Some Free-living Heterotrophic Flagellates from Marine Sediments of Incheon and Ganhwa Island, Korea

Won Je Lee*

School of Biological Sciences, University of Sydney, NSW 2006, Australia

Key Words:
Biogeography
Endemism
Heterotrophic flagellate
Taxonomy
Protist
Marine sediment

Heterotrophic flagellates occurring in the marine sediments of Incheon and Ganhwa Island are reported. Fifty-six species from 38 genera were encountered in this survey and two new taxa were recorded: *Cyrannomonas australis* sp. nov. and *Gweamonas unicus* sp. nov. There was little evidence for endemism because all flagellates including the two new taxa described here have been found from other habitats in Australia which are geographically remote from Korea. This study supports the model that free-living heterotrophic flagellates have a world-wide distribution.

The importance of heterotrophic flagellates as consumers in planktonic ecosystems has been well established (e.g. Azam et al., 1983). Generally, methodological difficulties and lower relevance to the issues of global carbon flux have meant that the benthic ecosystems have been less well studied than the water column. There have been a number of recent efforts to redress the growing imbalance (Bak and Nieuwland, 1989; Patterson et al., 1989; Alongi, 1991; Gasol, 1993; Hondeveld et al., 1994, 1995; Starink et al., 1996a, b; Epstein, 1997a, b; Hamels et al., 1998; Dietrich and Arndt, 2000; Lee and Patterson, 2002).

Recently there have been a number of studies describing the species and composition of the benthic heterotrophic flagellates (Vørs, 1992a; Ekeborn et al., 1996; Patterson and Simpson, 1996; Bernard et al., 2000; Lee and Patterson, 2000; Al-Qassab et al., 2002; Schroeckh et al., unpublished data), but there have been no similar studies in Korea.

The aims of this study are to document the diversity of heterotrophic flagellates in Korea, and to use that information to address issues of endemism in this group (Lee and Patterson, 1998; Patterson and Lee, 2000).

Materials and Methods

This study was carried out in Ulwangri Beach (sandy sediments; 126° 36E, 37° 44N) of Incheon and in Changhwari (muddy sediments; 126° 22E, 37° 36N) of Ganhwa Island, Korea in January and November 2001, respectively. Sediments were taken from intertidal sediments to a depth of about 1 cm from 1 m² quadrat and transported into a laboratory in cool condition. The sediments were placed in plastic trays in 1 cm deep layers. Cover slips (No. 2.2 cm × 2.2 cm) were placed on the lens tissue laid on the sediments. After 12-24 hours, the flagellates were observed under an Olympus microscope equipped with photographic facilities (see Lee and Patterson, 2000).

The samples collected at Changhwari were transported to Sydney for analysis, and were prepared as mentioned above. The flagellates were observed using a DMR microscope (Leica) equipped with photographic and video facilities. The samples were maintained at room temperature for 7 days.

Observations

Nomenclature here follows the ICZN (International Commission on Zoological Nomenclature, 1999). I apply here the use of the relative dimension ‘CL’ where 1.0 CL represents the length of the cell body along its longitudinal axis.

It was difficult to establish the identities of some species due to insufficient information, but they are recorded here to establish their occurrence in marine sediments (eg., *Cercomonas* sp.1, *Anyromonas* sp., Protist 1 and Protist 2).

**Choanoflagellida Kent, 1880**

*Salpingoeca infusum* Kent, 1880

(Fig. 1A)

Synonym: *Salpingoeca longipes* Kent, 1880

**Description:** Cells are oval and about 4.5 μm long in an oval loricca with a pointed posterior end. Single flagellum is about 1 CL. The cell body fills out the posterior part of the loricca. The cells attach to the substrate by the short pedicel. Found at Ulwangri Beach.

**Remarks:** Generally, the observations are in accord...
with the observations of Tong (1997c) and Tong et al. (1997). This species has been described from subtropical Australia, Denmark, England, France, Gulf of Finland, and USA (Kent, 1980; Griesmann, 1913; Norris, 1965; Boucaud-Camou, 1967; Tong, 1997c; Tong et al., 1997; Lee and Patterson, 2000). *Salpingoeca infusionum* is regarded as a synonym of *S. marina* James-Clark, 1867 (Griesmann, 1913; Boucaud-Camou, 1967), but according to Tong (1997c) these two species can be distinguished by the stiffness of the lorica and because the lorica of *S. infusionum* is slightly wider anteriorly than that of *S. marina*. Many previously reported species assigned to *Salpingoeca* are very similar in lorica length and shape, and the identities of species are unclear (Værøe, 1992a).

**Cryptomonadida Senn, 1900**  
*Goniomonas amphinema* Larsen and Patterson, 1990  
(Figs. 1B, 2A)

**Description:** Cells are oblong, flattened and about 4.5 μm long with several delicate stripes on both sides. Two flagella inserting in an anterior lateral pocket are similar in length; one directed anteriorly, one posteriorly. The row of ejectosomes is at times difficult to observe. The cells move by swimming. Found at Ulwangri Beach.

**Remarks:** This species has been found in marine sites in subtropical and tropical Australia, North Atlantic, Denmark, England, Fiji, Gulf of Finland, and Panama, and the reported size range is 4-8 μm (Larsen and Patterson, 1990; Lee and Patterson, 2000; Al-Qassab
et al., 2002). Goniomonas amphinema is distinguished from G. pacifica Larsen and Patterson, 1990 by the flagellar orientation when swimming and by the smaller size. Food ingestion takes place near the flagellar insertion.
**Goniomonas pacifica** Larsen and Patterson, 1990
(Figs. 1C, 2B)

*Description*: Cells are truncated anteriorly, rounded posteriorly, and are 5-8 µm long. The cells have several distinct longitudinal ridges on both sides and with a row of ejectosomes near the anterior end. Two flagella of similar length emerge from a small anterior depression and are directed anteriorly. When swimming, the two flagella diverge in different directions. Found at Ulwangi Beach.

*Remarks*: *Goniomonas pacifica* has been reported from marine sites in subtropical and tropical Australia, North Atlantic, Brazil, Denmark, England, Gulf of Finland, Hawaii, and Panama, with a cell length of 3-15 µm (Larsen and Patterson, 1990; Lee and Patterson, 2000; Al-Qassab et al., 2002). This species mostly resembles *Goniomonas truncata* Stein, 1878 in general appearance and the ranges of the length of the two species overlap (G. pacifica, 3-15 µm long; G. truncata, 3-25 µm long). Further study is required to establish well-defined identities for these species.

Heterolobosea Page and Blanton, 1985
*Percolomonas* sp.
(Figs. 1D, 2C)

*Description*: Cells are oval in shape, 5.5-7 µm long, and laterally compressed with only two flagella emerging from the end of a ventral depression. The non-acronemal longer flagellum is 3-4 CL and thinner than the short flagellum. The short one is slightly shorter than CL and usually lies in the groove. The cells move by skidding or gliding. Found at Changhwari.

*Remarks*: The cells described here resemble *Percolomonas denhami* in appearance and length with the exception of the number of flagella. The genus was known as having four flagella, but Tong (1997a) included *Percolomonas denhami* with three flagella; one short, one medium and one long. *Percolomonas denhami* was reported to be in the length ranges of 5-8 µm from subtropical Australia including Shark Bay (Toğ, 1997a) and Port Jackson (Tong et al., 1998). The cells observed here can be easily distinguished from the other common species, *P. cosmopolitanus*, by its smaller size and having only two flagella. The general appearance and moving pattern of the cells are similar to *Carpediemonas membranifera*, but *Percolomonas* sp. is distinguished by the beating pattern of the short flagellum. I have observed commonly this taxon in several sites in Australia (Shark Bay, Gippsland Basin, Botany Bay), but have not seen three flagella in this taxon. Probably this taxon is a different species from *P. denhami*. Further study is required to establish the identities of these taxa.

Kinetoplastida Honigberg, 1963
*Bodo designis* Skuja, 1948

(Figs. 1E, 2D)

*Description*: Cells are elliptical and 5.5-10 µm long with two unequal flagella emerging from a subapical pocket. The anterior flagellum is about 1 CL or slightly shorter and curves back over the rostrum. The acronemal posterior flagellum is 2.5-3 CL and has a sinuous profile in swimming cells. The cells rotate around their longitudinal axes when swimming. The nucleus is located near the middle of the cell. Commonly observed from Changhwari and Ulwangi Beach.

*Remarks*: *Bodo designis* has been reported from marine sites in Antarctica, North Atlantic, subtropical and tropical Australia, Brazil, Denmark, Fiji, Gulf of Finland, Greenland, Hawaii, and Panama, and its previously reported cell length is from 4 to 15 µm (Lee and Patterson, 2000; Al-Qassab et al., 2002). Generally, the observations are consistent with those of the previous authors. It may be characterised by the rotating behaviour of swimming cells.

*Bodo platyrhynchus* Larsen and Patterson, 1990
(Fig. 1F)

Observed from Ulwangi Beach. See Larsen and Patterson (1990) and Lee and Patterson (2000) for more details. This species was described from marine sites in subtropical Australia, Brazil and Hawaii with lengths from 3.5 to 7.5 µm (Larsen and Patterson, 1990, Lee and Patterson, 2000).

*Bodo saliens* Larsen and Patterson, 1990
(Figs. 1G, 2E)

*Description*: Cells are usually elongate elliptical, 6-12 µm long and somewhat inflexible. Two flagella unequal in length emerge subapically from a shallow pocket. The anterior flagellum is about 1 CL and is held forwards with a single anterior curve held perpendicular to the substrate. The acronemal posterior flagellum is about 3 CL and typically directed straight behind the cell. The cells swim in rapid darting in straight lines. Commonly observed from Changhwari.

*Remarks*: This species has been found in marine sediments in North Atlantic, subtropical and tropical Australia, Brazil, arctic Canada, Denmark, West Greenland, Hawaii, Gulf of Finland, and Panama, and its previously reported size ranges are 4-15 µm long (Lee and Patterson, 2000; Al-Qassab et al., 2002). The observations are in accord with those of the previous observers. *Bodo saliens* is characterized by the rapid darting movement and the posterior flagellum directed in a straight line when the cell is swimming.

*Hemistasia phaeocystica* (Scherffel, 1900)
Elbrächter et al., 1996
(Fig. 1H)

*Synonyms*: *Hemistasia klebsi* Griessmann, 1913;
Entomosigma peridinioides Schiller, 1925; Cryptaulax marina sensu Thronsden, 1969

Observed from Ulwangri Beach, and see Lee and Patterson (2000) and Elbrachter et al. (1996) for more details. This species has been reported from marine sites in subtropical Australia, Germany, and Danish Wadden Sea, with a cell length of 12-25 μm (Griessmann 1913, Thronsden, 1969; Elbrachter et al. 1996; Lee and Patterson, 2000). Hemistasia mostly resembles Rhynchobodo in being flexible and in having a spiral groove, but can be distinguished by the presence of the apical papilum.

Rhynchobodo simius Patterson and Simpson, 1996 (Fig. 1f)

Observed from Changhwari. See Patterson and Simpson (1996) for more details. This species has been previously reported from hypersaline sites in subtropical Australia, with a length of 9-16 μm (Patterson and Simpson, 1996; Al-Qassab et al., 2002) and was also observed from normal marine sites in Botany Bay (Lee, unpublished observations).

Rhynchomonas nasuta Klebs, 1893 (Figs. 1j, 2f)

Description: Cells are 4-6 μm long and flexible with a bulbous motile snout, which contains a mouth and beats slowly. The anterior flagellum lies alongside the snout and is hard to see. The acronematic trailing flagellum is 2-2.5 CL. The cells consume attached bacteria. The cells move by gliding. Found at Changhwari and Ulwangri Beach.

Remarks: Rhynchomonas nasuta has previously been reported to be found from 3 to 11 μm long and has been found in marine sites in Antarctica, North Atlantic, tropical and subtropical Australia, Brazil, Canada, Denmark, Fiji, Gulf of Finland, Greenland, Hawaii, Norway, and Equatorial Pacific (Lee and Patterson, 2000; Al-Qassab et al., 2002). The observations are in good agreement with those of Lee and Patterson (2000). This species can be distinguished from small heterotrophic flagellates by the bulbous snout.

Euglenida Btuscheck, 1884
Anisonema trepidum Larsen, 1987 (Figs. 1k, 2h)

Description: Cells are oblong and 12-14 μm long and flattened with a wedge-shaped ingestion organelle, which is difficult to observe. There are three distinct grooves on the dorsal and ventral faces of the cell. Two emergent flagella are of unequal length. The anterior flagellum is about 1.5 CL and beats freely, and the trailing posterior flagellum is stronger than the anterior flagellum, is about 4 CL and tapers distally.

The reservoir and nucleus are in the left side of the cell. The cells glide quickly in straight lines and jerk when changing direction. Found at Ulwangri Beach.

Remarks: Anisonema trepidum was found in marine sites in tropical and subtropical Australia, Brazil, Danish Wadden Sea, Fiji, and Hawaii, and the cell length was previously reported to be from 9 to 20 μm (Lee and Patterson, 2000; Al-Qassab et al., 2002). Generally, the observations agree with those of Lee and Patterson (2000), except for the presence of an ingestion organelle. Anisonema trepidum is distinguished from A. aequus Dujardin, 1841 by its smaller size, cell appearance and behaviour. This species is also similar to Anisonema glaciale Larsen and Patterson, 1990 in its movement, but is distinguished by its smaller size.

Heteronema exaratum Larsen and Patterson, 1990 (Figs. 1l, 2g)

One cell (about 10 μm long) observed from Changhwari, and see Larsen and Patterson (1990) and Lee and Patterson (2000) for more details. This species has been found in marine sites in subtropical and tropical Australia and Fiji with previously reported length from 15 to 20 μm (Larsen and Patterson, 1990; Patterson and Simpson, 1996; Al-Qassab et al., 2002).

Heteronema ovale Kahl, 1929 (Figs. 1m, 2i-j)

Description: Cells are ovate, 17-25 μm long, flattened, and metabolic without the pointed posterior end of the cell and with an ingestion organelle. The pellicular striations follow a S-helix on the ventral and dorsal faces of the cell, and have associated refractive bodies. Two flagella are of almost equal length about 1.3-1.5 CL and point in different directions when swimming. The posterior flagellum has a knob at its base and is stronger than the anterior one. The reservoir and nucleus are in the left side of the cell. The cells move by skidding or by vigorous squirming in contact with a substrate. Found at Ulwangri Beach.

Remarks: This species has been found at marine sites in tropical and subtropical Australia, and in the Baltic Sea (Kahl, 1929; Ekeborn et al., 1996; Lee and Patterson, 2000; Al-Qassab et al., 2002). Generally, the observations are in good agreement with the descriptions of Lee and Patterson (2000). Heteronema ovale may be confused with H. exaratum Larsen and Patterson, 1990 and H. larseni, but can be distinguished from them by its vigorous squirming movements, the lack of the pointed posterior end of the cell, or the cell length (see Lee and Patterson, 2000).

Notosolenus urceolatus Larsen and Patterson, 1990 (Figs. 1n, 2k, 2q)
Description: Cells are posteriorly broad and anteriorly narrow with a small neck near the anterior end of the cell, and are 11-13 μm long. The cells are with three dorsal keels, two lateral ridges and three fine ventral ridges; the left ventral curves slightly from the anterior to the posterior and forms an arc. Two flagella are of unequal length; the anterior flagellum is about 1.3 CL, and the posterior flagellum about 1 CL. The reservoir lies in the right side of the cell and the nucleus in the left. The cells glide slowly with the anterior flagellum.

Found at Ulwangri Beach.

Remarks: This species was reported from subtropical and tropical Australia, and Brazil, and its previously reported cell lengths are from 11 to 22 μm (Larsen and Patterson, 1990; Lee and Patterson, 2000; Al-Qassab et al., 2002). The cells observed here are in good agreement with the observations for the 'urceolate' cells of Lee and Patterson (2000). *Notosolanus urceolatus* is similar in having dorsal ridges or keels to *N. esulcis* Larsen, 1987 but *N. esulcis* has four shallow dorsal ridges. This species is distinguished from *N. hemicircularis* Lee and Patterson, 2000 by its larger size and the absence of a semicircular hyaline collar.

**Petalomonas abscissa** (Dujardin, 1841) Stein, 1859 (Fig. 1D)

Observed from Changhwhari, and see Larsen and Patterson (1990) and Lee and Patterson (2000) for more details. This species has been reported with lengths from 9.5 to 25 μm from marine sites in subtropical and tropical Australia, Brazil, and the Danish Wadden Sea (Lee and Patterson, 2000; Al-Qassab et al, 2002).

**Petalomonas intortus** Lee and Patterson, 2000 (Figs. 1S, 2L)

Description: Cells are rounded, 5-7 μm long, very flattened with tiny bodies adhering to the cell surface and without structures visible on the dorsal face. One flagellum emerges from the flagellar canal, and is about 1.5 CL. The cells move slowly by gliding with the flagellum. The ovate reservoir is situated adjacent to the antero-posterior axis of the cell. Found at Ulwangri Beach.

Remarks: *Petalomonas intortus* is characterised by striations on the ventral face of the cell and particles adhering to the cell surface (Lee and Patterson, 2000), but the striations may be difficult to observe. This species is distinguished from most other species in the *Petalomonas* by the adhering particles and ventral striations. It is mostly similar to *P. boadicea* Larsen and Patterson, 1990 which has rhomboid excrescences and a shorter flagellum. The ventral striations in *P. boadicea* were not reported by Larsen and Patterson (1990).

**Petalomonas minor** Larsen and Patterson, 1990.

(Figs. 1P, 2M)

Description: Cells are ovate-rhomboid and about 9 μm long with one flagellum about 1 CL. A longitudinal dorsal keel lies to the right of the midline. The reservoir is located in the right side of the cell and the nucleus is in the left side. The cells glide with the flagellum directed forwards. Found at Changhwhari and Ulwangri Beach.

Remarks: This species has been reported from marine sites in subtropical and tropical Australia and Fiji, and the previously reported length ranges from 6 to 11 μm (Larsen and Patterson, 1990; Lee and Patterson, 2000). It was also reported by Al-Qassab et al (2002), but I do not regard that the cells reported by Al-Qassab et al. are the same as the cells reported by Larsen and Patterson (1990) and Lee and Patterson (2000). The observations are in accordance with that of Lee and Patterson (2000). *Petalomonas minor* is characterized by its ovate-rhomboid shape and having a longitudinal dorsal keel.

**Petalomonas minuta** Hollande, 1942 (Figs. 1Q, 2N)

Synonym: *Petalomonas medicoanelata* var. *pusilla* Klebs, 1893; *Petalomonas minutula* Christen, 1962

Observed from Changhwhari and Ulwang Beach, and see Lee and Patterson (2000) for more details. This species has been found in marine sites in subtropical and tropical Australia, Brazil, Danish Wadden Sea, Denmark, Fiji, Gulf of Finland, and North Atlantic, and the previously reported cell lengths for this species range from 5 to 12 μm (Larsen and Patterson 1990; Lee and Patterson, 2000; Al-Qassab et al., 2002). It mostly resembles *Notosolanus apocampus* Stokes, 1884 in its general appearance and cell length and in having a deep dorsal groove, but it can be distinguished by the lack of a posterior flagellum and by the short anterior flagellum.

**Petalomonas poosilla** Larsen and Patterson, 1990 (Figs. 1R, 2O)

Synonym: *Petalomonas pusilla* Skuja, 1948 (ICBN)

Description: Cells are ovate to ellipsoidal, 5.7-5.5 μm long, and somewhat flattened, and have a single emergent flagellum which is 1-1.5 CL. The cells have no surface structures. The reservoir is in the right side of the cell and the nucleus in the left side. The cells move by gliding. Found at Changhwhari and Ulwangri Beach.

Remarks: *Petalomonas poosilla* has been found in marine sites in subtropical Australia, Brazil, Danish Wadden Sea, Fiji, Gulf of Finland, Hawaii and NE Canada with a cell length range of 4-12 μm (Larsen and Patterson, 1990; Lee and Patterson, 2000; Al-Qassab et al., 2002). This species has been described without ridges (Skuja, 1948; Larsen and Patterson,
but more recent accounts report the presence of ridges (Patterson and Simpson, 1996; Lee and Patterson, 2000; Al-Qassab et al., 2002; Schroeckh et al., unpublished data). *Petalomonas poosilla* resembles *P. minuta* in general appearance, but can be distinguished by the lack of a longitudinal dorsal groove. This species is similar to *P. cantuscygni* Cann and Pennick, 1986 in having dorsal ridges, but *P. cantuscygni* never has fewer than six dorsal ridges.

**Pluteus vitrea** Dujardin, 1841  
(Fig. 1U)

Observed from Ulwangri Beach, and see Al-Qassab et al. (2002) and Lee and Patterson (2000). This species has been found at marine sites in subtropical and tropical Australia, Brazil, Fiji, Hawaii, and USA, and the previously reported length range is from 13 to 25 μm (Lee and Patterson, 2000; Al-Qassab et al., 2002).

**Sphenomonas cfr. angusta** Skuja, 1956  
(Figs. 1T, 2P)

**Description:** Cell is oblong to ovate, about 12 μm long, and not flattened with several pellicular strips and without grooves. Two flagella unequal in length emerge from a flagellar pocket; the anterior flagellum is about 1.2 CL and its proximal part moves actively; the posterior flagellum is about 0.3 CL. One large inclusion occupies the posterior part of the cell. The nucleus is in the left side of the cell. One cell observed from Ulwangri Beach.

**Remarks:** The cell observed here resembles *Sphenomonas angusta* in general shape and length, but has several pellicular strips and does not have a dorsal groove, which is a diagnostic character for *S. angusta*. *Sphenomonas angusta* has been usually found in freshwater sites (Skuja, 1956; Schroeckh et al., unpublished data) and also found in marine sites in subtropical Australia only by Lee and Patterson (2000). *Sphenomonas angusta* can be distinguished from other species in the genus by its smaller size and having one groove.

**Stephanopogonidae** Corliss, 1961

**Stephanopogon colpoda** Entz, 1884  
(Figs. 3C, 4A)

**Description:** Cells are 20-30 μm long, flexible and dorso-ventrally flattened with several rows of kineties. The ventral surface terminates anteriorly as three bars. The cells move by crawling or swimming with flagella. Ingestion of diatoms took place at a broad apical mouth. Rarely observed from Ulwangri Beach.

**Remarks:** *Stephanopogon* contains six nominal species: *S. apogon*, *S. colpoda* Entz, 1884; *S. mesnili* Lwoff, 1923; *S. minuta* Lei et al., 1999; *S. mobilensis* Jones and Owen, 1974; *S. paramesnili* Lei et al., 1999. *Stephanopogon colpoda* has been found at marine sites in subtropical and tropical Australia, Brazil, Denmark, and USA, and the previously reported cell lengths are from 18 to 30 μm (Entz, 1984; Kahl, 1930; Dragesco, 1963; Lackey and Lackey, 1963, 1970; Jones and Owens, 1974; Larsen and Patterson, 1980; Al-Qassab et al., 2002). The observations are in agreement with the previous observations. This species is distinguished from *S. apogon* by the bars at the anterior end of the cell, but is difficult to distinguish from *S. mesnili*, *S. minuta*, *S. mobilensis* and *S. paramesnili* because all have bars at the anterior end of the cell. Further studies are needed to establish the identities of these species.
Stramenopiles Patterson, 1989
Bicosoecids Grassé, 1926
*Bicosoea epiphytica* Hilliard, 1971
(Fig. 3D)

*Synonym: Bicosoea pulchra* Hilliard, 1971

*Description:* Cells are spherical or ovate and 3.5-6 μm long in a cylindrical lorica about 10-11 μm long. The lorica is everted at the anterior end. There is a fold or ridge at the anterior end of the cell. Two flagella insert near the base of the fold or ridge. The front flagellum is about 2 CL and beats with a sine-wave, and the posterior flagellum is about 1.5 CL, lies in a ventral groove and attaches to the lorica. The lorica attaches to the substratum using a short stalk. Found at Uliwangi Beach.

*Remarks:* Generally, the observations are in agreement with the observations by Tong (1997b). *Bicosoea epiphytica* was found in marine sites in England and Belize, with a lorica length of 8-25 μm (Vørs, 1993a...
under the name of Bicosoeca pulcra; Tong, 1997b). There are some more species with a cylindrical lorica: Bicosoeca borealis Hilliard, 1971 (15-17.6 μm), B. epiphytica Hilliard, 1971 (8.27.5 μm), B. maris Picken, 1941 (10 μm), B. pulcra Hilliard, 1971 and B. vacillans Stolc, 1888 (17.25 μm). Bicosoeca pulcra is a synonym of B. epiphytica (Tong, 1997b). This species is distinguished from B. borealis by its lorica everted at the anterior end, from B. maris by having a short pedicel, and from B. vacillans by having less striations (10-12 striations per 10 μm), compared to 24 striations per 10 μm in B. vacillans.

Cafeteria roenbergensis Fenchel and Patterson, 1988 (Figs. 3E, 4B)

Description: Cells are D-shaped, 3.3-5.5 μm long and laterally compressed with a shallow groove. Two flagella emerge subapically, and are of similar length and slightly longer than the cell; the anterior flagellum directed perpendicular to the ventral face of the cell of attached cells, the posterior flagellum is reflexed, passing over one face of the cell and then attaching to the substrate by the tip. In swimming cells, the anterior flagellum is directed forwards and beats with a sine-wave, and the posterior flagellum is directed backwards and trails. Usually the cells move fast following a spiral path, but sometimes move slowly. Found at Ulwangri Beach.

Remarks: This species has been reported from marine sites in Antarctica, Australia, North Atlantic, Baltic, Denmark, England, Gulf of Finland, Greenland, and equatorial Pacific, and previous studies reported the size range to be from 2-10 μm (Lee and Patterson, 2000; Al-Qassab et al., 2002). The observations are in agreement with those of Lee and Patterson (2000). Cafeteria roenbergensis can be distinguished from the other species of the genus (see Lee and Patterson, 2000). This species may not be clearly distinguished from Acronema sippevissettenis Teal et al., 1998, the flagella of which are said to be acronemal. Further study is required to establish the identity of these two species.

Pseudobodo tremulans Griessmann, 1913 (Figs. 3F, 4D)

Synonym: Monas neglecta James-Clark, 1867

Description: Cells are 3.5-5 μm long with an anterior collar around the anterior part of the cell. The anterior flagellum with a sine-wave beating pattern is about 3 CL, and the posterior flagellum is about 1.5 CL and attaches to the substrate by its tip. The cells move by swimming with the anterior flagellum directed forwards. Found at Ulwangri Beach.

Remarks: Pseudobodo tremulans has been found in marine sites in Antarctica, Australia, Brazil, Denmark, and Hawaii, with a cell length of 3-8 μm (Lee and Patterson, 2000; Al-Qassab et al., 2002). This species mostly resembles Cafeteria minuta (Ruinen, 1938) Larsen and Patterson, 1990 in having a long anterior flagellum and in cell shape and length, but can be distinguished by a collar (mouth) around the anterior part of the cell.

Pedinellids Zimmermann et al., 1984 Actinomonas mirabilis Kent, 1880 / Pteridomonas danica Patterson and Fenchel, 1985 (Figs. 3G, 4E)


Description: Cells are 3.5-5.5 μm long with one flagellum emerging from the anterior end of the cell. The flagellum with an undulating beat is about 3 CL. The anterior part of the cell is slightly broader than the posterior part. The cells have a ring of arms around the flagellum and below the equator of the cell; the arms around the flagellum are evenly spaced. The cells usually swim rapidly, but occasionally attach to the substrate with a long posterior stalk. Small particles are seen on the cell surface. Found at Changhwari and Ulwangri Beach.

Remarks: Cell length was previously reported to be from 4 to 8 μm. These species have been found at marine sites in Antarctica, North Atlantic, subtropical and tropical Australia, Brazil, Danish Wadden Sea, England, Fiji, France, and Hawaii (Kent, 1880; Griessmann, 1913; Fenchel, 1982; Larsen, 1985; Patterson and Fenchel, 1985; Larsen and Patterson, 1990; Patterson et al., 1993; Tong, 1997b; Tong et al., 1997; Vars, 1993a, b). According to Lee and Patterson (2000), Actinomonas mirabilis and Pteridomonas danica are very similar and are hard to distinguish with confidence at the light microscopical level, but Actinomonas mirabilis more frequently has posterior or lateral arms and two anterior wreaths of arms; it typically has a more substantial flagellum. At the ultrastructural level, Actinomonas mirabilis is distinguished from Pteridomonas danica because of flagellar transitional bands in P. danica (Larsen, 1985; Patterson and Fenchel, 1985; Larsen and Patterson, 1990).

Ciliophrys infusionum Clerckowski, 1876 (Fig. 3H)

Synonyms: Ciliophrys marina Caullery, 1909; Dimorpha monomastix Penard, 1921

Observed from Changhwari, and see Larsen and Patterson (1990) and Lee and Patterson (2000). This species has been found at marine sites in SE North America, subtropical and tropical Australia, Denmark, England, English Channel, Fiji, Gulf of Finland, Hawaii, Mediterranean, Norway, and equatorial Pacific, with a cell length of 3.5-20 μm (Larsen and Patterson, 1990;
Lee and Patterson, 2000; Al-Qassab et al., 2002).

Stramenopiles incertae sedis

*Developayella elegans* Tong, 1995
(Figs. 3I, 4C)

**Description:** Cells are oval and 4-5 μm long. Two flagella emerging from a depression in the right anterior part of the ventral side of the cell are of similar length about 1.8 CL. The cells attach to the substrate by means of the posterior flagellum. In attached cells the anterior flagellum is held in a curve and beats slowly up and down, and the posterior flagellum beats rapidly with a shallow excursion. The cells move by swimming. Found at Changhwarai and Ulwangri Beach.

**Remarks:** This species has been found at subtropical Australia and England, with a cell length of 3.5 to 10 μm (Lee and Patterson, 2000; Al-Qassab et al., 2002). The observations are in agreement with the description of Tong (1995). When this species attaches to the substrate, it can be easily distinguished from other small free-living flagellates, such as *Cafeteria*, *Jakoba*, *Mallawimonas*, and *Phyllostomus*, which are similar in having two flagella and a large ventral depression, by the beat pattern of the flagella.

Apusomonadidae Karpov and Mylnikov, 1989

*Amastigomonas debruynei* de Saedeleer, 1931
(Figs. 3J, 4G)

**Synonyms:** *Thecamonas trahens* Larsen and Patterson, 1990; *Amastigomonas borokensis* Hamar, 1979; *A. caudata* Zhukov, 1975

**Description:** Cells are 3.5-7 μm long, flexible and
dorso-ventrally flattened. The anterior flagellum emerges from the tip of a laterally directed sleeve and beats slowly in a small angle. The acronematic posterior flagellum is about 1.5 CL, lies in a groove along the margin of the cell, trails under the cell. Strands of cytoplasm are drawn out behind the cell. The cells move slowly by gliding. Commonly observed from Changhwari and Ulwangri Beach.

**Remarks:** This species has been recorded from marine sites in subtropical and tropical Australia, North Atlantic, Brazil, Arctic Canada, Denmark, England, Gulf of Finland, Greenland, Hawaii, and Panama, with a cell length of 3-7.5 μm (Lee and Patterson, 2000; Al-Qassab et al., 2002). The criteria for identifying species within *Amastigomonas* are given by Lee and Patterson (2000). Mylnikov (1999) included five more species of *Amastigomonas*: *A. gigantea* Mylnikov, 1999 (23-25 μm long), *A. gribennis* Mylnikov, 1999 (5-7 μm long), *A. klosteris Arndt and Mylnikov*, 1999 (12-20 μm long), *A. marina* (Mylnikov, 1989) Mylnikov, 1999 (5-8 μm long), *A. muscula* Mylnikov, 1999 (7-8 μm long). *Amastigomonas debruynei* mostly resembles *A. gribennis* in cell length and shape, but can be distinguished as indicated under *Amastigomonas gribennis* below.

*Amastigomonas gribennis* Mylnikov, 1999
(FIG. 3K)

**Description:** Cells are ovate to elliptical, about 7 μm long, dorso-ventrally flattened and flexible. The short anterior flagellum emerges subapically near the anterior end of the cell and beats actively up and down. The acronematic posterior flagellum emerges just below the anterior flagellum, is about 1.3 CL, lies in a groove and protrudes behind the cell. The nucleus is subapically situated. The cells glide fast on the substrate and when moving the short anterior flagellum appears to be used. Found at Ulwangri Beach.

**Remarks:** This species was first described from the Black Sea by Mylnikov (1999) and was also observed from marine sites in tropical and subtropical Australia (Lee, unpubl. obs.). It resembles *Amastigomonas debruynei* in general appearance and cell length, but is distinguished because this species always glides quickly with the anterior flagellar beating and because it appears to do not have a sleeve. *Amastigomonas debruynei* always glides slowly, is more flexible than *A. gribennis*, its anterior flagellum has a slow beating and emerges from the tip of the sleeve.

*Amastigomonas mutabilis* (Griessmann) Molina and Nerad, 1991
(Figs. 3L, 4F)

**Synonyms:** *Rhynchosomonas mutabilis* Griessmann, 1913; *Thecamonas mutabilis* Larsen and Patterson, 1990

**Description:** Cells are elliptical, 9-18 μm long, dorso-ventrally flattened and flexible. The anterior flagellum arises from the flexible sleeve around its base, is 0.5-0.7 CL and is the same thickness as the posterior flagellum. The recurrent posterior flagellum is about 1.5 CL and trails under the body, to which it attaches loosely in a slight groove. The cells may or may not have granules along side the recurrent flagellum. Strands of cytoplasm are drawn out behind the posterior end of the moving cell. The cells move by gliding. Found at Changhwari, and Ulwangri Beach.

**Remarks:** This species has been described from marine sites in subtropical Australia, Brazil, Denmark, England, France, Greenland, and North Atlantic, with a cell length of 7-20 μm (Lee and Patterson, 2000; Al-Qassab et al., 2002). *Amastigomonas mutabilis* is distinguished from *A. debruynei* and *A. gribennis* by its larger size and the presence of granules alongside the posterior flagellum.

Cercomonadida Vickerman, 1983
*Cercomonas* sp. 1
(Fig. 3M)

**Description:** Cell is about 13 μm long, flexible, anteriorly narrow and posteriorly broad. Two flagella insert apically; the anterior flagellum is about 1 CL, acronematic, and beats slowly from side to side, the posterior flagellum is about 1.5 CL and trails behind the cell body. The posterior flagellum appears to lie in a ventral groove. Strands of cytoplasm are drawn from the posterior end of the cell. The cell moves slowly by gliding. One cell found at Changhwari.

**Remarks:** This cell observed here appears to be the same as the cells observed by Lee and Patterson (2000) and Tong (1994) as *Cercomonas* sp. Species identities in the genus *Cercomonas* are unclear and this genus is in urgent need of attention (Lee and Patterson, 2000).

*Cercomonas* sp. 2
(Fig. 3N)

**Description:** Cells are 12-15 μm long, flexible, slightly bulged anteriorly and pointed posteriorly. The anterior flagellum emerges from the bulged anterior end of the cell and is about 1.5 CL. The posterior flagellum emerges subapically from a small depression, is about 2 CL, beats somewhat actively when moving, and does not adhere to the cell body. Strands of cytoplasm are drawn out from the posterior end of the cell. The nucleus is located in the anterior part of the cell. The cells have no ventral groove. The cells move by gliding and contain food materials under the cell surface. Found at Changhwari.

**Remarks:** Small *Cercomonas* taxa (< 20 μm) with a slim body include species such as *C. cylindrica*, *C. aestivalis*, *C. jao*, *C. lowyianus* and *C. tataires*, but *Cercomonas* sp. 2 is distinguished from these taxa by...
Taxonomy of Marine Flagellates

the posterior flagellum that does not adhere to the body. This organism is similar to Cercomonas primitive (Massart) Mignot and Brugerolle (1975), but C. primitive is about two times bigger (it is about 32 μm long) and is pointed or narrow at both ends of the cell. It was also found in Shark Bay by Al-Qassab et al. (2002, 135, Fig. 18).

Massisteria marina Larsen and Patterson, 1990
(Figs. 3O, 4H, 4L)

Description: The cells are 3-5 μm long and dorso-ventrally flattened. The cells produce delicate pseudopodia with extrusomes, extending radially from the cell and normally adhering to the substrate. Two curved flagella are short and arise from the dorsal side of the cell and are somewhat inactive. Found at Ulwangri Beach.

Remarks: The observations are in agreement with those of Larsen and Patterson (1990) and Lee and Patterson (2000). This species has been found at marine sites in subtropical and tropical Australia, Brazil, Denmark, Gulf of Finland, equatorial Pacific, and Panama, with a cell length of 2-9.5 μm (Lee and Patterson, 2000; Al-Qassab et al., 2002).

Kathablepharidae Varsi, 1992

Platychloromonas psammobia Larsen and Patterson, 1990
(Fig. 3P)

Observed from Ulwangri Beach, and see Larsen and Patterson (1990) and Lee and Patterson (2000) for more details. This species has been found at marine sites in subtropical Australia, Danish Wadden Sea, England, and Fiji, with a cell length of 15-20 μm (Larsen and Patterson, 1990; Lee and Patterson, 2000). It can be distinguished from other heterotrophic flagellates by being flattened and its two rows of extrusomes coiled posterior flagellum (Lee and Patterson, 2000).

Thaumatomonadidae Patterson and Zoiffel, 1991

Protaspis gemmifera Larsen and Patterson, 1990
(Figs. 3Q, 4L-J)

Description: Cells are oblong, 12-15 μm long, and dorso-ventrally flattened. Cell surface is very warty. Two flagella insert subapically and are of unequal length; the anterior flagellum is about 1.3 CL and beats actively, and the posterior flagellum is about 2 CL and trails behind the cell. The roundish nucleus is situated anteriorly below the flagellar insertion and has caps. The cells move by fast gliding with the beating of the anterior flagellum. Found at Ulwangri Beach.

Remarks: Generally, the observations agree with the original description of Lee and Patterson (2000). This species has been found at marine sites in subtropical Australia, Brazil, and North Atlantic, and cell lengths were previously reported as 10-17 μm (Larsen and Patterson, 1990; Patterson et al., 1993; Lee and Patterson, 2000). It is similar to P. verrucosa Larsen and Patterson (1990) in cell shape and length, but can be distinguished by its fast swimming pattern and by the longitudinal ventral furrow in P. verrucosa. The genus contains ten nominal species: P. gemmifera Larsen and Patterson, 1990; P. glans Skuja, 1939; P. major Skuja, 1938; P. metahiza Skuja, 1939; P. obovata Skuja, 1948; P. obliqua Larsen and Patterson, 1990; P. simplicia Varsi, 1992; P. tanyopsis Nomis, 1961; P. tegere Larsen and Patterson, 1990 and P. verrucosa Larsen and Patterson, 1990.

Protaspis obliqua Larsen and Patterson, 1990
(Figs. 3S, 4K)

Description: Cells are oblong, 14-23 μm long, and dorso-ventrally flattened with a ventral median groove; subapically, the right margin of the groove forms a protrusion. Two flagella insert near the protrusion and are of unequal length; the anterior flagellum is about 0.5 CL and the posterior flagellum is about 1 CL. The nucleus has no nuclear caps and is located subapically in a median position, but in a dividing cell it was located in the right side of the cell. Pseudopodia may be produced from the groove. The cells glide slowly. Found at Ulwangri Beach.

Remarks: This species has been described from marine sites in subtropical Australia, Fiji, and England, with a cell length of 8.5-32 μm (Larsen and Patterson, 1990; Tong, 1997b; Lee and Patterson, 2000). The observations are in accordance with those of Lee and Patterson (2000). Protaspis obliqua can be characterized by the presence of the protrusion near the flagellar insertions.

Protaspis tegere Larsen and Patterson, 1990
(Figs. 3R, 6H)

Description: Cells are oblong, ovate or obovate, 20-22 μm long, and slightly flattened with a longitudinal median ventral groove. Cell surface is warty. Two flagella are unequal in length and insert subapically; the anterior flagellum is as long as the cell and the posterior flagellum is about 2 CL and trails under the cell. The nucleus is with anterior caps and is located anteriorly near the mid-line of the cell. The cells move by gliding with the beating of the anterior flagellum. Found at Ulwangri Beach.

Remarks: The observations are in good agreement with the original description by Larson and Patterson (1990). This species has been reported from marine sites in subtropical and tropical Australia, Fiji, and Hawaii, with a cell length of 14-25 μm (Lee and Patterson, 2000). Protaspis tegere resembles P. major Skuja, 1939 and P. metahiza Skuja, 1939 in cell shape, but P. major (24-40 μm long) and P. metahiza
(27.5-36 μm long) are slightly bigger. *Protaspis major* has an oblique ventral groove.

Excavates Patterson and Simpson, 1999

_Carpediemonas bialata_ (Ruinen) Lee and Patterson, 2000

(Fig. 5A)

Basionym: *Cryptobia bialata* Ruinen, 1938

Observed from Changhwari, and see Lee and Patterson (2000) for more details. This species has been described from marine sites in subtropical Australia, with a cell length of 6-14 μm (Ruinen, 1938; Lee and Patterson, 2000). It often co-occurs with *Carpediemonas membranifera* Ekeborn et al., 1996.

_Carpediemonas membranifera* Ekeborn et al., 1996

(Figs. 5B, 6D)

_Description:* Cells are elliptical or obovate and 4-8 μm long with a longitudinal ventral groove, which extends most of cell length. Two flagella are unequal in length; the anterior flagellum bent over backwards emerges from the anterior end of the cell, is slightly longer than the cell, and beats stiffer. The posterior flagellum emerges from the anterior end of the ventral groove, is acronematic, is about 3 CL, and beats actively in the ventral groove. The cells move by skidding with the anterior flagellum beating with a stiff paddling motion. Found at Changhwari.

Remarks: This species has been described from marine sites in subtropical the tropical Australia and Brazil, and previously reported cell lengths are 3-9 μm (Larsen and Patterson, 1990; Ekeborn et al., 1996; Simpson and Patterson, 1999; Bernard et al., 2000; Lee and Patterson, 2000; Al-Qassab et al., 2002). It can be distinguished from *Carpediemonas bialata* by its smaller size and the relatively long acronematic posterior flagellum.

_Protista incertae sedis_

_Ancyromonas sigmoides* Kent, 1880

(Figs. 5C, 6A)

_Description:* Cells are oval, 3-5 μm long and dorsally flattened. The cells have a shallow groove ventrally near an antero-lateral margin of the cell. Two flagella of unequal length; the thin anterior flagellum emerges from an anterior depression, is about 1 CL,
and beats stiffly or may beat actively at times, and the acronemal posterior flagellum is 1.5-3 CL. Moves by gliding. Commonly found at Changhwari and Ulwangri Beach.

**Remarks:** This species has been reported from marine sites in Antarctica, subtropical the tropical Australia, Arctic Canada, Denmark, Fiji, Gulf of Finland, Greenland, Hawaii, Eastern Pacific (hydrothermal vent), and Panama, and previously reported lengths range from 2-7.6 μm (Atkins et al., 2000; Bernard et al., 2000; Lee and Patterson, 2000; Al-Qassab et al., 2002). The observations are in good agreement with those of previous authors. It is similar to *Metopion fluens* Larsen and Patterson, 1990, but can be distinguished by the anterior flagellum directed forward; both flagella in *M. fluens* are directed to the rear. *Ancyromonas sigmoideus* can be distinguished from *Ancyromonas sinistra* Al-Qassab et al., 2002 by the laterally flattened body and its cell shape (A. sinistra is spherical) and because A. sinistra has a rugose flange on the left anterior-lateral margin of the cell.

*Ancyromonas* sp.  
(Fig. 5D)

**Description:** Cells are ovoid to roundish, 5-7 μm long, and somewhat laterally flattened. The cells have two thickened flagella, which insert separately by a shallow and wide snout at the anterior end of the cell. Both flagella are thin at the tip (acronemal). The anterior flagellum is slightly longer than the cell and beats stiffly, and the posterior flagellum is 2-2.2 CL and is directed posteriorly. The nucleus is located subapically near the flagellar insertion. The cells glide fast with the beating of the anterior flagellum. Found at Ulwangri Beach.

**Remarks:** This organism is tentatively assigned to *Ancyromonas* because it glides, is laterally flattened, and has one short flagellum emerging from the anterior end and one long trailing flagellum emerging subapically from the ventral depression. It is distinguished from *A. sinistra* by the lack of a rugose flange on the left anterior-lateral margin. Other *Ancyromonas* species do not glide with the anterior flagella directed posteriorly. *Ancyromonas* sp. is similar to *Protaspis* species such as *P. simplex* in that the nucleus is located anteriorly, but is distinguished by the orientation of the flagella and because this species is dorso-ventrally flattened.

*Barthelona vulgaris* Bernard et al., 2000  
(Figs. 5E, 6B)

**Description:** Cells are ovoid, 6-8 μm long, and have two flagella inserting subapically. The anterior flagellum is about 1.5 CL and the posterior one is 2.5 CL. A groove extends from near the flagellar pocket to the posterior edge of the cell following the cell margin. Moves by swimming. Found at Changhwari.

**Remark:** This species has been found at marine sites in subtropical Australia, with a cell length of 5-8 μm (Bernard et al., 2000; Lee and Patterson, 2000). It resembles some *Bodo* species, but is easily distinguished by the groove and the feeding behaviour (Lee and Patterson, 2000).

*Clatriavia cavis* Lee and Patterson, 2000  
(Fig. 5F)

Observed one cell (about 12 μm long) from Ulwangri Beach. See Lee and Patterson (2000) for more details. This species has been reported from marine sites in subtropical Australia and England, and previously reported cell lengths are 6-10 μm (Tong, 1994; Lee and Patterson, 2000; Al-Qassab et al., 2002). This genus contains two nominal species; *C. mobilis* Massart, 1900 and *C. parva* Schouteden, 1907.

*Cyranoemonas* gen. nov.

**Diagnosis:** Bilflagellated colourless protists of unknown affinities. Body flattened and flexible with ventral depression subapically. Flagella unequal, inserting into ventral depression. One flagellum directed anterior-laterally, the other trailing. Moves by gliding.

**Type species:** *Cyranoemonas australis* sp. nov.

(Figs. 5G, 6E-G. Type micrographs: Figs. 6E-G)

*Cyanoemonas australis* sp. nov.  
(Figs. 5G, 6E-G. Type micrographs: Figs. 6E-G)

**Diagnosis:** *Cyanoemonas* 4.5-5 μm long, flexible. Anterior flagellum of about 1 CL, posterior flagellum about 1.5 CL.

**Description:** Cells are ovoid, 4.5-5 μm long, dorso-ventrally flattened, and somewhat flexible. The anterior part is concavely depressed. Two thickened flagella emerge from the right side of the cell and are not acronemal. The anterior flagellum is about the length of the cell and flickers stiffly forwards. The posterior flagellum inserts to the left of the anterior flagellum, is 1.5 CL, and trails behind the cell. The nucleus is located anteriorly. The cells contain small food materials. The cells glide slowly with the anterior flagellum.

Observed commonly from Ulwangri Beach. This species was also observed in Botany Bay and Gippsland Basin, Australia (Lee, unpubl. obs.). The photographs are of cells from Gippsland Basin.

**Remarks:** This species is the same as 'Cyro' in Tong (1994). According to Tong (1994), bacteria are ingested into the anterior ventral groove, just below the anterior flagellum. It is reminiscent of *Rhynchomonas nasuta* in gliding and beating behaviour of the anterior flagellum, but *R. nasuta* has the bulbous snout that is characteristic for the genus and an acronemal trailing flagellum. *Cyanoemonas australis* is distinguished from *Ancyromonas* species because of its flexibility and by
the flagellar insertion. This species can be distinguished from other small gliding flagellates by its flagellar insertion. It resembles *Amastigomonas* species, but can be distinguished by the lack of a sleeve surrounding the anterior flagellum and by having a thickened, highly visible posterior flagellum. This species is similar to *Protaspis gemmifera* Larsen and Patterson, 1990 in general appearance, but is distinguished by its flexible body and smaller size.

**Discocelis punctata** Larsen and Patterson, 1990  
(Figs. 5H, 6C)

**Description:** Cells are disc-shaped, 6.5-9 μm long, laterally flattened, anteriorly concave and posteriorly convex. Two flagella emerge from an indentation on the anterior margin of the cell; the shorter flagellum is less than 1.5 μm long, is hard to see at times and is inactive, and the long flagellum is about 1.4 CL and trails behind the cell. There is a line of bodies around
the margin of the cell. The nucleus is in the anterior part of the cell. Glides smoothly in closely contact with the substrate. Found at Ulwangri Beach.

Remarks: Discocellia punctata has been described from marine sites in subtropical Australia, Brazil, and Fiji (Larsen and Patterson, 1990; Tong et al., 1998; Lee and Patterson, 2000) and previously reported cell length is 6-9 μm. This species has been distinguished from D. saleuta Vars (1968) by the bigger size and the presence of the peripheral bodies (Vars, 1988; Larsen and Patterson, 1990). The cell length ranges overlap, and according to Larsen and Patterson (1990) and Vars (1988) the peripheral bodies may be seen in D. saleuta. Further study is required to distinguish between these two species clearly.

Gweamonas unicus gen. nov.

Diagnosis: Uniflagellated colourless protists of unknown affinities. Body rigid and not flattened with ventral depression subapically. One flagellum inserting into ventral depression, directed posteriorly when moving and coiled up when resting. Cell glides.

Type species: Gweamonas unicus nov. spec.

Etymology: Australian aboriginal tribes (Eora/Dharawal) call “Quibray Bay” Gwea

Gweamonas unicus sp. nov.
(Figs. 5I, 6I-K. Type micrographs: Figs 6I-K)

Diagnosis: Gweamonas 4-7μm long with ridges on both sides of cell. One flagellum of 1.5-2 CL, emerging from ventral depression, and directed posteriorly when moving and coiled up when resting. Moves by gliding with the body.

Description: Cells are 4-7 μm long, rigid and not flattened with a short ventral depression. The anterior part of the cell is somewhat concave and the left margin appears to be higher than the right side of the anterior part. The cells have prominent ridges on both sides of the cell. One flagellum emerges from the mid-right side of the cell, passes the ventral groove, and is 1.5-2 CL. When the cell is gliding, the flagellum directs posteriorly, but when the cell rests, it coils up counterclockwise. The cells move by gliding with the body trembling. Rarely observed from Ulwangri Beach. This species was firstly found at Quibray Bay and also found at Shark Bay and Gipsland Basin, Australia (Lee, unpubl. obs.). The photographs are of cells from Gipsland Basin.

Remarks: This species resembles Peltomonas haneri Ekelund and Røn, 1997 in having one flagellum arising from the ventral depression, but can be distinguished by the cell shape (Peltomonas is saucer-shaped) and slightly bigger size (P. haneri, 2-3.5 μm), and by having ridges on both faces of the cell. Peltomonas haneri swims rapidly in small jerks in zigzag line while Gweamonas unicus glides on the substrate in straight line. Gweamonas unicus is also similar to Monochrysis lutheri Droop, 1953 in having one flagellum inserting into a ventral depression and curved when at rest, but can be distinguished by its ridges and because Monochrysis lutheri is a green flagellate. This species resembles Kiuokia species in having one flagellum and in gliding pattern, but can be distinguished by the ridges and the orientation of the flagellum, and because the flagellum in Gweamonas unicus coils up counterclockwise. The flagellum in Kiuokia emerges from the anterior end (K. yastava Vars., 1992) or from the posterior end of the cell (K. kaloista Tong et al., 1997).

Heterochromonas opaca Skuja, 1948
(Fig. 5J)

Description: Cell is oval, about 10 μm long, rigid and somewhat dorso-ventrally flattened, and with an anterior protrusion and a nucleus subapically. Cell surface is warty. The cell has a ventral depression, which two flagella insert subapically into: the anterior flagellum is about 1 CL, and the posterior flagellum is about 1.5 CL. Moves by gliding or swimming in counter-clockwise direction with the anterior flagellum directed forwards. One cell found at Ulwangri Beach.

Remarks: This species was first found in freshwater sites by Skuja (1948) and then found in a marine site in subtropical Australia with a cell length of 18 μm (Lee and Patterson, 2000). This study extends the cell length. It can be distinguished from other species in the genus Heterochromonas by the anterior protrusion (Lee and Patterson, 2000).

Metopion fluens Larsen and Patterson, 1990
(Figs. 5K, 6L)

Description: Cells are ovate, 4-8 μm long, laterally compressed, and with a small rostrum anterior to the flagellar insertion. Two flagella are of unequal length, emerge from a ventral depression located in the left side of the cell; the long, thickened flagellum is 1.5-1.8 CL and is not tapered at the tip, and the shorter flagellum may be difficult to observe. The nucleus is situated near the groove. Moves by gliding. Found at Changhwari and Ulwangri Beach.

Remarks: The observations are in accord with those of Lee and Patterson (2000). This species has been found in marine sites in subtropical Australia, Denmark, Brazil, England, Fiji, and Gulf of Finland, and previously reported cell length is from 3 to 9 μm (Lee and Patterson, 2000; Al-Qassab et al., 2002).

Metromonas grandis Larsen and Patterson, 1990
(Figs. 5L, 6M)

Description: Cells are slightly roundish, 5-8 μm long and dorso-ventrally flattened. One side of the cell appears folded. The cells have two flagella; the longer
flagellum is about 1.5 CL and trails behind the cell when gliding, and the short inactive flagellum is less than 1 \( \mu m \) long and inserts to the right of the major flagellum, and is always present, but is hard to observe at times. When the cell attaches to the substrate with the longer flagellum, it moves with a nodding action - like a pendulum. The nucleus is near the flagellar insertion. Found at Ulwangi Beach.

**Remarks:** This species was described from marine sites in subtropical Australia, Brazil, Fiji, and Hawaii, and cell length reported was 5 to 12 \( \mu m \) (Lee and Patterson, 2000; Al-Qassab et al., 2002). Generally, the observations are in agreement with those of Lee and Patterson (2000). *Metromonas grandis* is distinguished from *M. simplex* (Griessmann, 1913; Larsen and Patterson, 1990) by its slightly larger size, shape, and folded margin. The folded margin may be a good diagnostic character for this species (Lee and Patterson, 2000). Skvortzov (1957) introduced nine new taxa with one long flagellum into Ancyromonas, but these species may be gliding stages of Metromonas. The short flagellum in *Metromonas* is easy to overlook.

*Metromonas simplex* (Griessmann, 1913) Larsen and Patterson, 1990

(Fig. 5M)

**Basionym:** *Phyllomitus simplex* Griessmann, 1913

**Description:** Cells are ovate, 4-6 \( \mu m \) long, and dorso-ventrally flattened, and with smooth pellicle. Two flagella of unequal length arise from the posterior part of the cell and always present; the major flagellum is about 1.8 CL and may be attached to the substrate, and the short inactive flagellum is about 1 \( \mu m \) long and inserts to the right of the major flagellum. The cells normally attach to the substrate and swing from side to side like a pendulum and the cells also glide. Found at Changhwari and Ulwangi Beach.

**Remarks:** *Metromonas simplex* has been found in marine sites in Antarctica, subtropical the tropical Australia, Brazil, Arctic Canada, Denmark, England, Fiji, Gulf of Finland, France, Germany, Arctic Greenland, and Hawaii, with a cell length of 3-9 \( \mu m \) (Lee and Patterson, 2000; Al-Qassab et al., 2002). *Metromonas simplex* may feed on bacteria and flagellates through the lateral margin (Patterson, unpubl. obs.) or the anterior part of the cell (Griessmann, 1913).

*Phyllomitus granulatus* Larsen and Patterson, 1990

(Figs. 5N, 6N)

**Description:** Cells are sac-shaped, about 12 \( \mu m \) long, and flexible. Refractile granules underlie the cell surface. Two flagella emerge from the anterior pocket. The anterior flagellum beats with a sine-wave, is slightly longer than the cell, and is directed to the front and slightly to the right during swimming. The posterior flagellum inserts to the left of the anterior flagellum and is about 0.5 CL. Cytoplasm is drawn out at the posterior end. The nucleus is located below the anterior pocket or near the centre of the cell. Found at Ulwangi Beach.

**Remarks:** This species has been reported from marine sites in subtropical Australia, Brazil, Demark, and Hawaii (Larsen and Patterson, 1990; Vørs, 1992b; Lee and Patterson, 2000) and previously recorded cell length ranges from 8 to 18 \( \mu m \). Generally, our observations are in accord with those of Lee and Patterson (2000). *Phyllomitus granulatus* can be distinguished from all species of the genus *Phyllomitus* by its granules. This genus will be transferred to *Pseudo-phylldimitus* because it does not have the two adhering flagella, a diagnostic character of *Phyllomitus* (Lee, unpubl. data).

**Protist 1**

(Figs. 5O, 6O)

**Description:** Cell is oval-shaped, about 12 \( \mu m \) long, laterally flattened, and rigid. There are no surface structures on both faces of the cell. Two flagella arise near the anterior-lateral side of the cell separately by a small protrusion. Both flagella are of similar length, about 1 CL and not acronemetic; the anterior flagellum beats backward in a small excursion and the posterior flagellum is usually held down. The nucleus is located in the centre of the cell. The cell moves by skidding. When the cells rest, the anterior flagellum lies along the margin of the cell. One cell observed from Ulwangi Beach. This organism was also found at Kogarah Bay and Gippsland Basin in Australia (Lee, unpubl. obs.).

**Remarks:** This organism is similar to *Platythelomomas psammobia* Larsen and Patterson in flatness of the cell, but is distinguished by the flagellar orientation, the absence of the flagellar pocket, and because this species lacks two rows of extrusomes. It can be distinguished from other small flagellates by the cell appearance such as flatness and the lack of surface structure.

**Protist 2**

(Figs. 5P, 6P)

**Description:** Cells are oblong, 13-15 \( \mu m \) long, dorso-ventrally flattened and rigid. The anterior part of the cell forms a relatively wide depression, which continues to a mid-ventral groove. The cell has a small protrusion, which is directed laterally and separates the insertion of the flagella. Two flagella of unequal length are not acronemetic; the anterior flagellum inserts subapically into the ventral groove and is slightly longer than the cell, and the posterior flagellum inserts just below the anterior flagellum and is about 1.8 CL. When the cells are moving, the anterior flagellum is directed to the front and beats in a sine-wave, and the posterior flagellum is directed to the rear and beats
also in a sine-wave. The cells move fast by swimming. Found at Ulwangri Beach. This organism was also found at Kogarah Bay and Gippsland Basin, Australia (Lee, unpubl. obs.).

Remarks: This organism is similar to *Phyllomitus granulatus*, but is distinguished because its posterior flagellum has an undulating beating pattern when swimming and because it is ridged and flattened. It may be distinguished from other swimming flagellates by its flagellar orientation.

**Unidentified flagellates**

A number of other heterotrophic flagellates have been observed, but not frequently enough to emerge with a clear concept of their identities. These include *Monosiga* sp., *Kentrosiga* sp., *Diplonema* sp., *Rhynchobodo* sp., a swimming stramenopile 5.5-8 μm long with flagella arising the anterior end of the cell, and two species of *Salpingoeca*.

**Discussion**

This study was undertaken to contribute to understanding of geographical distribution of marine heterotrophic flagellates (e.g., Vörös, 1992a; Ekeborn et al., 1996; Larsen and Patterson, 1990; Patterson and Simpson, 1996; Tong et al., 1996; Lee and Patterson, 2000; Al-Qassab et al., 2002). The recent finding is that most of free-living heterotrophic flagellates have a worldwide distribution (Lee and Patterson, 1998; Patterson and Lee, 2000).

Lee and Patterson (1998), Patterson and Lee (2000) and Al-Qassab et al. (2002) showed that the communities from geographic regions do not cluster together but that they cluster on the type of habitat (those from the water column cluster together and stay away from those from benthic sites) using the Primer cluster algorithm (Clarke, 1993) to compare communities from different geographical locations. The community observed here has considerable overlap with those reported previously from intertidal marine benthic sites although two new species are reported here for the first time - of the 56 species encountered in this study, 54 have previously been found in one or more other continents. Two species reported here were also observed in remote sites (Lee, unpubl. obs. in Australia). In conclusion, there was no evidence for endemism and this study supports the model (Lee and Patterson, 1998) that free-living heterotrophic flagellates have a cosmopolitan distribution.

**Acknowledgements**

I would like to thank Prof. J. K. Choi (Inha University) and Prof. D. J. Patterson (University of Sydney) for laboratory facilities, and Namjoo Park for her encouragement and patience. The author would like to thank the two anonymous referees for comments.

**References**


