

## Morphological Redescriptions of Three *Condylostoma* Ciliates (Heterotrichida: Condylostomatidae) New to Korea

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### ABSTRACT

Heterotrichous ciliates were isolated from marine and brackish habitats in Korea, and their morphology, infraciliature and morphometrical characters were investigated using silver impregnated methods. These three *Condylostoma* species were identified as *Condylostoma curva* Burkovsky, 1970, *C. minutum* Bullington, 1940 and *C. spatiosum* Ozaki and Yagiu in Yagiu, 1944. The species of *Condylostoma* based on morphology are highly variable in most of characters and distinguished as following. *Condylostoma curva* is oval to elongate ellipsoidal, size about  $245 \times 100 \mu\text{m}$  *in vivo*, and conspicuously dark greenish brown with cortical granules on their surface, buccal cavity relatively large about 40% of body length, 5-11 macronuclear nodules, 4-8 frontal cirri serially arranged and 22-38 somatic kineties. *Condylostoma minutum* is elongate ellipsoidal and the size about  $310 \times 55 \mu\text{m}$  *in vivo*, buccal field about 35% of body length, 12-20 macronuclear nodules, adoral zone consisted of 82-107 membranelles, large and long one frontal cirrus and 38-44 somatic kineties. *Condylostoma spatiosum* is large elongate ellipsoidal, size about  $670 \times 105 \mu\text{m}$  *in vivo*, buccal cavity about 25% of body length, 11-25 macronuclear nodules, 111-144 adoral membranelles, membrane-like 2 frontal cirri, 49-74 somatic kineties. These three *Condylostoma* species are described here for the first time in Korea.

**Keywords:** *Condylostoma*, marine, brackish water, redescription, heterotrichs, morphology, ciliate

### INTRODUCTION

The genus *Condylostoma* is one of the well-known heterotrichous taxa that has a large body size and a pouch-like cell shape. The members of *Condylostoma* are found in marine and brackish water, freshwater and terrestrial habitats. Since being established the genus *Condylostoma*, more than 30 species have been described and only several species among them described by silver impregnated methods (Kahl, 1932; Bullington, 1940; Villeneuve-Brachon, 1940; Yagiu, 1944; Bock, 1955; Fauré-Fremiet, 1958; Dragesco, 1960; Burkovsky, 1970; Hartwig, 1973; Dragesco and Dragesco-Kernéis, 1986; Carey, 1992; Foissner, 1995; Petz et al., 1995; Al-Rasheid, 1999; Foissner et al., 1999; Song et al., 2003; Shao et al., 2006; Chen et al., 2007). Their morphological characters are indistinctive for species identification because almost all characters have high variations in each species (e.g., body size, number of somatic kineties, ratio of oral field) (Song et

al., 2003; Shao et al., 2006; Chen et al., 2007). In the present work, we redescribe three *Condylostoma* species, *C. curva* Burkovsky, 1970, *C. minutum* Bullington, 1940 and *C. spatiosum* Ozaki and Yagiu in Yagiu, 1944 isolated for the first time from saline waters in Korea.

### MATERIALS AND METHODS

#### Sample collection and enrichment

Three *Condylostoma* species were collected from saline waters in Korea: *C. curva* was collected in November, 2011, marine water (salinity 35‰) from littoral zone with some algae at Jukbyeon-ri, Jukbyeon-myeon, Uljin-gun, Gyeong-sangbuk-do ( $37^{\circ} 03' 32''\text{N}$ ,  $129^{\circ} 25' 44''\text{E}$ ). *Condylostoma minutum* in October, 2011 stagnant marine water (salinity 30‰) on the rock with some debris at Pyoseon-ri, Pyoseon-myeon, Seogwipo-si, Jeju-do ( $33^{\circ} 19' 22''\text{N}$ ,  $126^{\circ} 50' 45''\text{E}$ ).

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*Condylostoma spatiosum* in January, 2008 brackish water (salinity 5‰) of riverine with twigs, leaves, wood and some sand at the Taehwagang River, Taehwa-dong, Jung-gu, Ulsan (35° 33' 06" N, 129° 17' 04" E).

The ciliates samples were delivered to the lab and transferred to a Petri dish (87 mm in diameter). These ciliates were cultured at room temperature enriched with dried wheat grain which provided for fungal and bacterial nutrients.

### Morphological observation and identification

The morphology and behavior of living specimens were observed under a stereo microscope (Olympus SZH10; Olympus, Tokyo, Japan; Leica WILD M8; Leica Instruments, Inc., Exton, PA, USA) and an optical microscope (Axio Imager A1; Carl Zeiss, Oberkochen, Germany) at low (50-400×) and high (1,000×; immersion oil) magnifications using a DIC device. The living images were captured using a CCD camera (Axio Cam MRc; Carl Zeiss). The infraciliatures were observed using silver impregnated specimens by the protargol method (Wilbert, 1975; Foissner, 1992). Terminology and taxonomic classification followed Chen et al. (2007), Lynn (2008), and Shao et al. (2006).

## SYSTEMATIC ACCOUNTS

Phylum Ciliophora Doflein, 1901

Subphylum Postciliodesmatophora Gerassimova and Servin, 1976

Class Heterotrichea Stein, 1859

Order Heterotrichida Stein, 1859

<sup>1</sup>\*Family Condylostomatidae Kahl in Doflein and Reichenow, 1929

<sup>2</sup>\*Genus *Condylostoma* Bory de Saint-Vincent, 1824

<sup>3</sup>\**Condylostoma curva* Burkovsky, 1970

(Table 1, Figs. 1, 2)

*Condylostoma curva* Burkovsky, 1970: 58; Song et al., 2003: 457.

*Condylostoma arenarium*: Kahl, 1932: 455 (fig. 6 only); Dragesco and Dragesco-Kernéis, 1986: 393.

**Material examined.** Thirteen living and 22 protargol impregnated specimens were observed respectively and analyzed biometrically.

**Diagnosis.** Body size about 245 × 100 μm *in vivo*, oval to elongated ellipsoidal shaped, buccal cavity about 40% of body length, macronuclear moniliform with 5-11 nodules, yellowish brown cytoplasm, dark greenish brown cortical

granules, 80-112 adoral membranelles, 4-8 frontal cirri, 22-38 somatic kineties.

**Description.** Body size 210-285 × 70-125 μm, usually about 245 × 100 μm *in vivo* (Table 1). Shape elongated ellipsoidal, dorsoventrally slightly flattened, anterior end truncated and slanted left side, posterior end gradually tapered and narrowly rounded, widest in mid-body (Figs. 1A, 2A). Oral cavity fairly deep with transversely striated inner wall (Fig. 2E). Macronucleus aligned with the right margin of the body, distinctly nodulated and connected by fine threads, composed of 5-11 usually 8 nodules with many small nucleoli, anterior-most macronuclear nodule size about 25 × 15 μm in impregnated preparations (Figs. 1A, C, 2B, J). No contractile vacuole. Cortex very flexible and contractile. Dark greenish brown cortical granules ellipsoidal, size about 0.5-1 μm, arranged 1-3 irregular rows in between kineties (Figs. 1F, G, 2G, H, N). Cytoplasm slightly yellow with some lipid-like droplets and food vacuoles (Fig. 2A, B). Movement moderately slow, usually gliding on bottom.

Somatic kineties arranged longitudinally 22-38 rows, usually commenced near the buccal field, formed suture posteriorly, consisted of dikinetids and somatic cilia about 10 μm long *in vivo* (Table 1, Figs. 1B, C, 2I, L). Four to eight frontal cirrus near apical end of right margin, on outside of buccal cavity and 15-20 μm long *in vivo* (Table 1, Figs. 1A, B, E, 2D, M).

The adoral zone of membranelles conspicuously covered the left side of buccal field, occupied 32-46% of the body length with the proximal portion extending spirally into the cytopharynx, consisting of 80-112 adoral membranelles (Table 1, Figs. 1A, B, E, 2C, F, K). The paroral membrane located on the inner side of buccal cavity, conspicuously long and smoothly undulated and composed of cilia about 25 μm in length *in vivo* (Figs. 1A, E, 2C, K).

**Distribution.** Africa (Benin), Asia (China, Korea), Europe (Germany, Russia).

**Remarks.** The accurate identification of *Condylostoma* species is difficult because they have high variations in many characters, fewer unique characters, overlapping of characteristics in many features, and inappropriate literature caused by previous insufficient descriptions (Kahl, 1932; Bullington, 1940; Villeneuve-Brachon, 1940; Yagiu, 1944; Fauré-Fremiet, 1958; Burkovsky, 1970; Dragesco and Dragesco-Kernéis, 1986; Song et al., 2003; Shao et al., 2006; Chen et al., 2007).

We identified *Condylostoma curva* Burkovsky, 1970 based on three main characters of the body shape, the color of cortical granules and the pattern of frontal cirri. The original population of *C. curva* described by Burkovsky (1970) was

Korean name: <sup>1</sup>\*터진입섬모충과, <sup>2</sup>\*터진입섬모충속, <sup>3</sup>\*노랑터진입섬모충

**Table 1.** Morphometric data on *Condylostoma curva*, *C. minutum*, and *C. spatiosum*

Characters	Species	Mean	Min	Max	Med	SD	SE	CV	n
Body, length <i>in vivo</i> (μm)	<i>C. curva</i>	244.2	210	285	236	24.73	6.86	10.12	13
	<i>C. minutum</i>	314.7	264	390	307	36.41	8.35	11.57	19
	<i>C. spatiosum</i>	671.1	480	800	700	94.28	22.22	14.05	18
Body, width <i>in vivo</i> (μm)	<i>C. curva</i>	100.9	71	123	99	13.33	3.70	13.21	13
	<i>C. minutum</i>	54.3	44	71	54	8.03	1.84	14.80	19
	<i>C. spatiosum</i>	104.4	80	130	110	14.90	3.51	14.26	18
Body, width/body, length <i>in vivo</i> (%)	<i>C. curva</i>	42.1	25.4	56.4	41.9	8.96	2.49	21.29	13
	<i>C. minutum</i>	17.9	13.0	26.3	17.3	3.63	0.83	20.36	19
	<i>C. spatiosum</i>	15.8	11.8	20.8	15.9	2.86	0.67	18.14	18
Body, width (μm)	<i>C. curva</i>	129.2	70	193	131	30.99	6.93	23.98	20
	<i>C. minutum</i>	86.0	58	108	88	12.29	2.68	14.28	21
	<i>C. spatiosum</i>	406.0	286	540	374	90.02	34.02	22.17	11
Body, length (μm)	<i>C. curva</i>	261.9	157	373	262.5	55.21	11.77	21.08	22
	<i>C. minutum</i>	311.0	180	399	309	56.98	12.43	18.32	21
	<i>C. spatiosum</i>	209.9	166	251	204	34.64	13.09	16.51	11
Body, width/body, length (%)	<i>C. curva</i>	48.2	33.3	62.6	48.6	7.40	1.66	15.36	20
	<i>C. minutum</i>	28.2	21.6	36.4	27.2	4.73	1.03	16.75	21
	<i>C. spatiosum</i>	52.9	39.0	67.1	52.0	9.02	3.41	17.06	11
Buccal field, length <i>in vivo</i> (μm)	<i>C. curva</i>	94.1	69	119	92	16.03	4.83	17.03	11
	<i>C. minutum</i>	111.6	76	138	114	15.88	3.64	14.23	19
	<i>C. spatiosum</i>	157.8	110	200	150	30.09	7.09	19.07	18
Buccal field, length (μm)	<i>C. curva</i>	92.6	63	115	95	13.15	3.19	14.20	17
	<i>C. minutum</i>	97.7	64	125	100	15.61	3.41	15.98	21
	<i>C. spatiosum</i>	39.3	31.7	45.8	39.7	4.60	1.39	11.71	11
Buccal length/body, length <i>in vivo</i> (%)	<i>C. curva</i>	36.2	29.7	40.1	36.4	2.95	0.68	8.14	19
	<i>C. spatiosum</i>	23.8	16.0	40.0	23.1	5.75	1.35	24.10	18
	<i>C. curva</i>	33.7	26.9	43.9	32.6	4.44	1.11	13.20	16
Buccal length/body, length (%)	<i>C. minutum</i>	31.9	23.5	40.4	30.1	4.78	1.04	14.99	21
	<i>C. curva</i>	8.2	5	11	8.5	2.32	0.95	28.37	6
	<i>C. minutum</i>	15.8	12	20	16	2.62	0.68	16.61	15
Macronuclear nodules, number	<i>C. spatiosum</i>	18.5	11	25	19	4.27	1.29	23.05	11
	<i>C. curva</i>	101.2	80	112	104	9.15	2.54	9.04	13
	<i>C. minutum</i>	92.4	82	107	93	7.79	1.89	8.43	17
Adoral membranelles, number	<i>C. spatiosum</i>	126.5	111	144	126	8.93	2.83	7.06	10
	<i>C. curva</i>	5.1	4	8	5	1.12	0.31	21.97	13
	<i>C. minutum</i>	1.0	1	1	1	0.00	0.00	0.00	18
Frontal cirri, number	<i>C. spatiosum</i>	2.0	2	2	2	0.00	0.00	0.00	10
	<i>C. curva</i>	33.8	22	38	36	4.13	0.95	12.19	19
	<i>C. minutum</i>	40.3	38	44	40	1.98	0.70	4.92	8
Somatic kineties, number	<i>C. spatiosum</i>	59.1	49	74	57	7.78	2.01	13.16	15
	<i>C. curva</i>	77.6	47	94	80	14.94	5.28	19.24	8
	<i>C. minutum</i>								

Data based on impregnated specimens except body length, width and buccal field length *in vivo*.

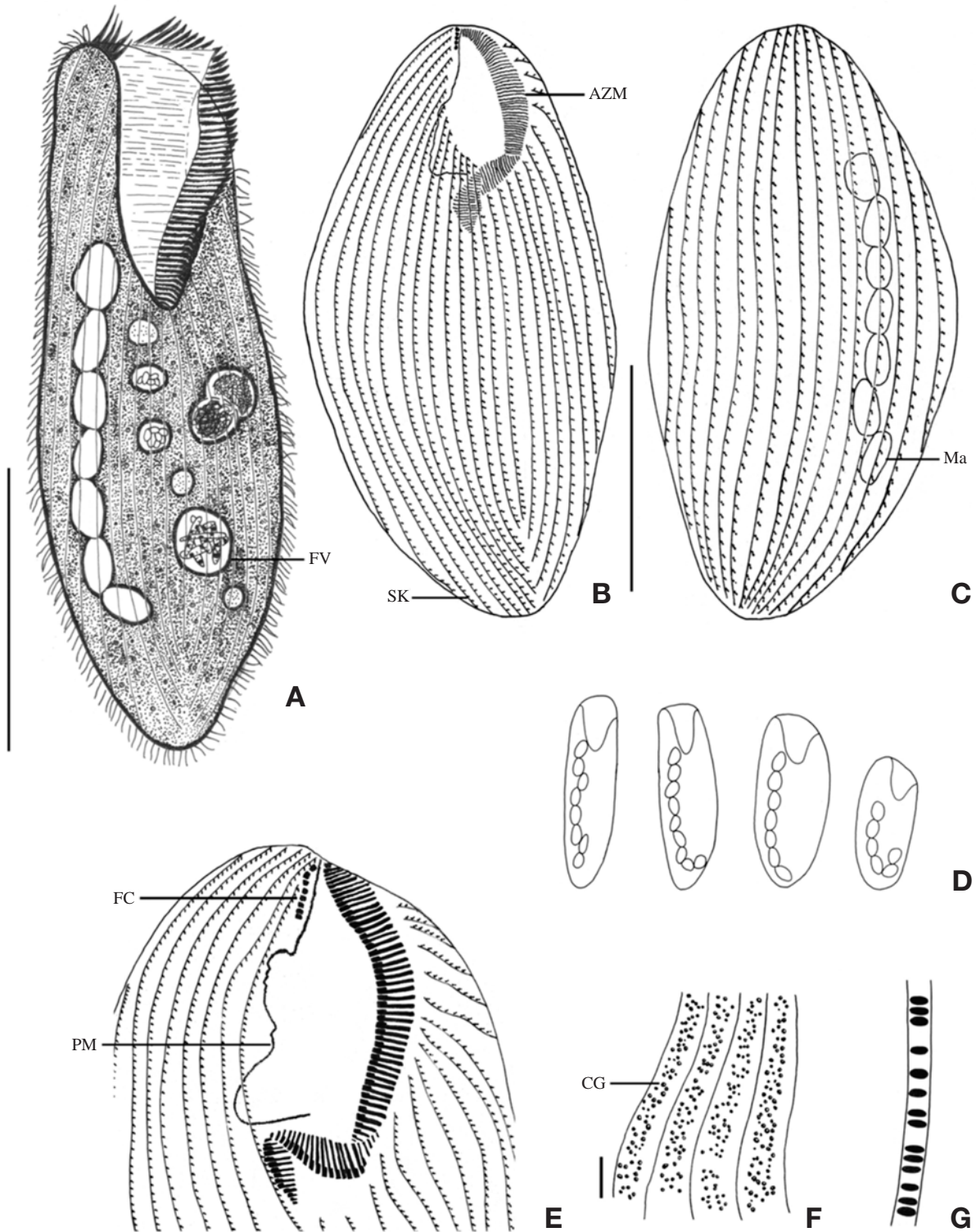
Mean, arithmetic mean; Min, minimum; Max, maximum; Med, median; SD, standard deviation; SE, standard error; CV, coefficient of variation in %; n, number of specimens investigated.

collected from Russia. We compared the Korean and the Russian populations those are slightly different in contractile vacuole (absent vs. present) and body size (210-285 μm vs. 120-200 μm). However, Song et al. (2003) mentioned that the presence of the contractile vacuole in Burkovsky (1970) was a food vacuole. The Chinese populations of Song et al. (2003) actually corresponded to the Korean population of *C. curva* in terms of all morphological key characters (Table 2, Fig. 7C-F).

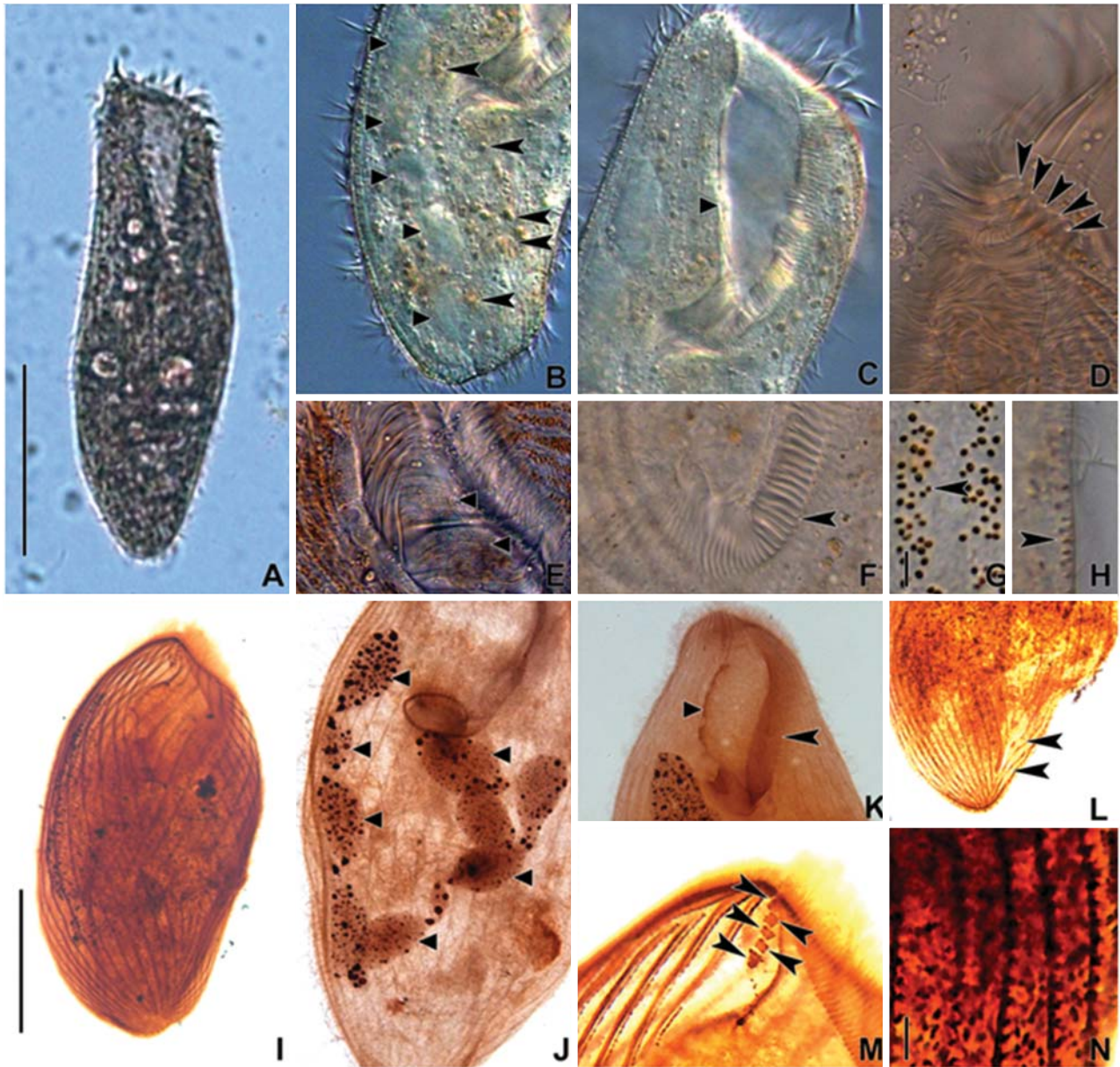
The descriptions of the two populations of *Condylostoma*

*arenarium* sensu Kahl (1932) and Dragesco and Dragesco-Kernéis (1986) are in agreement with *C. curva*. The one of Kahl's populations is similar to *C. curva* in the body size, body shape, shape of cortical granules, 4-5 frontal cirri and being from a brackish habitat. The African population of Dragesco and Dragesco-Kernéis is similar to *C. curva* in the body shape and the buccal field ratio (Fig. 7A, B) (Kahl, 1932; Dragesco and Dragesco-Kernéis, 1986; Song et al., 2003).

*Condylostoma curva* Burkovsky, 1970 differs from *C. magnum* Spiegel, 1926, *C. spatiosum* Ozaki and Yagi in Yagi,



**Fig. 1.** Morphology and infraciliature of *Condyllostoma curva* from live specimens (A, D, F, G) and after protargol impregnation (B, C, E). A, Ventral view of a typical individual; B, Ventral view of impregnated specimen; C, Dorsal view of impregnated specimen; D, Varied body shapes and macronuclear patterns; E, Ventral view of buccal field; F, Pattern of cortical granules; G, Lateral view of cortical granules. AZM, adoral zone of membranelles; CG, cortical granule; FC, frontal cirrus; FV, food vacuole; Ma, macronucleus; PM, paroral membrane; SK, somatic kineties. Scale bars: A, C=100  $\mu$ m, F=5  $\mu$ m.



**Fig. 2.** Microphotographs of *Condylostoma curva* from live specimens (A-H) and after protargol impregnation (I-N). A, Ventral view of a typical individual; B, Moniliform macronuclear nodules (triangular arrowheads) and cytoplasmic inclusion (arrowheads); C, Buccal field (triangular arrowhead); D, Frontal cirri (arrowheads); E, Buccal field to indicate the stripes of inner wall (triangular arrowheads); F, Proximal end of adoral zone of membranelles (arrowhead); G, Pattern of cortical granules (arrowhead); H, Lateral view of cortical granules (arrowhead); I, Ventral side view; J, Impregnated macronuclear nodules (triangular arrowheads); K, Paroral membrane (triangular arrowhead) and adoral zone of membranelles (arrowhead); L, Suture (arrowheads); M, Frontal cirri (arrowheads); N, Impregnated cortical granules. Scale bars: A, I=100  $\mu$ m, G, N=5  $\mu$ m.

1944 and *C. granulorum* Bullington, 1940 in body length *in vivo* (210-285  $\mu$ m vs. 200-400  $\mu$ m vs. 400-800  $\mu$ m vs. 400-700  $\mu$ m), number of frontal cirri (4-8 vs. 1-2 vs. 2 vs. 2 vs. 1-3), number of adoral membranelles (80-112 vs. 150-200 vs. 113-153 vs. 123-210) (Petz et al., 1995; Song and Wilbert, 1997; Song et al., 2003). *Condylostoma curva* is similar to *C.*

*minutum* Bullington, 1940 and *C. arenarium* Spiegel, 1926 in body length *in vivo*, number of somatic kineties, number of macronuclei. However, *C. curva* and *C. minutum* are different in number of frontal cirri (4-8 vs. 1-2); *C. curva* differs from *C. arenarium* in number of adoral membranelles (80-112 vs. 60-70) (Borror, 1963; Chen et al., 2007).

<sup>1</sup>\**Condylostoma minutum* Bullington, 1940  
(Table 1, Figs. 3, 4)

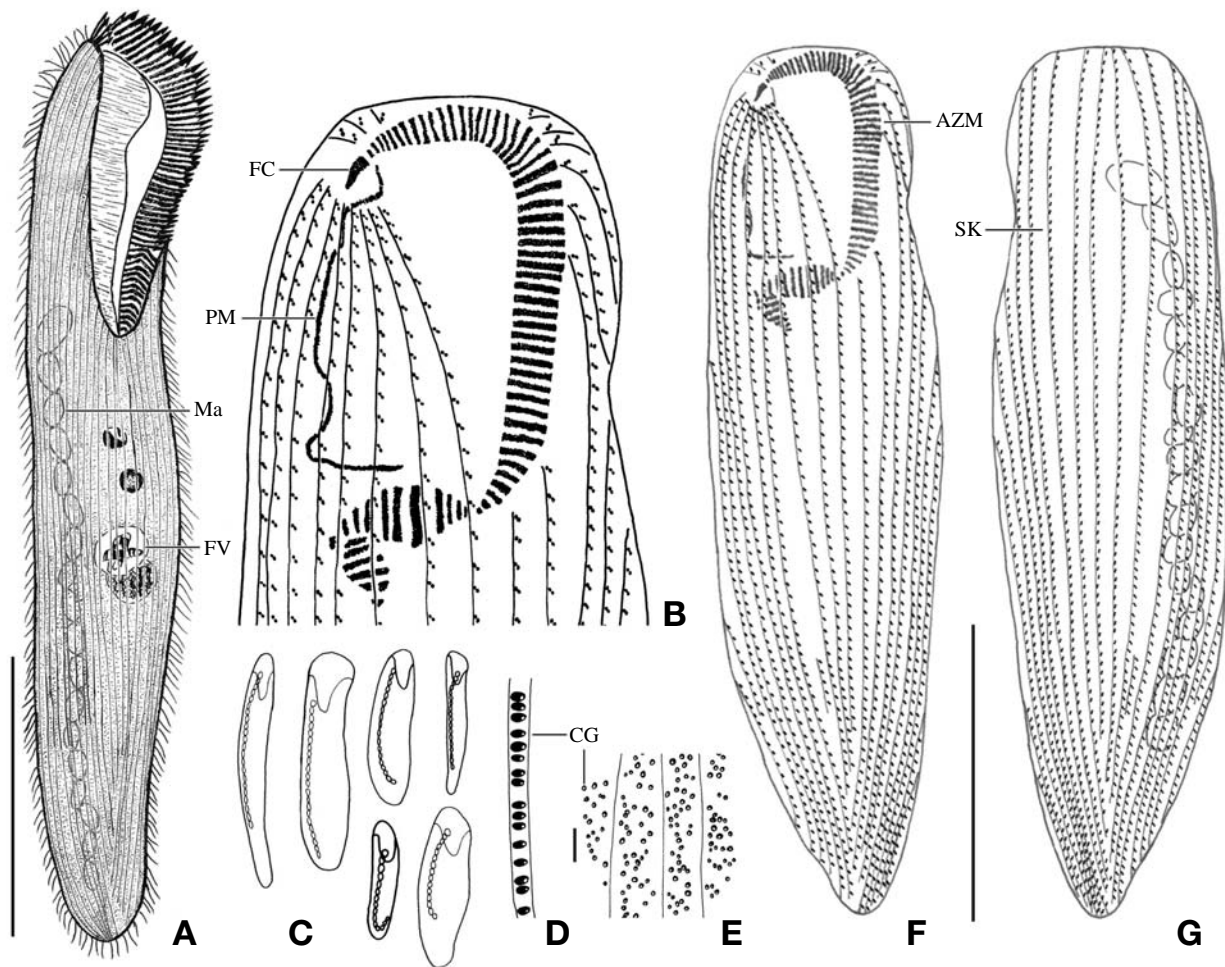
*Condylostoma minutum* Bullington, 1940: 193; Chen et al., 2007: 299.

**Material examined.** Twenty living and 21 protargol impregnated specimens were observed respectively and analyzed biometrically.

**Diagnosis.** Body size about 315 × 55 μm *in vivo*, elongated ellipsoidal shaped, buccal cavity about 35% of body length, macronucleus moniliform with 12-20 nodules, 82-107 adoral membranelles, 1 frontal cirrus, 38-44 somatic kineties.

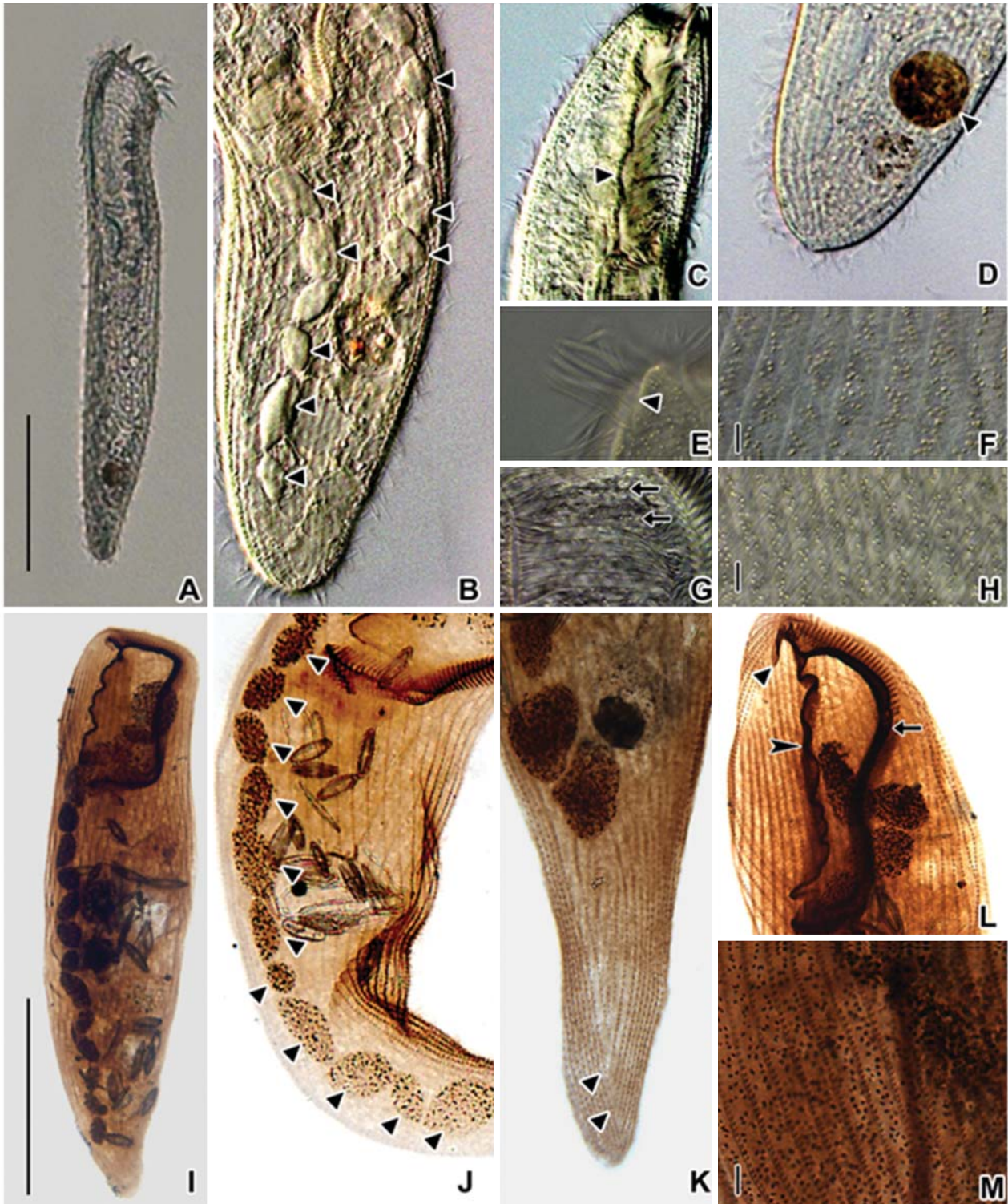
**Description.** Body size 265-390 × 45-70 μm, usually about

315 × 55 μm *in vivo* (Table 1). Shape elongated ellipsoidal, dorsoventrally slightly flattened, anterior end truncated and slanted left side, posterior end gradually tapered and narrowly rounded, widest in mid-body (Figs. 3A, C, 4A). Oral cavity fairly deep with transversely striated inner wall (Fig. 4A, G). Macronucleus aligned with the right margin of the body, distinctly nodulated and connected by fine threads, composed of 12-20 usually 16 nodules with many small nucleoli, anterior-most macronuclear nodule size about 28 × 18 μm in protargol impregnated preparations (Figs. 3A, G, 4B, J). No contractile vacuole. Cortex very flexible and contractile. Greenish yellow ellipsoidal cortical granules size about 1 μm, arranged irregular rows in between kineties (Figs. 3D, E, 4F,



**Fig. 3.** Morphology and infraciliature of *Condylostoma minutum* from live specimens (A, C-E) and after protargol impregnation (B, F, G). A, Ventral view of a typical individual; B, Ventral view of buccal field; C, The various body shape and macronuclear nodules pattern; D, Lateral view of cortical granules; E, Ventral view of cortical granules; F, Ventral view of impregnated specimen; G, Dorsal view of impregnated specimen. AZM, adoral zone of membranelles; CG, cortical granule; FC, frontal cirrus; FV, food vacuole; Ma, macronucleus; PM, paroral membrane; SK, somatic kineties. Scale bars: A, G=100 μm, E=5 μm.

Korean name: <sup>1</sup>\*작은터진입섬모충



**Fig. 4.** Microphotographs of *Condylostoma minutum* from live specimens (A-H) and after protargol impregnation (I-M). A, Ventral view of a typical individual; B, Moniliform macronuclear nodules (triangular arrowheads); C, Paroral membrane (triangular arrowhead); D, Food vacuole (triangular arrowhead); E, Frontal cirrus (triangular arrowhead); F, H, Cortical granules; G, Striated inner wall on buccal cavity (arrows); I, Ventral side view; J, Moniliform macronucleus (triangular arrowheads); K, Suture of posterior end (triangular arrowheads); L, To show adoral zone of membranelles (arrow), frontal cirrus (triangular arrowhead), paroral membrane (arrowhead); M, Impregnated cortical granules between somatic kineties. Scale bars: A, I=100  $\mu$ m, F, H, M=5  $\mu$ m.

H, M). Cytoplasm colorless with some food vacuoles (Figs. 3A, 4D). Movement moderately slow, usually gliding on bottom.

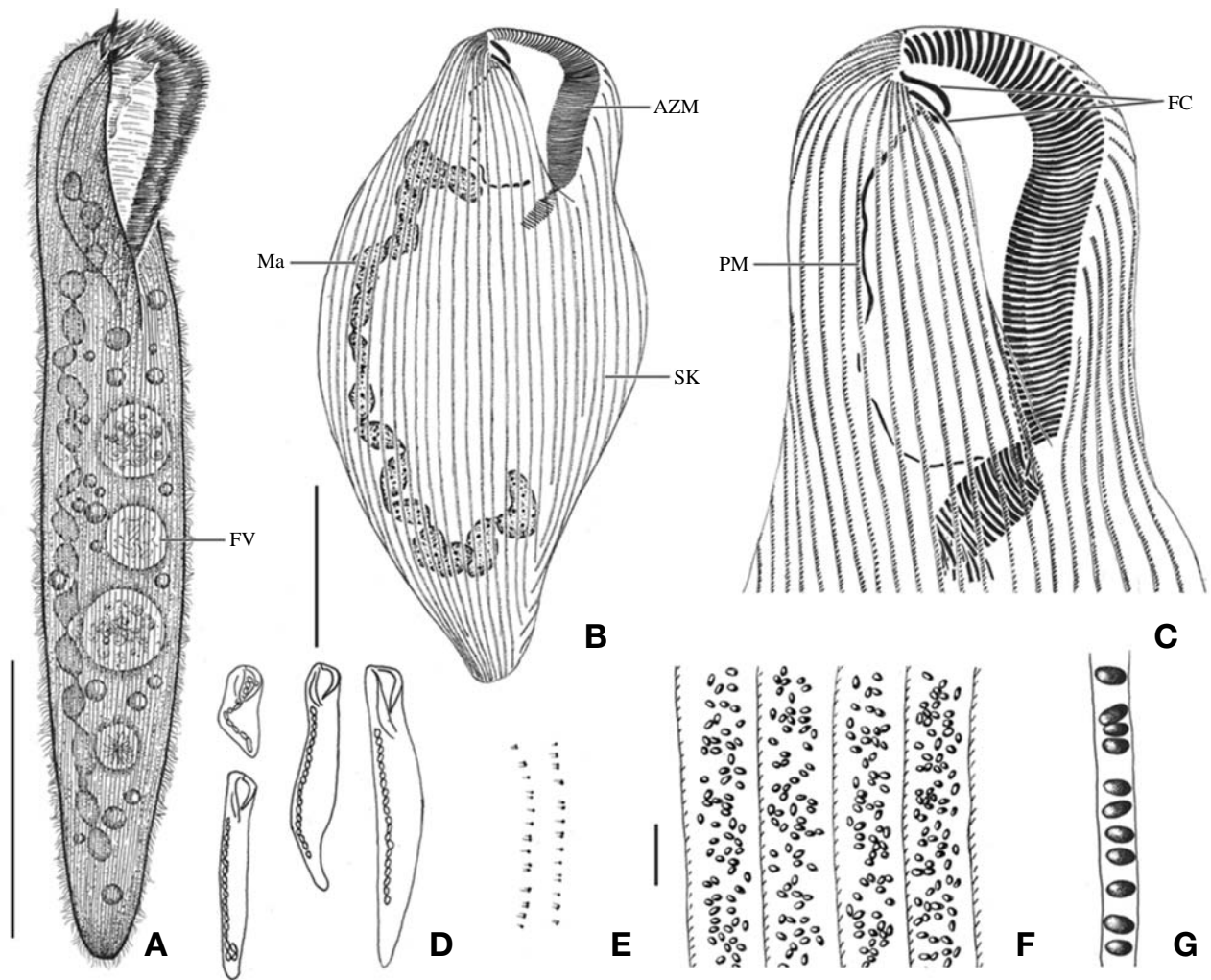
Somatic kineties arranged longitudinally 38-44 rows, usually commenced near the buccal field, formed suture posteriorly, consisted of dikinetids and somatic cilia about 10  $\mu\text{m}$  long *in vivo* (Figs. 3F, G, 4K). One frontal cirrus near apical end of right margin, on outside of buccal cavity and 15-20  $\mu\text{m}$  long *in vivo* (Figs. 3A, B, F, 4E, L).

The adoral zone of membranelles conspicuously covered the left side of the buccal field, occupied 30-40% of the body length, with the proximal portion extending spirally into the cytopharynx, consisting of 82-107 adoral membranelles (Figs. 3A, B, F, 4A, I, L). The paroral membrane located on the

inner side of the buccal cavity, total length 47-94  $\mu\text{m}$  in impregnated preparations, conspicuously long and smoothly undulated with a cilia about 25  $\mu\text{m}$  in length *in vivo* (Figs. 3B, 4C).

**Distribution.** Asia (China, Korea), South America (Mexico).

**Remarks.** The Korean population of *Condylostoma minutum* closely resembles the Gulf of Mexico and Chinese populations of it with respect to body size, number of fragments of the macronucleus, number of adoral membranelles, ratio of adoral zone of membranelles. However, this Korean population differs from the Chinese population in number of somatic kineties (38-44 vs. 26-33) and number of frontal cirri (1 vs. 1-2) (Table 2, Fig. 7G-I) (Bullington, 1940; Chen et al., 2007).



**Fig. 5.** Morphology and infraciliature of *Condylostoma spatiosum* from live specimens (A, D-G) and after protargol impregnation (B, C). A, Ventral view of a typical individual; B, Ventral view of impregnated specimen; C, Ventral view of buccal field; D, Various body shape and macronuclear nodules pattern; E, Infraciliature of somatic dikinetids; F, Pattern of cortical granules; G, Lateral view of cortical granules. AZM, adoral zone of membranelles; FC, frontal cirrus; FV, food vacuole; Ma, macronucleus; PM, paroral membrane; SK, somatic kineties. Scale bars: A=200  $\mu\text{m}$ , B=100  $\mu\text{m}$ , F=5  $\mu\text{m}$ .



*Condylostoma minutum* differs from *C. magnum* and *C. spatiosum* in body length *in vivo* (265-390  $\mu\text{m}$  vs. 400-800  $\mu\text{m}$  vs. 400-700  $\mu\text{m}$ ), number of frontal cirri (1 vs. 2 vs. 2), number of somatic kineties (38-44 vs. 47-56 vs. 51-63), number of adoral membranelles (82-107 vs. 150-200 vs. 113-153) (Song and Wilbert, 1997; Chen et al., 2007).

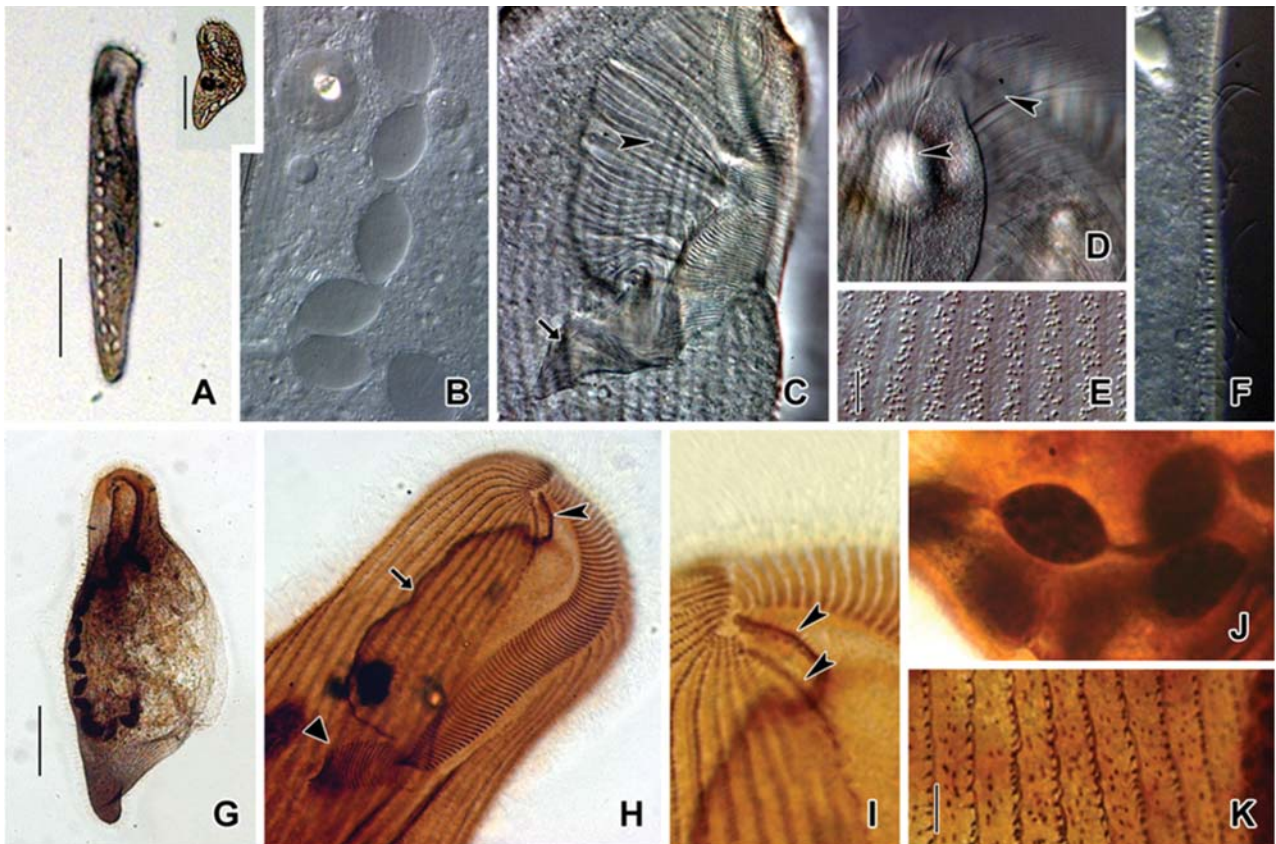
<sup>1</sup>\**Condylostoma spatiosum* Ozaki and Yagiu in Yagiu, 1944 (Table 1, Figs. 5, 6)

*Condylostoma spatiosum* Ozaki and Yagiu in Yagiu, 1944: 163; Shao et al., 2006: 11; Chen et al., 2007: 306; Wilbert and Song, 2008: 990.

**Material examined.** Eighteen living and 11 protargol impregnated specimens were observed respectively and analyzed biometrically.

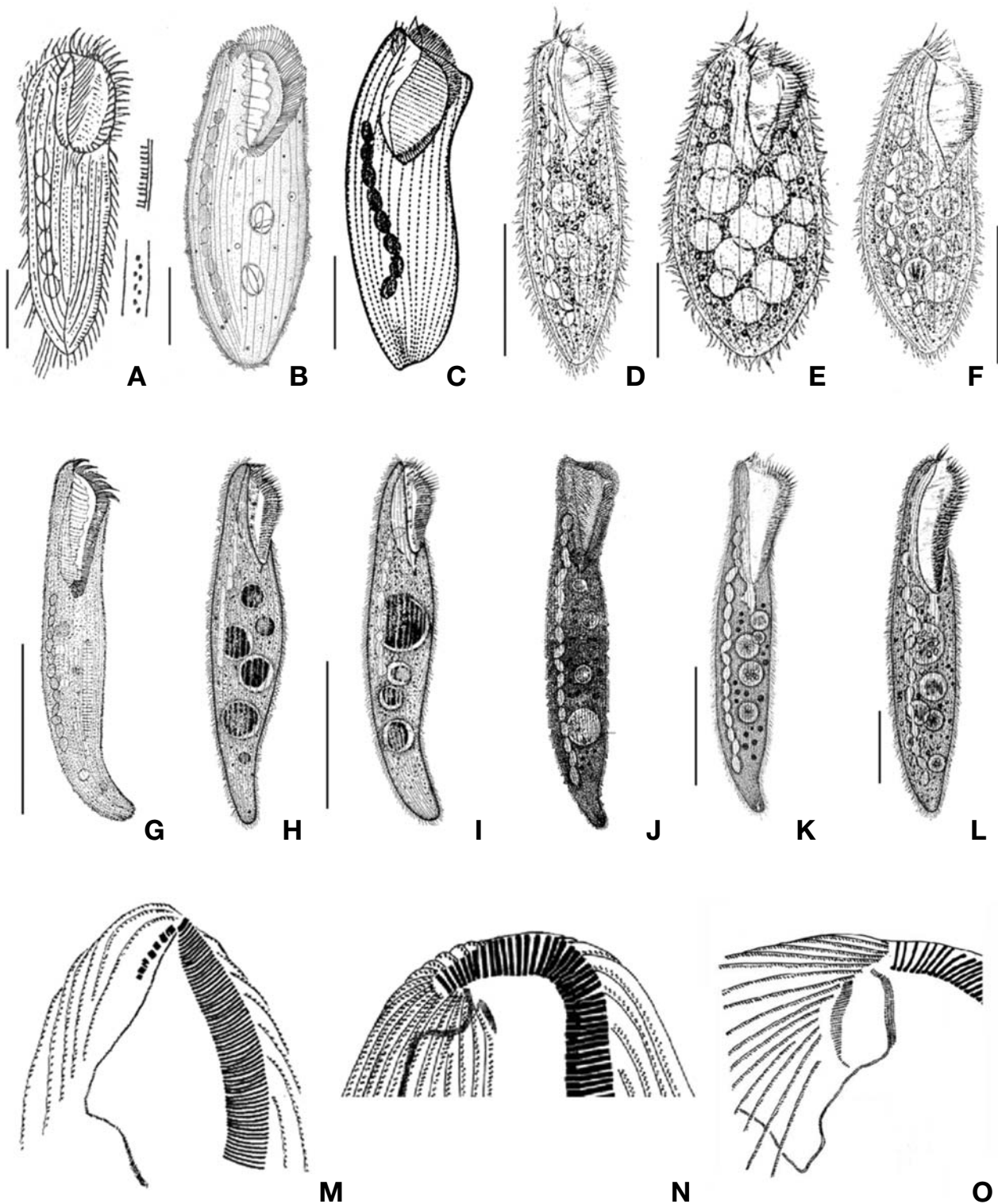
**Diagnosis.** Body size about 670  $\times$  105  $\mu\text{m}$  *in vivo*, elongated ellipsoidal shaped, buccal cavity about 25% of body length, macronucleus moniliform with 11-25 nodules, 111-144 adoral membranelles, 2 frontal cirri, 49-74 somatic kineties.

**Description.** Body size of 480-800  $\times$  80-130  $\mu\text{m}$ , usually about 670  $\times$  105  $\mu\text{m}$  *in vivo* (Table 1). Shape elongated ellipsoidal, dorsoventrally slightly flattened, anterior end truncated and slanted left side, posterior end gradually tapered and narrowly rounded, body margin slightly parallel (Figs. 5A, D, 6A). Oral cavity fairly deep with transversely striated inner wall (Figs. 5A, 6C). Macronucleus aligned usually with the right margin of the body, distinctly nodulated and connected by threads, composed of 11-25 usually 19 nodules with many small nucleoli in impregnated preparations (Figs. 5A, B, 6B, J). No contractile vacuole. Cortex very flexible and contractile. Slightly yellowish ellipsoidal cortical gran-



**Fig. 6.** Microphotographs of *Condylostoma spatiosum* from live specimens (A-F) and after protargol impregnation (G-K). A, Ventral side view; B, Moniliform macronuclear nodules; C, Buccal field to indicate the stripes of inner wall (arrowhead) and the cytopharynx (arrow); D, Location of frontal cirri (arrowheads); E, Pattern of cortical granules; F, Lateral view of cortical granules; G, Ventral side view in impregnated specimen; H, Ventral view of frontal cirri (arrowhead), paroral membrane (arrow) and cytopharynx (triangular arrowhead); I, Location of frontal cirri (arrowheads); J, Macronuclear nodules and threads; K, Cortical granules in impregnated specimen. Scale bars: A=200  $\mu\text{m}$ , Inset in A=200  $\mu\text{m}$ , E, K=5  $\mu\text{m}$ , G=100  $\mu\text{m}$ .

Korean name: <sup>1</sup>\*넓은터진입섬모충



**Fig. 7.** A-F, M, *Condylostoma curva* Burkovsky, 1970 (A, from Kahl, 1932; B, from Dragesco J, Dragesco-Kernéis A, 1986; C, from Burkovsky, 1970; D-F, from Song et al., 2003); M, The apparatus of frontal cirri (from Song et al., 2003); G-L, N, *C. minutum* Bullington, 1940 (G, from Bullington, 1940; H, I, Chen et al., 2007); N, The apparatus of frontal cirrus (from Chen et al., 2007); J-L, O, *C. spatiosum* Ozaki and Yagiu in Yagiu, 1944 (J, from Ozaki and Yagiu in Yagiu, 1944; K, L, from Shao et al., 2006); O, The apparatus of frontal cirri (from Chen et al., 2007). Scale bars: A-C, E, F=50  $\mu$ m, D, G, I, L=100  $\mu$ m, K=200  $\mu$ m.

**Table 2.** Comparisons of previous studies of *Condylostoma curva*, *C. minutum*, and *C. spatiosum*

Characters/Species	<i>C. curva</i>	<i>C. minutum</i>	<i>C. spatiosum</i>	<i>C. curva</i>	<i>C. curva</i>	<i>C. minutum</i>	<i>C. minutum</i>	<i>C. spatiosum</i>	<i>C. spatiosum</i>
Body, length <i>in vivo</i> ( $\mu\text{m}$ )	210-285	265-390	480-800	150-350	120-200	200-400	199-264	400-700	364-1320
Frontal cirri, number	4-8	1	2	4-8	5	1-2	–	2	3
Somatic kineties, number	22-38	38-44	49-74	22-32	20-25	26-33	32-40	51-63	47-64
Macronuclear nodules, number	5-11	12-20	11-25	5-13	7-9	10-15	ca 13	13-22	17-31
Adoral membranelles, number	80-112	82-107	111-144	68-108	–	67-103	–	113-153	ca. 80
Buccal field ratio of body length (%)	27-44	20-40	16-40	35-45	–	ca 25	ca 25	25-33	ca 22
Cytoplasm color	Yellowish brown	Colorless	Grayish	Yellowish	–	Yellow-brownish	–	Yellow-grayish	–
Cortical granules	Ellipsoidal, dark greenish brown	Ellipsoidal, greenish yellow	Ellipsoidal, yellowish gray	Ellipsoidal, dark-grayish	–	Ellipsoidal, dark-grayish	–	Ellipsoidal, dark-grayish	Pale yellowish green
Data sources	Present species	Present species	Present species	Song et al. (2003)	Burkovsky (1970)	Chen et al. (2007)	Bullington (1940)	Shao et al. (2006)	Yagiu (1944)

–, data unavailable.

ules about  $0.5\text{-}0.8 \times 0.7\text{-}1.5 \mu\text{m}$  in size and about 1-5 irregular rows in between kineties (Figs. 5F, G, 6E, F, K). Cytoplasm colorless with some small inclusions  $4 \mu\text{m}$  *in vivo*, lipid-like droplets and occasionally large food vacuoles (Figs. 5A, 6A). Movement moderately slow, usually gliding on bottom.

Somatic kineties arranged longitudinally in 49-74 rows, mostly commenced near the buccal field, formed suture posteriorly, consisted of dikinetids and somatic cilia about  $12 \mu\text{m}$  in length *in vivo* (Fig. 5B, E). Frontal cirri near the apical end of right margin, two membrane-like cirri were located, respectively, on outside of the buccal cavity, about  $40 \mu\text{m}$  in length *in vivo* and on the apical end of the paroral membrane and connected with paroral, about  $20 \mu\text{m}$  in length *in vivo* (Figs. 5C, 6D, H, I, 7O).

The adoral zone of membranelles which conspicuously covered the left side of the buccal field, occupied 16-40% of the body length, the proximal portion extending spirally into the cytopharynx, consisting of 111-144 adoral membranelles (Figs. 5A, C, 6C, H). The paroral membrane located on the inner side of the buccal cavity in impregnated preparations, was conspicuously long and smoothly undulated (Figs. 5C, 6H).

**Distribution.** Asia (China, Japan, Korea), Antarctica

**Remarks.** This Korean population of *Condylostoma spatiosum* Ozaki and Yagiu in Yagiu, 1944 closely resembles with the Chinese and Japanese populations which have similar characters in body size (480-800 vs. 400-700 vs. 364-1,320),

number of frontal cirri (2 vs. 2 vs. 3), and number of somatic kineties (49-74 vs. 51-63 vs. 47-64). The number of adoral membranelles is conspicuously less than the others in the Japanese population. The colors of cortical granules are different (Korean, yellowish gray; Chinese, dark gray; Japanese, yellowish green). However, this can be a variable character because it is depends on the subjective or the microscopic field. The Korean population has a variation in the pattern of cortical granules dense or loose (Table 2, Fig. 7J-L) (Yagiu, 1944; Shao et al., 2006; Chen et al., 2007).

This present species is different from the *Condylostoma magnum* Spiegel, 1926 in number of adoral membranelles (111-144 vs. 150-200) (Song and Wilbert, 1997; Shao et al., 2006).

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## REFERENCES

Al-Rasheid KAS, 1999. Records of marine interstitial Heterotrichida (Ciliata) from the Saudi Arabian Jubail marine wildlife

- sanctuary in the Arabian Gulf. Arab Gulf Journal of Scientific Research, 17:127-141.
- Bock KJ, 1955. *Condylostoma vastum* nov. spec., und *Aspidisca pertinens* nov. spec., zwei sandbewohnende Ciliaten aus dem Küstengebiet der Kieler Bucht. Zoologischer Anzeiger, 154:302-304.
- Borror AC, 1963. Morphology and ecology of the benthic ciliated protozoa of Alligator Harbor, Florida. Archiv für Protistenkunde, 106:465-534.
- Bullington WE, 1940. Some ciliates from Tortugas. Papers from the Tortugas Laboratory of the Carnegie Institution of Washington, 32:179-222.
- Burkovsky IV, 1970. The ciliates of the mesopsammon of the Kandalaksha Gulf (White Sea). II. Acta Protozoologica, 8: 47-64.
- Carey PG, 1992. Marine interstitial ciliates: an illustrated key. Chapman and Hall, London, pp. 1-351.
- Chen X, Song W, Al-Rasheid KAS, Warren A, Long H, Shao C, Al-farraj SA, Gong J, Hu X, 2007. The morphology of three marine heterotrichous ciliaes, *Condylostentor auriculatus* (Kahl, 1932) Jankowski, 1978, *Condylostoma minutum* Bullington, 1940 and *C. spatiosum* Ozaki & Yagiu in Yagiu, 1944 (Ciliophora: Heterotrichida). Acta Protozoologica, 46: 289-309.
- Dragesco J, 1960. Ciliés mésopsammiques littoraux: systématique, morphologie, écologie. Travaux de la Station Biologique de Roscoff, 12:1-356.
- Dragesco J, Dragesco-Kernéis A, 1986. Ciliés libres de l'Afrique intertropicale: introduction á la connaissance et á l'étude des ciliés. Faune Tropicale, 26:1-559.
- Fauré-Fremiet E, 1958. Le cilie *condylostoma tenuis* n. sp. et son algue symbiote. Hydrologica, 10:43-48.
- Foissner W, 1992. Protargol methods. In: Protocols in protozoology (Eds., Lee JJ, Soldo AT). The Society of Protozoologists, Allen Press, Lawrence, KS, p. C 6.1-C 6.8.
- 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, Berger H, Schaumberg J, 1999. Identification and ecology of limnetic plankton ciliates. Informationsberichte des Bayer. Landesamtes für Wasserwirtschaft, 3/99:1-793.
- Hartwig E, 1973. The ciliates of the tidal beach on the island Sylt (North Sea) I. Systematic. Mikrofauna Meeresboden, 18:387-453.
- Kahl A, 1932. Urtiere oder Protozoa. I: Wimpertiere oder Ciliata (Infusoria). 3. Spirotricha. Die Tierwelt Deutschlands, 25: 399-650.
- Lynn DH, 2008. The ciliated protozoa: characterization, classification, and guide to the literature. 3rd ed. Springer Publishers, New York, pp. 1-605.
- Petz W, Song W, Wilbert N, 1995. Taxonomy and ecology of the ciliate fauna (Protozoa, Ciliophora) in the endopagial and pelagial of the Weddell Sea, Antarctica. Stafia, 40:1-223.
- Shao C, Song W, Hu X, Ma H, Zhu M, Wang M, 2006. Cell division and morphology of the marine ciliate, *Condylostoma spatiosum* Ozaki and Yagiu (Ciliophora, Heterotrichida) based on a Chinese population. European Journal of Protistology, 42:9-19.
- Song W, Warren A, Ji D, Wang M, Al-Rasheid KAS, 2003. New contributions to two heterotrichous ciliates, *Folliculina simplex* (Dons, 1917), *Condylostoma curva* Burkovsky, 1970 and one lincnophorid, *Lincnophora lynbycola* Fauré-Fremiet, 1937 (Protozoa, Ciliophora): descriptions of morphology and infraciliature. Journal of Eukaryotic Microbiology, 50: 449-462.
- Song W, Wilbert N, 1997. Morphological investigations on some free living ciliates (Protozoa, Ciliophora) from China Sea with description of a new hypotrichous genus, *Hemigastrostyla* nov. gen. Archiv für Protistenkunde, 148:413-444.
- Villeneuve-Brachon S, 1940. Recherches sur les ciliés hétérotiches: Cinétome, argyrome, myonèmes. Formes nouvelles ou peu connues. Archives de Zoologie Experimentale et Generale, 82:1-180.
- Wilbert N, 1975. Eine Verbesserte Technik der Protargolimprägung für Ciliaten. Mikrokosmos, 64:171-179.
- Wilbert N, Song W, 2008. A further study on littoral ciliates (Protozoa, Ciliophora) near King George Island, Antarctica, with description of a new genus and seven new species. Journal of Natural History, 42:979-1012.
- Yagiu R, 1944. Studies on the ciliates *Condylostoma* I: taxonomy. Journal of Science of the Hiroshima University, 10:161-184.

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