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Review of the family Solemyidae (Mollusca: Bivalvia) from Japan, and description of the new species

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日本産キヌタレガイ科（軟体動物：二枚貝）のレビューと新種の記載

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Key words: Solemyidae, Mollusca, Bivalvia, chemosynthetic community, Japan

キーワード: キヌタレガイ科，軟体動物，二枚貝類，化学合成群集，日本

The gills of the family Solemyidae are harboring chemosynthetic symbiosis. The Solemyidae are classified into the genus *Solemya* (ligament is internal) and *Acharax* (ligament is external). Genus *Solemya* is divided into subgenera *Solemya* and *Petrasma* by the location of the shell beak. The family have been reported from the Cretaceous and the later. This revision of Japanese family Solemyoidae is recorded by 2 genera and 2 subgenera, 17 species :*Solemya* (*Solemya*) *angusticaudata* NAGAO, *S.* (*S.*) *suprajurensis* HAYAMI, *S.* (*S.*) *kobayashi*, *S.* (*Petrasma*) *pusilla* (GOULD), *S.* (*P.*) *peruernicosa* KURODA, *S.* (*P.*) *murotoensis* (KOBAYASHI), *Acharax cretacea* KANIE & HISHIDA, *A. bosoana* (HATAI & KOIKE), *A. dalli* (CLARK), *A. murotoensis* (NATORI), *A. yessoensis* (KANEHARA), *A. johnsoni* (DALL), *A. japonicus* (DUNKER), *A. yokosukensis* KANIE & KURAMOCHI, *A. gigas* (KANNO). *Solemya* (*Petrasma*) *miuraensis* and *Acharax*. sp. are new species.

キヌタレガイ科二枚貝の鰓は，化学合成細菌を共生させ，肥大化していることが知られている。本科は，靱帯が内在するキヌタレガイ属（*Solemya*属）と靱帯が外在するスエヒロキヌタレガイ属（*Acharax*属）に区分されている。本科の化石は，日本の白亜紀以降の地層からしばしば化学合成生物群集と共産することが報告されている。本報告では，日本産キヌタレガイ科について現生種を含めて再検討を行い，2属2亜属17種を記載する。*Solemya* (*Solemya*) *angusticaudata* NAGAO; *S.* (*S.*) *suprajurensis* HAYAMI; *S.*(*S.*) *kobayashi* TAMURA; *S.* (*Petrasma*) *pusilla* (GOULD) キヌタレガイ; *S.* (*P.*) *peruernicosa* KURODA アブラキヌタレガイ, *S.* (*P.*) *murotoensis* (KOBAYASHI); *Acharax cretacea* KANIE & NISHIDA; *A. bosoana* (HATAI & KOIKE); *A. dalli* (CLARK); *A. murotoensis* (NATORI); *A. yessoensis* (KANEHARA); *A. johnsoni* (DALL) スエヒロキヌタレガイ; *A. japonicus* (DUNKER)アサヒキヌタレガイ; *A. yokosukensis* KANIE & KURAMOCHI ダイオウキヌタレガイ; *A. gigas* (KANNO)。そのうち，*Solemya* (*Petrasma*) *miuraensis* ミウラキヌタレガイと*Acharax*. sp. は新種である。

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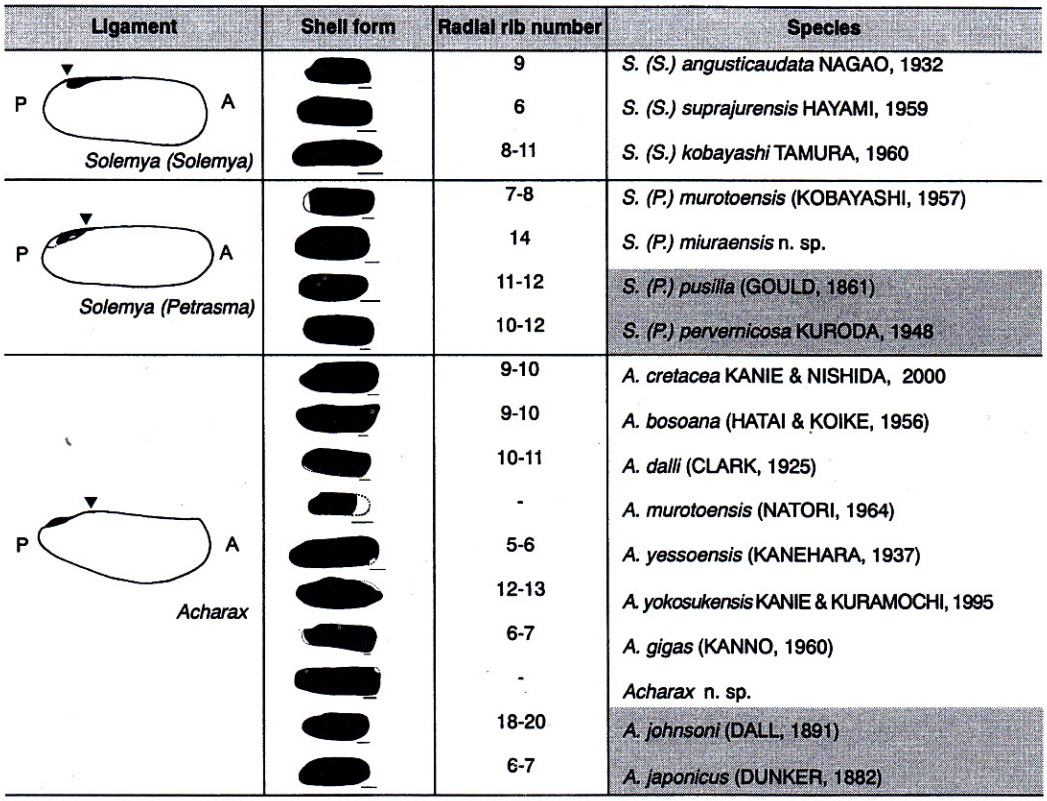


Fig. 1 Various morphologies of the Family Solemyidae of 17 species.
P: posterior, A: anterior. Shadow background is modern species (scale bar: 1 cm). Family Solemyidae are classified into the genus *Solemya* (ligament is internal) and *Acharax* (ligament is external). Genus *Solemya* is divided into subgenera *Solemya* and *Petrasma* by the location of the shell beak.

Introduction

Family Solemyidae were reported from the Devonian beds to modern waters. These groups were known as primitive Bivalvia. Recent species of the Solemyidae are living on sandy or muddy bottom from tidal zone to deep sea, and several species are regarded as the chemosynthetic mollusca. Fossil species were often reported in the chemosynthetic communities.

We review two genera and 16 species of the family Solemyidae, then describe two new species.

Brief review of the Solemyidae

The family Solemyidae were found in the Devonian to Recent. COX *et al.* (1969) classified of the family Solemyidae into the genus *Solemya* (ligament is internal on the resilifer) and the *Acharax* (ligament is external) based on shell morphology (Fig. 1). The genus *Solemya* includes subgenera *Janeia, Solemya, Petrasma* and *Solmyarina.* Subgenus *Janeia* was known in the Devonian to

Carboniferous (COX *et al.*,1969). *Solemya* was from the Jurassic to Recent (HAYAMI, 1959), *Petrasma* was from the Pliocene to Recent (YOKOYAMA, 1928), *Solmyarina* was the Oligocene to Recent (COX *et al.*, 1969). The above subgenera were raised to genera *Solemya*, *Petrasma* and *Solmyarina* by HABE (1977). We follow the systematic classification by COX *et al.* (1969).

Systematic description

Order Solemyoida DALL, 1889
キヌタレガイ目
Family Solemyidae H. ADAMS & A. ADAMS, 1857
Type species: *Solemya australis* LAMARCK, 1818

Shell form is elongate to oval, thin to thick, small to extra large sized. Beak situates at the posterior part. Shell surface is ornamented with weak radial ribs. A hinge tooth is absent. Fringed epiderm covers the shells.

Genus *Solemya*, LAMARCK, 1818
Type species: *Tellina togata* POLI, 1795

Thin shell forms elongate to oval. Small to medium sized shell. Beak situates at posterior part. Ligament is internal on the resilifer.

Subgenus *Solemya*, LAMARCK, 1818
Type species: *Tellina togata* POLI, 1795

Thin shell forms elongate to oval, small size in this genus. Beak situates at the posterior part. Ligament is internal on resilifer. Lateral patch of ligament in front of resilifer. Shell surface is ornamented with weak ribs.

Solemya (*Solemya*) *angusticaudata* NAGAO, 1932 (Fig. 2-1)

Type Locality: Ponbetsu River, a branch of the Ikushunbetsu River, Mikasa City, central Hokkaido, Mikasa Formation of the Middle Yezo Group.

Age: Late Albian (KANIE and SAKAI, 1997)-Maastrichtian (NAGAO, 1938) of the Cretaceous.

Description: The shell is thin, small to middle size in the holotype specimen (right valve, 56 mm long: 20 mm high). Dorsal margin is straight. Anterior and posterior margin are rounded. Ventral margin nearly straight or weakly caved. Beak posteriorly situates. Ligament is internal. The ribs are strong at the anterior end of the shell surface, weak and obscure at the central and posterior parts. The radial ribs count 9.

Solemya (*Solemya*) *suprajurensis* HAYAMI, 1959

Type Locality: Shokawa River, Makito area of northern Gifu Prefecture, Mitarai Formation of the Tetori Group.

Age: Callovian under the Middle Jurassic (HAYAMI, 1959) to Middle Jurassic (KOMATSU *et al.*, 2001).

Description: The shell is thick and medium size (holotype: 45.0 mm long. 17.0 mm high. 5.0 mm thick). Dorsal margin straight, anterior and posterior margin are rounded. Ventral margin is nearly straight or somewhat carves. Beak situates posterior (72%). Ligament is internal. The ribs are strong at the anterior and posterior end, weak or obscure at

central part. The radial ribs count 9.

Solemya (*Solemya?*) *kobayashi* TAMURA, 1960

Type Locality: Iwasa and Karaiwa, Kochi Prefecture, Yatsuji Formation of the Torinosu Group.

Age: Late Jurassic (TAMURA, 1960).

Description: The shell is thick and middle size. Dorsal margin straight, anterior and posterior margin are rounded. Ventral margin is nearly straight or caves. Ligament is internal. On the illustration (TAMURA, pl. 2, figs. 4 & 5), the beak appeared to project. Beak situates posterior (76%). The radial ribs count 8-11. The ligament is uncertain in the holotype specimen (38.0 mm long and 10.0 mm high).

Subgenus *Petrasma* DALL, 1908

Type species: *Solemya borealis* TOTTEN, 1834

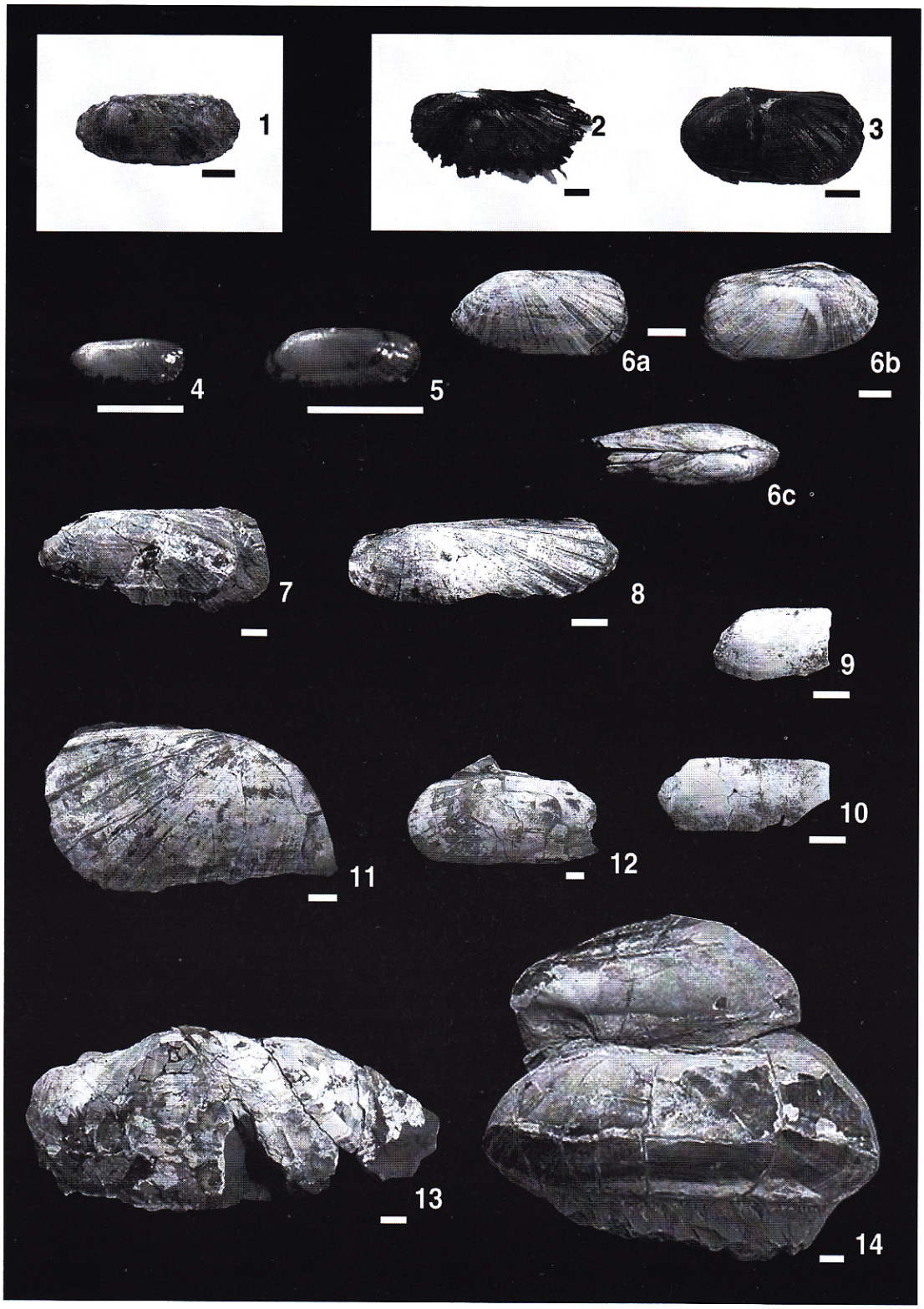
Shell elongate to oval, thin, small to medium size. Beak situates posteriorly. Ligament is internal, and 1 or 2 plate on resilium. Ribs are weak on the shell surface.

Fig. 2 Family Solemyidae from Japan. (scale bar: 1 cm)

1. *Solemya* (*Solemya*) *angusticaudata* NAGAO from the Ponbetsu River, a brach of the Ikushunbetsu River, Mikasa City, central Hokkaido, Mikasa Formation of the Middle Yezo Group. YCM-GP1097.
2. *Acharax johnsoni* (DALL) from off Hatsushima, Sagami Bay, 1187 m in water depth.
3. *Solemya* (*Petrasma*) *pervernicosa* KURODA from off Hatsushima, Sagami Bay, 1187 m depth.
4. *Solemya* (*Petrasma*) *pusilla* (GOULD) from Sagami Bay. YCM-H2713.
5. *Acharax japonicus* (DUNKER) from Sagami Bay. YCM-H2715.

6 a,b,c. *Solemya* (*Petrasma*) *miuraensis* n. sp., Holotype from east cliff of the southern entrance of the Shinsawayama Tunnel, Ikegami, Yokosuka City, Kanagawa Prefecture. Hayama Formation. YCM-GPIg29.

7. *Acharax cretacea* KANIE & NISHIDA from the upper course of the Sanjussen-zawa, Horokanai-cho, northwestern Hokkaido. Member My4 of the Middle Yezo Group. YCM-GP1180.
8. *Acharax yessoensis* (KANEHARA) from Morai-mura, Atsuta-gun, Hokkaido. Morai Formation. YCM-GP1187.
9. *Acharax* n. sp. from Daido Junior High school, Kanazawa-ku, Yokohama City, Kanagawa Prefecture, Nojima Formation. YCM-GP1182.
10. *Acharax* n. sp. from Daido Junior High school, Kanazawa-ku, Yokohama City, Kanagawa Prefecture, Nojima Formation. YCM-GP1183.
11. *Acharax johnsoni* (DALL) from Nosshappu, Wakkanai City, Hokkaido. Wakkanai Formation. YCM-GP1184.
12. *Acharax johnsoni* (DALL) from Nosshappu, Wakkanai City, Hokkaido. Wakkanai Formation. YCM-GP1185.
13. *Acharax yokosukensis* KANIE & KURAMOCHI from east cliff of the southern entrance of the Shinsawayama Tunnel, Ikegami, Yokosuka City, Kanagawa Prefecture. Hayama Formation. YCM-GPIg36.
14. *Acharax gigas* (KANNO) from Shinden, Matsuida-cho, Gunma Prefecture. Haradajino Formation of the Tomioka Group. YCM-GP1167.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Solemya* (*Petrasma*) *murotoensis
(KOBAYASHI, 1957)

1957: *Solemya* (*Acharax ?*) *murotoensis* KOBAYASHI

Type Locality: Sakamoto, Muroto, Kochi Prefecture, Muroto Formation of the Torinosu Group.

Age: Paleogene (KOBAYASHI, 1957).

Description: The shell is thick and medium size in the holotype specimen about 60.0mm long and 21.5 mm high. Dorsal margin is straight, and the anterior and posterior margin are round. Ventral margin nearly carves. Beak situates posterior (about 75%). The ribs are strong at the posterior end of the shell surface, and weak at the anterior to central parts. The radial ribs count 7 to 8.

Solemya* (*Petrasma*) *miuraensis n. sp.
ミウラキヌタレガイ
(Fig. 2-6a, 6b, 6c)

Further description is in the chapter "Description of two new species".

Solemya* (*Petrasma*) *pusilla (GOULD, 1861) キヌタレガイ (Fig. 2- 4)

1928; *Solemya* labeosa YOKOYAMA

Type Locality: Hakodate (9 m in depth), Japan.

Age: Pliocene (YOKOYAMA, 1928) to Recent.

Description: The shell is thin and small size. Dorsal margin is straight, anterior and posterior margin are round. Ventral margin slightly carves. Beak situates at the posterior part (83 %). The ribs are strong at the posterior end, and weak at the anterior to central part. The radial ribs count 11 to 12.

Recent distribution: Southern Hokkaido to Kyusyu. 0 - 20 m in depth (HABE, 1977).

Solemya* (*Petrasma*) *pervernicosa KURODA, 1948 アブラキヌタレガイ (Fig. 2 - 3)

Type Locality: off Cape Erimo, Hokkaido, north Japan.

Age: Recent.

Description: The shell is thin and medium size (holotype specimen is 53.0 mm long, 21.0mm high). Dorsal margin is straight, Anterior and posterior margin are round. Ventral margin nearly carves. Beak situates posterior (76%). The ribs are stronger on posterior at the end, weaker at anterior to central part. The radial ribs count 10-12.

Recent distribution: Sagami Bay to Hokkaido. 150-1500 m (OKUTANI *et al.*, 1989).

Genus ***Acharax*** DALL, 1908
スエヒロキヌタレガイ属

Type species: *Solemya johnsoni* DALL, 1891 Shell form is elongate. Small to large sized with thin to thick shell. Beak situates at the posterior or postero-central part. Ligament is external, on nymph. Shell surface is ornamented with weak ribs often strongly at posterior part. .

Acharax cretacea KANIE & NISHIDA, 2000
(Fig. 2- 7)

Type Locality: Upper course of the Sanjussen-zawa, Horokanai-cho, north-western Hokkaido. Member My4 of the Middle Yezo Group.

Age: Early Cenomanian.

Description: The shell is thin and middle sized in the holotype specimen (100.0 mm long, 41.3 mm high). Dorsal margin is nearly straight. The anterior and posterior margin are rounded, and ventral margin is nearly straight or carved. Beak situates 75-69% from the anterior part. Ligament is opisthodetic (situates between the beak and the posterior end). Ribs are strong at the anterior end, weak and obscure at the posterior and central parts. The radial ribs count 9 to 10.

Acharax bosoana (HATAI & KOIKE, 1956)

1956: *Solemya* (*Acharax*) *bosoana* HATAI & KOIKE

Type Locality: Okuzure, Katsuyama-machi, Awa-gun, Chiba Prefecture. Hota Group

Age: Miocene.

Description: The shell is thin and middle size (Holotype, 82.0 mm long, 27.0 mm high). Dorsal margin is straight, Anterior and posterior margin are round. Ventral margin is nearly straight or weakly carves. Beak situates posterior 72% from the anterior part. Ligament is opisthodetic. Ribs are strong at the posterior end of shell surface, and weak and obscure at the anterior and central parts. The radial ribs count 9 to 10.

Acharax dalli (CLARK, 1925)

1925: *Solemya* (*Acharax*) *dalli* CLARK
1954: *Solemya tokunagai elongate* AOKI
1960: *Solemya* (*Acharax*) *dailli* KANNO
1964: *Solemya* (*Acharax*) *dailli* NATORI

Type Locality: Washington, northwest America

Age: Late Oligcene (KANNO, 1960) to early Miocene (NATORI, 1964).

Description: The shell is thin and small in size. Dorsal margin straight. Anterior and posterior margin are rounded. Ventral margin nearly straight or carves. Postero-dorsal margin is inclined steeply backwards. Beak situates posteriorly 75%. Ligament is opisthodetic. Ribs are strong and wide at the anterior to posterior end of shell surfaces, weak on middle part. The radial ribs count 10 to 11.

The species reported from the Ushikubitoge Formation (Upper Oligcene), Gunma Prefecture and the Muro Formation (lower Miocene) in Ukekawa-mura, Wakayama Prefecture (NATORI, 1964).

Acharax muroensis (NATORI, 1964)

1964: *Solemya* (*Acharax*) *murotoensis* NATORI

Type Locality: Ukekawa-Mura, Kii Peninsula, Wakayama Prefecture. Muro Formation.

Age: Oligocene-Early Miocene (NATORI, 1964).

Description: The shell is thin and small size (Holotype, 22.0 mm long, 10.5 mm high, 2.3 mm thick). Dorsal margin is straight, the anterior and posterior margin are rounded. Ventral margin is nearly straight or weakly carves. Beak situates at the posterior part. Ligament is opisthodetic, wholly external. The ribs are strong at the central part of the shell, weak and obscure at the anterior and posterior end.

Acharax yessoensis (KANEHARA, 1937)
(Fig. 2-8)

Type Locality: Morai-mura, Atsuta-gun, Hokkaido. Morai Formation.

Age: Early Pliocene (KANEHARA, 1937).

Description: The shell is thick and middle size (Holotype, Shell: 84.0 mm long, 26. mm high, 7.6 mm thick). Dorsal margin is straight. The anterior and posterior margin are rounded. Ventral margin is nearly straight or caves. Postero-dorsal margin is inclined steeply backwards. Beak situates posteriorly (78%). Ligament is opisthodetic. Ribs are strong and wide spacing at the anterior and posterior end, weakening at the central part. The radial ribs count 5 to 6.

Acharax johnsoni (DALL, 1891)
スエヒロキヌタレガイ
(Figs. 2-2, 11, 12)

1925: *Solemya tokunagai* YOKOYAMA

1948: *Solemya* (*Acharax*) *tibai* KURAODA

Type Locality: Western North America.

Age: Early Miocene to Recent.

Description: The shell is thin and middle to large-sized. Dorsal margin is straight, the anterior and posterior margin are round. Ventral margin is nearly straight. Beak is situates posteriorly (78%). Ligament opisthodetic, wholly external. The ribs are strong at the anterior and posterior end, weak and obscure at the central parts of shell surface. The radial ribs count 18 to 20.

Recent distribution: North to Sagami Bay and its north waters in 100-1500 m in water depth (OKUTANI *et al.*, 1989).

Acharax yokosukensis KANIE & KURAMOCHI, 1995 ダイオウキヌタレガイ
(Fig. 2-13)

1994: *Acharax* aff. *tokunagai* OGASAWARA, HISADA & KITADA

1995: *Acharax* n. sp. KANIE, KURAMOCHI, ASAMI & KANNO

Type Locality: East cliff of the southern entrance of the Shinasawama Tunnel, Ikegami, Yokosuka City, Kanagawa Prefecture. Hayama Formation.

Age: Early Miocene (OGASAWARA. *et al.*, 1994); early Middle Miocene (KANIE and KURAMOCHI, 1995).

Description: The shell is hugely large, elongate, with thick shell. Dorsal margin is straight, the anterior and posterior margin are rounded. The antero-dorsal margin is slightly concave postero-dorsal end; truncated anterior margin, and rounded posterior end. Maximum shell height locates near the beak. The section of the shell extremely inflates in the central part. Beak in the adult is at antero-centrally (62-66%), but in immature stage slightly shift anteriorly. Hinge line nearly straight, with a ligament at the postro-dorsal margin which is external. Surface of the shell is ornamented with 12-13 distinct radial ribs which are predominant in the both side of anterior and posterior, and faint radials in the mid-disk.

Acharax gigas (KANNO, 1960)
(Fig. 2-14)

1960: *Solemya* (*Acharax*) *gigas* KANNO

Type Locality: Chikado, Chichibu City, Gunma Prefecture. Hiranita Formation of the Tomioka Group

Age: Middle Miocene (KANNO, 1960);

early Middle Miocene (KANIE *et al.*, 1999).

Description: The shell is hugely large, elongate, with thin shell. Dorsal margin straight, the anterior margin is weakly rounded and truncated. Posterior margin is rounded. Ventral margin is nearly straight. The section of the shell extremely inflates in the central part. Beak situates posteriorly (66-79%). Hinge line nearly straight, with a wide and long ligament at the postro-dorsal margin, which is external. Ligament opisthodetic, wholly external. Surface of the shell ornamented with wide-spaced ribs that are strong at the anterior part. The radial ribs count 6 to 7.

Acharax n. sp. (Figs. 2- 9, 10)

Further description is in the chapter "Description of two new species".

Acharax japonicus (DUNKER, 1882)
アサヒキヌタレガイ (Fig. 2- 5)

1928: *Solemya yamakawai* YOKOYAMA

Type Locality: Japanese waters

Age: Pliocene (BABA, 1990) to Recent.

Description: The shell is thin and middle size. Dorsal margin is straight. Anterior and posterior margin is rounded. Ventral margin nearly straight or weakly carves. Beak situates posterior (76%). Ligament opisthodetic, wholly external. Ribs are strong at the anterior end of shell surface. The radial ribs count 6 to 7.

Recent distribution: Kyusyu to Hokkaido, 0-20 m in water depth (HABE, 1977).

Description of the new species

Solemya* (*Petrasma*) *miuraensis n. sp.
ミウラキヌタレガイ (新称)
(Fig. 2-6a, 6b, 6c)

1995: *Solemya* sp. KANIE, KURAMOCHI, ASAMI and KANNO, fig. 3, 1a-1d.

Type Locality: East cliff of the southern entrance of the Shinsawayama Tunnel, Ikegami, Yokosuka City, Kanagawa Prefecture. Hayama Formation

Age: early Middle Miocene (ca. 15 Ma).

Material: Holotype (YCM-GPIg29) from east cliff of the southern entrance of the Shin-sawayama Tunnel, Ikegami, Yokosuka City, Kanagawa Prefecture. Hayama Formation..

Description: Only one specimen is in hand. The shell is thin and medium size in the holotype (53.3 mm long, 23.7 mm high). Dorsal margin is straight, the anterior and posterior margin are rounded. Ventral margin is nearly straight. Beak situates posteriorly (76%). The ribs on the shell surface are ornamented by strong and wide-spaced ribs at the anterior and posterior end, then weak and obscure at the central part. The radial ribs count 14.

Measurements in mm:

Length(L)	Height(H)	H/L	Breadth*2	U	U/L
53.3	23.7	0.45	8.3(16.5)	40.5	0.76

U: distance between anterior margin and beak.

Comparison: This new species is close to *S.* (*P.*) *pervernicosa* KURODA, but the latter has 10 to 12 ribs. *S.* (*P.*) *pusilla* (GOULD) is smaller and elongate form than this new species.

Fossil occurrence: associated with *Acharax yokosukensis* and calcareous concretions.

Acharax n. sp.

(Figs. 2- 9, 10; 3)

Type Locality: Daido Junior High school, Kanazawa-ku. Yokohama City, Kanagawa Prefecture, Nojima Formation of the Kazusa Group.

Age: Late Pliocene.

Materials: YCM-GP1182 (left valve) and 1183 (right valve) from Daido Junior High school, Kanazawa-ku, Yokohama City, Kanagawa Prefecture, Nojima Formation.

Description: The shell is very thick and middle size. Elongate shell form. Dorsal margin is straight, anterior and posterior margin are rounded. Ventral margin is nearly straight. Beak situates posteriorly. Ligament is external. Shell surface of ornamentation are weak ribs. In the inner side of the valve, it is characterized with broad-spaced "nimpha" at the antero-dorsal part (Fig. 3). The specimens studied are almost all fragments, therefore further materials are required.

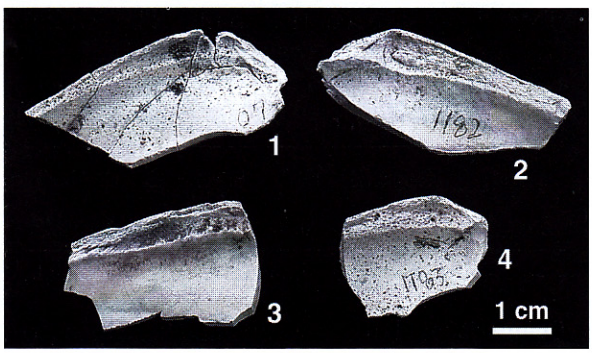

Fig. 3 *Acharax n.* sp. from Daido Junior High school, Kanazawa-ku. Yokohama City, Kanagawa Prefecture. Nojima Formation. Inner side view of the antero-dorsal part.
1: YCM-GP1184, 2: YCM-GP1182, 3. YCM-GP1188, 4. YCM-GP1189.

Comparison: This new species is close to *A. johnsoni* (DALL), but distinguished in stronger ribs on shell surface, and thin shell. This new species is characterized in thick shell and very elongate form among other species under the genus *Acharax*.

Fossil occurrence: associated with *Lucinoma* cf. *kamakurensis* and *Lucinoma* sp. (Yokohama Fossil Research Group, 1993)

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