Journal of Species Research 10(3):301-320, 2021

New record of 21 ciliate species (Protozoa, Ciliophora) from South Korea

Atef Omar[1,2] and Jae-Ho Jung[3,*]

[1]*Natural Science Research Institute, Gangneung-Wonju National University, Gangneung 25457, Republic of Korea*
[2]*Department of Zoology, Al Azhar University, Assiut, Egypt*
[3]*Department of Biology, Gangneung-Wonju National University, Gangneung 25457, Republic of Korea*

**Correspondent: jhjung@gwnu.ac.kr*

During a field survey of indigenous Korean ciliates, we collected 21 unrecorded species from aquatic (freshwater and brackish water [salinity about 1.0‰] samples) and terrestrial (moss and soil samples) habitats. The morphology of these species was studied based on live observation, protargol, silver carbonate and silver nitrate impregnation, and scanning electron microscope. These species belong to seven classes as follows: 1) class Heterotrichea - *Blepharisma seculum*; 2) class Spirotrichea - *Birojimia terricola*, *Bistichella variabilis*, *Deviata bacilliformis*, *Oxytricha paragranulifera*, *Parabistichella* cf. *variabilis*, *Steinia sphagnicola*, *Stichotricha aculeata*, *Stylonychia* cf. *notophora*, and *Tetmemena bifaria minima*; 3) class Armophorea - *Metopus es*; 4) class Litostomatea - *Acropisthium mutabile*, *Pseudomonilicaryon japonicum*, and *Rimaleptus alpinus*; 5) class Phyllopharyngea - *Podophrya bivacuolata*; 6) class Nassophorea - *Drepanomonas pauciciliata*; and 7) class Oligohymenophorea - *Dexiostoma campylum*, *Frontonia atra*, *Histiobalantium natans viridis*, *Opisthonecta minima*, and *Tetrahymena rostrata*. Here, we provide a brief diagnosis and remark for each species.

Keywords: biodiversity, estuary, moss, redescription, silver impregnation, soil

© 2021 National Institute of Biological Resources
DOI:10.12651/JSR.2021.10.3.301

Introduction

The phylum Ciliophora Doflein, 1901 is one of the most diverse protistan phyla in aquatic and terrestrial habitats (Finlay *et al*., 1996; 2004; Foissner *et al*., 2008; Lynn, 2008; Agatha, 2011; Foissner, 2016; Warren *et al*., 2017). Korean habitats show high ciliate diversity, with about 500 recorded species in the last few decades (Jung *et al*., 2017; Kwon *et al*., 2019). During 2019 and 2020, we collected many unrecorded ciliate species from freshwater, estuaries, mosses, and soil. In the present study, we provide a brief redescription, remarks, and photomicrographs for 21, newly recorded, ciliate species from Korea. The 21 species belong to 15 families, 12 orders, and seven classes. The familial classification of the species *Bistichella variabilis* and *Parabistichella variabilis* are considered incertae sedis and *B. variabilis* He and Xu, 2011 is awaiting to be transferred to the genus *Parabistichella* because of the presence of transverse cirri, a key feature for the genus *Parabistichella* (Foissner, 2016; Kim *et al*., 2019).

Materials and Methods

The ciliate species were collected from terrestrial soil, mosses, freshwater, and brackish water in Korea. The collection locality and date are described in the 'Material examined' section of each species. The aquatic samples were collected and immediately transferred to the laboratory. The soil and moss samples were air-dried for at least two weeks and rewetted using the non-flooded Petri dish method (Foissner *et al*., 2002). The raw cultures of aquatic samples were set up with two or three rice grains at room temperature (about 20°C). Morphology was observed using a stereomicroscope (Olympus SZ11, Japan), an optical microscope (Olympus BX53) at low (×40–200) to high (×400–1000) magnifications, and captured using a digital camera (Olympus DP74). Protargol powder was synthesized using the method of Pan *et al*. (2013). The permanent slides were prepared using the protargol impregnation method of the 'procedure A' and/or the 'wet' silver nitrate method (Foissner, 2014). The scanning electron microscopy technique was conducted

following Foissner (2014) and Moon *et al.* (2019). The differential through-focal images of the protargol-impregnated specimens were merged using the software of Helicon Focus 6.8.0 (HeliconSoft Ltd, Ukraine). The basic terminology and taxonomic classification follow Lynn (2008). The specific terminology of each taxon follows the previous studies.

Results and Discussion

Phylum Ciliophora Doflein, 1901
Subphylum Postciliodesmatophora Gerassimova and Seravin, 1976
Class Heterotrichea Stein, 1859
Order Heterotrichida Stein, 1859
Family Blepharismidae Jankowski in Small and Lynn, 1985
Genus *Blepharisma* Perty, 1849

1. *Blepharisma seculum* Isquith *et al.*, 1965 (Fig. 1)

Material examined. Terrestrial moss collected from Mungyeong Saejae Provincial Park, Mungyeong-si, Gyeongsangbuk-do, Korea (36°45′57″N, 128°4′29″E) on 29 March 2020.
Diagnosis. Body size 60−85 × 18−25 μm after protargol impregnation (n = 5); body fusiform with tapered anterior end and broad and rounded posterior end; macronucleus ellipsoidal with 1−4 micronuclei attached to it; cortical granules pale pink *in vivo*; adoral zone of membranelles occupies more than half of body length and composed of 28−30 membranelles; on average 14 somatic kineties.
Distribution. USA and Korea.
Remarks. *Blepharisma seculum* can be distinguished from other congeners by the pale pink color of the cortical granules. However, it is most similar to *B. lateritium* (Ehrenberg, 1831) Stein, 1859 in body size but differs significantly in the number of somatic ciliary rows (~14 vs. 35−46), the number of adoral membranelles (28−30 vs. 70−88), and the color of the cortical granules (pale pink vs. red). It is also similar to *B. bimicronucleatum* Villeneuve-Brachon, 1940 and *B. hyalinum* Ruinen, 1938 in body size (60−85 vs. 60−110 and 60−100 μm, respectively). *Blepharisma seculum* is also similar to *B. bimicronucleatum* in the color of cortical granules but differs mainly in having ~14 (vs. 18−23) somatic kineties and 28−30 (vs. 35−40) adoral membranelles. Also, *B. seculum* differs from *B. hyalinum* in the color of cortical granules (pale pink vs. colorless) (Foissner, 1980; 1989; Isquith *et al.*, 1965; Pan and Stoeck, 2017).
Voucher slides. One slide with protargol-impregnated specimens was deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20104).



Fig. 1. Photomicrographs of *Blepharisma seculum* after protargol impregnation. A, B. Ventral (A) and dorsal (B) view showing the body shape, the adoral zone of membranelles, and the nuclear apparatus. AZM, adoral zone of membranelles; MA, macronucleus; MI, micronucleus. Scale bars = 20 μm.

Subphylum Intramacronucleata Lynn, 1996
Class Spirotrichea Bütschli, 1889
Subclass Stichotrichia Small and Lynn, 1985
Order Urostylida Jankowski, 1979
Family Urostylidae Butschli, 1889
Genus *Birojimia* Berger and Foissner, 1989

2. *Birojimia terricola* Berger and Foissner, 1989 (Fig. 2)

Material examined. Terrestrial soil sample collected from a footpath behind Gangneung-Wonju National University, Gangneung, Korea (37°46′30.4″N, 128°51′46.2″E) on 3 January 2020.
Diagnosis. Body size about 145 × 30 μm after protargol impregnation (n = 6); body elongate ellipsoid; many macronuclear nodules and several micronuclei; cortical granules within and between dorsal kineties, colorless, impregnated with protargol; adoral zone of membranelles covered about 30−35% of cell length with about 25 membranelles; 4 right and 1 left marginal row; 3 frontal, 1 buccal cirrus, about 12 midventral pairs, 2 pretransverse, and 4 transverse cirri; 6 dorsal kineties and 4 or 5 caudal cirri.
Distribution. Brazil, Japan, Venezuela, and Korea.
Remarks. The genus *Birojimia* comprises three species:

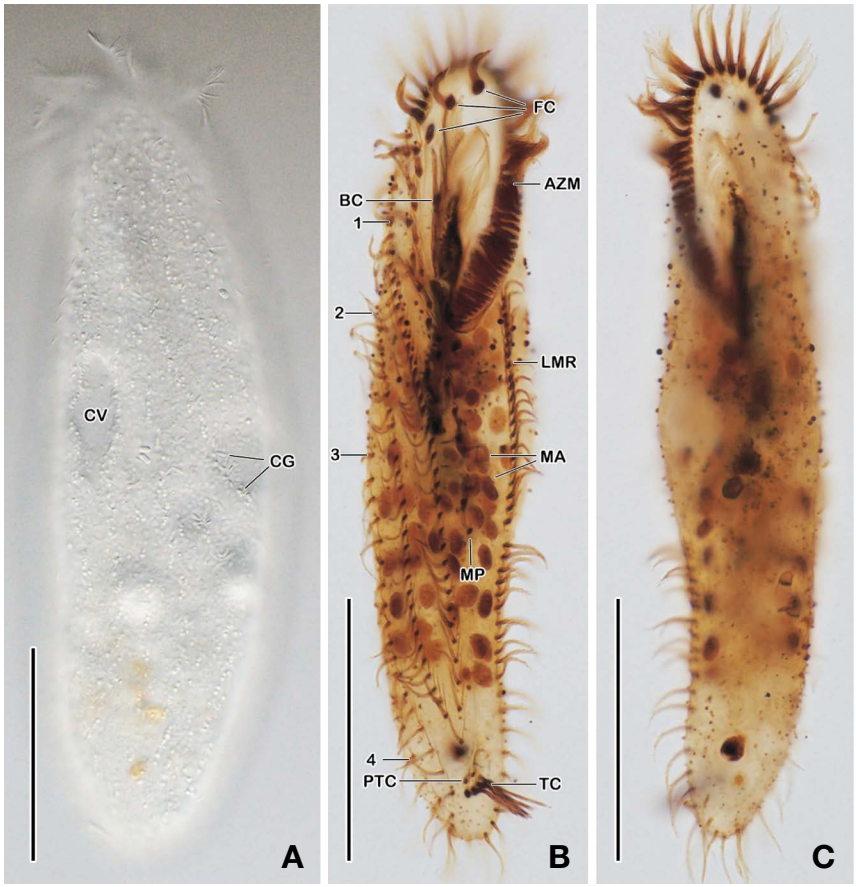

Fig. 2. Photomicrographs of *Birojimia terricola* from life (A) and after protargol impregnation (B, C). A. Dorsal view showing the body shape, and the arrangement of the cortical granules. B, C. Ventral (B) and dorsal (C) view showing the ciliature, and the nuclear apparatus. 1–4, right marginal rows; AZM, adoral zone of membranelles; BC, buccal cirrus; CG, cortical granules; CV, contractile vacuole; FC, frontal cirri; LMR, left marginal row; MA, macronuclei; MP, midventral pairs; PTC, pretransverse cirri; TC, transverse cirri. Scale bars = 50 μm.

Birojimia terricola Berger and Foissner, 1989 (type species); *Birojimia litoralis* Foissner, 2016; and *Birojimia soyaensis* Kim *et al*., 2016. The Korean population of *Birojimia terricola* corresponds well with the type of *B. terricola* from Japan (Berger and Foissner, 1989). All populations described are very similar and differ only in few overlapping morphometric data (Foissner, 2016). This species is also most similar to *B. soyaensis*, which was characterized by having small and spherical cortical granules based on a surface view and a higher number of caudal cirri (Kim *et al*., 2016). However, we cannot exclude the conspecificity of *B. soyaensis* and *B. terricola* because the cortical granules of *B. soyaensis* have the same size and shape as those of *B. terricola* when seen on the cell margin. Also, both have similar number of caudal cirri when including the posterior few cirri of the compound rows 5 and 6 in the original description of Berger and Foissner (1989).

Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20105, NNIBRPR20106).

Order Stichotrichida Fauré-Fremiet, 1961
Genus *Bistichella* Berger, 2008.

3. *Bistichella variabilis* He and Xu, 2011 (Fig. 3)

Material examined. Terrestrial soil sample collected from a footpath behind Gangneung-Wonju National University, Gangneung, Korea (37°46′30.4″N, 128°51′46.2″E) on 3 January 2020.

Diagnosis. Body size about 155 × 40 μm after protargol impregnation (n = 5); body elongate; 4 macronuclear nodules and 4 or 5 micronuclei; adoral zone of membranelles covered about 25% of cell length with about 36 membranelles; 1 right and 1 left marginal row with 48 cirri each on average, right marginal row commences on dorsal side; 3 frontal, about 6 buccal, frontoventral rows III–VI composed of 1–3, 5 or 6, 33–41, 6–10 cirri each, and

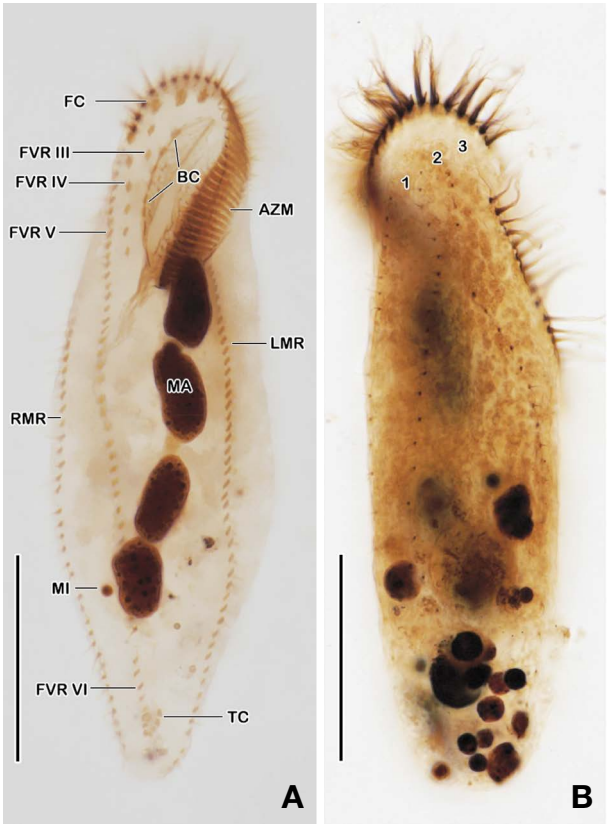

Fig. 3. Photomicrographs of *Bistichella variabilis* after protargol impregnation (A, B). A, B. Ventral (A) and dorsal (B) view showing the body shape, somatic and oral ciliature, and nuclear apparatus. 1–3, dorsal kineties; AZM, adoral zone of membranelles; BC, buccal cirri; FC, frontal cirri; FVR III–VI, frontoventral rows; LMR, left marginal row; MA, macronucleus; MI, micronucleus; RMR, right marginal row; TC, transverse cirri. Scale bars = 30 μm.

5 transverse cirri; 3 dorsal kineties.

Distribution. China and Korea.

Remarks. The Korean population of *Bistichella variabilis* agrees with the type population described by He and Xu (2011), but has a smaller body size and less number of cirri. This species was missed by Foissner (2016), who improved the generic diagnosis of the genus *Parabistichella* Jiang *et al*., 2013. This species is awaiting to be transferred to the genus *Parabistichella* because of the presence of the transverse cirri, which is a characteristic of the genus *Parabistichella*.

Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20107, NNIBRPR20108).

Genus *Parabistichella* Jiang *et al*., 2013.

4. *Parabistichella* cf. *variabilis* Jiang *et al*., 2013 (Fig. 4)

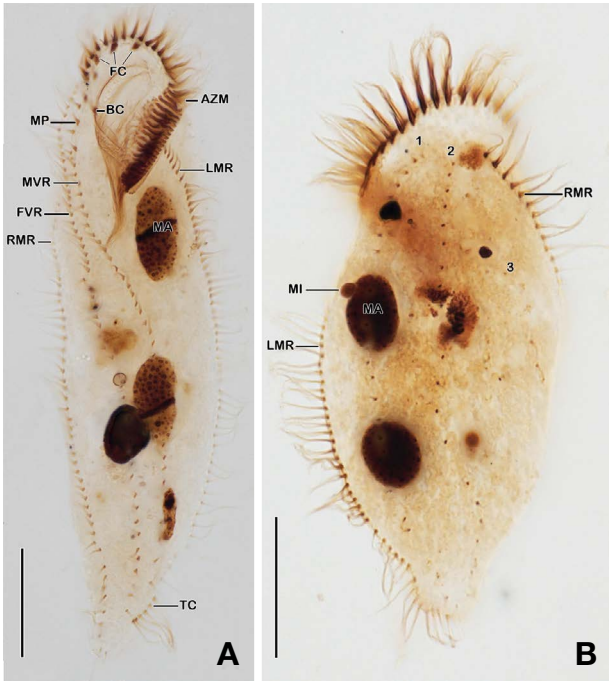

Fig. 4. Photomicrograph of *Parabistichella* cf. *variabilis* after protargol impregnation. A. Ventral side showing the body shape, the somatic ciliature, the oral ciliature, and nuclear apparatus. B. Dorsal side showing the three dorsal kineties and the right marginal row commencing on the dorsal side. 1–3, dorsal kineties; AZM, adoral zone of membranelles; BC, buccal cirrus; FC, frontal cirri; FVR, frontoventral row; LMR, left marginal row; MA, macronucleus; MI, micronucleus; MP, midventral pairs; MVR, midventral row; RMR, right marginal row; TC, transverse cirri. Scale bars = 30 μm.

Material examined. Terrestrial soil sample collected from a footpath behind Gangneung-Wonju National University, Gangneung, Korea (37°46′30.4″N, 128°51′46.2″E) on 3 January 2020.

Diagnosis. Body size 97–142 × 35–40 μm after protargol impregnation (n = 5); body elongate, 2 macronuclear nodules and about 3 micronuclei; adoral zone of membranelles covered about 26–31% of cell length with about 33–36 membranelles; right and left marginal row with about 41–59 and 51–55 cirri, respectively, right marginal row commences on dorsal side; 3 frontal, 1 buccal cirrus, about 4 midventral pairs, midventral row composed of 28–31 cirri, frontoventral row of 39–46 cirri on average, and 6 or 7 transverse cirri; 3 dorsal kineties.

Distribution. China and Korea.

Remarks. The Korean population of *Parabistichella variabilis* agrees with the type population in most features (Jiang *et al*., 2013). However, the only differences between the two populations are the non-overlapping body size (97–142 vs. 167–268 μm after protargol impregnation) and the number of the adoral membranelles (33–36

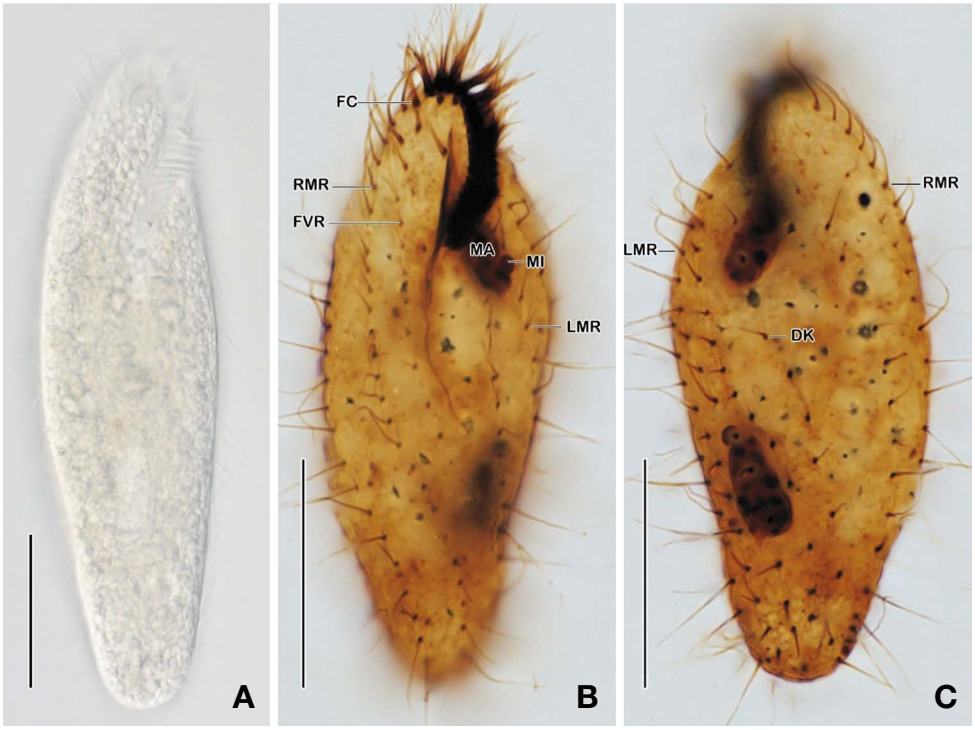

Fig. 5. Photomicrographs of *Deviata bacilliformis* from life (A) and after protargol impregnation (B, C). A. Ventral view showing the body shape and the adoral zone of membranelles. B, C. Ventral (B) and dorsal (C) view showing the 5 right and 5 left marginal rows and the single dorsal kinety. DK, dorsal kinety; FC, frontal cirri; FVR, frontoventral row; LMR, left marginal rows; MA, macronucleus; MI, micronucleus; RMR, right marginal rows. Scale bars = 30 μm.

vs. 43−51), suggesting that they could be distinct species.
Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20109, NNIBRPR20110).

Family Deviatidae Foissner, 2016
Genus *Deviata* Eigner, 1995

5. *Deviata bacilliformis* (Gelei, 1954) Eigner, 1995 (Fig. 5)

Material examined. Freshwater sample collected from Gangneung-Wonju National University, Gangneung, Korea (37°46′14″N, 128°51′56″E) on 7 April 2020.
Diagnosis. Size *in vivo* 125−142 × 37−45 μm (n = 4); body elongate ellipsoidal; usually 2 ellipsoidal distinctly separated macronuclear nodules and 2 micronuclei; cytoplasm studded with food vacuoles; contractile vacuole left to mid-body; adoral zone occupies about 20% of body length and composed of about 18 adoral membranelles; 3 frontal cirri, 1 buccal and 1 parabuccal cirrus, undulating membranes parallel; one midventral cirral row extends to mid-body; 4 or 5 right marginal cirral rows, usually bipolar; 4 or 5 left marginal cirral rows; 1 dorsal kinety with bristles about 4 μm long.
Distribution. Cosmopolitan.
Remarks. The Korean population of *Deviata bacilliformis* agrees with the Argentinian population (Küppers and Claps, 2010) in most aspects, such as the body shape, shape of the nuclear apparatus, and the two outermost marginal cirral rows, which commence with few bristles (Küppers and Claps, 2010; Berger, 2011). The Chinese population studied by Li *et al*. (2014) differs from the Korean population in having lower number of marginal rows (3 vs. 4 or 5 in the right and left side, respectively). *Deviata bacilliformis* can be easily distinguished from other congeners by the number of dorsal kineties (1 vs. 2) (Berger, 2011).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20111, NNIBRPR20112).

Family Spirofilidae von Gelei, 1929
Genus *Stichotricha* Perty, 1849

6. *Stichotricha aculeata* Wrzesniowskiego, 1866 (Fig. 6)

Material examined. Freshwater sample collected from a temporary puddle, after rainfall, on a footpath behind



Fig. 6. Photomicrographs of *Stichotricha aculeata* from life (A) and after protargol impregnation (B, C). A. Ventral view showing body outline and the narrow, curved anterior portion containing the adoral zone of membranelles. B, C. Ventral (B) and dorsal (C) view showing the body shape and the somatic ciliature. Scale bars = 30 μm.

Gangneung-Wonju National University, Gangneung, Korea (37°46′30″N, 128°51′46.8″E) on 25 June 2020.
Diagnosis. Body size *in vivo* about 115 × 20 μm (n = 5); body slender elongate, anterior portion narrow and curved, body flexible and slightly contractile; inhabiting detritus-covered lorica; 2 macronuclear nodules and 2 micronuclei; adoral zone of membranelles covered up to 50% of body length and composed of about 30 membranelles, elongated cilia on distalmost 3 membranelles; 4 spiral cirral rows; about 3 frontal, 1 buccal cirrus; 2 dorsal kineties.
Distribution. Antarctica, Austria, Central America, Germany, Hungary, USA, and Korea.
Remarks. The Korean population of *Stichotricha aculeata* agrees with previous descriptions in most features, especially the body size, the somatic ciliature, and habitats. The tubicolous genus *Stichotricha* contains only two species, *S. aculeata* and *S. secunda* Kahl, 1932, which can be separated from each other by the absence vs. presence of symbiotic algae (Kahl, 1932; Gelei, 1954; Foissner, 1980; Foissner *et al*., 1991; Bourland, 2015).
Voucher slides. One slide with protargol-impregnated specimens was deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20113).

Family Oxytrichidae Ehrenberg, 1830
Genus *Oxytricha* Bory de St. Vincent in Lamouroux, Bory de St. Vincent and Deslongchamps, 1824

7. *Oxytricha paragranulifera* Chao *et al*., 2014 (Fig. 7)

Material examined. Terrestrial moss sample collected from Geomundo Island, Samsan-myeon, Yeosu-si, Jeollanam-do, Korea (34°1′41.60″N, 127°18′44.10″E) on 11 July 2019.
Diagnosis. Body size 70–90 × 30–35 μm after protargol impregnation (n = 5); body ellipsoid to ovate *in vivo*, 2 macronuclear nodules and about 2 micronuclei; cortical granules colorless, densely scattered on dorsal and ventral side, impregnated with protargol; adoral zone of membranelles covered about 30–35% of cell length with about 25 membranelles; 1 right and 1 left marginal row with 26 cirri each; 3 frontal, 1 buccal cirrus, 4 ventral, 3 postoral, 2 pretransverse, and 5 transverse cirri; 6 dorsal kineties and 3 caudal cirri.
Distribution. China and Korea.
Remarks. The Korean population of *O. paragranulifera* agrees very well with the type population from China (Shao *et al*., 2014). However, it has higher number of cirri in the right and left marginal row (26 vs. 18–25 each). *Oxytricha paragranulifera* is very similar to *O. granulifera* Foissner and Adam, 1983 but they can be distinguished from each other by the arrangement of cortical granules (short irregular rows vs. long rows along and between dorsal kineties (Foissner and Adam, 1983; Shao *et al*., 2014).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20114, NNIBRPR20115).

Genus *Steinia* Diesing, 1866

8. *Steinia sphagnicola* Foissner, 1989 (Fig. 8)

Material examined. Saline water sample (1.1‰) collected from Soonpo Wetlands, Gangneung, Korea (37° 49′13.1″N, 128°53′18.1″E) on 17 October 2019.
Diagnosis. Body size 100–120 × 40–55 μm after protargol impregnation (n = 7); body ellipsoidal *in vivo*, obovate after impregnation; 2 macronuclear nodules and 2 micronuclei each attaching to a macronucleus; adoral zone of membranelles covered about 50% of cell length with 33–37 membranelles; undulating membranes in *Steinia* pattern; 1 right and 1 left marginal row with 19–21 and 17–20 cirri, respectively; 3 frontal, 1 buccal, 4 ventral, 3

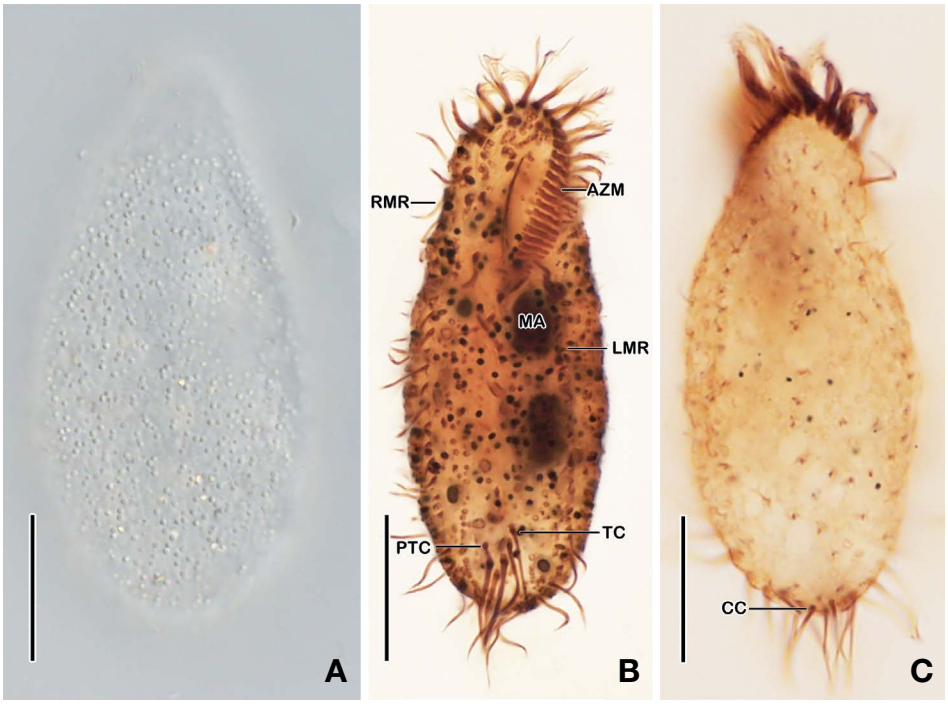

Fig. 7. Photomicrographs of *Oxytricha paragranulifera* from life (A) and after protargol impregnation (B, C). A. Dorsal view showing the body shape, and the arrangement of the cortical granules. B, C. Ventral (B) and dorsal (C) view showing the ciliature, and the nuclear apparatus. AZM, adoral zone of membranelles; CC, caudal cirri; LMR, left marginal row; MA, macronucleus; PTC, pretransverse cirri; RMR, right marginal row; TC, transverse cirri. Scale bars = 20 μm.

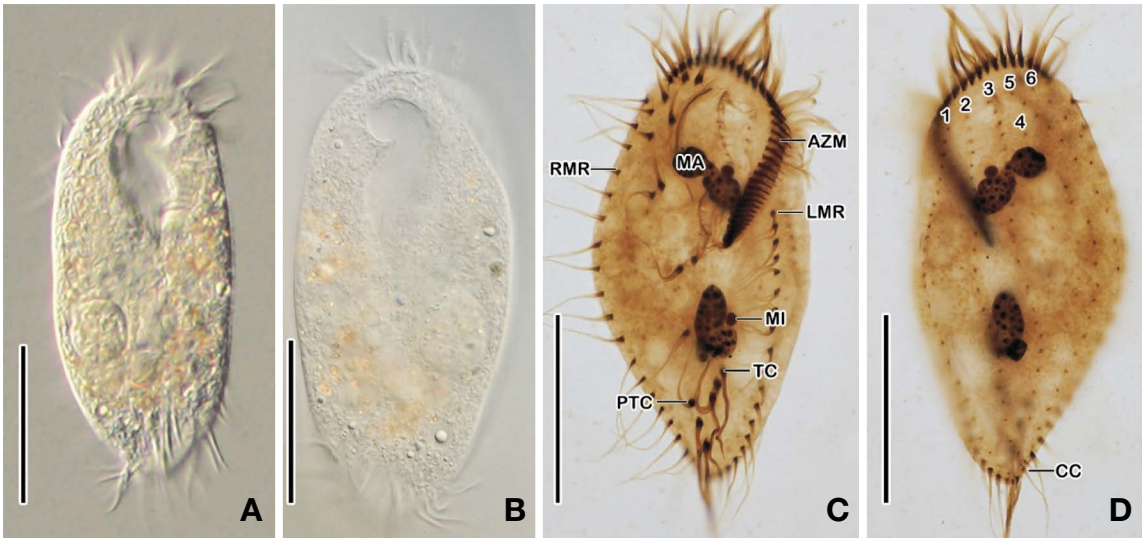

Fig. 8. Photomicrographs of *Steinia sphagnicola* from living specimens (A, B) and after protargol impregnation (C, D). A, B. Ventral (A) and dorsal (B) view showing body outline. C. Ventral ciliature. D. Dorsal kineties. 1–6, dorsal kineties; AZM, adoral zone of membranelles; CC, caudal cirri; LMR, left marginal row; MA, macronucleus; MI, micronucleus; PTC, pretransverse cirri; RMR, right marginal row; TC, transverse cirri. Scale bars = 50 μm.

postoral, 2 pretransverse, and 5 transverse cirri arranged in two groups; 6 dorsal kineties and 3 caudal cirri.

Distribution. Austria, France, Germany, Poland, and Korea.

Remarks. The Korean population of *S. sphagnicola* is very similar to the type population described by Foiss-

ner (1989) in all aspects, but it is slightly smaller (100–120 × 40–55 μm vs. 130–160 × 50–80 μm). *Steinia sphagnicola* differs from other congeners in the arrangement of the transverse cirri (i.e., two separate groups vs. one group) (Voss and Foissner, 1996; Berger, 1999).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20116, NNIBRPR20117).

Genus *Stylonychia* Ehrenberg, 1830

9. *Stylonychia* cf. *notophora* (Fig. 9)

Material examined. Freshwater sample collected from Jukheon Reservoir, Gangneung, Korea (37°46′5.6″N, 128°51′40.6″E) on 23 July 2020.
Diagnosis. Body size 80–100 × 30–40 μm after protargol impregnation (n = 8); body ellipsoidal, 2 macronuclear nodules and 2 micronuclei each attaching to a macronuclear nodule; adoral zone of membranelles covered about 40–50% of cell length with 37–40 membranelles; undulating membranes in *Stylonychia* pattern; 1 right and 1 left marginal row with 25–28 and 16–18 cirri, respectively; 3 frontal, 1 buccal, 4 ventral, 3 postoral, 2 pretransverse, and 5 transverse cirri arranged in two groups. 6 dorsal kineties and 3 ordinarily separated caudal cirri.
Distribution. Austria, Bulgaria, Cameroon, Chad, China, Czechoslovakia, Germany, Greece, Japan, USA, Venezuela, Korea.
Remarks. The Korean population of *Stylonychia notophora* agrees with the description of Buchar (1957) and Dragesco and Dragesco-Kernéis (1986). However, they differ in the arrangement and length of the caudal cirri (ordinary vs. close together and about 25% of body length) and the number of adoral membranelles (37–40 vs. 33–36) (Buchar, 1957; Berger, 1999). *Stylonychia notophorides* Foissner, 2016 is also very similar to the present species but differs mainly in the very long (vs. ordinary) caudal cirri, the number of adoral membranelles (24–29 vs. 37–40), and the number of cirri in the right and left marginal row (9–16, 9–12 vs. 25–28, 16–18, respectively) (Foissner, 2016).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20118, NNIBRPR20119).

Genus *Tetmemena* Eigner, 1999

10. *Tetmemena bifaria minima* Kumar *et al*., 2016 (Fig. 10)

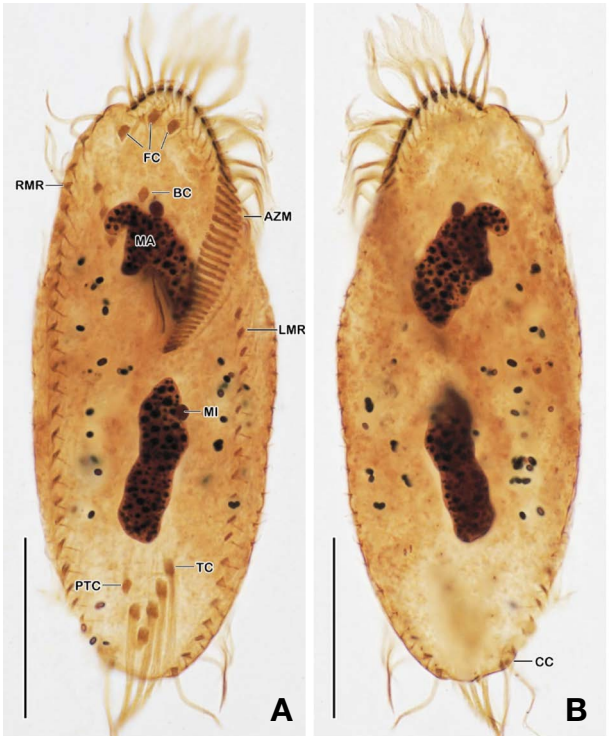

Fig. 9. Photomicrographs of *Stylonychia* cf. *notophora* after protargol impregnation (A, B). Ventral (A) and dorsal (B) view showing the body shape somatic and oral ciliature. AZM, adoral zone of membranelles; BC, buccal cirrus; CC, caudal cirri; FC, frontal cirri; LMR, left marginal row; MA, macronucleus; MI, micronucleus; PTC, pretransverse cirri; RMR, right marginal row; TC, transverse cirri. Scale bars = 30 μm.

Material examined. Terrestrial soil sample collected from Gyeongpo Gasiyeon Wetlands, Gangneung, Korea (37°47′25.09″N, 128°53′52.23″E) on 25 September 2019.
Diagnosis. Body size 70–80 × 30–40 μm after protargol impregnation (n = 9); body ellipsoidal to broadly ellipsoid, 2 macronuclear nodules and 2 micronuclei each attaching to a macronucleus; adoral zone of membranelles covered about 30% of cell length with 23–27 membranelles; undulating membranes in *Stylonychia* pattern; 1 right and 1 left marginal rows with 12–15 and 9–11 cirri, respectively; 3 frontal, 1 buccal, 4 ventral, 3 postoral, 2 pretransverse, and 5 transverse cirri arranged in two groups. 6 dorsal kineties and 3 caudal cirri.
Distribution. Argentina, Italy, and Korea
Remarks. The Korean population of *T. bifaria minima* agrees very well with the type population from Italy in all features (Kumar *et al*., 2016), but differs slightly from the Argentinian population by the smaller body length (75 vs. 100 μm) (Küppers *et al*., 2009). It also differs from *T. bifaria bifaria* (Stokes, 1887) Berger, 2001 by the lower numbers of the adoral membranelles (25 vs. 37) and the right (14 vs. 19 on average) and left (10 vs.

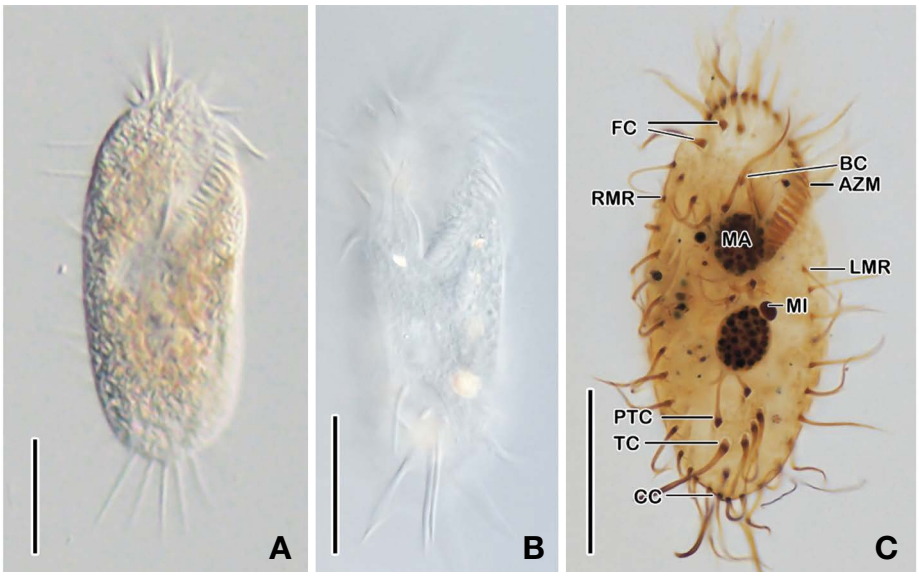

Fig. 10. Photomicrographs of *Tetmemena bifaria minima* from life (A, B) and after protargol impregnation (C). A, B. Ventral views showing the body shape and the transverse and caudal cirri projecting from posterior body end. C. Ventral view showing the ventral ciliature. AZM, adoral zone of membranelles; BC, buccal cirrus; CC, caudal cirri; FC, frontal cirri; LMR, left marginal row; MA, macronucleus; MI, micronucleus; PTC, pretransverse cirri; RMR, right marginal row; TC, transverse cirri. Scale bars = 30 μm.

19 on average) marginal cirri (Wirnsberger *et al*., 1985).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20120, NNIBRPR20121).

Class Armophorea Lynn, 2004
Order Metopida Jankowski, 1980
Family Metopidae Kahl, 1927
Genus *Metopus* Claparède and Lachmann, 1858

11. *Metopus es* (Müller, 1776) Lauterborn, 1916 (Fig. 11)

Material examined. Freshwater sample collected from a temporary puddle, after rainfall, on a footpath behind Gangneung-Wonju National University, Gangneung, Korea (37°46′30″N, 128°51′46.8″E) on 7 April 2020.
Diagnosis. Size *in vivo* about 135 × 40 μm (n = 3); body elongate ellipsoidal, slightly sigmoidal, distinctly twisted anteriorly and narrowed posteriorly; preoral dome convex with ventral side distinctly convex and studded with brownish granules; 1 ellipsoidal macronucleus and 1 micronucleus in or slightly anterior to mid-body; cortex covered with minute cortical granules in rows between ciliary rows; on average 25 ciliary rows; perizonal stripe consists of 5 rows not arranged in false kineties; adoral zone comprises 36 membranelles on average; caudal cilia longer than somatic cilia.
Distribution. Cosmopolitan.

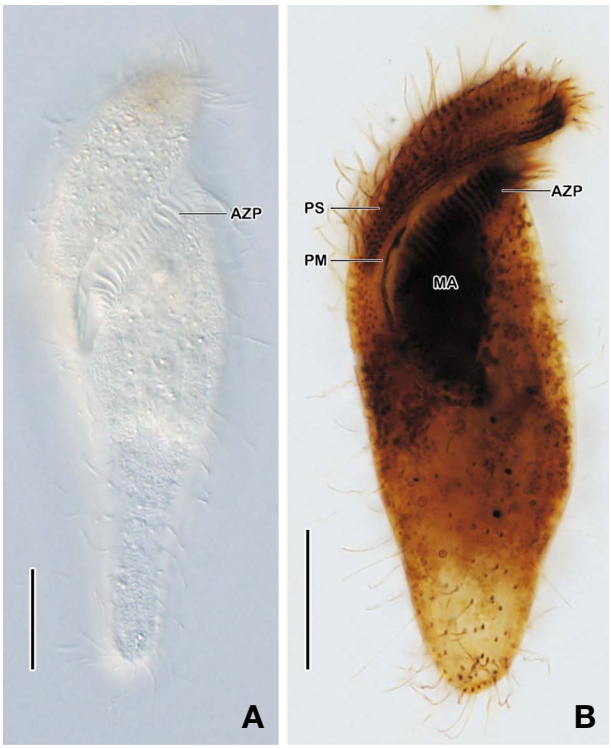

Fig. 11. Photomicrographs of *Metopus es* from life (A) and after protargol impregnation (B). A. Ventral view showing the torsion of the body and the adoral zone of membranelles. B. Ventral view showing the somatic and oral ciliature, the perizonal ciliary stripe, and the nuclear apparatus. AZP, adoral zone of polykinetids; MA, macronucleus; PM, paroral membrane; PS, perizonal ciliary stripe. Scale bars = 20 μm.

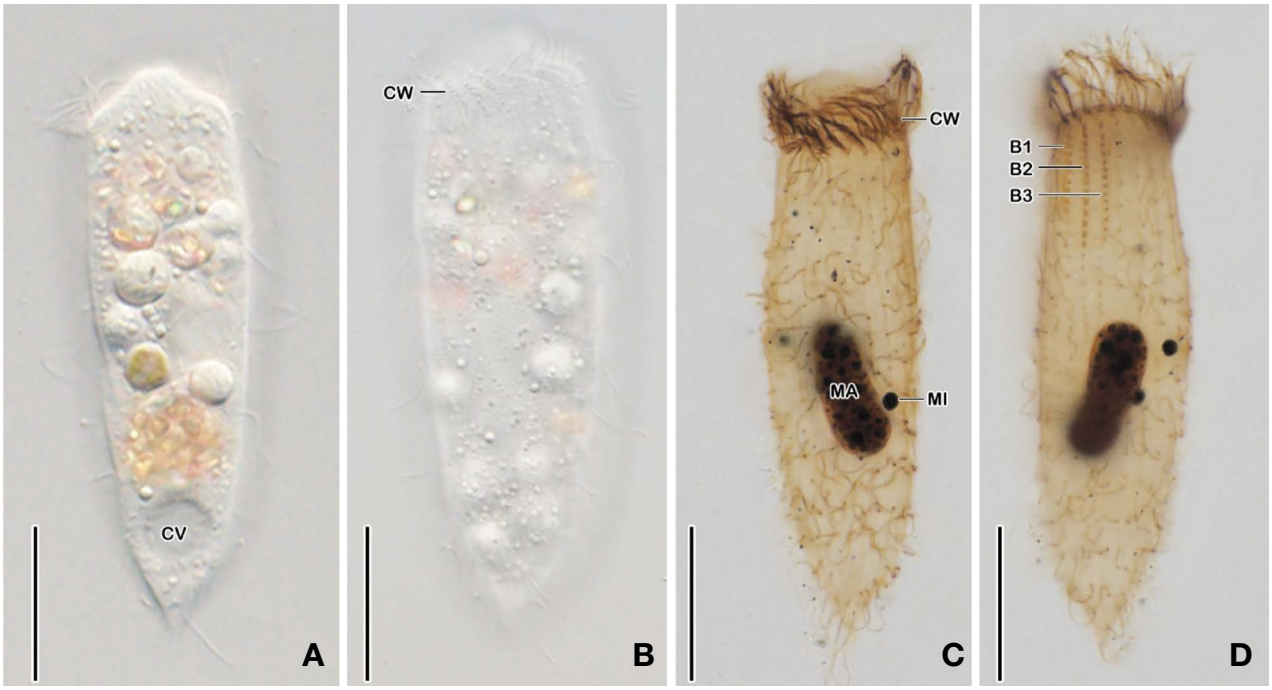

Fig. 12. Photomicrographs of *Acropisthium mutabile* from life (A, B) and after protargol impregnation (C, D). A, B. Ventral views showing the body shape, the subterminally located contractile vacuole, and the subapical ciliary wreath. C. Ventral view showing the nuclear apparatus and the somatic ciliature. D. Dorsal view showing the three dorsal brush rows. B1−3, dorsal brush rows; CV, contractile vacuole; CW, subapical ciliary wreath; MA, macronucleus; MI, micronucleus. Scale bars = 20 μm.

Remarks. The Korean population of *Metopus es* agrees with the description of Bourland *et al*. (2017) in most features. *Metopus es* is easily confused with other congeners, but it is characterized by a combination of features such as the ciliary rows number, the adoral membranelles number, and the size and position of the nuclear apparatus (Bourland and Wendell, 2014; Bourland *et al*., 2017).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20122, NNIBRPR20123).

Class Litostomatea Small and Lynn, 1981
Subclass Haptoria Corliss, 1974
Order Haptorida Corliss, 1974
Family Acropisthiidae Foissner and Foissner, 1988
Genus *Acropisthium* Perty, 1852

12. *Acropisthium mutabile* Perty, 1852 (Fig. 12)

Material examined. Freshwater sample collected from a temporary puddle, after rainfall, on a footpath behind Gangneung-Wonju National University, Gangneung, Korea (37°46′30″N, 128°51′46.8″E) on 25 June 2020.
Diagnosis. Size *in vivo* about 75 × 25 μm and after protargol impregnation (n = 5); body slenderly ellipsoidal with pointed posterior end; cytoplasm clear containing 1 oblong macronucleus surrounded by 1−3 micronuclei and scattered rod-shaped extrusomes; contractile vacuole located subterminally; 19 or 20 monokinetidal somatic kineties each curves anteriorly to right side forming subapical ciliary wreath; 3 dorsal brush rows consist of dikinetids and monokinetids; oral opening anteriorly and slightly curved to right side.
Distribution. Cosmopolitan.
Remarks. The Korean population of *Acropisthium mutabile* agrees very well with the description of Foissner (1984) in most aspects. *Balantidion pellucidum* Eberhard, 1862 is the most similar species to *A. mutabile*. Both have densely arranged oralized somatic kinetids (subapical ciliary wreath), usually three dikinetidal dorsal brush rows, and rod-shaped extrusomes. However, they belong to different genera and can easily be separated from each other by the flat (vs. conical) oral bulge and the longitudinal (vs. curved) subapical ciliary wreath (Foissner, 1984; Foissner *et al*., 1999).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20124, NNIBRPR20125).

Family Dileptidae Jankowski, 1978
Genus *Pseudomonilicaryon* Foissner, 1997

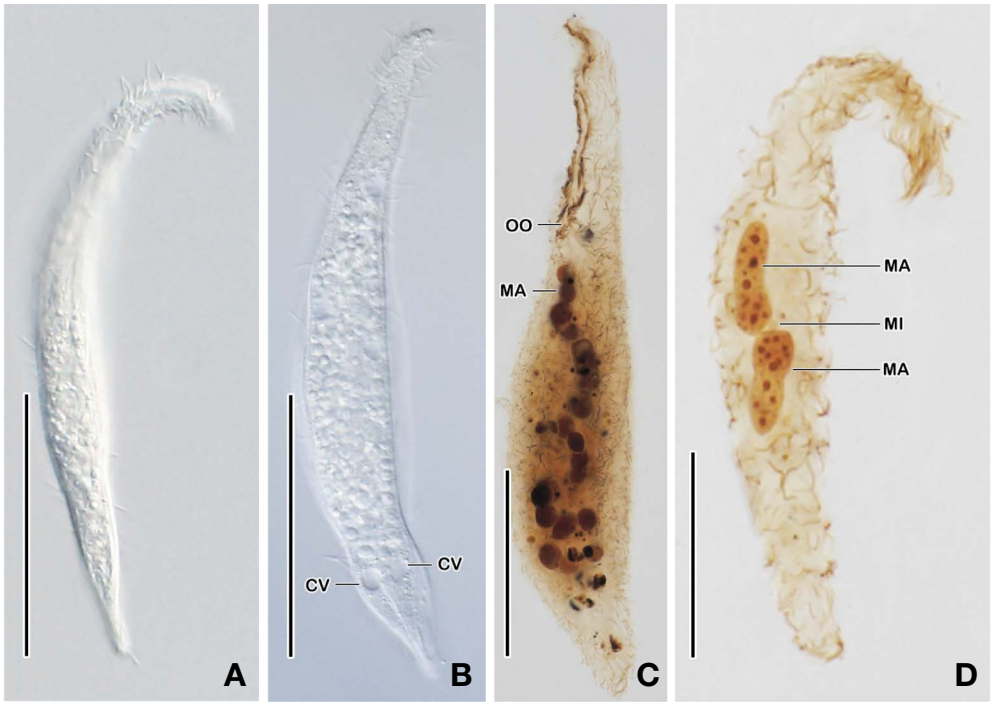

Fig. 13. Photomicrographs of *Pseudomonilicaryon japonicum* (A–C) and *Rimaleptus alpinus* (D) from life (A, B) and after protargol impregnation (C, D). A, B. Left side views showing the body shape and the contractile vacuoles location. C. Left side view showing body shape, somatic ciliature and oral opening. D. left side showing body shape, ciliature, and nuclear apparatus. CV, contractile vacuoles; MA, macronuclear nodule; MI, micronucleus; OO, oral opening. Scale bars = 50 μm (A–C) and 30 μm (D).

13. *Pseudomonilicaryon japonicum* Foissner, Agatha and Berger, 2002 (Fig. 13A–C)

Material examined. Terrestrial moss sample collected from Mungyeong Saejae Provincial Park, Mungyeong-si, Gyeongsangbuk-do, Korea (36°45′57″N, 128°4′29″E) on 29 March 2020.
Diagnosis. Body size 200–250 × 50–60 μm after protargol impregnation (n = 3); body narrowly dileptid with narrow posterior end; macronucleus moniliform, composed of about 20–26 nodules; 2 rows of contractile vacuoles on ventral and dorsal side; ovate with posterior end distinctly broader than anterior; 2 shapes and sizes of cortical granules, type I narrowly ellipsoid, type II oblong; about 30–36 somatic ciliary rows.
Distribution. Japan, Venezuela, and Korea.
Remarks. The Korean *Pseudomonilicaryon japonicum* is very similar to the type population described by Foissner *et al*. (2002) but slightly differs in the smaller body size (200–250 × 50–60 μm vs. 239–544 × 46–93 μm after protargol impregnation) and the less number of somatic ciliary rows (33 vs. 39 on average) and macronuclear nodules (20–26 vs. 20–35) (Foissner *et al*. 2002; Vd'ačný and Foissner, 2012).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20126, NNIBRPR20127).

Family Dimacrocaryonidae Vd'ačný *et al*., 2011
Genus *Rimaleptus* Foissner, 1984

14. *Rimaleptus alpinus* (Kahl, 1931) Vd'ačný and Foissner, 2012 (Fig. 13D)

Material examined. Terrestrial moss collected from Mungyeong Saejae Provincial Park, Mungyeong-si, Gyeongsangbuk-do, Korea (36°45′57″N, 128°4′29″E) on 29 March 2020.
Diagnosis. Body size about 100 × 20 μm after protargol impregnation (n = 5); body slenderly dileptid with proboscis about 30% of body length; 2 contractile vacuoles on dorsal side; 2 ellipsoidal macronuclear nodules with a single micronucleus in between; about 10 somatic ciliary rows; 2 preoral kineties composed of oblique dikinetids; 2 brush rows with long bristles.
Distribution. Australia, Austria, Germany, Netherlands, Slovakia, Japan, and Korea.
Remarks. The Korean population of *Rimaleptus alpinus* agrees with previous descriptions especially from Foissner (1989). Six species belong to the *Rimaleptus alpinus* group and characterized by two contractile vacuoles and

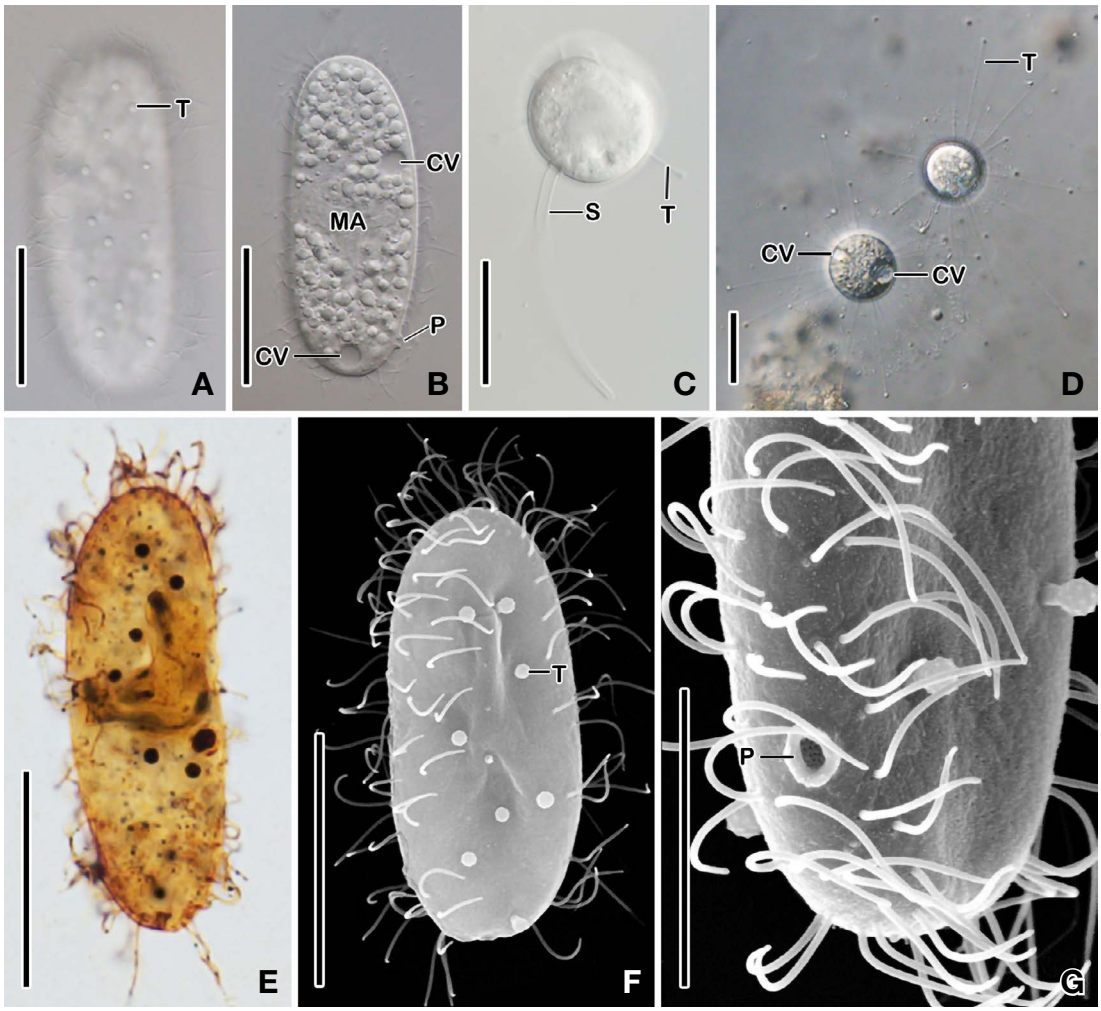

Fig. 14. Photomicrographs of *Podophrya bivacuolata* from life (A–D), after protargol impregnation (E), and scanning electron microscope (F, G). A, B. Lateral views of swarmers showing the clavate tentacles and the ciliary stripes. C, D. Adult cells with long tentacles and stalk. E. Swarmer showing the cell shape and the ciliary pattern. F, G. Swarmers showing the cell shape and the precursor of the stalk. CV, contractile vacuole; MA, macronucleus; P, stalk precursor; S, stalk; T, tentacles. Scale bars = 30 μm (A–D), 20 μm (E, F), and 10 μm (G).

two dorsal brush rows except *R. binucleatus* (Kahl, 1931) Foissner, 1984 and *R. conspicuus* (Kahl, 1931) Vd'ačný and Foissner, 2012 which have multi rows. *Rimaleptus alpinus* can be easily distinguished from other species in the group by the long (vs. short) brush cilia, the less number of ciliary rows (~10 vs. ≥12 on average), and the smaller body size (~100 vs. >120 μm on average) (Foissner, 1989; Vd'ačný and Foissner, 2012).

Voucher slides. One slide with protargol-impregnated specimens was deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20128).

Class Phyllopharyngea de Puytorac *et al*., 1974
Subclass Suctoria Claparede and Lachmann, 1858
Order Exogenida Collin, 1912
Family Podophryidae Haeckel, 1866
Genus *Podophrya* Ehrenberg, 1834

15. *Podophrya bivacuolata* Foissner, 2004 (Fig. 14)

Material examined. Soil sample collected from a footpath behind Gangneung-Wonju National University, Gangneung, Korea (37°46′30.4″N, 128°51′46.2″E) on 3 January 2020.

Diagnosis. Swarmers about 70 × 30 μm *in vivo* (n = 4), 38–46 × 15–18 μm after protargol impregnation; body shape oblong with a longitudinal ciliated girdle with 4 or 5 widely spaced ciliary rows, unciliated areas studded with short, capitate tentacles; macronucleus long in midbody. Adults globular 20–27 μm across and with long stalk and tentacles up to 50 μm long (n = 7); 2 contractile vacuoles; feeding on ciliates especially hypotrichs.

Distribution. Austria, Korea.

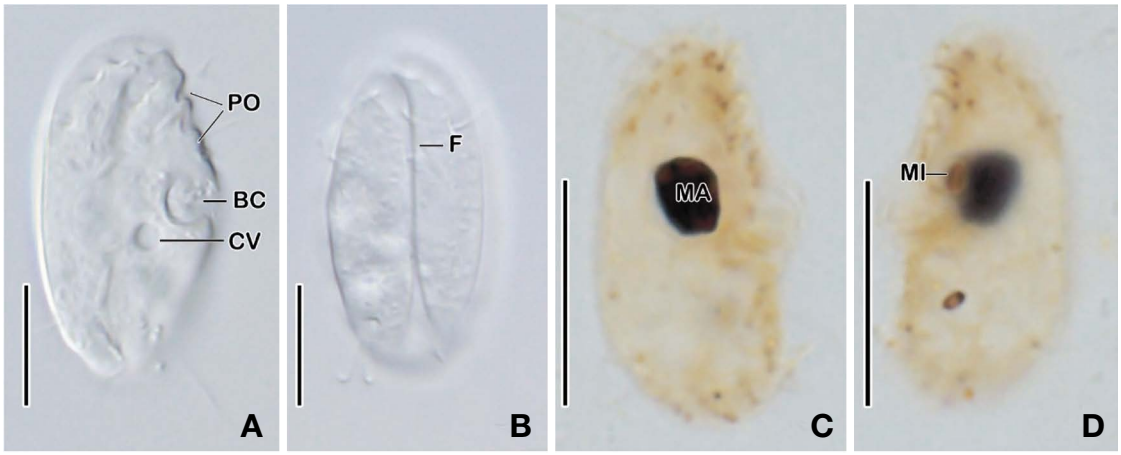

Fig. 15. Photomicrographs of *Drepanomonas pauciciliata in vivo* (A, B) and after protargol impregnation (C, D). A. right side view showing the crenelation in ciliary pits and the oral apparatus in mid-body. B. Left side view showing the deep narrow furrow. C. Right side ciliature. D. Left side ciliature. BC, buccal cavity; CV, contractile vacuole; F, furrow; MA, macronucleus; MI, micronucleus; PO, preoral kineties. Scale bars = 10 μm.

Remarks. The Korean population of *Podophrya bivacuolata* agrees with the original description of Foissner (2004). It is most similar to *Podophrya magna* (Maupas, 1881) Curds, 1986 in having two contractile vacuoles but the swarmers of the latter have only cilia while those of *P. bivacuolata* have both cilia and tentacles (Curds, 1986; Foissner, 2004). The two contractile vacuoles found also in the loricated suctorian ciliate *Paracineta lauterborni* Sondheim, 1929. However, the genera *Podophrya* and *Paracineta* differ in the absence vs. presence of semi-lorica that covers a part of the body and the freshwater or terrestrial vs. marine habitat (Foissner, 1995).

Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20129, NNIBRPR20130).

Class Nassophorea Small and Lynn, 1981
Order Microthoracida Jankowski, 1967
Family Microthoracidae Wrzesniowski, 1870
Genus *Drepanomonas* Fresenius, 1858

16. *Drepanomonas pauciciliata* Foissner, 1987 (Fig. 15)

Material examined. Terrestrial moss sample collected from Hambaeksan Mountain, Gohan-eup, Jeongseon-gun, Gangwon-do, Korea (37°9′23.8″N, 128°54′59.3″E) on 17 May 2018.

Diagnosis. Size *in vivo* about 20 × 12 μm (n = 6); body semi ellipsoidal with ventral side distinctly convex; 1 macronucleus and 1 micronucleus; cortex rigid, right side smooth except of minute crenelation in ciliary pits; left side with longitudinal, deep and narrow furrow; contractile vacuole slightly posterior and dorsal to oral structures; cytopyge posterior and left to contractile vacuole; extrusomes lenticular and left of somatic kineties; 9 somatic and 3 preoral kineties, each kinety contains few dikinetids and few monokinetids with large gaps in the middle; preoral kineties contain 2 or 3 dikinetid each with a single monokinetid posteriorly; oral apparatus in mid-body containing oral membranelles and oral primordium.

Distribution. Cosmopolitan.

Remarks. The Korean population of *D. pauciciliata* is identical to the type population (Foissner, 1987) in the size, shape, the ciliary pattern, and the deep, narrow furrow on the left side. *Drepanomonas pauciciliata* is most similar to *D. revoluta* Penard, 1922, but differs mainly in the deep, narrow left side furrow (vs. two ridges forming a wide furrow in between in *D. revoluta*). It is also similar to *D. hymenofera hymenofera* (Horvath, 1956) Omar and Foissner, 2013 in having a narrow furrow in the left side. However, they differ mainly in the body size (20 × 12 μm vs. 40 × 18 μm) and the highly reduced (vs. ordinary) number of somatic basal bodies, for instance, unlike *D. h. hymenofera*, *D. pauciciliata* lacks basal bodies in the second and third quarters of somatic kineties 3 and 4 (Penard, 1922; Foissner, 1987; Omar and Foissner, 2013).

Voucher slides. One slide with protargol-impregnated specimens was deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20131).

Class Oligohymenophorea de Puytorac *et al.*, 1974
Subclass Hymenostomatia Delage and Herouard, 1896
Order Tetrahymenida Fauré-Fremiet in Corliss, 1956
Family Turaniellidae Didier, 1971

Genus *Dexiostoma* Jankowski, 1967

17. *Dexiostoma campylum* (Stokes, 1886) Jankowski, 1967 (Fig. 16)

Material examined. Terrestrial moss collected from Mungyeong Saejae Provincial Park, Mungyeong-si, Gyeongsangbuk-do, Korea (36°45′57″N, 128°4′29″E) on 29 March 2020.

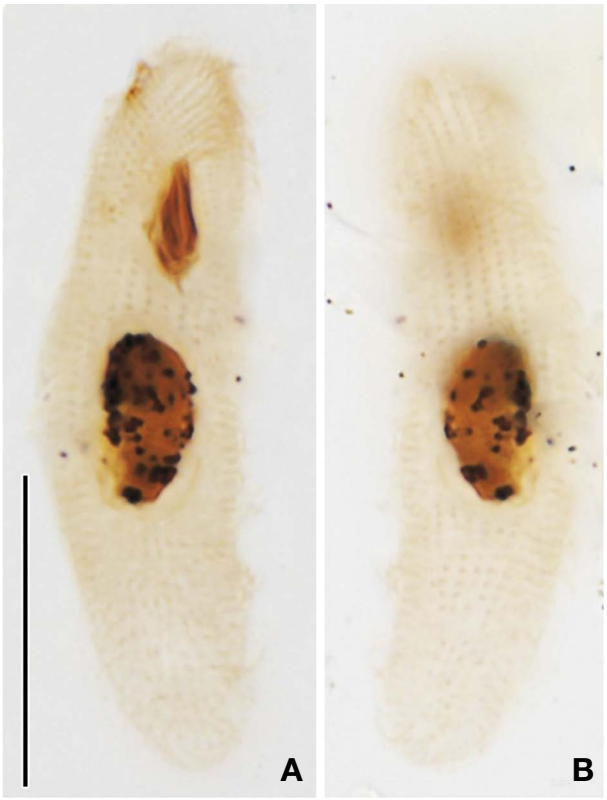

Fig. 16. Photomicrographs of *Dexiostoma campylum* after protargol impregnation (A, B). Ventral (A) and dorsal (B) view of the same specimen showing somatic ciliature, oral ciliature, and nuclear apparatus. Scale bar = 20 μm.

Diagnosis. Body size about 55 × 20 μm after protargol impregnation (n = 3); body slender, length:width ratio 2–3 : 1; 1 subterminal contractile vacuole; 1 globular to broadly ellipsoidal macronuclear nodule with a single micronucleus attached to it; buccal infraciliature tetrahymenid composed of paroral on right side of buccal cavity and 3 adoral membranelles; about 30 somatic ciliary rows.

Distribution. Cosmopolitan.

Remarks. The Korean population of *Dexiostoma campylum* agrees with previous descriptions, especially that of Ganner and Foissner (1989) in most characters. In their taxonomic study on the genus *Dexiostoma*, Ganner and Foissner (1989) revealed that the species *Dexiostoma campylum* was synonymized many times because of its similarity with the genera *Paramecium*, *Tetrahymena*, *Colpidium*, and *Glaucoma* (Jankowski, 1967; Ganner and Foissner, 1989; Foissner *et al*., 1994). However, the variability of the number of somatic ciliature (16–33) within populations could indicate cryptic species, as suggested by Ganner and Foissner (1989).

Voucher slides. One slide with protargol-impregnated specimens was deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20132).

Family Tetrahymenidae Corliss, 1952
Genus *Tetrahymena* Furgason, 1940

18. *Tetrahymena rostrata* (Kahl, 1926) Corliss, 1952 (Fig. 17)

Material examined. Freshwater sample collected from a temporary puddle, after a rainfall, on a footpath behind

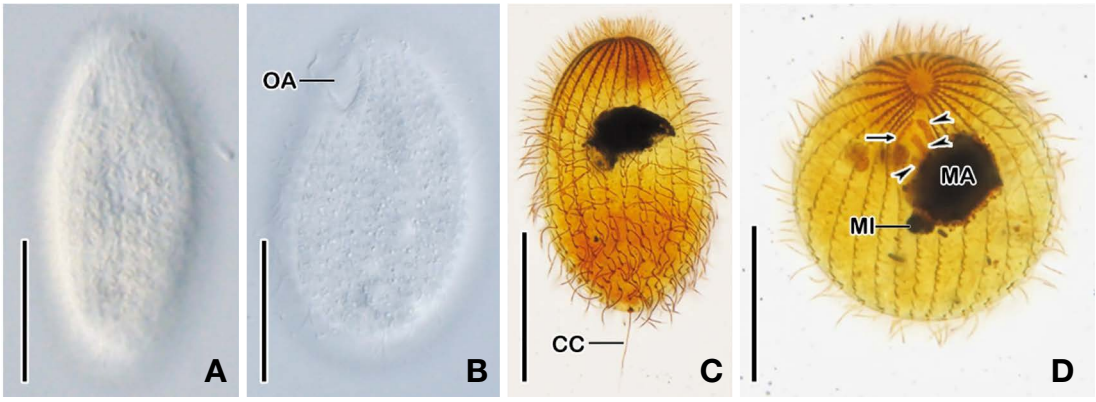

Fig. 17. Photomicrographs of *Tetrahymena rostrata* from life (A, B) and after silver carbonate impregnation (C, D). A, B. Ventral views showing the body shape and the location of the oral apparatus. C, D. Dorsal (C) and ventral (D) view showing the somatic ciliature, the nuclear apparatus, the oral membranelles (arrowheads), and the paroral (arrow). CC, caudal cilium; MA, macronucleus; MI, micronucleus; OA, oral apparatus. Scale bars = 20 μm.

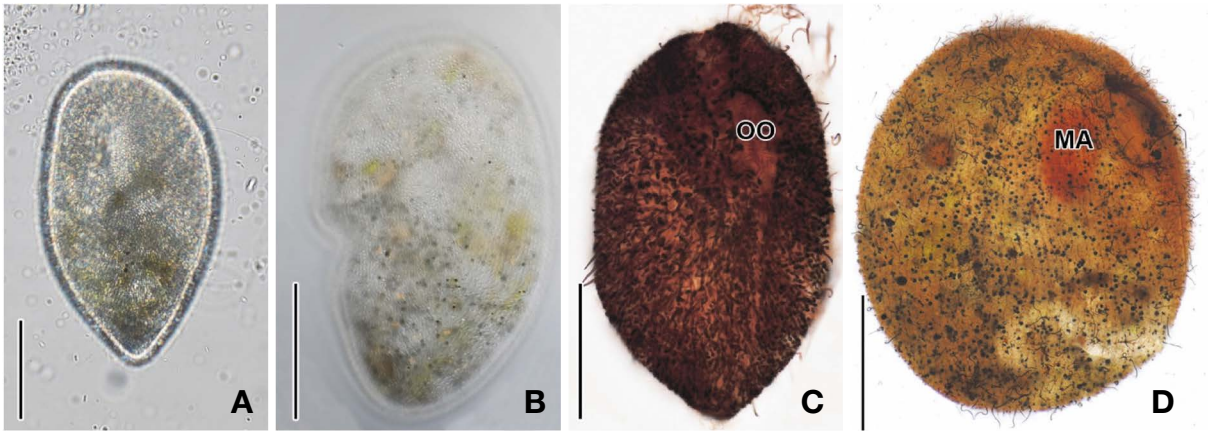

Fig. 18. Photomicrographs of *Frontonia atra* from life (A, B), after protargol impregnation (C), and silver carbonate impregnation (D). A, B. Ventral (A) and lateral (B) view showing the body shape, the location of nuclear apparatus. Note the tapered posterior end. C, D. Ventral (C) and ventrolateral (D) view showing the location of the oral apparatus and ciliature. MA, macronucleus; OO, oral opening. Scale bars = 50 μm.

Gangneung-Wonju National University, Gangneung, Korea (37°46′30″N, 128°51′46.8″E) on 25 June 2020.

Diagnosis. Length *in vivo* 35−50 × 20−25 μm; body has two shapes, slenderly ellipsoid theronts and broadly ellipsoid trophonts; pellicle indented at base of cilia; cytoplasm colorless filled with food vacuoles contain bacteria; 1 or 2 macronuclear nodules with 1 micronucleus at mid-body; invariably 25 somatic ciliary rows including 2 postoral rows; oral apparatus consists of semicircular dikinetidal paroral right of oral opening and 3 membranelles on left wall of buccal cavity; a single subterminal contractile vacuole with 2 excretory pores; a single caudal cilium.

Distribution. Cosmopolitan.

Remarks. The Korean population of *T. rostrata* agrees with other populations in the body size, shape and habitat but differs mainly in the smaller body size and the lower number of somatic ciliary rows (invariably 25 vs. 26−31 from Foissner (1987; 2016) and 29−44 from Segade *et al*. (2009)). This species is also very similar to *T. setosa* (Schewiakoff, 1893) McCoy, 1975 in the overall shape and size but differs significantly in the formation of resting cysts (present vs. absent) (Kahl, 1926; 1931; Corliss, 1952; 1973; Foissner, 1987; 2016; Segade *et al*., 2009; 2015).

Voucher slides. Two slides with protargol-impregnated specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20133, NNIBRPR20134).

Subclass Peniculia Fauré-Fremiet in Corliss, 1956
Order Peniculida Fauré-Fremiet in Corliss, 1956
Suborder Frontoniina Small and Lynn, 1985
Family Frontoniidae Kahl, 1926
Genus *Frontonia* Ehrenberg, 1838

19. *Frontonia atra* (Ehrenberg, 1833) Bütschli, 1889 (Fig. 18)

Material examined. Freshwater sample collected from Gyeongpo Gasiyeon Weblands, Gangneung, Korea (37°47′26.9″N, 128°53′47.4″E) Freshwater on 23 July 2020.

Diagnosis. Size *in vivo* about 150 × 95 μm (n = 5); body ovate to teardrop-shaped, broadly rounded anteriorly and pointed posterior; cytoplasm full of dark pigments possibly depending on food inside food vacuoles; a single contractile vacuole posterior to mid-body; extrusomes numerous and about 10 μm long *in vivo*, stain darkly after protargol impregnation; macronucleus globular to ellipsoidal near body center; oral apparatus in anterior half of body composed of undulating membrane on right side of oral apparatus and 3 very close peniculae with 5, 4, 4 ciliary rows at left side, a suture extends from oral opening to posterior body end; about 90 ciliary rows.

Distribution. Europe and Korea.

Remarks. The Korean population of *Frontonia atra* agrees very well with the previously described populations. Regarding the teardrop shape, *F. atra* is similar to *F. acuminata* (Ehrenberg, 1833) Bütschli, 1889 and *F. terricola* Foissner, 1987. However, it differs from both species in having larger body size (150 × 95 μm vs. 115 × 75 and 82 × 43 μm) and a higher number of somatic kineties (~90 vs. 55−60 and ~68) (Kahl, 1932; Dragesco and Njine, 1971; Dragesco and Dragesco-Kernéis, 1986; Foissner *et al*., 1994). Further, both *F. cana* Reuter, 1961 and *F. nigricans* Penard, 1922 have similar coloration in the cytoplasm, and *F. nigricans* could be a synonym of *F. atra* because of the tapered posterior end (Reuter, 1961; Foissner *et al*., 1994).

Voucher slides. Two slides with protargol-impregnated



Fig. 19. Photomicrograph of *Histiobalantium natans viridis* after protargol impregnation, left side showing body outline, ciliature, nuclear apparatus, and oral apparatus. M1−3, adoral membranelles; MA, macronuclei; MI, micronucleus; PM, paroral membrane. Scale bar = 20 μm.

specimens were deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20135, NNIBRPR20136).

Subclass Scuticociliatia Small, 1967
Order Pleuronematida Fauré-Fremiet in Corliss, 1956
Family Histiobalantiidae de Puytorac and Corliss in Corliss, 1979
Genus *Histiobalantium* Stokes, 1886

20. *Histiobalantium natans viridis* Kahl, 1931 (Fig. 19)

Material examined. Saline water sample (0.4−1.0‰) collected from Gyeongpo Stream, Gangneung, Korea (37°47′27″N, 128°54′20″E) on 14 April 2020.
Diagnosis. Body size 55−80 × 30−35 μm after protargol impregnation (n = 7); body slenderly to broadly ovate; 2, usually connecting, macronuclear nodules with irregular shape and 2 inconspicuous micronuclei each attaching to a macronuclear nodule; about 60 somatic ciliary rows; adoral membranelles in anterior part of oral cavity, membranelles 1 and 2 parallel to each other, membranelle 1 consists of 3 rows of basal bodies, with a triangular segment anteriorly, membranelle 2 composed of about 6 rows of basal bodies, membranelle 3 oblique to both of them; paroral membrane on right side of oral opening, with a characteristic notch dividing it into 2 parts, the posterior of which is semicircular.
Distribution. Europe, Japan, USA, and Korea.
Remarks. *Histobalantium natans viridis* is well-known species recently redescribed in a comprehensive study by Foissner *et al*. (2009) from Biwa Lake in Japan. The Korean population of *H. natans viridis* matches very well the Japanese population in most features. On the other hand, the European population described by Dragesco and Iftode (1972) differs from both the Korean and Japanese (Asian) populations in the structure of membranelles 1 (2 rows of basal bodies vs. 3 rows and with triangular segment anteriorly) (Dragesco and Iftode, 1972; Foissner *et al*., 2009).
Voucher slides. One slide with protargol-impregnated specimens was deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20137).

Subclass Peritrichia Stein, 1859
Order Sessilida Kahl, 1933
Family Opisthonectidae Foissner, 1976
Genus *Opisthonecta* Fauré-Fremiet, 1906

21. *Opisthonecta minima* Foissner, 1975 (Fig. 20)

Material examined. Freshwater sample collected from a temporary puddle, after rainfall, on a footpath behind Gangneung-Wonju National University, Gangneung, Korea (37°46′30″N, 128°51′46.8″E) on 25 June 2020.
Diagnosis. Size *in vivo* about 90 × 43 μm (n = 3); body ellipsoid to broadly ellipsoid; macronucleus C-shaped located transversely in mid-body; a single contractile vacuole at anterior body portion; circular silverlines up to 60 striations between peristomial lip and trochal band and 30 striations between trochal band and scopula; infundibular polykineties 1−3 each consists of 3 rows, polykinety 3 with shorter inner row and longer and diverged outer 2 rows.
Distribution. Australia, Europe, North America, South America, and Korea.
Remarks. The Korean population of *O. minima* is similar to the type population in the body size and the presence of a single contractile vacuole but differs only in the number of silverline striations (total 90 vs. 60). *Opisthonecta minima* is also similar to *O. henneguyi* Fauré-Fremiet, 1906 in the appearance but is smaller (90 vs. 155 μm) and has less number of silverline striations (90 vs. 108 in total) and contractile vacuoles (1 vs. 2 or 3) (Foissner, 1975; 1978).
Voucher slides. One slide with protargol-impregnated specimens was deposited at the Nakdonggang National Institute of Biological Resources (NNIBRPR20138).

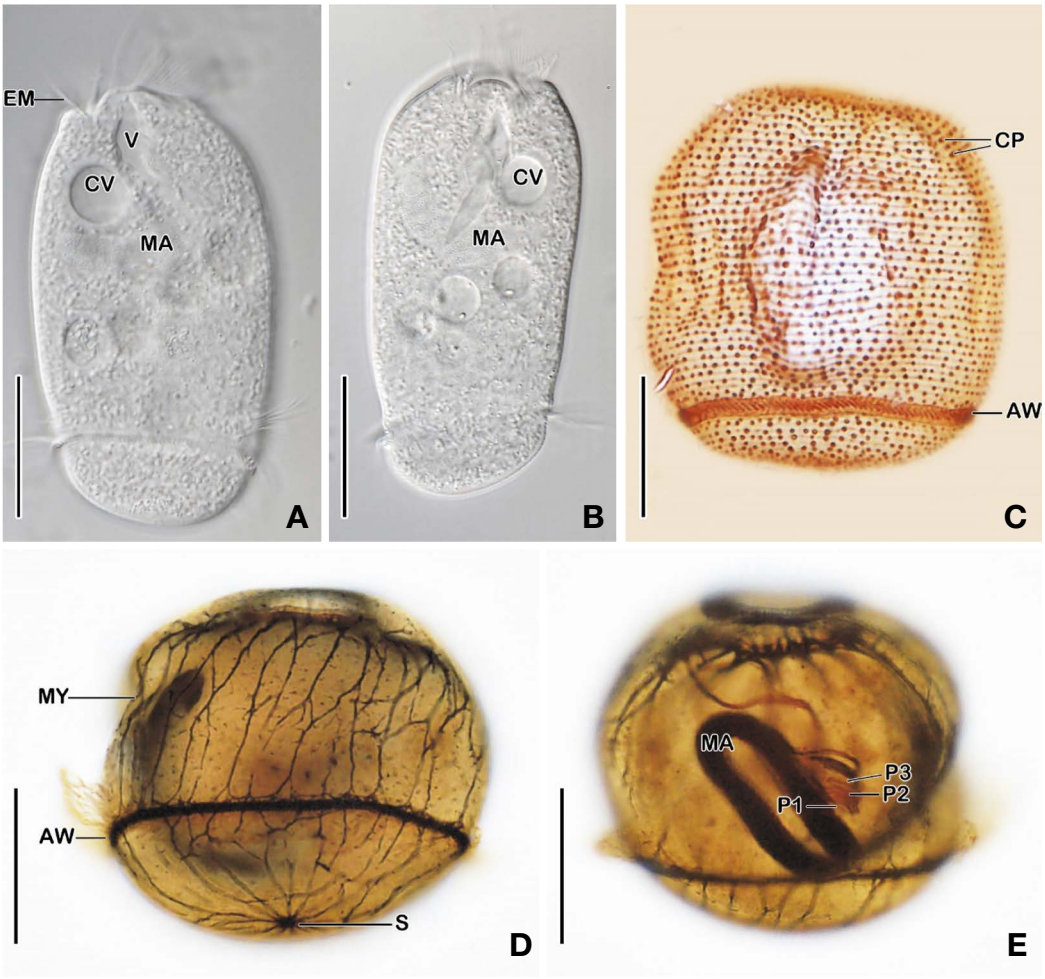

Fig. 20. Photomicrographs of *Opisthonecta minima* from life (A, B), after silver nitrate (C), and after protargol impregnation (D, E). A, B. Lateral views showing the body shape, the aboral wreath, the single contractile vacuole, and the food vacuoles. C. Lateral view showing the ciliature and silverline pattern. D, E. Lateral views of the same specimen showing the myoneme strands, the macronucleus, and the oral polykinetids. AW, aboral ciliary wreath; CP, cortical pores; CV, contractile vacuole; EM, epistomial membrane; MA, macronucleus; MY, myonenes; P1–3, oral polykinetids; S, scopula; V, vestibulum. Scale bars = 30 μm.

Acknowledgements

We are grateful to Ji Hye Moon for providing the aquatic samples. This study was supported by the grant from the Nakdonggang National Institute of Biological Resources (NNIBR), funded by the Ministry of Environment (MOE) of the Republic of Korea (NNIBR202101102).

References

Agatha, S. 2011. Global diversity of aloricate Oligotrichea (Protista, Ciliophora, Spirotricha) in marine and brackish sea water. PLoS One 6:e22466.

Berger, H. 1999. Monograph of the Oxytrichidae (Ciliophora, Hypotrichia). Monographiae Biologicae 78:1-1080.

Berger, H. 2011. Monograph of the Gonostomatidae and Kahliellidae (Ciliophora, Hypotricha). Monographiae Biologicae 90:1741.

Berger, H. and W. Foissner. 1989. Morphology and biometry of some soil hypotrichs (Protozoa, Ciliophora) from Europe and Japan. Bulletin of the British Museum of Natural History (Zoology) 55:19-46.

Bourland, W.A. 2015. Morphology, ontogenesis and molecular characterization of *Atractos contortus* Vorosvary, 1950 and *Stichotricha aculeata* Wrzesniowskiego, 1866 (Ciliophora, Stichotrichida) with consideration of their systematic positions. European Journal of Protistology 51:351-373.

Bourland, W.A., J. Rotterová and I. Čepička. 2017. Redescription and molecular phylogeny of the type species for two main metopid genera, *Metopus es* (Müller, 1776) Lauterborn, 1916 and *Brachonella contorta* (Levander, 1894) Jankowski, 1964 (Metopida, Ciliophora), based on

broad geographic sampling. European Journal of Protistology 59:133-154.

Bourland, W.A. and L. Wendell. 2014. Redescription of *Atopospira galeata* nov. comb. and *A. violacea* nov. comb. with redefinition of *Atopospira* nov. stat. and *Brachonella* Jankowski, 1964 (Ciliophora, Armophorida). European Journal of Protistology 50:356-372.

Buchar, J. 1957. Fauna nálevniků dolniho úseku patoka botči. Casopis Narodniho Musea 126:137-143 (in Czech with German summary).

Corliss, J.O. 1952. Le cycle autogamique de *Tetrahymena rostrata*. Paris 235:399-402.

Corliss, J.O. 1973. History, taxonomy, ecology and evolution of species of *Tetrahymena*. In: A.M. Elliott (ed.), Biology of *Tetrahymena*. Dowden, Hutchinson, & Ross, Stroudsburg, Pa:1-55.

Curds, C.R. 1986. A revision of the Suctoria (Ciliophora, Kinetofragminophora) 4. *Podophrya* and its morphological relatives. Bulletin of the British Museum of Natural History (Zoology) 50:59-91.

Dragesco, J. and A. Dragesco-Kernéis. 1986. Ciliés libres de l'Afrique intertropicale. Introduction á la connaissance et á l'étude des ciliés. Faune tropicale 26:1-559.

Dragesco, J. and F. Iftode. 1972. *Histiobalantium natans* (Clap. & Lachm., 1858) morphologie, infraciliature, morphogenése (Holotriche Hymenostomatida). Protistologica 8:347-352.

Dragesco, J. and T. Njiné. 1971. Complements a la connaissance des cilies libres du Cameroun. Annales de la Faculte des Sciences du Cameroun 7-8:97-140.

Finlay, B.J., G.F. Esteban and T. Fenchel. 2004. Protist diversity is different? Protist 155:15-22.

Finlay, B.J., J.O. Corliss, G.F. Esteban and T. Fenchel. 1996. Biodiversity at the microbial level: the number of free-living ciliates in the biosphere. The Quarterly Review of Biology 71:221-237.

Foissner, W. 1975. Opisthonectidae (Ciliata, Peritrichida) nov. fam. und Revision der Genera *Telotrochidium* (Kent) und *Opisthonecta* (Fauré-Frermiet). Protistologica 11:395-414.

Foissner, W. 1978. *Opisthonecta bivacuolata* nov. spec, *Telotrochidium cylindricum* nov. spec, und *Epistylis alpestris* nov. spec, drei neue peritriche Ciliaten aus dem Hochgebirge. Annalen des Naturhistorischen Museums in Wien 81:549-565.

Foissner, W. 1980. Taxonomische Studien Öber die Ciliaten des Grossglocknergebietes (Hohe Tauern, Österreich) IX. Ordnungen Heterotrichida und Hypotrichida. Berichte des Naturwissenschaftlich-medizinischen Vereins in Salzburg 5:71-117.

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. 1987. Neue terrestrische und limnische Ciliaten (Protozoa, Ciliophora) aus Österreich und Deutschland. Sitzungsberichte der Akademie der Wissenschaften, Wien 195:217-268.

Foissner, W. 1989. Morphologie und Infraciliature einiger neuerund wenig bekannter terrestrischer und limnischer Ciliaten. Sitzungsberichte der Akademie der Wissenschaften, Wien 196:173-247.

Foissner, W. 1995. Tropical protozoan diversity: 80 ciliate species (Protozoa, Ciliophora) in a soil sample from a tropical dry forest of Costa Rica, with descriptions of four new genera and seven new species. Archiv für Protistenkunde 145:37-79.

Foissner, W. 2004. Some new ciliates (Protozoa, Ciliophora) from an Austrian floodplain soil, including a giant, red "flagship" *Cyrtohymena* (*Cyrtohymenides*) *aspoecki* nov. subgen., nov. spec. Denisia 13:369-382.

Foissner, W. 2014. An update of 'basic light and scanning electron microscopic methods for taxonomic studies of ciliated protozoa'. International Journal of Systematic and Evolutionary Microbiology 64:271-292.

Foissner, W. 2016. Terrestrial and semiterrestrial ciliates (Protozoa, Ciliophora) from Venezuela and Galápagos. Denisia 35:1-912.

Foissner, W. and H. Adam. 1983. Morphologie und Morphogenese des Bodenciliaten *Oxytricha granulifera* sp. n. (Ciliophora, Oxytrichidae). Zoologica Scripta 12:1-11.

Foissner, W., S. Agatha and H. Berger. 2002. Soil ciliates (Protozoa, Ciliophora) from Namibia (Southwest Africa), with emphasis on two contrasting environments, the Etosha region and the Namib Desert. Denisia 5:1-1459.

Foissner, W., H. Berger and F. Kohmann. 1994. Taxonomische und ökologische revision der Ciliaten des saprobiensystems. Band III: Hymenostomata, Prostomatida, Nassulida. Informationssberichte des Bayerischen Landesamtes für Wasserwirtschaft 1/94:1-548.

Foissner, W., H. Blatterer, H. Berger and F. Kohmann. 1991. Taxonomische und ökologische revision der Ciliaten des saprobiensystems. Band I: Cyrtophorida, Oligotrichida, Hypotrichia, Colpodea. InformationsberichteBayer. Landesamtes Wasserwirtsch 1/91:1-478.

Foissner, W., A. Chao and L.A. Katz. 2008. Diversity and geographic distribution of ciliates (Protista: Ciliophora). Biodiversity and Conservation 17:345-363.

Foissner, W., Y. Kusuoka and S. Shimano. 2009. Morphological and molecular characterization of *Histiobalantium natans viridis* Kahl, 1931 (Ciliophora, Scuticociliatia). European Journal of Protistology 45:193-204.

Ganner, B. and W. Foissner. 1989. Taxonomy and ecology of some ciliates (Protozoa, Ciliophora) of the saprobic system. III. Revision of the genera *Colpidium* and *Dexiostoma*, and establishment of a new genus, *Paracolpidium* nov. gen. Hydrobiologia 182:181-218.

Gelei, J. 1954. Über die Lebensgemeinschaft einiger temporärerTümpel auf einer Bergwiese im Börzsönygebirge (Oberungarn) III. Ciliaten. Acta Biologica Hungarica

5:259-343.

He, Y. and K. Xu. 2011. Morphology and small subunit rDNA phylogeny of a new soil ciliate, *Bistichella variabilis* n. sp. (Ciliophora, Stichotrichia). Journal of Eukaryotic Microbiology 58:332-338.

Isquith, I.R., A.J. Repak and H.I. Hirshfield. 1965. *Blepharisma seculum*, sp. nov., a member of the subgenus (Compactum). Journal of Protozoology 12:615-618.

Jankowski, A.W. 1967. The boundaries and composition of the genera *Tetrahymena* and *Colpidium*. Zoologicheskiĭ Zhurnal 46:17-23 (in Russian with English summary).

Jiang, J., J. Huang, L. Li, C. Shao, K.A.S. Al-Rasheid, S.A. Al-Farraj and Z. Chen. 2013. Morphology, ontogeny, and molecular phylogeny of two novel bakuellid-like hypotrichs (Ciliophora: Hypotrichia), with establishment of two new genera. European Journal of Protistology 49:78-92.

Jung, J.-H., M.-H. Park, S.Y. Kim, J.M. Choi, G.-S. Min and Y.-O. Kim. 2017. Checklist of Korean ciliates (Protozoa: Ciliophora). Journal of Species Research 6:241-257.

Kahl, A. 1926. Neue und wenig bekannte Formen der holotrichen und heterotrichen Ciliaten. Archiv für Protistenkunde 55:197-438.

Kahl, A. 1931. Urtiere oder Protozoa I: Wimpertiere oder Ciliata (Infusoria) 2. Holotricha außer den im 1. Teil behandelten Prostomata. In: F. Dahl (ed.), Die Tierwelt Deutschlands und der angrenzenden Meeresteile. Gustav Fischer Verlag, Jena, T. 21:181-398.

Kahl, A. 1932. Urtiere oder Protozoa I: Wimpertiere oder Ciliata (Infusoria) 3. Spirotricha. Die Tierwelt Deutschlands und der angrenzenden Meeresteile. Gustav Fischer Verlag, Jena, T. 25:399-650.

Kim, K.-S., J.-H. Jung and G.-S. Min. 2016. A new soil ciliate, *Birojimia soyaensis* nov. spec. (Ciliophora: Urostylida) from South Korea. Acta Protozoologica 55:135-144.

Kim, J.H., A. Omar and J.-H. Jung. 2019. Morphology and phylogeny of the soil ciliate *Parabistichella multilineae* sp. nov. (Protozoa: Ciliophora: Hypotricha). Zoological Science 36:242-249.

Kumar, S., D. Bharti, P. Quintela-Alonso, M.K. Shin and A. La Terza. 2016. Fine-tune investigations on three stylonychid (Ciliophora, Hypotricha) ciliates. European Journal of Protistology 56:200-218.

Küppers, G.C. and M.C. Claps. 2010. Morphology and notes on morphogenesis during cell division of *Deviata polycirrata* n. sp. and of *Deviata bacilliformis* (Gelei, 1954) Eigner, 1995 (Ciliophora: Kahliellidae) from Argentina. Journal pf Eukaryotic Microbiology 57:273-284.

Küppers, G.C., M.C. Claps and E.C. Lopretto. 2009. Ciliates (Protozoa) from dried sediments of a temporary pond from Argentina. Revista Mexicana de Biodiversidad 80:581-592.

Kwon, C.B., M.K. Shin, S.Y. Kim, S.-J. Kim, Y.-O. Kim and J.-H. Jung. 2019. Phylum CILIOPHORA. In: National Institute of Biological Resources (ed.), National species list of Korea II Vertebrates, invertebrates, protozoans. Designzip. pp. 673-697 (in Korean).

Li, F., Z. Lv, Z. Yi, S.A. Al-Farraj, K.A.S. Al-Rasheid and C. Shao. 2014. Taxonomy and phylogeny of two species of the genus *Deviata* (Protista, Ciliophora) from China, with description of a new soil form, *Deviata parabacilliformis* sp. nov. International Journal of Systematic and Evolutionary Microbiology 64:3775-3785.

Lynn, D.H. 2008. The ciliated protozoa: Characterization, classification, and guide to the literature. Springer, New York.

Moon, J.H., J.H. Kim, P. Quintela-Alonso and J.-H. Jung. 2019. Morphology, morphogenesis, and molecular phylogeny of *Neobakuella aenigmatica* n. sp. (Ciliophora, Spirotrichea, Bakuellidae). Journal of Eukaryotic Microbiology 67:54-65.

Omar, A. and W. Foissner. 2013. Description of two new *Drepanomonas* taxa and an account on features defining species in *Drepanomonas* Fresenius, 1858 (Ciliophora, Microthoracida). European Journal of Protistology 49:420-437.

Pan, X., W.A. Bourland and W. Song. 2013. Protargol synthesis: an in-house protocol. Journal of Eukaryotic Microbiology 60:609-614.

Pan, H. and T. Stoeck. 2017. Redescription of the halophile ciliate, *Blepharisma halophilum* Ruinen, 1938 (Ciliophora, Heterotrichea, Heterotrichida) shows that the genus *Blepharisma* is nonmonophyletic. European Journal of Protistology 61:20-28.

Penard, E. 1922. Études sur les Infusoires d'Eau Douce. Georg & Cie, Genève: 331 pp.

Reuter, J. 1961. Einige faunistische und ökologische Beobachtungen über Felsentümpel-Ziliaten. Acta Zoologica Fennica 99:1-42.

Segade, P., C.P. Kher, D.H. Lynn and R. Iglesias. 2009. Morphological and molecular characterization of renal ciliates infecting farmed snails in Spain. Parasitology 136:771-782.

Segade, P., N. García, J.M. García Estévez, C. Arias and R. Iglesias. 2015. Encystment/excystment response and serotypic variation in the gastropod parasite *Tetrahymena rostrata* (Ciliophora, Tetrahymenidae). Parasitology Research 115:771-777.

Shao, C., Z. Lv, Y. Pan, K.A.S. Al-Rasheid and Z. Yi. 2014. Morphology and phylogenetic analysis of two oxytrichid soil ciliates from China, *Oxytricha paragranulifera* n. sp. and *Oxytricha granulifera* Foissner and Adam, 1983 (Protista, Ciliophora, Hypotrichia). International Journal of Systematic and Evolutionary Microbiology 64:3016-3027.

Vd'ačný, P. and W. Foissner. 2012. Monograph of the dileptids (Protista, Ciliophora, Rhynchostomatia). Denisia 31:1-529.

Voss, H.-J. and W. Foissner. 1996. Divisional morphogenesis in *Steinia sphagnicola* (Ciliophora, Hypotrichida): a comparative light and scanning electron microscopic

study. European Journal of Protistology 31:31-46.

Warren, A., D.J. Patterson, M. Dunthorn, J.C. Clamp, U.E.M. Achilles-Day, E. Aescht, S.A. Al-Farraj, S. Al-Quraishy, K. Al-Rasheid, M. Carr, J.G. Day, M. Dellinger, H.A. El-Serehy, Y. Fan, F. Gao, S. Gao, J. Gong, R. Gupta, X. Hu, K. Kamra, G. Langlois, X. Lin, D. Lipscomb, C.S. Lobban, P. Luporini, D.H. Lynn, H. Ma, M. Macek, J. Mackenzie-Dodds, S. Makhija, R.I. Mansergh, M. Martín-Cereceda, N. McMiller, D.J.S. Montagnes, S. Nikolaeva, G.O. Ong'ondo, B. Pérez-Uz, J. Purushothaman, P. Quintela-Alonso, J. Rotterová, L. Santoferrara, C. Shao, Z. Shen, X. Shi, W. Song, T. Stoeck, A. La Terza, A. Vallesi, M. Wang, T. Weisse, K. Wiackowski, L. Wu, K. Xu, Z. Yi, R. Zufall and S. Agatha. 2017. Beyond the "Code": A guide to the description and documentation of biodiversity in ciliated protists (Alveolata, Ciliophora). Journal of Eukaryotic Microbiology 64:539-554.

Wirnsberger, E., W. Foissner and H. Adam. 1985. Morphological, biometric, and morphogenetic comparison of two closely related species, *Stylonychia vorax* and *S. pustulata* (Ciliophora: Oxytrichidae). Journal of Protozoology 32:261-268.

Submitted: July 13, 2021
Revised: July 21, 2021
Accepted: July 21, 2021