
 Suborder **ARCHISTOMATINA**
BUETSCHLIIDAE
Buetschlia parva Schuberg, 1888 A T P

Suborder **BLEPHAROCORYTHINA**
BLEPHAROCORYTHIDAE
Charonina equi (Hsiung, 1930) A T P

Suborder **ENTODINIOMORPHINA**
OPHRYOSCOLECIDAE
Diplodinium anacanthum f. *anisacanthum* (Dogiel,
 1925) A T P
Diplodinium a. f. diacanthum (Dogiel, 1925) A T P
Diplodinium a. f. monacanthum (Dogiel, 1925) A T P
Diplodinium a. f. pentacanthum (Dogiel, 1925) A T P
Diplodinium a. f. tetracanthum (Dogiel, 1925) A T P
Diplodinium a. f. triacanthum (Dogiel, 1925) A T P
Diplodinium costatum Dogiel, 1925 A T P
Diplodinium dogieli Kofoid & MacLennan, 1932 A
 T P

Entodinium bicarinatum da Cunha, 1914 A T P
Entodinium biconcavum Kofoid & MacLennan, 1930
 A T P
Entodinium dilobum Dogiel, 1927 A T P
Entodinium dubardi Buisson, 1923 A T P
Entodinium indicum Kofoid & MacLennan, 1930
 A T P
Entodinium lobosopinosum Dogiel, 1927 A T P
Entodinium longinucleatum Dogiel, 1925 A T P
Entodinium nanellum Dogiel, 1922 A T P
Entodinium ovinum Dogiel, 1927 A T P
Entodinium rostratum Fiorentini, 1889 A T P
Entodinium sp. indet. Clarke et al. 1982 A T P
Eodinium bilobosum (Dogiel, 1927) A T P
Eodinium lobatum Kofoid & MacLennan, 1932 A
 T P
Eodinium posteroovesiculatum (Dogiel, 1927) A T P
Eodinium caudatum (Fiorentini, 1889) A T P
Epidinium ecaudatum (Fiorentini, 1889) A T P
Epidinium e. f. bicaudatum Dogiel 1927 A T P
Epidinium e. f. parvicaudatum Dogiel, 1927 A T P
Epidinium e. f. quadricaudatum Dogiel, 1927 A T P
Epidinium e. f. tricaudatum Dogiel, 1927 A T P
Epidinium sp. indet. Clarke et al. 1982 A T P
Eremoplastron bovis (Dogiel, 1927) A T P
Eremoplastron brevispinum Kofoid & MacLennan,
 1932 A T P
Eremoplastron monolobum (Dogiel, 1927) A T P
Eremoplastron rostratum (Fiorentini, 1889) A T P
Eudiplodinium maggii (Fiorentini, 1889) A T P
Eudiplodinium sp. indet. Clarke et al. 1982 A T P
Metadinium medium Awerinzew & Mutafova, 1914
 A T P
Metadinium tauricum (Dogiel & Federowa, 1925)
 A T P
Ostracodinium dilobum Dogiel, 1927 A T P
Ostracodinium mammosum (Railliet, 1890) A T P
Ostracodinium rugoloricatum Kofoid & MacLennan,
 1932 A T P

Class **PHYLOPHARYNGEA**
 Subclass **PHYLOPHARYNGIA**
 Order **CHLAMYDODONTIDA**
CHILODONELLIDAE
Chilodonella uncinata (Ehrenberg, 1838) F/T 4
Odontochlamys gouraudi Certes, 1891 F/T 1–4,6
Odontochlamys wisconsinensis (Kahl, 1931) T 3
Phascolodon elongatus Maskell, 1887 F E?
Trithigmostoma bavariensis (Kahl, 1931) T 1
Trithigmostoma cucullulus (Müller, 1786)† F/T 3,4
GASTRONAUTIDAE
Gastronauta membranaceus Bütschli, 1889 F/T 1,3,6
Dysteria astyla (Maskell, 1887) F E? (as *Aegyria*)
Dysteria distyla (Maskell, 1887) F E? (as *Aegyria*)

Subclass **SUCTORIDA**
 Order **EXOGENIDA**
EPHELOTIDAE
Ephelota gemmipara (Hertwig, 1876) M
OPHRYODENDRIDAE
Ophryodendron macquariae Johnston, 1938 M
PARACINETIDAE
Paracinetia crenata f. *pachytheca* Collin, 1912 M
Paracinetia limbata f. *convexa* Dons, 1921 M
PODOPHYRIDAE
Podophrya fixa (Müller, 1786) F
Sphaerophrya magna Maupas, 1881† F/T 4
Sphaerophrya terricola Foissner, 1986* T 8
METACINETIDAE
Metacinetia angularis (Maskell, 1888) F E? (as *Acinetia*)
Metacinetia mystacina (Ehrenberg, 1831) F

Order **ENDOGENIDA**
ENDOSPHERIDAE
Endosphaera engelmanni Entz, 1896 F/M

ACINETIDAE
Acinetia elegans Maskell, 1886 F E?
Acinetia flos Maskell, 1887 F E?
Acinetia lasanicola Maskell, 1887 F E?
Acinetia simplex Maskell, 1887 F E?
Acinetia speciosa Maskell, 1887 F E?
Acinetia tulipa Maskell, 1887 F E?
Trematosoma complanata (Gruber, 1884) F
TRICHOPHYRIDAE
Trichophrya epistylidis Claparède & Lachmann,
 1859 F

Class **NASSOPHOREA**
 Order **SYNHYMENIDA**
SCAPHIDIODONTIDAE
Chilodontopsis muscorum Kahl, 1931 T 3

Order **NASSULIDA**
NASSULIDAE
Nassula ambigua tumida Maskell, 1887 F E? † T 3

Order **MICROTHORACIDA**
MICROTHORACIDAE
Drepanomonas pauciciliata Foissner, 1987* T 8
Drepanomonas revoluta Penard, 1922 F/T 3,4,6
Drepanomonas sphagni Kahl, 1931 F/T 3,6
Leptopharynx costatus Mermod, 1914 F/T 1–10
Microthorax simulans (Kahl, 1926) T 3,4,10

Class **COLPODEA**
 Order **BRYOMETOPIDA**
BRYOMETOPIDAE
Bryometopus pseudochilodon Kahl, 1932 T 1–3,5
KREYELLIDAE
Kreyella muscicola Kahl, 1931 T 1–3,6
TECTOHYMENIDAE
Pseudokreyella terricola Foissner, 1985* T 10

Order **BRYOPHYRIDA**
BRYOPHYRIDAE
Bryophrya bavariensis (Kahl, 1931) T 4
Parabryophrya penardi (Kahl, 1931)* T 9

Order **BURSARIOMORPHIDA**
BURSARIIDAE
Bursaria truncatella Müller, 1773 F/T

Order **COLPODIDA**
COLPODIDAE
Bresslauer vorax Kahl, 1931 • T 3,4,6
Colpoda aspera Kahl, 1926* T 8
Colpoda cucullus (Müller, 1773) F/T 1–7,8
Colpoda hemneguyi Fabre-Domergue, 1889* T 10
Colpoda inflata (Stokes, 1884) T 1–10
Colpoda lucida Greeff, 1888* T 8,10
Colpoda magna (Gruber, 1879) F/T 3
Colpoda maupasi Enriques, 1908 F/T 3,8–10
Colpoda steinii Maupas, 1883 F/T 1–10
Tillina enormis Maskell, 1886 F E? (? *Ophryoglena*)
Tillina inequalis Maskell, 1886 F E?
MARYNIDAE
Mycterothrix tuamotuensis (Balbiani, 1887) T 3
GROSSGLOCKNERIDAE
Grossglockneria acuta Foissner, 1980* T 8,10
Mykophagophrys terricola (Foissner, 1985)* T 8–10
Nivaliella plana Foissner, 1980* T 8–10
Pseudoplatyophrya nana (Kahl, 1926)* T 8–10
Pseudoplatyophrya saltans Foissner, 1988* T 8–10

Order **CYRTOLOPHOSIDIDA**
CYRTOLOPHOSIDIDAE
Cyrtolophosis elongata (Schewiakoff, 1892)* F/T 8,9
Cyrtolophosis mucicola Stokes, 1885 F/T 1,3–7,10
Pseudocyrtolophosis alpestris Foissner, 1980* T 9,10
PLATYOPHYRIDAE

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Platyophrya macrostoma Foissner, 1980* T 8
Platyophrya spumacola Kahl, 1927* T 10
Platyophrya vorax Kahl, 1926 F/T 7,10

COLPODEA INCERTAE SEDIS

Pseudoglaucoma muscorum (Kahl, 1931) T 1-3,6

Class PROSTOMATEA Order PRORODONTIDA

COLEPIDAE
Coleps elongatus Ehrenberg, 1830 F
Coleps hirtus (Müller, 1786) F
PLAGIOPHYLIDAE
Urotricha globosa Schewiakoff, 1892 F
HOLOPHRYIDAE
Holophrya discolor Ehrenberg, 1833 F
Holophrya teres (Ehrenberg, 1833) F
PRORODONTIDAE
Prorodon microstoma Stout, 1954 F E?
Prorodon sulcatus Maskell, 1886 F E?

PROSTOMATEA INCERTAE SEDIS

Cryptocaryon irritans Brown, 1951 M

Class OLIGOHYMENOPHOREA

Subclass PENICULIA
Order PENICULIDA
Suborder FRONTONIINA
FRONTONIIDAE
Frontonia depressa (Stokes, 1886) • T 1,3-5,10
Frontonia fusca (Quennerstedt, 1869) M

Suborder PARAMECIINA

PARAMECIIDAE
Paramecium aurelia-complex (Müller, 1773) F
Paramecium bursaria (Ehrenberg, 1831) F
Paramecium caudatum Ehrenberg, 1833 F
Paramecium trichium Stokes, 1885 F
LEMBADIONIDAE
Lembadion bullinum (Müller, 1786) F
Lembadion lucens (Maskell, 1887) F (as *Thurophora*)
UROCENTRIDAE
Urocentrum turbo (Müller, 1786) F

Subclass SCUTICOCILIATIA

Order PHILASTERIDA
CINETOCHILIDAE
Cinetochilum margaritaceum (Ehrenberg, 1830) F/T 1,3,4,6,7
Sathrophilus muscorum (Kahl, 1931) • T 1-4,6,9
ORCHITOPHYRIDAE
Paranophrys elongata (Biggar & Wenrich, 1932) M
PSEUDOCOHNILEMBIDAE
Pseudocohnilembus pusillus (Quennerstedt, 1869) F/T 4
URONEMATIDAE
Homalogastra setosa Kahl, 1926 T 1-4,6
Uronema marinum Dujardin, 1841 M

INCERTAE SEDIS

Kahlilembus fusiformis (Kahl, 1926) F/T 1-3,7

Order PLEURONEMATIDA

CTEDOCTEMATIDAE
Ctedoctema acanthocryptum Stokes, 1884 F
CYCLIDIIDAE
Cyclidium brandoni Kahl, 1931 F E? (*Pleuronema cyclidium* Maskell, 1886)
Cyclidium glaucoma Müller, 1773 F/T 5-7
Cyclidium muscicola Kahl, 1931 T 1-3,7,10
Pleuronema coronatum Kent, 1881 F/M
Pleuronema crassum Dujardin 1841 F

Subclass HYMENOSTOMATIA

Order HYMENOSTOMATIDA
Suborder TETRAHYMENINA
TETRAHYMENIDAE
Tetrahymena pyriformis-complex Ehrenberg, 1830† F/T 3,6

Tetrahymena rostrata (Kahl, 1926) • F/T 1-4

SPIROZONIDAE

Stegochilum fusiforme Schewiakoff, 1892 F

TURANIELLIDAE

Colpidium colpoda (Losana, 1829) F
Colpidium striatum Stokes, 1886 F
Dexiostoma campylum (Stokes, 1886) F
GLAUCOMIDAE
Glaucoma colpidium Schewiakoff, 1892 F
Glaucoma scintillans Ehrenberg, 1830 F
OPHRYOGLENIDAE
Ophryoglena flava (Ehrenberg, 1833) F

Suborder OPHRYOGLENINA

OPHRYOGLENIDAE
Ophryoglena flava (Ehrenberg, 1833) F
ICHTHYOPHTHIRIIDAE
Ichthyophthirius multifiliis Fouquet, 1876 F/M

Subclass PERITRICHIA

Order SESSILIDA
ELLOBIOPHYRIDAE
Caliperia longipes Laird, 1953 M E?
SCYPHIDIIDAE
Scyphidia (Gerda) *acanthocini* Laird, 1953 M E?
EPISTYLIDIDAE
Campanella flavicans (Ehrenberg, 1831) F
Epistylis anastatica (Linnaeus, 1767) F
Epistylis leucoa Ehrenberg, 1838 F
Pyxicola cothurnioides Kent, 1880 F
Pyxicola pyxidiformis (D'Udekem, 1862) F
LAGENOPHYRIDAE
Lagenophrys cochinchinensis Santhakumari & Gopalan, 1980 M A
OPERCULARIIDAE
Opercularia cylindrata Wrzesniowski, 1870 F
Opercularia frondicola Precht, 1936 F/T 3 (c)
Opercularia nutans (Ehrenberg, 1831) F

Opercularia parallela Maskell, 1886 F E?

VAGINICOLIDAE

Cothurnia compressa f. *ovata* Dons, 1921 M
Cothurnia curvula Entz, 1884 M
Cothurnia grandis Perty, 1852 M (g)
Cothurnia maritima nodosa (Claparède & Lachmann, 1858) M
Cothurnia patellae Hutton, 1878 M E?
Cothurnia valvata (Stokes, 1893) F
Platycola decumbens (Ehrenberg, 1830) F
Platycola d. intermedia Maskell, 1887 F E?
Platycola donsi Kahl, 1933 M E?
Platycola longicollis Kent, 1881 F
Thuricola valvata (Wright, 1858) F
Vaginicola amphorella (Maskell, 1887) F E?
Vaginicola crystallina Ehrenberg, 1830 F
Vaginicola elongata (Fromentel, 1874) F
Vaginicola parallela (Maskell, 1887) F E?
VORTICELLIDAE

Carchesium polypinum (Linnaeus, 1758) F
Vorticella annularis Müller, 1773 F
Vorticella aperta Fromentel, 1876 F
Vorticella astyliformis Foissner, 1981* T 9,10
Vorticella brevistyla D'Udekem, 1864 F
Vorticella campanula Ehrenberg, 1831 F
Vorticella citrina Müller, 1773 F
Vorticella conoallaria (Linnaeus, 1758) F/T 6
Vorticella cratera Kent, 1881 F
Vorticella elongata Fromentel, 1876 F
Vorticella longifilum Kent, 1881 F
Vorticella marina Greeff, 1870 M
Vorticella microstoma Ehrenberg, 1830 • F/M/T 6 (e)
Vorticella mortenseni Dons, 1921 M
Vorticella nebulifera Müller, 1773 M
Vorticella n. similis Noland & Finley, 1931 F
Vorticella oblonga Kirk, 1886 M E?
Vorticella patellina Müller, 1776 F
Vorticella striata Dujardin, 1841 F/T 2,3-7 (d)
Vorticella s. octava Stokes, 1885 F/T 6 (d)
Vorticella zealandica Kirk, 1887 F E?
ZOOHAMNIIDAE
Zoothamnium affine granulatum Maskell, 1886 F E?
Zoothamnium cienkowski Wrzesniowski, 1877 M
Zoothamnium limpidum Maskell, 1887 F E?
ASTYLOZOONIDAE
Astylozoon pyriformis Schewiakoff, 1892 F E?

Order MOBILIDA

TRICHODINIDAE

Trichodina multidentis Laird, 1953 M E?
Trichodina parabanchiola Laird, 1953 M E?
URCEOLARIIDAE
Urceolaria gaimardiae Johnston, 1938 M E?

Class PLAGIOPYLEA

Order PLAGIOPYLIDA

PLAGIOPYLIDAE

Plagiopyla varians Maskell, 1887 F E?