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Taxonomy of 16 indigenous ciliate species (Protozoa, Ciliophora) from South Korea

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We collected indigenous Korean ciliate species from diverse aquatic and terrestrial habitats in 2018 and 2019. The morphology of these ciliates was revealed based on the observations of living cells, and protargol-impregnated and/or silver carbonate-impregnated specimens. During this study, we found 16 previously unrecorded Korean ciliate species, which are as follows: 1) class Heterotrichea - *Stentor introversus*; 2) class Spirotrichea - *Aspidisca orthopogon*, *Amphisiella sinica*, *Epiclintes auricularis rarisetus*, *Apokeronopsis wrighti*, *Pseudokeronopsis carnea*, *Trachelostyla pediculiformis*, *Strombidium apolatum*, and *Varistrombidium kielum*; 3) class Phyllopharyngea - *Chlamydodon obliquus*, *Dysteria aculeata*, and *Hartmannula angustipilosa*; 4) class Litostomatea - *Paraspathidium apofuscum*; and 5) class Oligohymenophorea - *Frontonia angusta solea*, *Metanophrys sinensis*, and *Uronemita binucleata*. Here, we provide a diagnosis for each species with a brief remark. Among them, the infraciliature of the poorly known species, *Stentor introversus* and *Dysteria aculeata*, is described for the first time. Further, we revise the Korean population of *Pseudokeronopsis pararubra*, which was previously misidentified as *Pseudokeronopsis carnea*.

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

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Introduction

Free-living ciliates are abundant and diverse, inhabiting aquatic and terrestrial habitats worldwide. To date, about 8,000 species have been described including fossil tintinnids and commensal species (Foissner, 2008; Warren *et al*., 2017). Researchers estimate that 83−89%, 27,000−40,000 biological species, of the free-living ciliates remain undiscovered (Finlay *et al*., 1996; 2004; Foissner *et al*., 2008; Lynn, 2008; Agatha, 2011; Foissner, 2016). In the last few decades, Korean ciliate diversity has been receiving more attention and about 200 species have been discovered in Korean habitats (Kwon *et al*., 2019). During 2018 and 2019, we collected tens of ciliate species living in different habitats, including freshwater, estuaries, marine intertidal zones, soil, and mosses. In the present study, 16 of these species are recorded and redescribed for the first time in Korea.

Materials and Methods

The locality information is described in the 'Material examined' section for each species. The terrestrial soil and moss samples were air-dried for at least two weeks, then cultured using the non-flooded Petri dish method (Foissner *et al*., 2002). The aquatic samples were collected and transferred to our laboratory as soon as possible. Cultures were set in Petri dishes and two or three wheat or rice grains were added to increase bacteria and fungi as food source at a temperature of about 20°C (Kim and Jung, 2019).

The morphology of live cells was observed using a stereomicroscope (Olympus SZ11, Japan) and an optical microscope (Olympus BX53, Japan) at low (×40−200) to high (×400−1000) magnifications, and photomicrographs were taken using a digital camera (Olympus DP74, Japan). Protargol powder was synthesized using the method of Pan *et al*. (2013) and protargol impregnated specimens

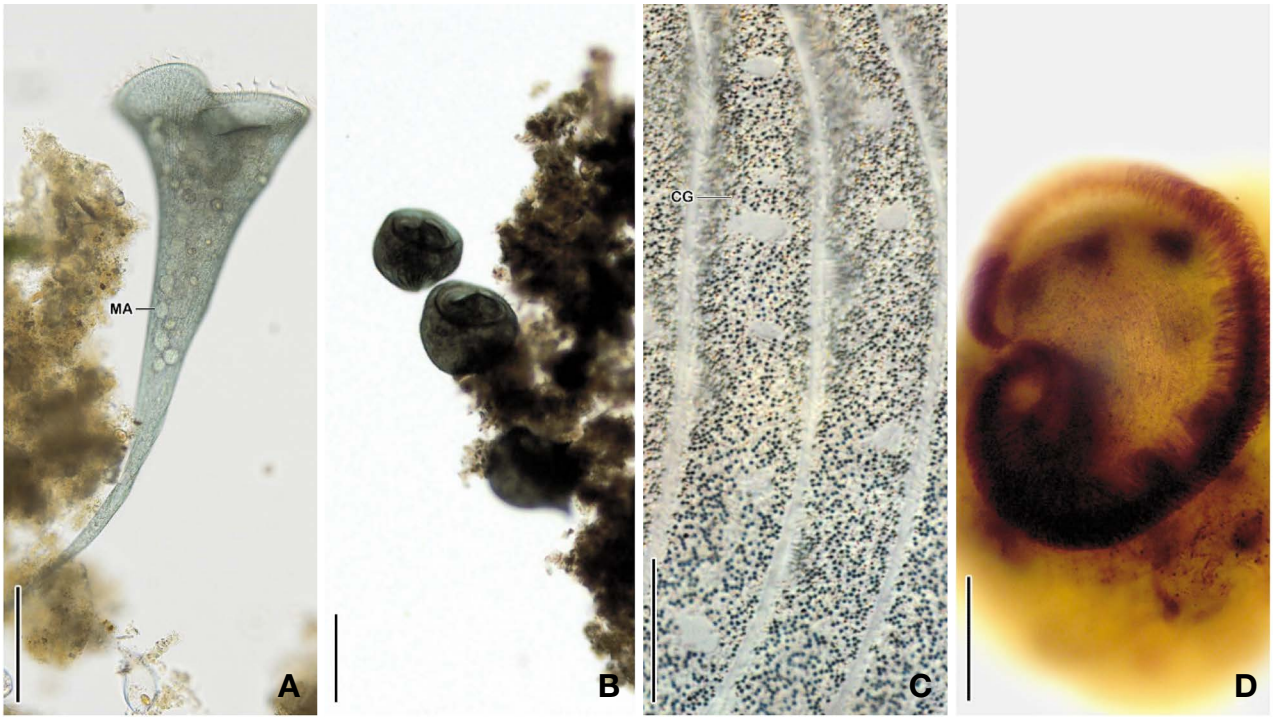

Fig. 1. Photomicrograph of *Stentor introversus in vivo* (A–C) and after protargol impregnation (D). A. Extended body. B. Contracted body. C. Two kinds of cortical granules (smaller reddish and larger turquoish). D. Buccal field. CG, cortical granules; MA, macronuclear nodule. Scale bars = 50 μm (A, D); 200 μm (B); 20 μm (C).

were prepared using the 'procedure A' method (Foissner, 2014). The silver carbonate method was performed only for *Frontonia angusta solea* (Foissner, 2014). 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 Berger (2008) and Lynn (2008). The specific terminology of each taxon follows the previous studies.

Results and Discussion

Phylum Ciliophora Doflein, 1901
Class Heterotrichea Stein, 1859
Order Heterotrichida Stein, 1859
Family Stentoridae Darus, 1863
Genus *Stentor* Oken, 1815

1. *Stentor introversus* Tartar, 1958 (Fig. 1)

Material examined. Brackish water with debris (salinity, 7.6‰) collected from Songji Lake, Oho-ri, Jugwang-myeon, Goseong-gun, Gangwon-do, Korea (38°20′12″N 128°31′4″E) on 17 May 2019.

Diagnosis. Extended body size *in vivo* 500–600 × 200–250 μm and trumpet-shaped, contracted body size 250–305 × 200–250 μm *in vivo* (n = 10) and pouch-shaped with retracted buccal field; cytoplasm colorless; 2 kinds of cortical granules densely arranged in between somatic kineties, larger granules turquoise and 0.4–0.5 μm in diameter, smaller granules reddish and 0.2–0.3 μm in diameter; 250 adoral membranelles; 60–73 somatic kineties; 16–20 buccal kineties including 1 peristomial kinety; moniliform macronucleus with 9–14 nodules.

Distribution. U.S.A. and Korea.

Remarks. *Stentor introversus* was not reported since the original description by Tartar (1958) from USA. It differs from the most similar species, *S. coeruleus* (Pallas, 1766) Ehrenberg, 1831, in the extended body size (500–600 μm vs. 1–2 mm), buccal field retracted when contracted (present vs. absent), and the number of types of cortical granules (2 vs. 1) (Foissner *et al*., 1992; Foissner and Wölfl, 1994).

Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110205, NIBRPR0000110206).

Class Spirotrichea Bütschli, 1889
Subclass Hypotrichia Stein, 1859
Order Euplotida Small & Lynn, 1985

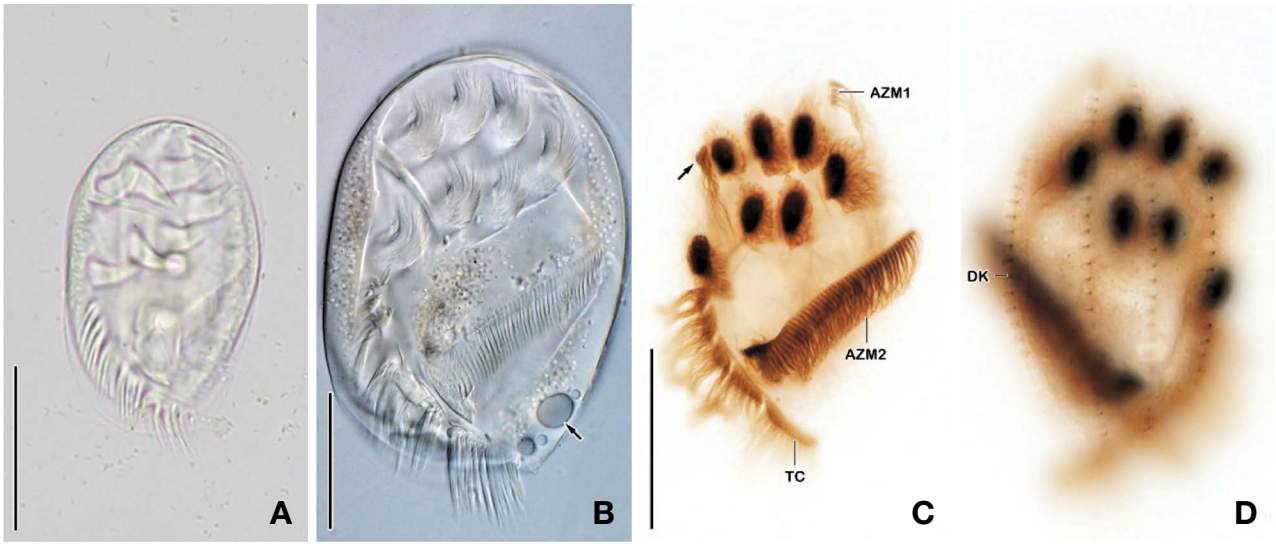

Fig. 2. Photomicrograph of *Aspidisca orthopogon in vivo* (A, B) and after protargol impregnation (C, D). A, B. Body shape *in vivo* (arrow indicates contractile vacuole in B). C. Ventral ciliature (arrow marks small frontoventral cirrus). D. Dorsal kineties. AZM1–2, adoral zone of membranelles 1 and 2; DK, dorsal kinety; TC, transverse cirrus. Scale bars = 50 μm (A, B); 30 μm (C).

Family Aspidiscidae Ehrenberg, 1830
Genus *Aspidisca* Ehrenberg, 1830

2. *Aspidisca orthopogon* Deroux & Tuffrau, 1965 (Fig. 2)

Material examined. Marine water with some debris (salinity, 29.3‰) collected from Hamdeok Beach, Jocheon-eup, Jeju-si, Jeju-do, Korea (33°32′36″N 126°39′51″E) on 8 Jun 2019.
Diagnosis. Body size *in vivo* 95–105 × 55–65 μm (n = 3); broad elliptical; 1 small and 7 distinct frontoventral cirri with *polystyla*-arrangement; single contractile vacuole located subterminally; 5 transverse cirri; 4 dorsal kineties; adoral zone of membranelles (AZM) bipartite, AZM1 composed of 4 membranelles; AZM2 composed of 41–45 membranelles, posterior thorn-like projection absent.
Distribution. China, Korea (Type locality is not mentioned).
Remarks. The Korean population of *Aspidisca orthopogon* corresponds very well to the Chinese population (Li *et al*., 2008). They only differ in the absence (vs. presence) of the thorn-like projection in the rear body end. *Aspidisca orthopogon* is also similar to *A. magna* in the body size (95–105 × 55–65 μm vs. 50–100 × 40–80 μm), but can be easily distinguished from this species and other congeners by the enormous posterior adoral zone (AZM2), which is composed of 41–45 membranelles (vs. 12–13 in *A. aculeata*, 15–18 in *A. magna*, and 14–21 in *A. leptapsis*) (Li *et al*., 2008; 2010).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at the National Institute of Biological Resources (NIBRPR0000110192, NIBRPR0000110193).

Subclass Stichotrichia Small & Lynn, 1985
Order Stichotrichida Faure-Fremiet, 1961
Family Amphisiellidae Jankowski, 1979
Genus *Amphisiella* Gourret & Roeser, 1888

3. *Amphisiella sinica* Li, Zhao, Ji, Al-Rasheid, Al-Farraj & Song, 2016 (Fig. 3)

Material examined. Marine water with some debris (salinity, 30.7‰) collected from Anin Beach, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′4.7″N 128° 59′ 24.2″E) on 22 Jan 2019.
Diagnosis. Body size *in vivo* about 110–170 × 30–40 μm (n = 5); elongate elliptical to fusiform with anterior portion slightly cephalized and curved leftwards; 2 macronuclear nodules; two kinds of colorless cortical granules: larger granules grouped along dorsal kineties; smaller distributed on whole cortex; ring-shaped structures with shallow brim, in anterior and posterior body portions; 55 adoral membranelles on average; median cirral row extends to transverse cirri, and consists of about 47 narrowly spaced cirri; left and right marginal row composed of about 44 and 43 cirri, respectively.
Distribution. China and Korea.
Remarks. The Korean population of *A. sinica* resembles the type population (Li *et al*., 2016). It is also similar to *A. annulata* in the body size, the general cirral pattern, the two macronuclear nodules, and the two types of cortical granules (Li *et al*., 2007). However, they differ mainly

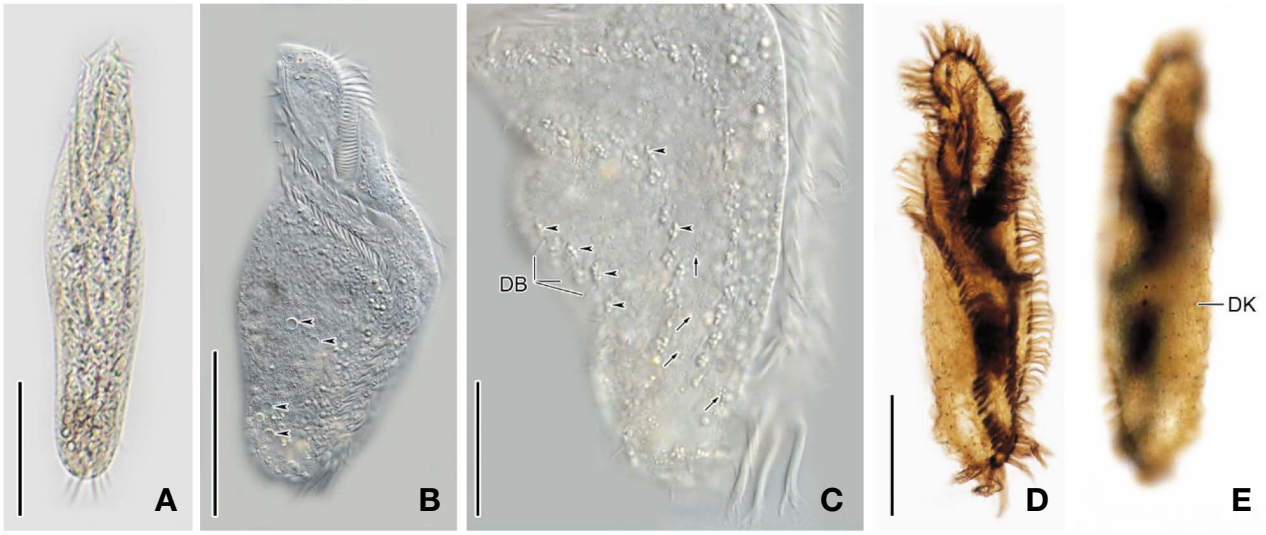

Fig. 3. Photomicrograph of *Amphisiella sinica in vivo* (A–C) and after protargol impregnation (D, E). A. Typical body shape *in vivo*. B. Cytoplasmic inclusions details (arrowheads mark ring-like structures). C. Cortical granulation around dorsal bristles (arrowheads) and patch-like smaller cortical granules (arrows). D. Ventral ciliature. E. Dorsal kineties. DB, dorsal bristles; DK, dorsal kinety. Scale bars = 50 μm (A, B, D); 20 μm (C).

in the number (many vs. few or absent) and the arrangement (in anterior and posterior part vs. if present, scattered in whole cytoplasm) of the ring-shaped structures, and the shape of the anterior body portion (cephalized vs. non-cephalized).

Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110188, NIBRPR0000110189).

Family Epiclintidae Wicklow & Borror, 1990
Genus *Epiclintes* Stein, 1863
Species *Epiclintes auricularis* (Claparède & Lachmann, 1858) Stein, 1864

4. *Epiclintes auricularis rarisetus* Hu, Fan, Lin, Gong & Song, 2009 (Fig. 4)

Material examined. Marine water with some debris (salinity, 30.7‰) collected from Anin Beach, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′4.7″N 128°59′24.2″E) on 10 Dec 2018.

Diagnosis. Body size *in vivo* 250–300 × 25–30 μm (n = 3); elongated and cephalized with long tail; highly contractile; paroral and endoral membrane short and parallel; about 28 adoral membranelles; 2 frontal cirri; 8 frontoventral rows; 4 cirri in frontral row 1; 4–6 cirri in frontral row 2; 5 cirri in frontral row 3; 12 or 13 cirri in frontral row 4; 11–13 cirri in frontal row 5; 11 or 12 cirri in frontal row 6; 7–10 cirri in frontal row 7; 9 or 10 cirri in frontal row 8; 25–27 left marginal cirri; 39–42 right marginal cirri; 13–17 transverse cirri; 22–25 macronuclear nodules; bar-shaped dorsal bristles; and 3 dorsal kineties.

Distribution. China and Korea.

Remarks. The Korean population of *Epiclintes auricularis rarisetus* corresponds very well with the type population (Hu *et al*., 2009). *Epiclintes auricularis rarisetus* and *E. auricularis auricularis* (Claparède & Lachmann, 1858) Stein, 1864 are different in the number of adoral membranelles (23–33 vs. 41–71), the number of frontal cirri (2 or 3 vs. usually 0 or 1), the number of frontal rows (8 or 9 vs. usually 11–15), the number of cirri in left marginal row (22–31 vs. 45–63), the number of cirri in right marginal row (35–54 vs. usually 63–129), the number of transverse cirri (10–18 vs. 18–43), and the number of macronuclear nodules (24–70 vs. 40–123) as described by Hu *et al*. (2009).

Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110211, NIBRPR0000110212).

Order Urostylida Jankowski, 1979
Family Pseudokeronopsidae Borror & Wicklow, 1983
Genus *Apokeronopsis* Shao, Hu, Warren, Al-Rasheid, Al-Quraishy & Song, 2007

5. *Apokeronopsis wrighti* Long, Liu, Liu, Miao, Hu, Lin & Song, 2008 (Fig. 5)

Material examined. Marine water (salinity, 29.3‰) col-

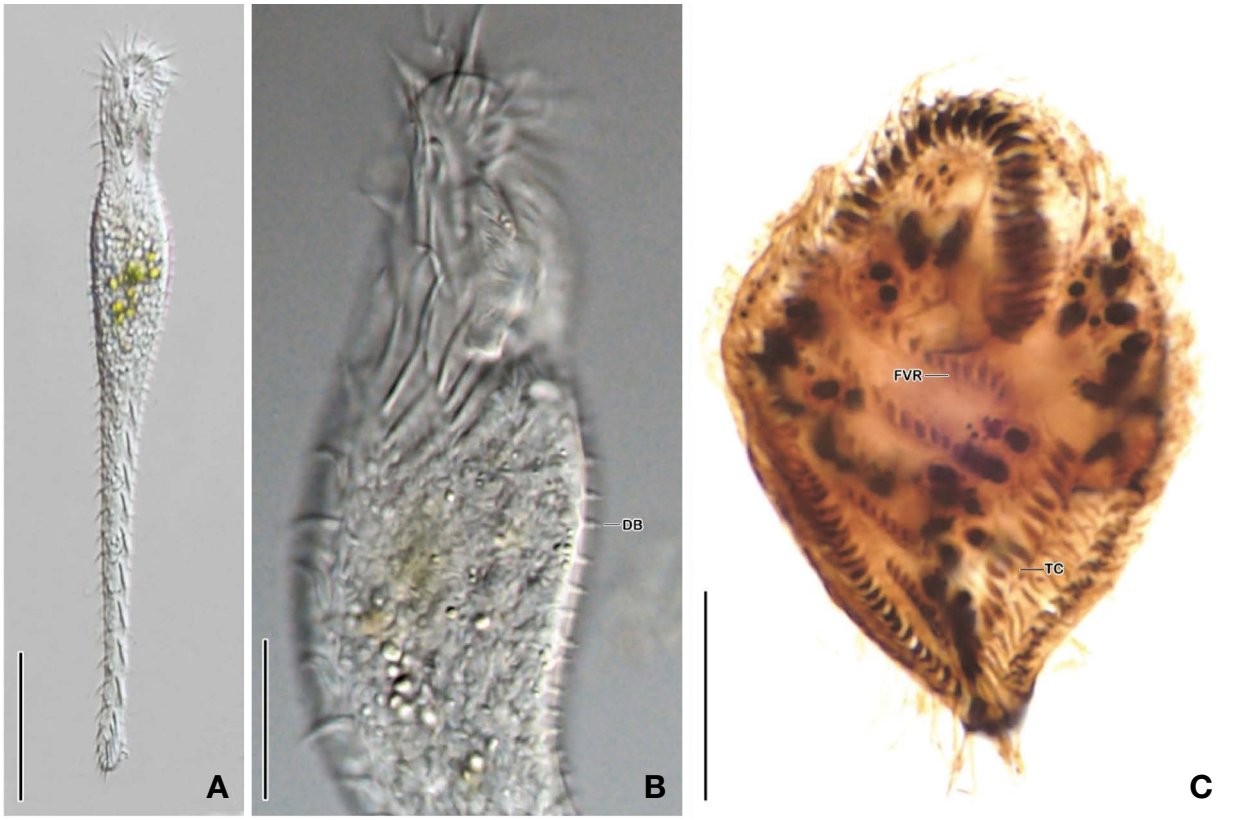

Fig. 4. Photomicrograph of *Epiclintes auricularis rarisetus in vivo* (A, B) and after protargol impregnation (C). A. Fully elongated and typical body shape *in vivo*. B. Detail of dorsal bristles on papillae. C. Ventral ciliature. DB, dorsal bristles; FVR, frontoventral row; TC, transverse cirri. Scale bars = 50 μm (A); 20 μm (B); 30 μm (C).

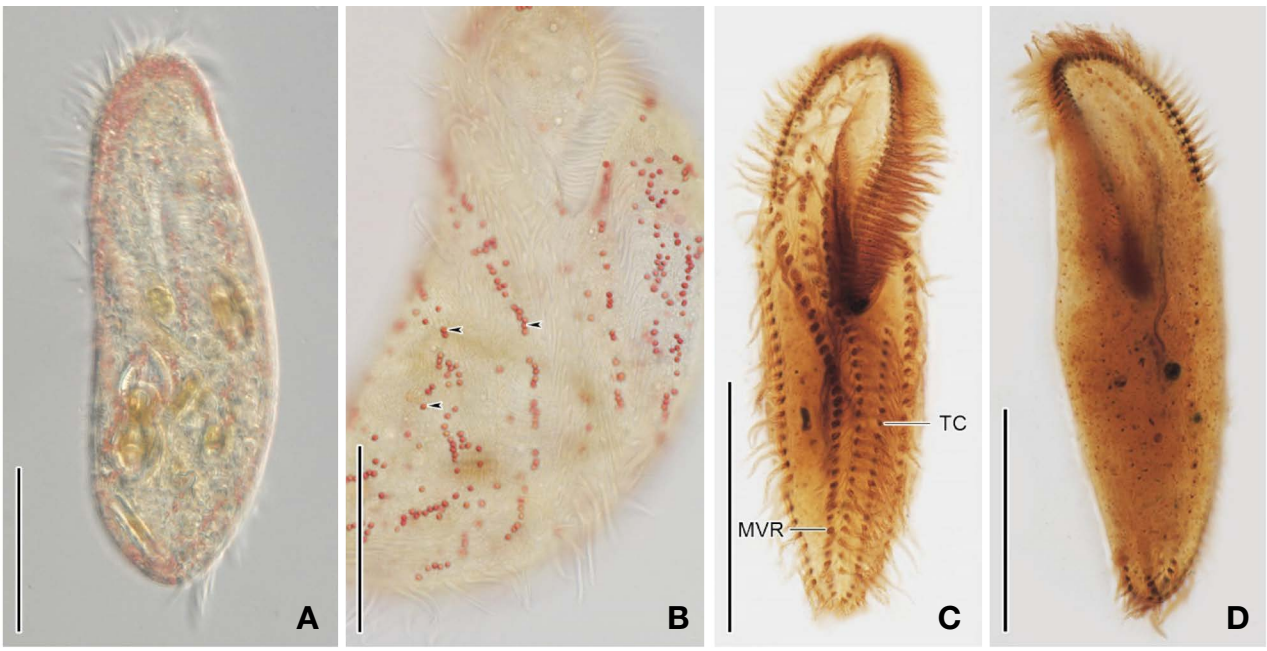

Fig. 5. Photomicrograph of *Apokeronopsis wrighti in vivo* (A, B) and after protargol impregnation (C, D). A. Typical body shape *in vivo*. B. Details of reddish cortical granulation (arrowheads) and greenish minute cortical granules distributed all over the cortex. C. Ventral ciliature. D. Dorsal kineties. MVR, midventral cirral row; TC, transverse cirrus. Scale bars = 50 μm.

Fig. 6. Photomicrograph of *Pseudokeronopsis carnea in vivo* (A) and after protargol impregnation (B, C). A. Body shape and details of the bright reddish cortical granulation. B. Ventral ciliature. C. Dorsal kineties. 1–5, dorsal kineties; CG, cortical granules; MVP, midventral pairs; PTC, pretransverse cirri; TC, transverse cirri. Scale bars = 50 μm.

lected from the mud flat of Oryun-ri, Dosan-myeon, Tongyeong-si, Gyeongsangnam-do, Korea (34°54′30.10″ N 128°20′3.90″E) on 6 May 2019.

Diagnosis. Body size *in vivo* 150–210 × 40–60 μm (n = 3); ellipsoidal with rounded anterior and posterior end; two types of cortical granules, type I brick red, globular to slightly ellipsoidal, about 1–2 μm across, and grouped in rows along the dorsal kineties and ciliary rows; type II greenish, minute, about 0.3 μm across, and arranged in rows all over the cortex; invariably 2 midventral rows with equal number (40–47) of cirri; 7–9 buccal, 2 or 3 frontoterminal cirri; left and right marginal rows with 31–43 and 33–44 cirri, respectively; 30–34 transverse cirri extending anteriorly beyond the level of mid-body; 3 dorsal kineties.

Distribution. China and Korea.

Remarks. The Korean population of *A. wrighti* is identical to the Chinese type population (Long *et al.*, 2008). *Apokeronopsis wrighti* is also similar to the closely related species *A. crassa* in most features but they can be easily distinguished from each other by the arrangement (in rows vs. sparsely arranged) of the cortical granules (Shao *et al.*, 2007).

Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110190, NIBRPR0000110191).

Genus *Pseudokeronopsis* Borror and Wicklow, 1983

6. *Pseudokeronopsis carnea* (Cohn, 1866) Wirnsberger, Larsen & Uhlig, 1987 (Fig. 6)

Material examined. Marine water (salinity, 26.9‰) col-

Fig. 7. Photomicrograph of *Trachelostyla pediculiformis in vivo* (A, B) and after protargol impregnation (C, D). A. Typical body shape *in vivo* and reddish cytoplasmic inclusions and the rod-shaped cortical granules (arrow). B. Dorsal side with cortical granules (arrows) and dorsal bristles. C. Ventral ciliature. D. Ventrolateral view showing the ventral ciliature and the caudal cirri. TC, transverse cirri. Scale bars = 30 μm.

lected under Gangmun Bridge on Gangmun-dong, Gangneung-si, Gangwon-do, Korea (37°47′48.0″N 128°54′51.0″E) on 19 Mar 2019.

Diagnosis. Body size *in vivo* 170−230 × 30−60 μm (n = 7); slender with rounded anterior and posterior end, anterior body portion slightly narrowed and posterior portion distinctly narrowed; flexible but not contractile; contractile vacuole left and posterior to body center; cortical granules orange to brownish in color, scattered all over the cortex and arranged around dorsal bristles and cirri; many macronuclear nodules (> 100); adoral zone of membranelles about 30% of body length and consists of 54−60 membranelles; right marginal row with 58−70 cirri, left marginal row with 54−60, 35−43 midventral pairs, 7−9 transverse, 2 pretransverse, 1 buccal cirri, and 5 dorsal kineties.

Distribution. China, Denmark, Germany, Japan, Netherland, United Kingdom, and Korea.

Remarks. The Korean population of *Pseudokeronopsis carnea* resembles the Chinese population (Song *et al*., 2006). In this study, we synonymize the previous Korean *P. carnea* (Baek *et al*., 2011) to *P. pararubra* on the basis of the length of the midventral rows (terminates at the level of transverse cirri in *P. carnea* vs. terminates far anterior to transverse cirri in *P. pararubra*) and the color of the cortical granules (bright orange-red in *P. carnea* vs. dark brick-red in *P. pararubra*) (Hu *et al*., 2004; Baek *et al*., 2011).

Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110201, NIBRPR0000110202).

Order Sporadotrichida Faure-Fremiet, 1961
Family Trachelostylidae Small & Lynn, 1985
Genus *Trachelostyla* Borror, 1972

7. *Trachelostyla pediculiformis* (Cohn, 1866) Borror, 1972 (Fig. 7)

Material examined. Marine water with some debris (salinity, 29.4‰) collected from Anin Beach, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′4.7″N 128°59′24.2″E) on 15 Jan 2019.

Diagnosis. Body size *in vivo* about 80−140 × 25−40 μm (n = 5); bipartite with ellipsoidal trunk and a neck struc-

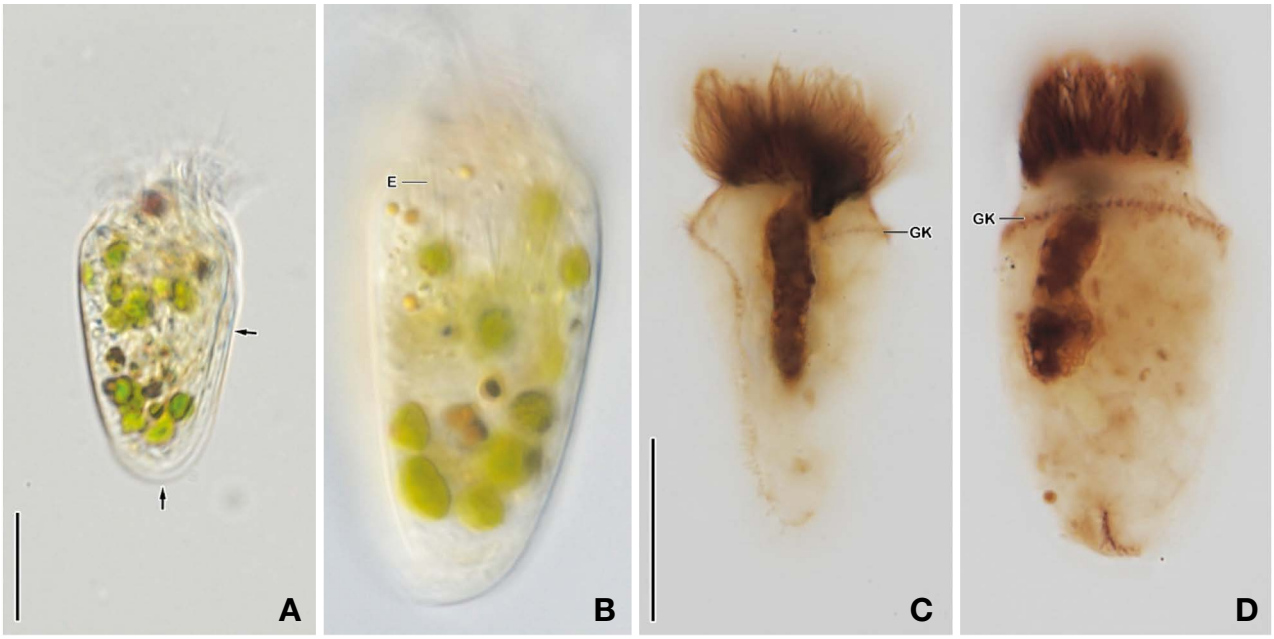

Fig. 8. Photomicrograph of *Strombidium apolatum in vivo* (A, B) and after protargol impregnation (C, D). A. Body shape *in vivo* with food vacuoles filled with green algae. Note that the body is covered with hemitheca (arrows). B. Extrusomes. C, D. Nuclear apparatus, the discontinuous girdle kinety, and the ventral kinety. E, extrusomes; GK, girdle kinety. Scale bars = 20 μm.

ture; cell flexible but not contractile; fusiform cortical granules distributed on ventral and dorsal side in short rows containing 1−4 granules; nuclear apparatus consists of 10−12 macronuclear nodules and 2−3 micronuclei;18 frontoventral transverse cirri.

Distribution. Worldwide.

Remarks. The Korean population of *Trachelostyla pediculiformis* agrees with other populations of *T. pediculiformis*. However, the Korean population is more similar to the type population (Cohn, 1866) because both have cortical granules, unlike the Chinese population (Gong *et al*., 2006). It should be noted that the cortical granules were not recognizable in the fresh samples and could only be observed after three months of cultivation.

Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110203, NIBRPR0000110204).

Subclass Oligotrichia Bütschli, 1887/1889
Order Strombidiida Petz & Foissner, 1992
Family Strombidiidae Fauré-Fremiet, 1970
Genus *Strombidium* Clapaède & Lachmann, 1859

8. *Strombidium apolatum* Wilbert & Song, 2005 (Fig. 8)

Material examined. Marine water with some debris (salinity, 29.3‰) collected from Hamdeok Beach, Jocheon-eup, Jeju-si, Jeju-do, Korea (33°32′36″N 126°39′51″E) on 8 Jun 2019.

Diagnosis. Body size *in vivo* 60−70 × 30−35 μm (n = 3); elongate obconical, dorsoventrally flattened, and partially covered with hemitheca; extrusomes conspicuous *in vivo*, about 15 μm in length; single elongate ellipsoidal macronucleus; apical protrusion filled with reddish granules; about 5 buccal and 15 collar membranelles; girdle kinety opened and left part of dikinetids directed to ventral kinety; ventral kinety arranged from ventral to dorso-lateral side.

Distribution. China, King George Island, and Korea.

Remarks. The Korean population of *Strombidium apolatum* agrees with the type population in most aspects except of the body size (60−70 × 30−35 μm vs. 50 × 40 μm). *Strombidium apolatum* can be easily distinguished from other congeners by the dorsoventrally flattened (vs. non-flattened) body, the discontinuous (vs. continuous) girdle kinety, and the presence (vs. absence) of the hemitheca that covers two thirds of body (Wilbert & Song, 2005; Xu *et al*., 2009).

Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110207, NIBRPR0000110208).

Genus *Varistrombidium* Xu, Sun, Clamp, Ma & Song, 2011

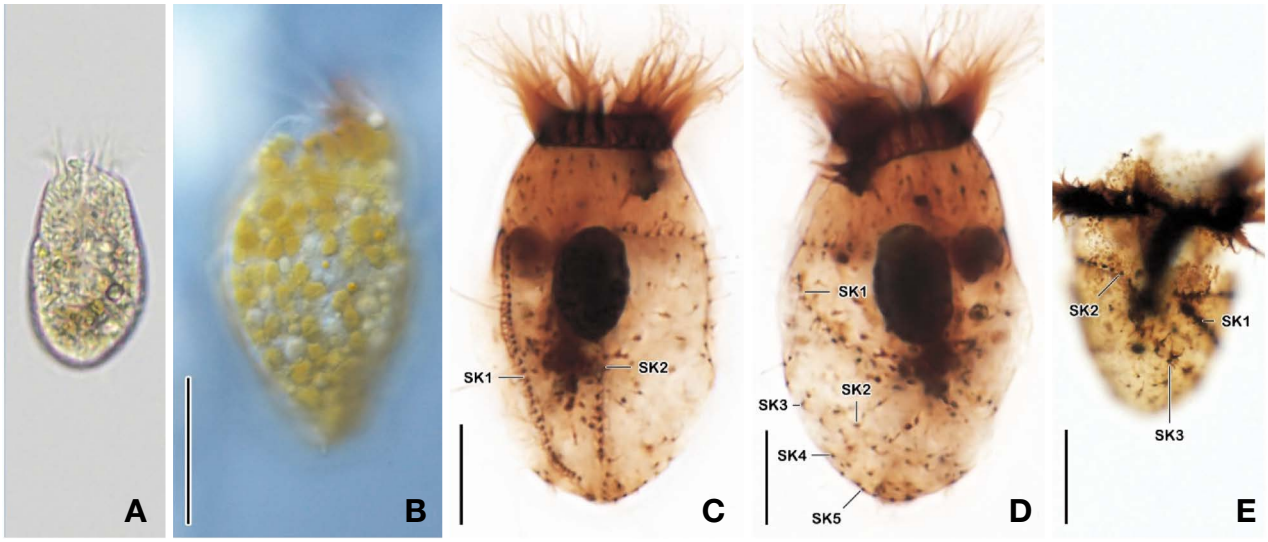

Fig. 9. Photomicrograph of *Varistrombidium kielum in vivo* (A, B) and after protargol impregnation (C–E). A, B. Body shape and cytoplasmic inclusions. C. Somatic kineties arrangement of right and dorsal side. D. Somatic kineties arrangement of left side. E. Somatic kineties of ventral side. SK1–5, somatic kineties 1–5. Scale bars = 20 μm (B, E); 10 μm (C, D).

9. *Varistrombidium kielum* (Maeda & Carey, 1985) Xu, Sun, Clamp, Ma & Song, 2011 (Fig. 9)

Material examined. Marine water with seaweed (salinity, 24.6‰) collected from Gunsuncheon Stream, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′27″N 128°59′2″E) on 16 Apr 2019.
Diagnosis. Body size *in vivo* 50–65 × 30–35 μm (n = 3); obconical to barrel shape; extrusomes conspicuous *in vivo*, about 10 μm in length; single ellipsoidal macronucleus; apical protrusion filled with reddish granules; about 7 buccal and 18 collar membranelles; 5 somatic kineties (SK), SK1 commences on left side, extends rightward, turning back and terminates near posterior end, SK2 commences below starting point of SK1, extends leftward in the opposite direction of SK1 and terminates near posterior end, SK3 parallel to SK2 and arranged only ventral side, SK4 and 5 arranged parallel to SK3 with gap; girdle and ventral kineties absent.
Distribution. China and Korea.
Remarks. *Varistrombidium kielum* is monotypic and characterized by complex arrangement of 5 somatic kineties (Xu *et al*., 2009; 2011).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110209, NIBRPR0000110210).

Class Phyllopharyngea de Puytorac, 1974
Subclass Cyrtophoria Faure-Fremiet in Corliss, 1956
Order Chlamydodontida Deroux, 1976
Family Chlamydodontidae Stein, 1859
Genus *Chlamydodon* Ehrenberg, 1835

10. *Chlamydodon obliquus* Kahl, 1931 (Fig. 10)

Material examined. Marine water collected from Sinwol mud flat, Goseong-eup, Goseong-gun, Gyeongsangnam-do, Korea (34°56′48.60″N 128°20′27.70″E) on 6 May 2019.
Diagnosis. Body size *in vivo* 150–240 × 110–150 μm (n = 5); outline ellipsoid to triangular; macronucleus 18–30 μm in diameter; on average 15 irregularly distributed contractile vacuoles; cross striated band continuous, anterior portion crossing to the dorsal surface; 43–46 right, 4 postoral, and 26–36 left kineties; about 7 terminal fragments on dorsal side; 11–14 nematodesmal rods.
Distribution. China, U.S.A., and Korea.
Remarks. The Korean population of *C. obliquus* is similar to the Chinese population (Gong *et al*., 2005) in most aspects. However, they differ in two overlapping features: the body size (150–220 μm vs. 120–180 μm) and the total number of somatic kineties (73–86 vs. 63–74). *Chlamydodon obliquus* can be easily distinguished from the closely related species *C. bourlandi* by the number of the contractile vacuoles (ca. 15 vs. 40–68), which is considered an important character to separate *Chlamydodon* spp. (Qu *et al*., 2018).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110194, NIBRPR0000111195).

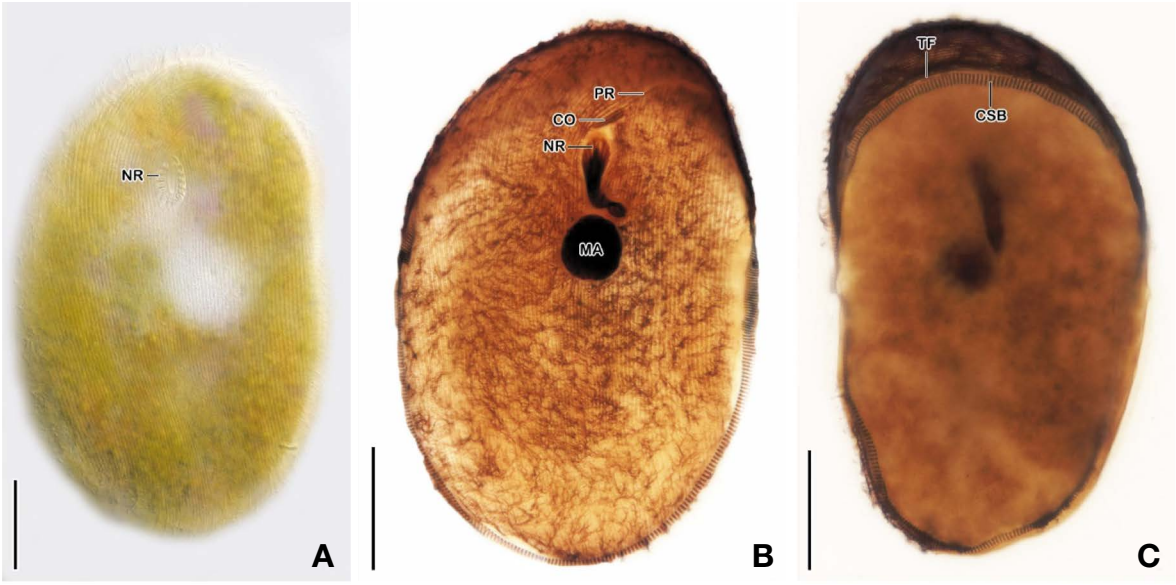

Fig. 10. Photomicrograph of *Chlamydodon obliquus in vivo* (A) and after protargol impregnation (B, C). A. Ventral side showing the cytostome, the ventral ciliature, and the food vacuoles filled with green algae. B. Ventral ciliature and cross striated band. C. Dorsal view. CO, circumoral kineties; CSB, cross striated bands; MA, macronucleus; NR, nematodesmal rods; PR, preoral kinety; TF, terminal fragments. Scale bars = 50 μm.

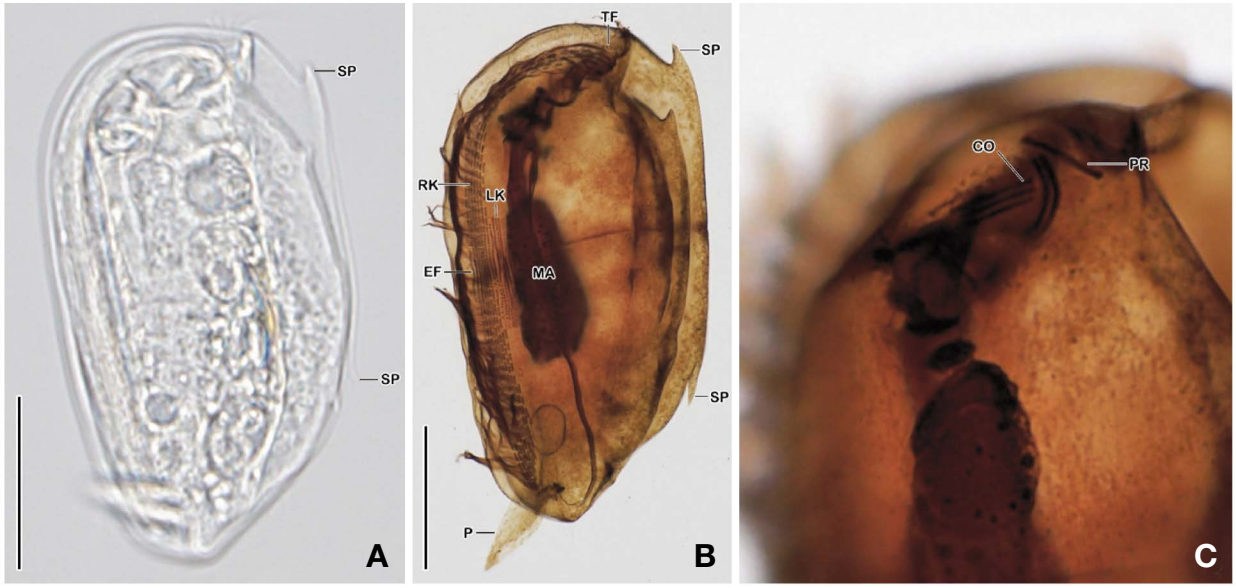

Fig. 11. Photomicrograph of *Dysteria aculeata in vivo* (A) and after protargol impregnation (B, C). A. Left side showing the dorsal spines and the podite. B. Right side somatic ciliature. C. Details of oral ciliature. CO, circumoral kineties; EF, equatorial fragments; LK, left kineties; MA, macronucleus; P, podite; PR, preoral kinety; RK, right kineties; SP, dorsal spines; TF, terminal fragments. Scale bars = 30 μm.

Order Dysteriida Deroux, 1976
Family Dysteriidae Claparède & Lachmann, 1958
Genus *Dysteria* Huxley, 1857

11. *Dysteria aculeata* Claparède & Lachmann, 1859 (Fig. 11)

Material examined. Brackish water (salinity, 23.9‰) collected under Gangmun Bridge on Gangmun-dong, Gangneung-si, Gangwon-do, Korea (37°47′48.0″N 128°54′51.0″E) on 13 Mar 2019.

Diagnosis. Body size *in vivo* 75−85 μm long (n = 2); rectangular with two dorsal spines; 8 ventral kineties in right

field, the three right-most of which extend dorsoapically, 5 short kineties in left equatorial field, typical generic oral apparatus, single preoral, 2 circumoral, and 3 left kineties; 2 or 3 contractile vacuoles; and lanceolate podite.
Distribution. France and Korea.
Remarks. The Korean *D. aculeata* population agrees with the original description of Claparède & Lachmann (1859) in the body shape and the presence of the two dorsal spines. However, the infraciliature of *D. aculeata* is not available from the two populations recorded so far from the North Sea (Claparède & Lachmann, 1859; type population) and the Mediterranean Sea (Gourret and Roeser, 1888) (Kahl, 1931).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110196, NIBRPR0000110197).

Family Hartmannulidae Poche, 1913
Genus *Hartmannula* Poche, 1913

12. *Hartmannula angustipilosa* Deroux & Dragesco, 1968 (Fig. 12)

Material examined. Marine water collected from Gangneunghang Port, Gyeonso-dong, Gangneung-si, Gangwon-do, Korea (37°46′18.45″N 128°57′5.64″E) on 12 Sep 2018.
Diagnosis. Body size 65×32 μm after protargol impregnation (n=1); body shape elongated elliptical, dorsoventrally flattened; single ellipsoidal macronucleus; 7 left kineties; 8 postoral kineties; 5 right kineties; 1 preoral kinety; 2 circumoral kineties; 15 pharyngeal rods; and a small podite in posterior body portion.
Distribution. King George Island and Korea.
Remarks. The Korean *H. angustipilosa* population is the most similar to the Antarctic population named *Hartmannula* cf. *angustipilosa* in terms of body size and shape, the number and shape of macronucleus, and number of pharyngeal rods (Wilbert and Song, 2005). Both the Korean and the Antarctic populations lack live observation because of the rarity of specimens.
Voucher slides. One slide with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110198).

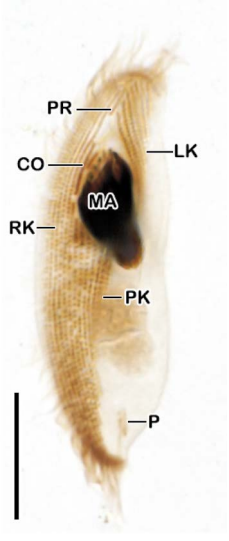

Fig. 12. Photomicrograph of *Hartmannula angustipilosa* after protargol impregnation. CO, circumoral kineties; LK, left kineties; MA, macronucleus; P, podite; PK, postoral kineties; PR, preoral kinety; RK, right kineties. Scale bar=20 μm.

Class Litostomatea Small and Lynn, 1981
Order Haptorida Corliss, 1974
Family Spathidiidae Kahl in Doflein and Reichenow, 1929
Genus *Paraspathidium* Noland, 1937

13. *Paraspathidium apofuscum* Long, Song, Al-Rasheid & Gong, 2009 (Fig. 13)

Material examined. Brackish water with seaweed (salinity, 20‰) collected from Gunsuncheon Stream, Gangdong-myeon, Gangneung-si, Gangwon-do, Korea (37°44′27″N 128°59′2″E) on 1 May 2019.
Diagnosis. Body size about 150×45 μm *in vivo*, 161–207×40–52 μm after protargol impregnation (n=6); body contractile, elongated elliptical with slightly bulged oral part; posteriorly located contractile vacuole with 2 distinct collecting canals; cytoplasmic extrusomes scattered throughout body, 6–8 μm in length; cortex punctate by deep ciliary pits; 2 macronuclear nodules; 34–47 monokinetidal somatic kineties with few dikinetids anteriorly; single circumoral kinety; perioral kinety opened and disturbed 3 brush rows.
Distribution. China and Korea.
Remarks. The Korean *P. apofuscum* population differs from the Chinese population in the presence (vs. absence) of the contractile vacuole's canals (Long *et al*., 2009). *Paraspathidium apofuscum* is different from *P. fuscum* (Kahl, 1928) Fjeld, 1955 in the number of somatic kineties (34–47 vs. 50–60), the presence (vs. absence) of the dorsal brush, and the opened (vs. closed) perioral kinety (Long *et al*., 2009).
Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110199, NIBRPR0000110200).

Class Oligohymenophorea de Puytorac *et al*., 1974
Order Peniculida Faure-Fremiet in Corliss, 1956
Family Frontoniidae Kahl, 1926

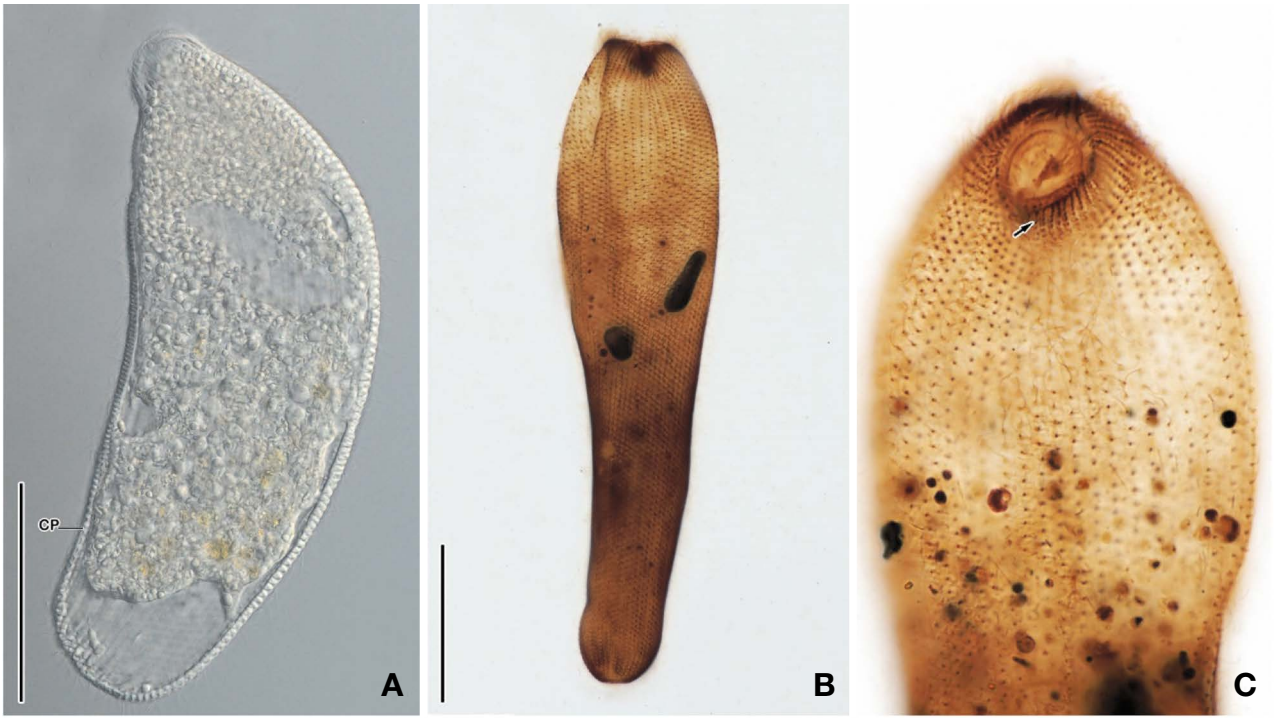

Fig. 13. Photomicrograph of *Paraspathidium apofuscum in vivo* (A) and after protargol impregnation (B, C). A. Contracted body showing the cytoplasmic inclusions and the deep ciliary pits on the cortex. B. Somatic kineties and two macronuclear nodules. C. Detail of oral ciliature showing the dikinetidal part in ciliary rows (arrow). CP, ciliary pits. Scale bars = 100 μm (A), 50 μm (B).

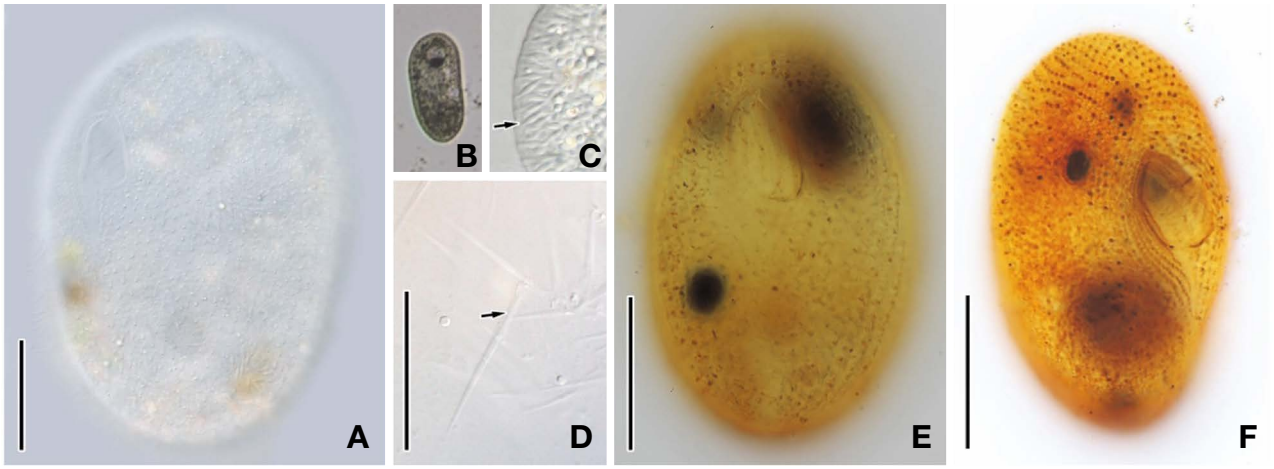

Fig. 14. Photomicrograph of *Frontonia angusta solea in vivo* (A–D), after protargol impregnation (E) and silver carbonate staining (F). A. Slightly squeezed living cell. B. Original body shape. C, D. Embedded and extruded extrusomes (arrows). E. Ventral ciliature of weakly impregnated specimen. F. Somatic and oral ciliature. Scale bars = 30 μm.

Genus *Frontonia* Ehrenberg, 1838
Species *Frontonia* angusta Kahl, 1931

14. *Frontonia angusta solea* (Foissner, 1987) Foissner, Agatha & Berger, 2002 (Fig. 14)

Material examined. Temporal pond on a lawn in Gangneung-Wonju National University, Jukheon-gil 7, Gangneung-si, Gangwon-do, Korea (37°46′12.4″N, 128°52′16.5″E) on 16 Aug 2019.

Diagnosis. Size *in vivo* about 95 × 45 μm (n = 5). Elongate obovate with round anterior end. Single contractile vacuole in mid-body with about 3 excretory pores. Buccal cavity about 20 μm long. About 60 ciliary rows, 3 posto-

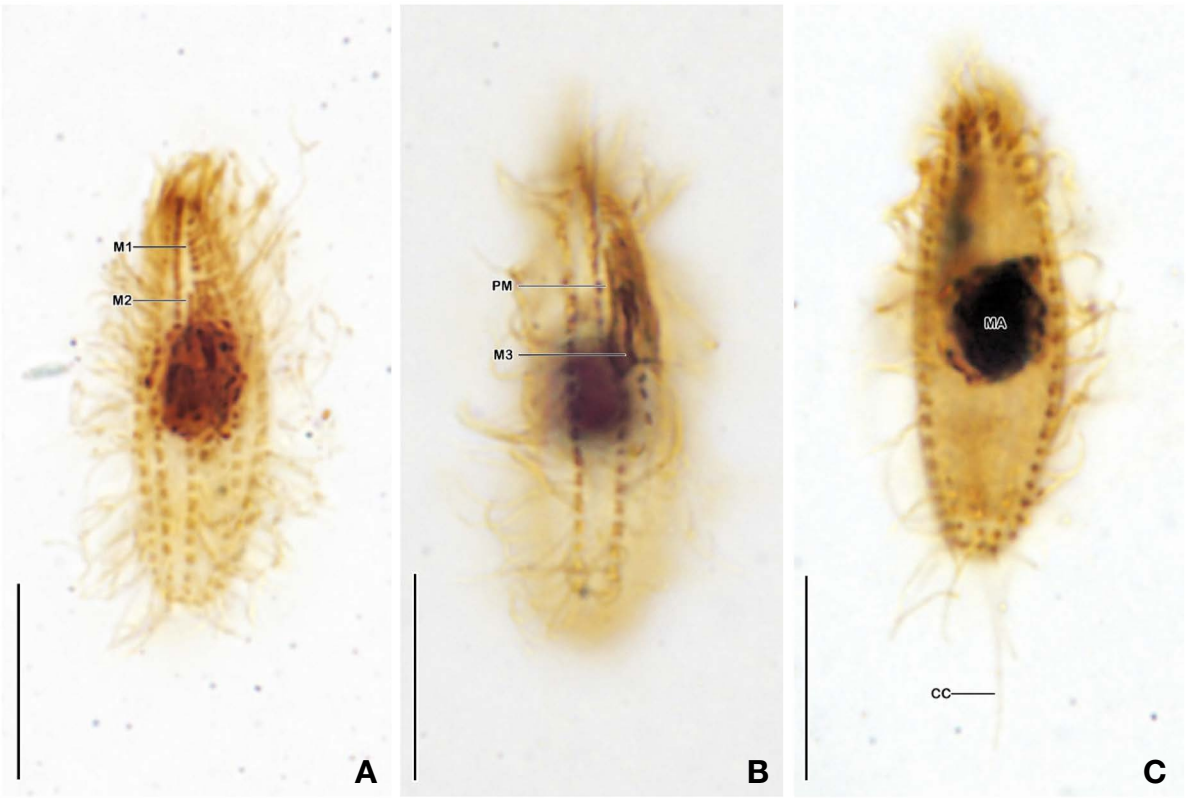

Fig. 15. Photomicrograph of *Metanophrys sinensis* after protargol impregnation. A, B. Somatic and oral ciliatures. C. Macronucleus and caudal cilium. CC, caudal cilium; M1−3, oral membranelles; MA, macronucleus; PM, paroral membrane. Scale bars = 20 μm.

ral kineties, and 4 vestibular kineties. Peniculi 1−3 each with 4 rows of basal bodies.

Distribution. Austria, Namibia, and Korea.

Remarks. The Korean *F. angusta solea* population agrees very well with the Namibian population (Foissner *et al*., 2002). It is distinguishable from the most similar subspecies (*F. angusta angusta*) by the smaller size (70−100 μm vs. 90−135 μm *in vivo*) and the number of somatic kineties (<70 vs. >90).

Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110215, NIBRPR0000110216).

Subclass Scuticociliatia Small, 1967
Order Philasterida Small, 1967
Family Orchitophryidae Cépède, 1910
Genus *Metanophrys* de Puytorac, Grolière, Roque & Detcheva, 1974

15. *Metanophrys sinensis* Song & Wilbert, 2000 (Fig. 15)

Material examined. Marine water collected from a beach in Jukgyodong, Mokpo-si, Jeollanam-do, Korea (34°47′18.5″N 126°21′57.8″E) on 14 Sep 2019.

Diagnosis. Body size about 20 × 8.5 μm after protargol impregnation (n = 10); elongate ellipsoidal body shape with pointed apex; cytostome extends in anterior 2/5 of body length; single spherical macronucleus; 11 or 12 somatic kineties; paroral membrane commences at level of middle part of membranelle 2; membranelles 1 consists of 2 longitudinal rows of basal bodies with 6 basal bodies each; membranelle 2 consists of 2 rows of basal bodies; membranelle 3 inconspicuous, usually close to membranelle 2 with small gap; single caudal cilium.

Distribution. China and Korea.

Remarks. The Korean *M. sinensis* population differs from the type population in the number of transverse basal bodies in membranelle 1 (6 vs. 7−11) (Song and Wilbert, 2000). *Metanophrys sinensis* differs from the most similar species, *M. similis* Song *et al*., 2002, in the number of rows in membranelle 1 (2 vs. 3) (Song *et al*., 2002).

Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110223, NIBRPR0000110224).

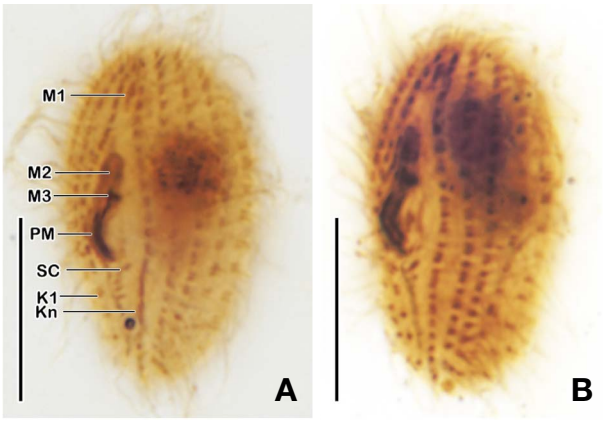

Fig. 16. Photomicrograph of *Uronemita binucleata*, details of somatic and oral ciliature after protargol impregnation(A, B). K1−n, somatic kineties; M1−3, oral membranelles; PM, paroral membrane; SC, scutica. Scale bars = 10 μm.

Order Philasterida Small, 1967
Family Uronematidae Thompson, 1964
Genus *Uronemita* Jankowski, 1980

16. *Uronemita binucleata* (Song, 1993) Liu, Gao, Al-Farraj & Hu, 2006 (Fig. 16)

Material examined. Marine water collected from a beach in Jukgyodong, Mokpo-si, Jeollanam-do, Korea (34°47′ 18.5″N 126°21′57.8″E) on 14 Sep 2019.
Diagnosis. Body size about 20 × 11 μm after protargol impregnation (n = 10); body inverted pear-shaped; frontal end truncated and with conspicuous apical plate; 2 spherical macronulear nodules; cytostome ends posterior to mid-body; about 17 somatic kineties, each kinety comprises of dikinetids anteriorly and monokinetids posteriorly; caudal cilium as along as body.
Distribution. China and Korea.
Remarks. *Uronemita binucleata* is most similar to *U. parabinucleata*, both species have two macronuclear nodules but differ mainly in the number (about 17 vs. 22 or 23) of somatic kineties (Liu *et al*., 2016). These two species differ from all other congeners in having two (vs. one) macronuclear nodules.
Voucher slides. Two slides with protargol-impregnated specimens were deposited at National Institute of Biological Resources (NIBRPR0000110217, NIBRPR0000110218).

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