The Journal of the Oceanological Society of Korea
Vol. 28, No. 3, pp. 202-211, September 1993

The Fine Structure of the Marine Epizoic Pennate Diatom *Pseudohimantidium pacificum* in Korean Coastal Waters

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韓國 沿岸의 附着性 羽狀 硅藻類 *Pseudohimantidium pacificum*의 微細 構造

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SEM and LM studies were made to examine the frustule of the marine epizoic diatom *Pseudohimantidium pacificum* Hustedt & Krasske and to examine the variability of frustule morphology. The length of the apical axis and the transapical axis were similar to other reports, but number of labiate processes showed a variation. The number of striae of Korean specimens were similar to those of other regions, but the areolae shape of striae showed elliptical type. *Pseudohimantidium pacificum* were planktonic, tychopelagic or epizoic attached to the prosome, the genital segment and abdomen of *Corycaeus affinis*. This species was newly recorded in Korean waters and the biogeographic boundary of this species can therefore be extended to the northern Pacific Ocean.

해양 부착성 규조류 *Pseudohimantidium pacificum*에 관하여 주사전자현미경 및 광학현미경을 통한 미세구조, 형태적 변이와 지리적 분포를 연구하였다. 세포의 정축과 횡축의 길이는 기왕의 보고와 유사하였으나 순상돌기의 수는 이보다 2~3개 더 많아 변이가 뚜렷하였다. 조선(striae)의 수도 기보고와 비슷하였고, 이의 모양은 현재까지 둥근형으로 보고되어 있으나 본 연구에서는 긴타원형이었다. 한편 본 규조류는 부유생활을 할 뿐 아니라 동물부유생물 중 요각류 *Corycaeus affinis*의 흉각과 두부의 촉각 주변에 많이 부착하고 있었다. 본종이 한국의 남서해역에서 분포하고 있음을 확인하였던 사실은 이 종이 북태평양의 황해에 37°30′N까지 분포함을 말해준다.

INTRODUCTION

The diatom family Protoraphidaceae comprised two genera, *Pseudohimantidium pacificum* Hustedt *et* Krasske and *Protoraphis* Simonsen (Simonsen, 1970). The main characteristics of this family are the S-shaped pseudoraphe and the row of larger pores at each valve ends (Simonsen, 1970). The genus *Pseudohimantidium* and the species *P. pacificum* were first described by Hustedt *et* Krasske (Krasske, 1941) from the northern marine Chilean waters. The original description of *P. pacificum* is as follows: **Vgl. Gattungscharaktere. Schalen sichelförmig, mit mehr oder weniger stark gewölbtem Dorsalrand und konkavem Ventralrand, an den stumpf gerundeten Enden zuweilen etwas vorgezogen, 44~78 μm lang, 9~11 μm breit. Transapikalstreifen im allgemeinen senkrecht zur Mittellinie, etwa 30~32**

in 10 μm, von zarteren, leicht welligen Längslinien gekreuzt, die gewöhnlich etwas enger stehen als die Transapikalrippen (Streifen daher zart punktiert).

Voigt (1958) identified a new variety of *P. pacificum* var. *minor* Voigt and a new species, *P. adriaticum*. Voigt (1958) found in fish stomachs from the Adriatic sea. Simonsen (1970, 1974) has shown that the previously described taxa, such as *P. pacificum* var. *minor* Voigt and *P. adriaticum* Voigt as well as taxa placed in other genera (*Hormophora rogallii* Jurilj, *H. zavodnikia* Jurilj and *Sameioneis carinaes* Russell & Norris), are conspecific with the taxa described by Hustedt & Krasske.

The species *P. pacificum* was attached to the stalks of the cyclopoid copepods, *Coryaeus sublatus*, *C. speciosus*, *C. giesbrechti* as well as harpacticoid copepods, *Euterpina acutifrons* (Jurilj, 1957; Voigt, 1959; Simonsen, 1970, 1974; Russell and Norris, 1971; Gibson, 1978). However, the specific parts of Harpacticoida and Cyclopoida of copepods body where *P. pacificum* is attached was not mentioned in detail.

This paper reports the occurrence of *P. pacificum* from Korean coastal waters. We have sampled specimens by phytoplankton net 4 times and zooplankton net 1 time in the southwestern coastal waters of Korea. The fine structure of *P. pacificum* and the body parts of Copepods where *P. pacificum* is attached was investigated. The morphology of the Korean specimens was compared with those collected from other regions and its biogeographical distribution is discussed.

MATERIALS AND METHODS

The materials were collected by a plankton net (mesh size, 30 μm) in April, July and November 1986 from the southern coastal waters of Korea and by a zooplankton net (mesh size, 100 μm) in December 1990 from the southwestern waters off Yungkwang (Table 1). Samples were fixed on board with 5% neutralized formalin.

Materials were cleaned (Hasle and Fryxell, 1970; Simonsen, 1974) and mounted in Pleurax or Hyrax for light microscopic examination. The samples mounted on the portions of a cleaned coverslips were placed on the aluminium stubs and coated with either carbon and gold-palladium or gold palladium for scanning electron microscope (Hitachi-X-650). The terms describing the diatom morphology was followed the recommendation prepared by the Working Committee on Diatom Terminology (Anonymous, 1975) from the Third Symposium on Recent and Fossil Marine Diatom, Kiel in West Germany.

Table 1. Sampling date and locations in Korean coastal waters

Date	St.	Localities	Remarks
25 Apr. 1986	13	Sonjuk Isl.	Net hauls
04 July 1986	1	Kae Isl.	〃
18 Nov. 1986	11	Yellow Sea	〃
27 Nov. 1986	2	Jinhae Bay	〃
05 Dec. 1990		Off Yungkwang coasts	Zooplankton samples

OBSERVATION

Valves lunate shaped and heteropolar, strongly convex, the dorsal margin noticeably convex, while the central generally concave, with rounded or subrostrate ends, 39~47 μm long, 9~11 μm wide. The axial area mostly median, narrow but wider at the center and narrowing toward ends. The axial area is flush with the valve face externally, while slightly elevated internally. At one end, the axial area bends abruptly ventrally, coming in contact with a sinuous groove contiguous with the labiate processes. Valve surface striate, striae 24~34 in 10 μm, the striae generally arranged perpendicular to the axial area. Near the axial area, the striae are composed of elliptical areolae, however toward the valve margin and at the apices, the areolae become more rounded and smaller. Labiate processes in each pole 4~11 in the internal view. In the external view a row of apical labiate processes appeared as a sinuous groove on either valve end.

DISCUSSION

P. pacificum is rather easily identifiable by the

Table 2. Measurements of *Pseudohimantidium pacificum* based on data from the literature and from the present study

	Apical axis μm	Transapical axis μm	Striae in 10 μm		Number of labiate processes	Number of areolae in 1 μm	Remarks
			Center	Ends			
Hustedt & Krasske 1941	44-78	9-11	30-32	–	–	–	
Voigt 1958	31-35	7, 5	–	–	–	–	as *P. pacificum* var. *minor* Voigt
Voigt 1959	85-106	8-10	27-28	–	–	–	as *P. adriaticum* Voigt
Simonsen 1970	31-102	8-12	28-33	28-34	–	2, 4-3, 2	
Simonsen 1970	85-113	8-11	27-18	27-28	–	2, 8-3, 2	as *P. adriaticum* Voigt
Russell & Norris 1971	28-70	9-15	–	–	5-9	±2	as *Sameioneis carinaes* Russell and Norris
Belyaeva 1973	40-112	8-12	–	–	–	–	
Belyaeva 1973	70-108	8-13	–	–	–	–	as *P. adriaticum* Voigt
Gibson 1978	32-53	7-15	30-40	30-40	–	–	
Gibson 1979a	–	–	30-40	–	–	2, 5-3, 5	
Navarro 1982	38-49	9-13	30	–	–	–	
Rivera *et al.* 1986	38-105	9.8-19	24-34	24-34	3-8	3-5	
	(70-90)	(12-14)	(25-28)	(25-28)		(3-4)	
Present study	34-76	9-14	24-34	24-34	4-11	3-4	

valve shape, the axial area and the row of labiate processes on both valve ends.

The length of the apical axis varied from 34 μm to 76 μm, while the transapical axis ranged from 9 μm to 14 μm. The length of apical axis was similar to specimens of the western Atlantic Ocean (Russell and Norris, 1971: Gibson, 1978: Navarro, 1982) and the southern Pacific Ocean (Krasske, 1941). However, the apical axis length of Korean specimens was smaller than that of specimens of the southern Pacific Ocean (Belyaeva, 1973: Rivera *et al.*, 1986) and the southern Atlantic Ocean (Simonsen, 1970). Transapical axis varied from 9 μm to 14 μm in Korean specimens. Voigt (1958) reported the transapical axis of 5 μm to 7 μm, while Rivera *et al.* (1986) 9.8~19 μm. The length of transapical axis of our specimens were similar to those described in Table 2.

The number of labiate processes of our specimens varied from 4 to 11. Rivera *et al.* (1986) reported that the number of labiate processes varied from 3~8, but an exception was existed where the number was the same at both ends. As shown in Table 2, the sample of Puget Sound, the northern Atlantic Ocean, posses 5~9 of labiate processes (Russell and Norris, 1971). Labiate processes of our specimens varied from 4 to 11, but it needs more examination. Hasle (1973) described the so-called mucilage pores as a labiate processes in the inner part of the valve. Gibson (1979b) insisted that the labiate processes of *P. pacificum* do not funtion as mucilage pores and argued the "I prefer to use the term labiate groove for this peculiar structure since this is descriptive of the structure and does not imply phylogenetic status". He also discussed the relationship between the apical grooves and the labiate processes.

The number of striae per 10 μm ranged from 24~34 both in the center and the ends. In the center, many authors reported the similar number of striae; 27~28 (Voigt, 1959: Simonsen, 1970), 30~32 (Krasske, 1941), 30~40 (Gibson, 1978, 1979 a). The striae were arranged perpendicular to the axial area in general. At the ends, striae proximal to the groove were arranged pararell to it, while at the very tip their arrangement was radial.

The striae of Korean specimens were composed of elliptical areolae. Rivera *et al.* (1986) reported

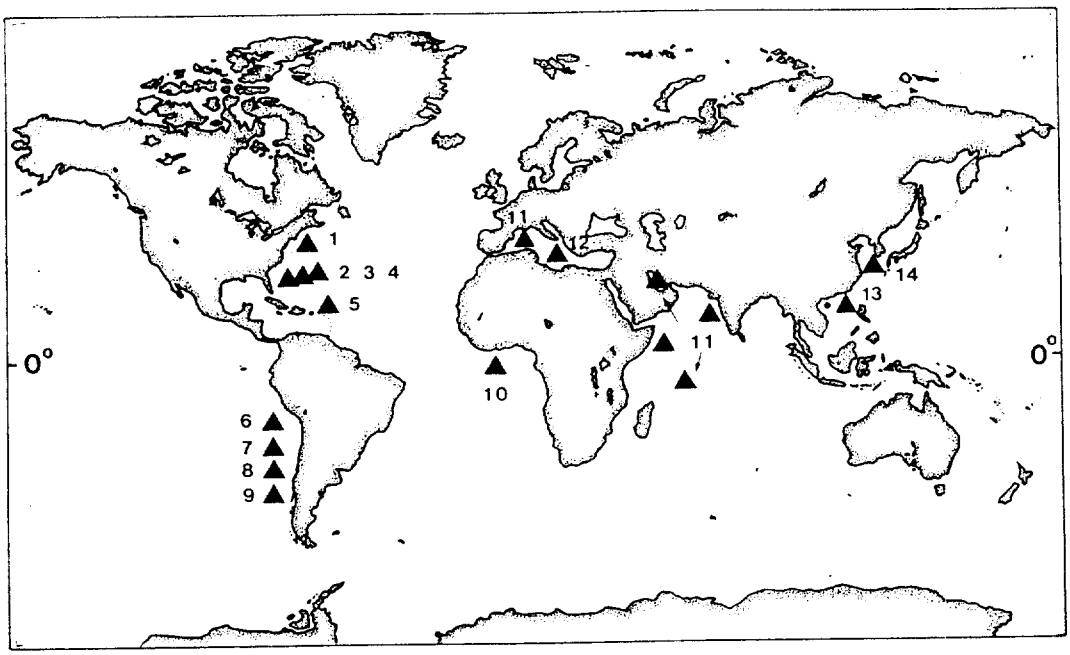


Fig. 1. Distribution of *Pseudohimantidium pacificum*.
1: Puget sound (Russell and Norris, 1971), 2, 3, 4: W. north Atlantic Ocean (Gibson, 1978, 1979a,b), 5: Caribbean Sea (Navarro; 1982), 6, 7, 8, 9: Chilean waters of S. Pacific Ocean (Rivera *et al.*, 1986: Krasske, 1941: Belyaeva, 1973: Gonzalez and Vergara, 1984), 10: Gulf of Gulnea (Simonsen, 1970), 11: Indian Ocean and Mediterranean Sea (Simonsen, 1974), 12: Adriatic Sea (Jurilj, 1957), 13: E. and S. China Sea (Voigt, 1959), 14: the present study.

that the areolae become more rounded and smaller toward the valve margin and at the apices. Number of areolae varied from 3 near the median line and 4 in 1 μm near the margin. Rivera *et al.* (1986) reported that areolae number was 3~5 in 1 μm, but Gibson (1978) showed 2 or 3 near the median line and 5 near the margin.

The species is known to an epizoic diatom on the copepod, *Corycaeus subulatus* (Russell and Norris, 1971: Simonsen, 1974: Gibson, 1978). In the present study *P. pacificum* was planktonic and attached to the copepod, *C. affinis* in the waters of Sonjuk Island, Kae Island, Jinhae Bay and Yellow Sea. The copepod, *C. subulatus* is a species widely distributed over the Korean coastal waters (Lee, 1972: Park *et al.*, 1973: Shim and Ro, 1982: Shim and Lee, 1983, 1986: Kim and Huh, 1983: Kang *et al.*, 1990). Therefore this diatom, *P. pacificum* could be widely distributed judging from the records of the Korean copepods. Our specimen was frequently observed on the prosome, the genital segment and abdomen of *Corycaeus affinis*.

P. pacificum was occasionally distributed in tropical to temperate waters (Fig. 1); the southern Pacific Ocean (Krasske, 1941: Belyaeva, 1973: Gonzalez and Vergara, 1984: Rivera *et al.*, 1986), Gulf of Guinea of Atlantic Ocean (Simonsen, 1970), the western north Atlantic Ocean (Russell and Norris, 1971: Gibson, 1978, 1979a,b), Caribbean Sea of Puerto Rico (Navarro, 1982) and Adriatic Sea (Jurilj, 1957), Indian Ocean and Mediterranean Sea (Simonsen, 1974) and the west-north Pacific Ocean (Voigt, 1959). Choi and Noh (1993) found this species as tychopelagic plankton in the coastal zone near Inchon harbor, Yellow Sea. The biogeographic boundary of this species can be extended to the northern Pacific Ocean based on the present study.

REFERENCES

Anonymous. 1975. Proposals for a standardization of

diatom terminology and diagnosis. Nova Hedwigia, Beih., **53**: 323-354.

Belyaeva, T. V. 1973. Distribution of the diatoms of the genus *Pseudohimantidium* Hustedt *et* Krasske. Bot. Zh. **58**: 883-885.

Choi, J. K. and J. H. Noh. 1993. The distribution of phytoplankton around the coastal water of Inchon. *In* the report on the environmental survey for the conservation of water quality by Inchon City. pp. 400-438.

Gibson, R. A. 1978. *Pseudohimantidium pacificum*, an epizoic diatom new to the Florida current (western North Atlantic Ocean). J. Phycol. **14**: 371-373.

Gibson, R. A. 1979a. Observations of stalk production by *Pseudohimantidium pacificum* Hust. & Krasske (Bacillariophyceace: Protoraphidaceae). Nova Hedwigia, Beih. **31**: 899-916.

Gibson, R. A. 1979b. An ultrastructure study of *Pseudohimantidium pacificum* Hust. & Krasske (Bacillariophyceae: Protoraphidaceae) with special reference to the labiate preocesses. Nova Hedwigia, Beih. **64**: 147-161.

Gonzalez, H. and L. Vergara. 1984. Interaccion Ecologica entre la Diatomea Epizoica *Pseudohimantidium pacificum* Hust. & Krasske, 1941 y Copepods del Genero *Corycaeus*. Rev. Biol. Mar. **20**: 77-90.

Hasle, G. R. 1973. The "mucilage pore" of pennate diatoms. Nova Hedwigia, Beih., **45**: 167-194.

Hasle, G. R. and G. A. Fryxell. 1970. Diatoms: cleaning and mounting for light and electron microscopy. Amer. Micr. Soc. Trans. **89**: 469-474.

Jurilj, A. 1957. Epibiontska flora na planktonskom kopepodima. Acta Bot. Croat. **16**: 93-104.

Kang, Y. S., S. H. Huh and S. S. Lee, 1990. Taxonomy and distribution of Corycaeidae (Copepoda: Cyclopoida) in the Korean waters in Summer. J. Oceanol. Soc. Korea, **25**: 49-61.

Kim, D. Y. and H. T. Huh, 1983. Seasonal variations of copepods in Garolim Bay. Bulletin of KORDI, **5**: 9-35.

Krasske, G. 1941. Die Kieselalgen des Chilenischen Kustenplanktons. Arch. Hydrobiol., **38**: 260-287.

Lee, S. S. 1972. Distribution of Copepods in Chinhae Bay and its adjacent region. Bull. Fish. Res. Dev. Agency, **9**: 7-27.

Navarro, J. N. 1982. A survey of the marine diatoms of Puerto Rico. IV. Suborder Araphidineae: Families Diatomaceae and Protoraphidaceae. Botanica Marina. **25**: 247-263.

Park, J. S., S. S. Lee and K. U. Bae. 1973. Studies on the relation between the food habits of mackerel, *Scomber japonica* Hauttryn and the composition of plankton in the south sea of Korea. Bull Fish. Res. Dev. Agency, **10**: 7-23.

Rivera, P. S., H. E. Gonzalez and H. L. Barrales. 1986. Cingulum and valve morphology of *Pseudohimantidium* Hustedt & Krasske (Bacillariophyceae). Phycologia. **25**: 19-27.

Russell, D. J. and R. E. Norris. 1971. Ecology and taxonomy of an epizoic diatom. Pac. Sci., **25**: 357-367.

Shim, J. H. and I. Ro. 1982. The composition and abundance distribution of zooplankton in the vicinity of Yeosu, Korea. Proc. Coll Nat. Sci., SNU, **8**: 165-183.

Shim, J. H. and T. S. Lee, 1983. A study on the zooplankton off the coast of Gunsan, Korea. Proc. Coll. Nat. Sci., SNU, **8**: 121-140.

Shim, J. H. and T. S. Lee, 1986. Studies of the plankton in southwestern water the East Sea (Sea of Japan). III. Zooplankton-standing stock, composition and distribution. J. Oceanol. Soc. Korea, **21**: 146-155.

Simonsen, R. 1970. Protoraphidaceae, eine neue Familie der Diatomeen. Nova Hedwigia, Beih, **31**: 377-394.

Simonsen, R. 1974. The diatom plankton of the Indian Ocean Expedition of R/V "METEOR" 1964-1965. Meteor Forsch. Ergeb. Reihe D, **19**: 1-107.

Voigt, M. 1958. Notes sur quelques diatomees appartenant au genre *Pseudohimantidium*. Vie *et* Milieu, **9**: 53-57.

Voigt, M. 1959. Nouvelle Note concernant le genre *Pseudohimantidium*. Vie *et* Milieu, **19**: 199-203.

Accepted September 16, 1993

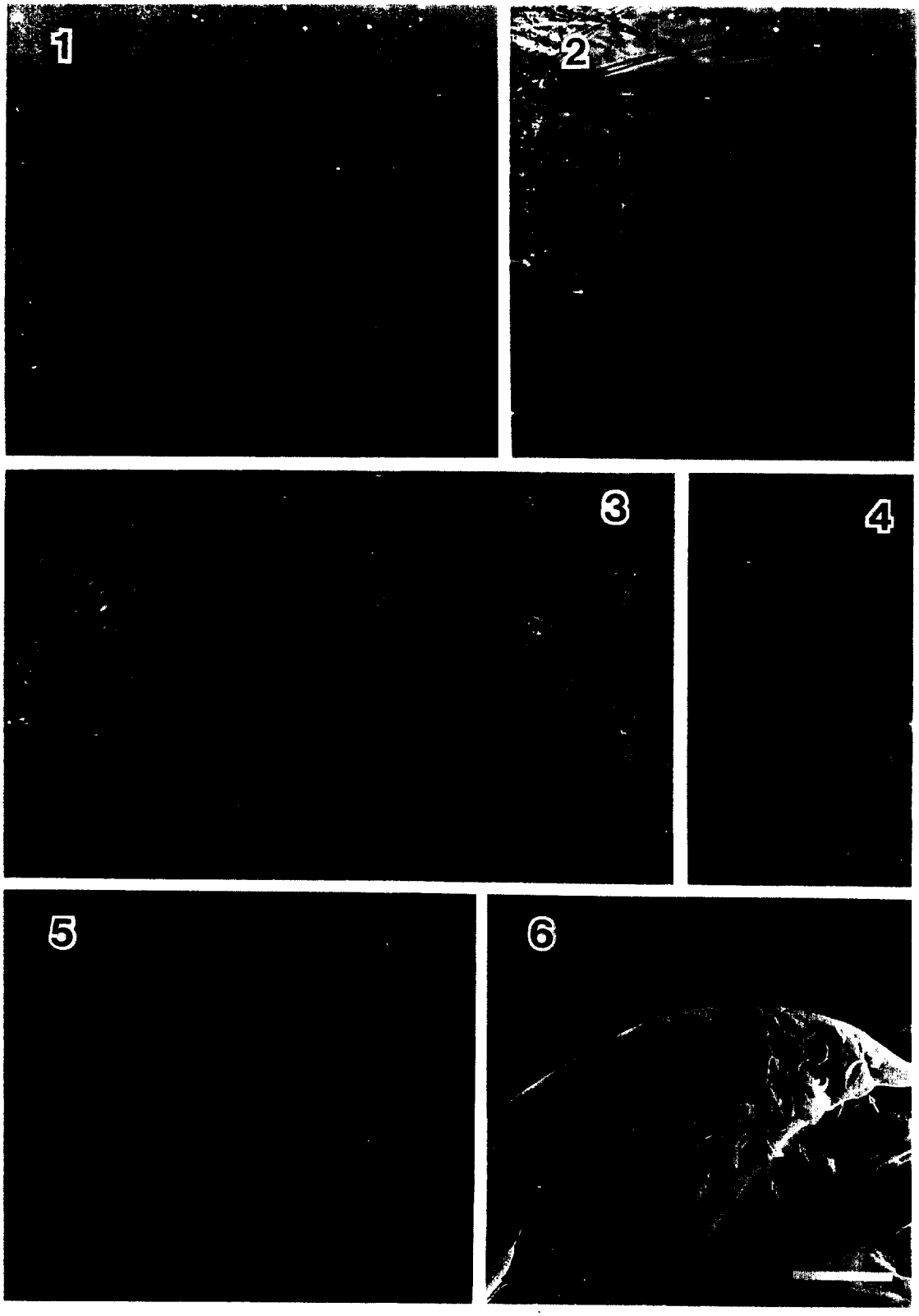
Figs. 1~5=LM, Fig. 6=SEM.

Fig. 1. LM. *Pseudohimantidium pacificum* attached to the genital segment and abdomen of *Corycaeus affinis* (×100).
Fig. 2. LM. Same to above (×200).
Fig. 3. LM. *P. pacificum* (arrow) attached to the prosome of *Corycaeus affinis* (×400).
Fig. 4. LM. Enlargement of flexible stalks of *P. pacificum* (×200).
Fig. 5. LM. Partitions found in the stalk of three cells (×400).
Fig. 6. SEM. Intact cell mass of *P. pacificum* on abdomen of *Corycaeus affinis* (scale 100 μm).

Figs. 7~12. SEM, scale 10 μm=7, 8, 12; 1 μm=9, 10 11.
Figs. 7~ 8. External valve view of upper straight axial area and opposite recurved axial area connected to groove.
Figs. 9~10 External view of groove connected to recurved axial area.
Figs. 11~12. External view of groove connected to recurved axial area.

Figs. 13~18. SEM, scale 10 μm=15, 17, 18; 1 μm=13, 14, 16.
Figs. 13~14. Internal valve view of upper straight axial area and opposite the recurved axial area connected to labiate process row.
Fig. 15. Internal valve view showing 3 striae in 10 μm.
Fig. 16. Internal view of elevated axial area.
Fig. 17. Internal view of axial area.
Fig. 18. Internal view of labiate process row connected to recurved axial area.

Figs. 19~24. SEM, all scale 1 μm.
Figs. 19~21. Lateral view of labiate processes.
Fig. 22. Showing a short-size labiate processes in the internal valve groove.
Fig. 23. Showing a long-size labiate processes in the internal valve groove.
Fig. 24. The variations of labiate processes showing closed-form of two labrum.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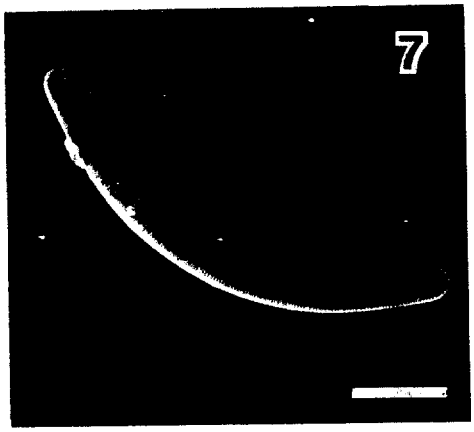
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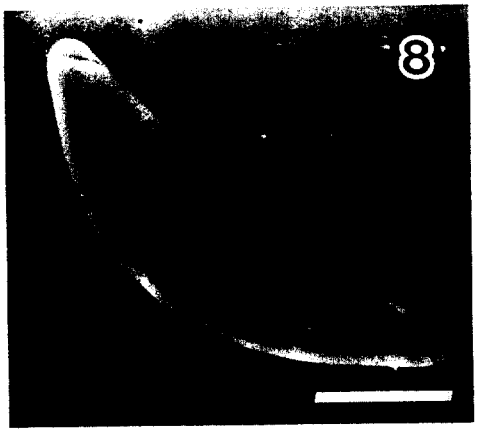
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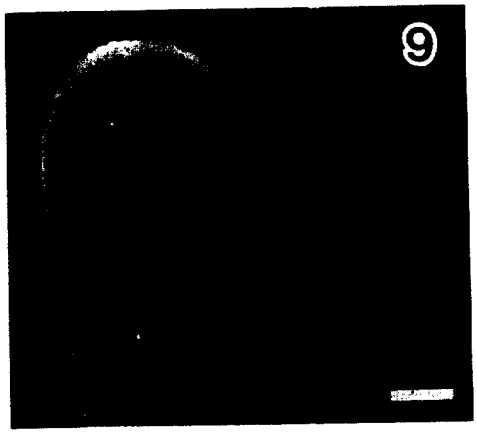
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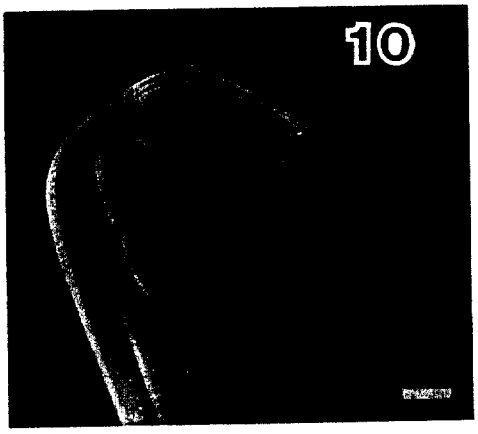
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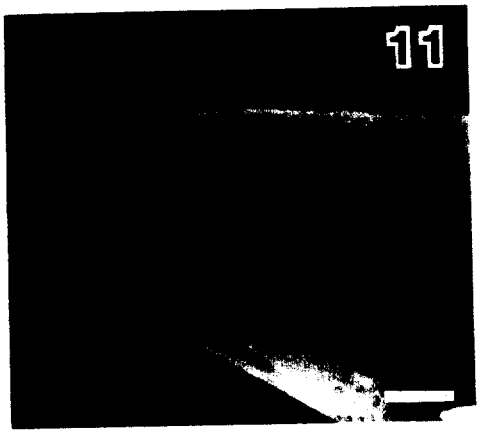
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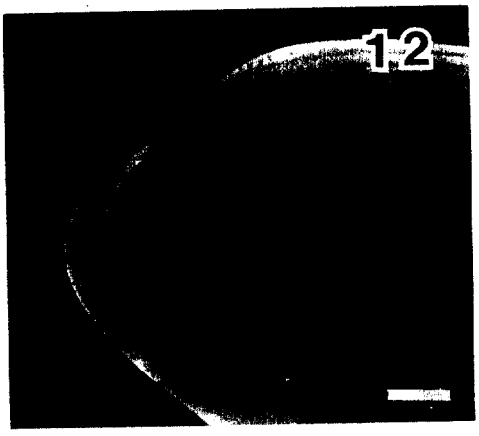
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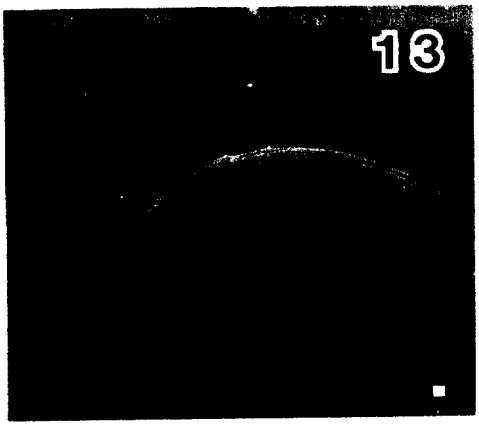
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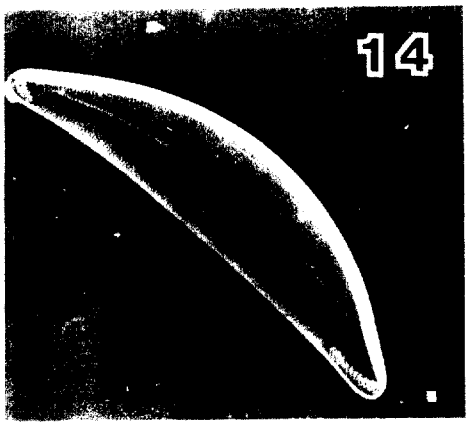
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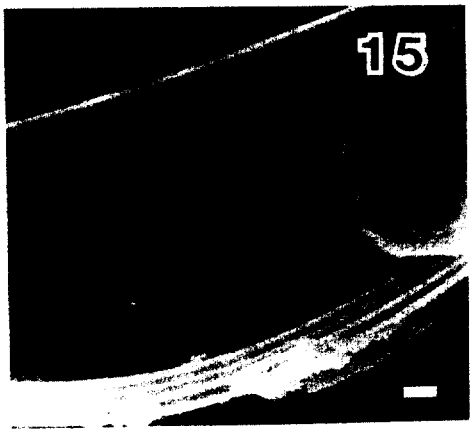
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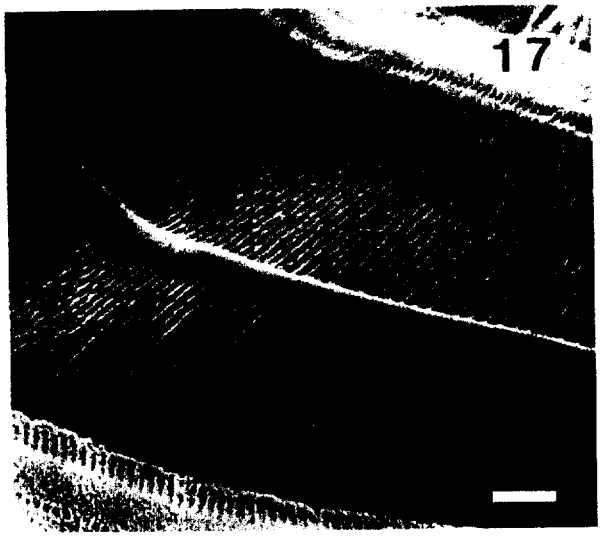
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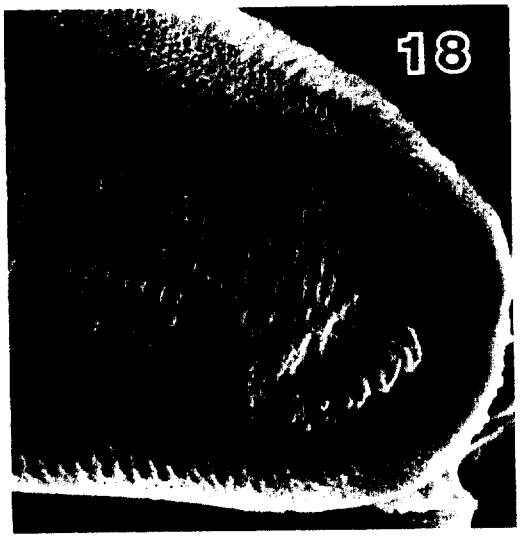
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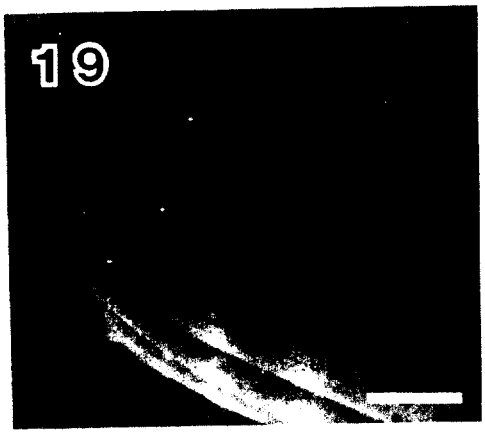
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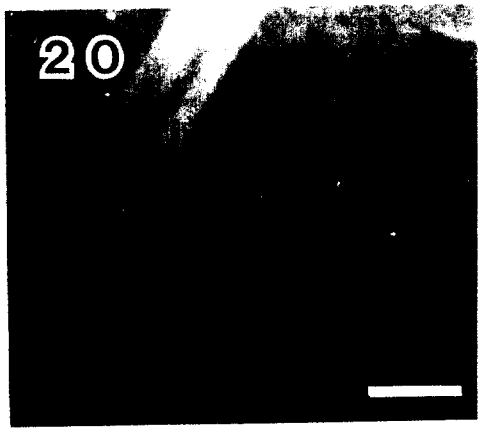
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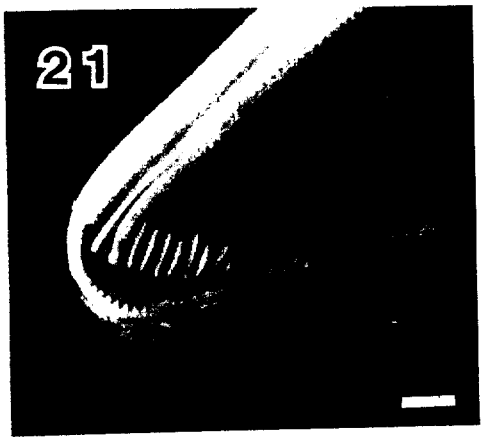
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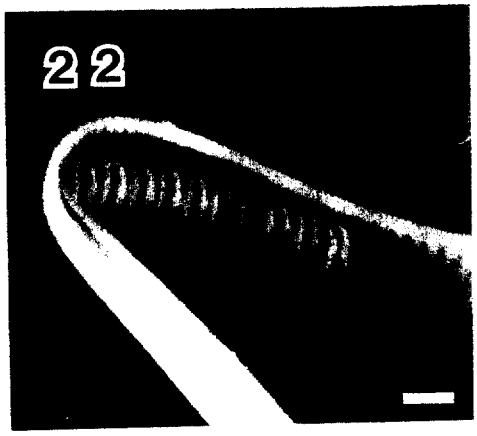
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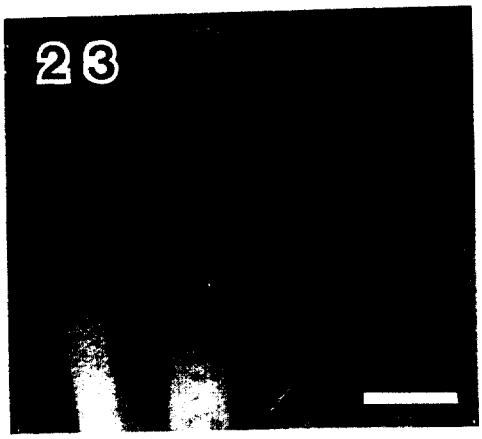
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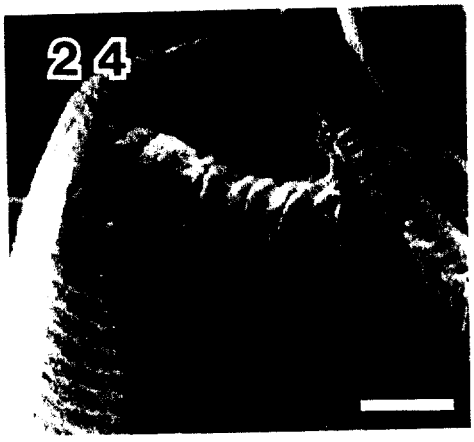
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