

## The Irregular Sea Urchins (Echinodermata: Echinoidea) from Taiwan, with Descriptions of Six New Records

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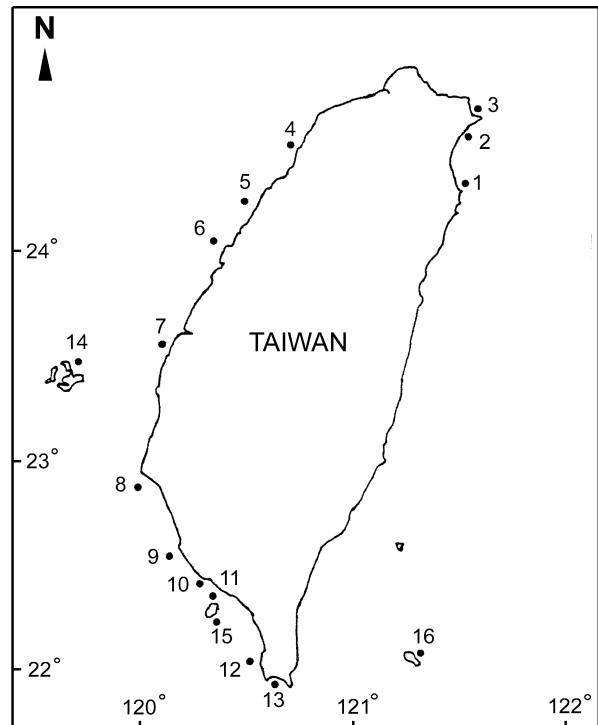
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**Shyh-Min Chao (2000)** The irregular sea urchins (Echinodermata: Echinoidea) from Taiwan, with descriptions of six new records. *Zoological Studies* 39(3): 250-265. Taiwan's irregular sea urchin fauna now comprises 19 valid species in 11 families. New records include *Fibularia ovulum* Lamarck (Fibulariidae), *Astriclypeus manni* Verrill (Astriclypeidae), *Linopneustes* sp. (Palaeopneustidae), *Schizaster lacunosus* (Linnaeus) (Schizasteridae), *Brissus latecarinatus* (Leske), and *Rhynobrissus pyramidalis* A. Agassiz (Brissidae). Species accounts and figures of 14 species collected by the author are presented.

**Key words:** Sea urchins, Irregular urchins, Echinoderms, Taiwan, Taxonomy.

Sea urchins may be either regular or irregular. Regular urchins have an almost spherical symmetry. Irregular urchins display varying degrees of bilateral symmetry. They are common macrobenthic organisms along the coasts of Taiwan. However, only a few papers dealing with them have been published (Tokunaga 1900, Ohshima 1927, Hayasaka 1948, Peng and Tiao 1971, Chen and Chang 1981, Shigei 1981, Wang 1984) on the ecology and systematics of these animals from the waters of Taiwan. The regular sea urchins from Taiwan have been revised by Chen and Chang (1981). However, there has been no study of the irregular urchins from Taiwan since Hayasaka (1948) except for a new species, *Taiwanaster mai* (now *Sinaechinocyamus mai*), described by Wang (1984).

Only 13 species in 7 families of irregular sea urchins were recorded from the waters of Taiwan before this study (Tokunaga 1900, Ohshima 1927, Hayasaka 1948, Peng and Tiao 1971, Shigei 1981, Wang 1984). There has been no systematic collection or description of irregular urchins from Taiwan. In the present study, since 1989, I have collected Taiwanese irregular sea urchins both by scuba and skin diving around the coasts of Taiwan and surrounding islands (the Pescadores, Hsiaoliuchiu, and Orchid I.) (Fig. 1). Beginning in 1994, trawls were made at regular intervals on the inshore sandy bottoms



**Fig. 1.** Map showing the collecting sites around Taiwan. 1, Nanfangao; 2, Tahsi; 3, Aoti; 4, Hsiangshan; 5, Tungshiao; 6, Wangkung; 7, Potsailiao; 8, Szutsaohu; 9, Kushan; 10, Chungyun; 11, Tungkang; 12, Wanlitung; 13, Nanwang; 14, Pescadore Is.; 15, Hsiaoliuchiu; 16, Orchid I.

around Taiwan to a depth of 200 m. During these expeditions, fourteen species of irregular urchins were collected, including 6 species and 4 families recorded from Taiwan for the first time.

The goal of this paper was to monograph the irregular urchins from Taiwan for the first time. Species accounts and figures of the 14 species collected by the author are presented. To date, nineteen valid species in 11 families of irregular urchins are known from Taiwan. A list of all species is presented in this paper. All materials are deposited in the National Museum of Natural Science (NMNS), Taichung, Taiwan. The following abbreviations are used in the text: t.l. = test length, t.w. = test width, t.h. = test height, t.h.m. = height of test margin, l.s. = length of longest spine, and NMNS = National Museum of Natural Science.

Identification was based primarily on *Monograph of shallow-water Indo-West Pacific echinoderms* (Clark and Rowe 1971), *The sea urchins of Sagami Bay* (Shigei 1986), and *The echinoderms of southern China* (Liao and Clark 1995). Terminology was adopted from Shigei (1986) (Figs. 2, 3).

### Synopsis of Irregular Urchins from Taiwan

Irregular urchins found in Taiwan are based on

Tokunaga (1900), Ohshima (1927), Hayasaka (1948), Peng and Tiao (1971), Shigei (1981), Wang (1984), and this study. An asterisk (\*) represents a new record.

#### Echinoneidae

*Echinoneus cyclostomus* Leske

#### Clypeasteridae

*Clypeaster reticulatus* (Linnaeus)

*Clypeaster virescens* Döderlein

#### Fibulariidae

\**Fibularia ovulum* Lamarck

#### Arachnoidae

*Arachnoides placenta* (Linnaeus)

#### Laganidae

*Laganum depressum* Lesson

*L. decagonale* (de Blainville)

*L. laganum* (Leske)

*Peronella lesueuri* (Valenciennes)

*P. orbicularis* (Leske)

#### Dendrasteridae

*Sinaechinocyamus mai* (Wang)

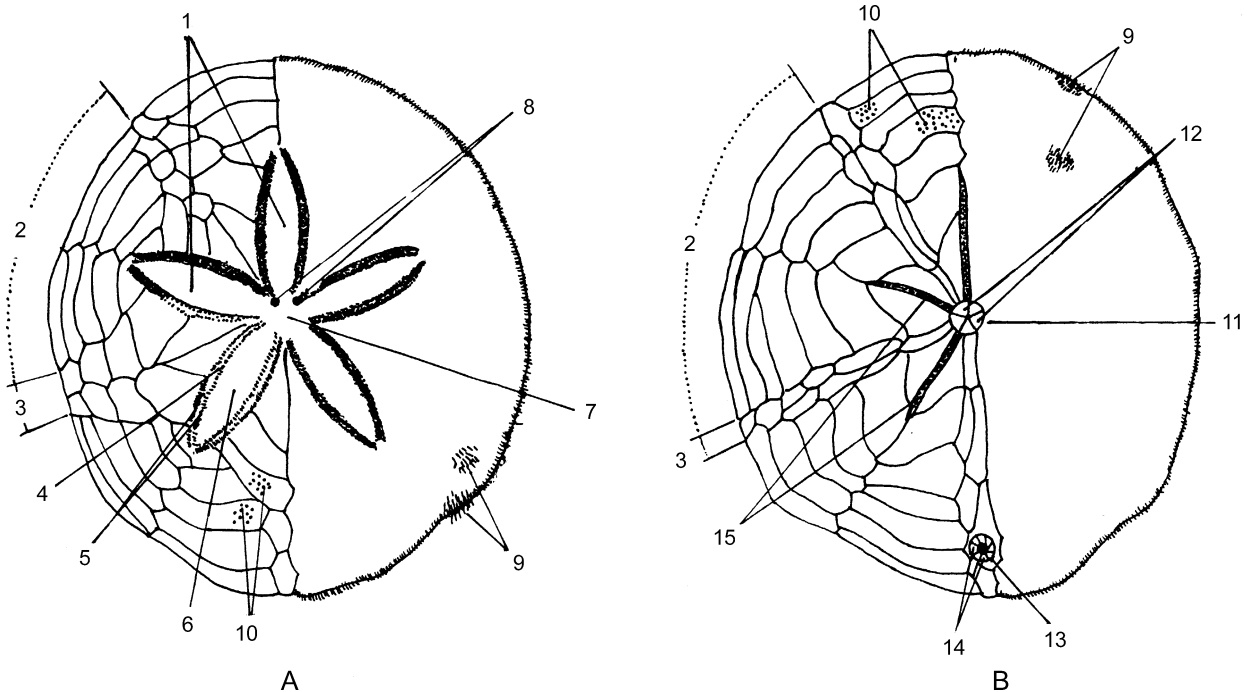
#### Astriclypeidae

\**Astriclypeus manni* Verrill

*Echinodiscus auritus* Leske

#### Palaeopneustidae

\**Linopneustes* sp.



**Fig. 2.** Laganidae (half denuded). A, aboral side; B, oral side. 1, petals; 2, ambulacrum; 3, interambulacrum; 4, poriferous zone; 5, pore pair; 6, interporiferous zone; 7, apical system; 8, genital pore; 9, spine; 10, tubercles; 11, peristome; 12, tooth; 13, periproct; 14, periproctal plate; 15, ambulacral groove (after Shigei 1986).

## Spatangidae

*Spatangus luetkeni* A. Agassiz*Pseudomaretia alta* (A. Agassiz)

## Schizasteridae

\**Schizaster lacunosus* (Linnaeus)

## Family Brissidae Gray

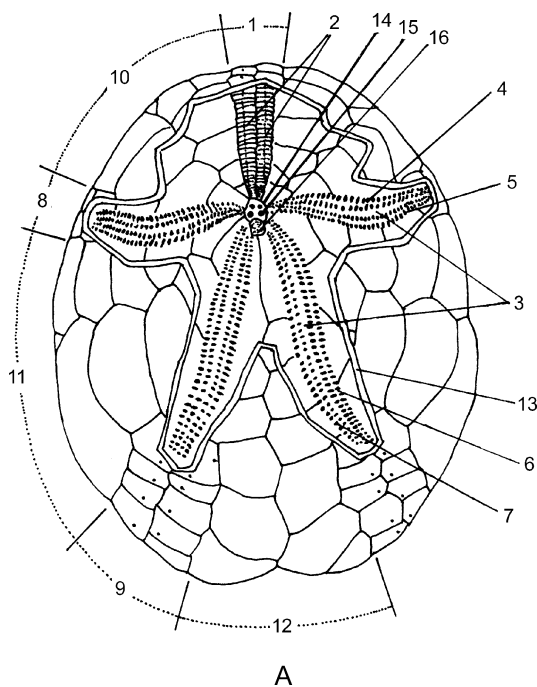
\**Brissus latecarinatus* (Leske)\**Rhynobrissus pyramidalis* A. Agassiz

## SPECIES ACCOUNTS

## Family Echinoneidae Agassiz and Desor

See: Liao and Clark 1995: 374; Rowe and Gates 1995: 215.

Test ovate. Both peristome and periproct on oral surface. Ambulacra simple, not forming phyllodes or petals. Tubercles not in regular series. Peristome oblique. Lantern and perignathic girdle present only in the young, leaving no trace in adults. Gill notches and buccal plates absent. No internal radiating walls. Genital pores 4.

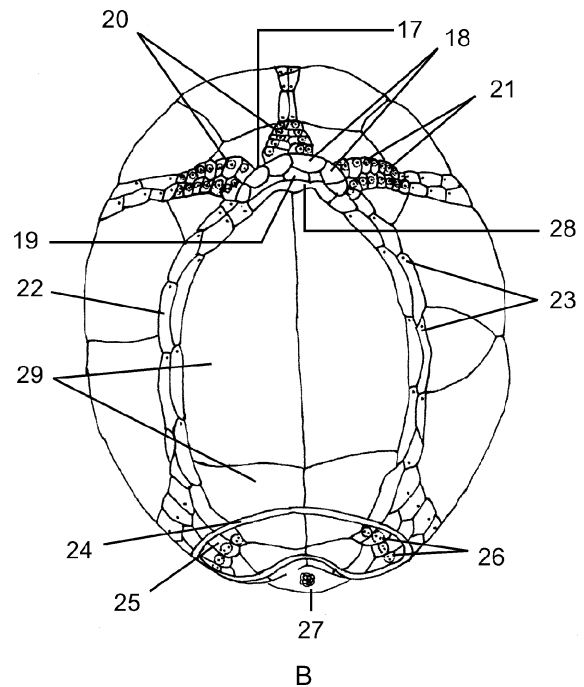
*Echinoneus cyclostomus* Leske

(Figs. 4-9)

*Echinoneus cyclostomus* Leske, 1778: 109, pl. 37, figs. 4, 5 (type locality: unknown); Clark and Rowe 1971: 145 (distribution), 158 (key), fig. 72b; Liao 1978: 118, pl. 2, fig. 6; Liao and Clark 1995: 374-375, fig. 219; Rowe and Gates 1995: 215.

**Materials:** NMNS-2328048, 4 specimens, Wanlitung, 14 June 1996; NMNS-2690084, 1 specimen, Aoti, 4 Sept. 1996; NMNS-2690085, 1 specimen, Hsiaoliuchiu, 11 July 1995.

**Description:** t.l./t.w./t.h./l.s. = 33/26/17/2 mm. Test rigid, small to medium, oval in outline. Both peristome and periproct on aboral surface, oblique ovate peristome in test center, narrow ovate periproct behind peristome. In ambitus, interambulacrum about 2.5 times that of ambularum. Ambulara slightly convex. Poriferous zones slightly sunken, running from apical system through peristome. Furrows connecting respiratory podial pores conspicuous, running in longitudinal series. Apical system rigid, with 4 genital pores. Oral surface almost flat except peristome which is slightly sunken. Surface with dense, small, imperforate primary tubercles. Spines short, dense on surface. Color in life usually pale brown with tube feet a con-



**Fig. 3.** Test of a spatangoid. A, aboral side; B, oral side. 1, frontal ambulacrum; 2, pore-series of frontal ambulacrum; 3, petals; 4, anterior pore-series of anterior petal; 5, posterior pore-series of anterior petal; 6, anterior pore-series of posterior petal; 7, posterior pore-series of posterior petal; 8, antero-lateral ambulacrum; 9, postero-lateral ambulacrum; 10, antero-lateral interambulacrum; 11, postero-lateral interambulacrum; 12, posterior interambulacrum; 13, peripetalous fasciole; 14, apical system; 15, genital pore; 16, madreporite; 17, peristome; 18, peristomial plates; 19, mouth; 20, phyllodes; 21, pores of phyllodes; 22, posterior ambulacrum; 23, pores of posterior ambulacrum; 24, subanal fasciole; 25, subanal region; 26, subanal pore pairs; 27, periproct; 28, labrum; 29, sternal system (after Shigei 1986).

trasting bright red. Denuded test whitish.

*Habitat:* Many denuded tests were collected from the intertidal zone to 4 m depth in the reef flats of southern Taiwan. Only 1 living individual was found under dead coral slabs from southern Taiwan. Liao (1978) states that they are common under coral heads near the low tide lines in tropical southern China. Sloan et al. (1979) found that they are shallow burrowers in sand under boulders on the seaward platforms of all coasts around Aldabra, also under boulders and coral heads in lagoons. This species has been recorded from 0-120 m depth (Liao and Clark 1995). I collected it from shallow water less than 5 m deep. A full description of the ecology including behavior and habitat of this echinoid is presented by Rose (1976).

*Distribution:* This echinoid species is known to be distributed in the Atlantic and Indo-West Pacific, widely found both in the West Indies and throughout the tropical Indo-West Pacific (Liao and Clark 1995).

#### Family Clypeasteridae L. Agassiz

See: Shigei 1986: 110; Liao and Clark 1995: 375; Rowe and Gates 1995: 202.

Test often aborally-orally flattened but sometimes vaulted, usually with strongly developed internal supports. Edge more or less tumid, not sharp. Circular, oval, or rounded pentagonal in outline, not perforated by lunules (slots). Ambulacra petaloid aborally; petals well developed. Ambulacral plates of petals alternating with large primary plates and smaller demiplates. Primary tubercles perforate, more or less subcrenulate. Aboral miliary spines very short and fine, ending in simple unmodified tips. Apical system central, monobasal. Genital pores 5. Periproct below margin (inferomarginal). Peristome central, usually sunken.

#### *Clypeaster reticulatus* (Linnaeus)

(Figs. 10-13)

*Echinus reticulatus* Linnaeus, 1758: 666 (type locality: 'Oceano Americano').

*Clypeaster reticulatus* Chang and Wu, 1957: 43, pl. 18, figs. 1-7; Clark and Rowe 1971: 144 (distribution), 160 (key), pl. 25, figs. 2-4; Liao 1978: 119-120, pl. 2, fig. 8; Liao and Clark 1995: 376, fig. 220, pl. 22, fig. 3; Rowe and Gates 1995: 204.

*Materials:* NMNS-2270016, 1 specimen, Nanwang, 14 Apr. 1995; NMNS-2270017, 3 specimens, Wanlitung, 17 Oct. 1994; NMNS-2572153, 1 specimen, Orchid I., 28 Apr. 1997.

*Description:* t.l./t.w./t.h./l.s. = 53/43/9/1.5 mm. Test rigid, oval to elongated pentagonal in outline,

longer than broad, with longer anterior end. Petaloid area raised slightly towards apex, but margin distinctly thick; sometimes surrounded by a depression encircling petaloid area so marked that center does not stand out above thick edge. Oral side distinctly concave; ambulacral groove conspicuous, extending from peristome to test margin and connecting to ends of petals. Petaloid area up to 2/3 of aboral surface; frontal petal longest, the anterior petals shortest, frontal petal/anterior petal/posterior petal = 15/12/14 mm. All petals closed distally. Poriferous zones not sunken. Pores of each pair separated by 1-3 fine tubercles. Furrows connecting respiratory podial pores shallow, inconspicuous. Periproct near test edge, inferomarginal, covered with dense spines. Apical system in test center, rigid, pentagonal in outline, with 5 genital pores. Poriferous madreporite in center of apical system, distinctly convex. Primary spine 1-3 mm in length. Dense primary tubercles randomly arranged on aboral and oral sides. Spines on oral surface longer than those on aboral surface. Test with strongly developed internal supports. Color in life uniformly greenish or brownish with some dark brownish spots on margins; denuded test whitish.

*Habitat:* Individuals were collected from sandy substrate at 2-5 m depth on reef flat.

*Distribution:* Entire tropical Indo-West Pacific from SE Africa to the Hawaiian Is.

#### *Clypeaster virescens* Döderlein

(Figs. 14-16)

*Clypeaster virescens* Döderlein, 1885: 102 (type locality: Sagami Bay and Bay of Kagoshima, Japan); Okada and Ugida 1981: 77; Shigei 1986: 113-114, pl. 27, figs. 1, 2, pl. 91, figs. 1-3; Imaoka et al. 1991: 156-157; Liao and Clark 1995: 376-377, fig. 221; Rowe and Gates 1995: 204.

*Material:* NMNS-3047003, 2 specimens, Nanfangao, 23 Oct. 1998.

*Description:* t.l./t.w./t.h./l.s. = 129/121/26/5 mm. Test very large and rigid, slightly longer than broad, rounded to pentagonal in outline. Petaloid area distinctly raised towards apex. Oral surface almost flat except peristome, which is concave. Test margin thins gently, t.h./t.h.m. = 26/7 mm. Petaloid area about 1/2 of aboral surface, frontal petal/anterior petal/posterior petal = 30/26/28 mm. All petals open distally; anterior wider open than others. Poriferous zones not sunken. Furrow connecting respiratory podial pores shallow. Periproct on oral side, near test edge (inferomarginal), covered with dense short spines. Primary spines 3-5 mm in length. Dense primary spines and primary tubercles arranged randomly, not in regular series. Secondary small spines

about 1.5 mm in length. Tridentate pedicellariae common on oral and aboral surfaces. Apical system in test center, rigid, with central poriferous madreporite. Genital pores 5, pentagonal in outline. Test with strongly developed internal supports. Color uniformly brownish except darker petals; denuded test brownish.

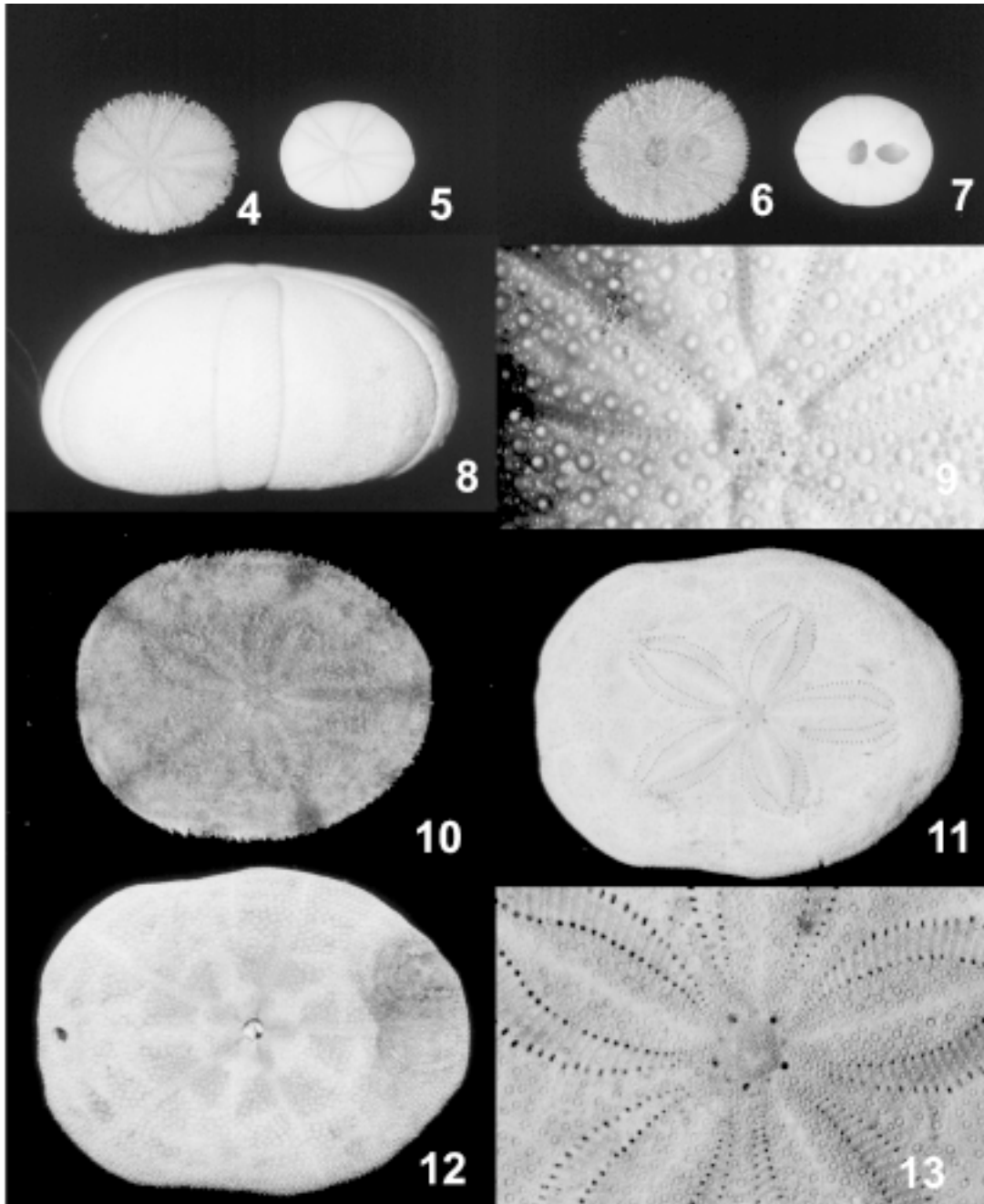
*Habitat:* Animals were occasionally trawled from

sandy substrate of ca. 200 m depth along northeastern Taiwan.

*Distribution:* Japan, the Philippines, Indo-China, and New Zealand seas.

#### Family Fibulariidae Gray

See: Shigei 1986: 114; Liao and Clark 1995: 378-379; Rowe and Gates 1995: 220.



**Figs. 4-9.** *Echinoneus cyclostomus* Leske. Figs. 4-7 (x 1). Fig. 8 (x 3). Fig. 10, apical system (x 16).  
**Figs. 10-13.** *Clypeaster reticulatus* (Linnaeus). Figs. 10-12 (x 1), fig. 13, apical system (x 3).

Test small, usually less than 15 mm long, ovate or flattened, never discoidal, rarely circular in outline. Petals short, more or less rudimentary, open distally. Pores large, not linked in pairs by common external depression, outer ones often alternating in position. Short or rudimentary food groove absent or indistinct. Internal skeletal supports absent or radial partitions only. Genital pores 4. Periproct on oral surface. Aboral miliary spines ending in crown-like expansion but not enveloped in bag.

***Fibularia ovulum* Lamarck**  
(Figs. 17, 18)

*Fibularia ovulum* Lamarck, 1816: 17 (type locality: North Male, Maldive Is.); Clark and Rowe 1971: 144 (distribution), 161 (key); Liao and Clark 1995: 382; Rowe and Gates 1995: 222.

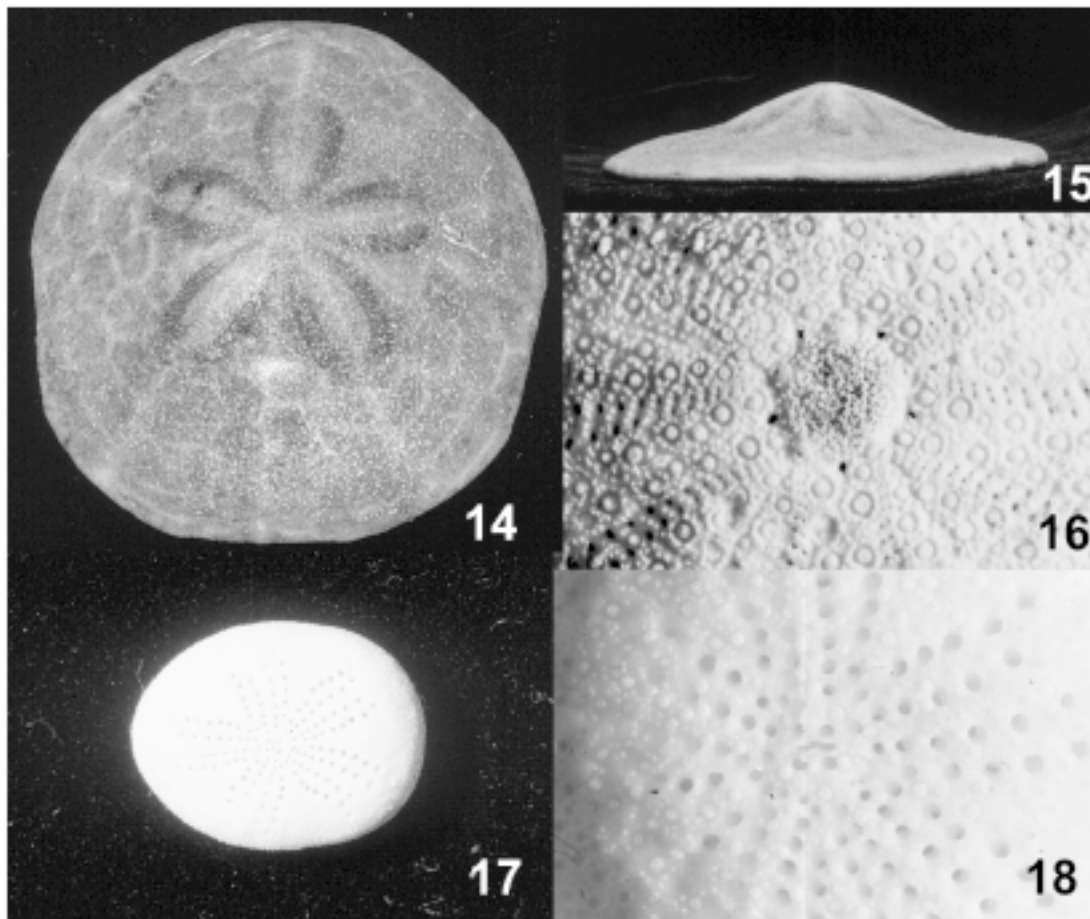
**Material:** NMNS-3211040, 1 specimen, Wanlitung, 20 June 1997.

**Description:** Test small, t.l./t.w./t.h. = 8.7/6.9/4.0

mm. Test oval from above, but more or less flattened, slightly pointed anteriorly and truncated posteriorly. Apical system and peristome in the center of aboral and oral sides, respectively. Petals short, each with 6-7 pore pairs. Pores large and round. Pores at distal end tending to penetrate the test obliquely. Primary tubercles irregularly distributed on test. Genital pores 4, about same size as pores of petals. A transverse depression of hydropore located between the 4 genital pores. Peristome oval, sunken. Periproct oblique, rhombic. Denuded test whitish.

**Habitat:** One denuded test was collected at 2 m depth from reef area of southern Taiwan. This species is a tropical inshore deposit feeder from shallow water to at least 50 m depth (Rowe and Gates 1995).

**Distribution:** East Africa and the Red Sea, Maldive Is., Bay of Bengal, Xisha Is. (S. China), the Philippines, and East Indies to the Gibert Is. (Liao and Clark 1995).



**Figs. 14-16.** *Clypeaster virescens* Döderlein. Figs. 14, 15 (x 0.8). Fig. 16, apical system (x 18).  
**Figs. 17, 18.** *Fibularia ovulum* Lamarck. Fig. 17 (x 4). Fig. 18 (x 40).

### Family Arachnoididae Duncan

See: Liao and Clark 1995: 378; Rowe and Gates 1995: 175.

Test of moderate size, very flat, margin thin, usually rounded in outline. Petals open, pseudo-compound with alternating demiplates. Ambulacral groove simple, well defined, continuing from peristome to apical system, without secondary tube feet in grooves. Secondary tube feet beyond petals in dense oblique series (combs), restricted to ambulacral areas. Genital pores 4. Periproct above margin. Peristome not sunken. Ambulacral grooves simple, well defined. Buccal membrane plated. Pedicellariae with 2 valves.

#### *Arachnoides placenta* (Linnaeus) (Figs. 19, 20)

*Echinus placenta* Linnaeus, 1758: 666 (type locality: 'Oceano Meridionali').

*Arachnoides placenta* Chang and Wu, 1957: 46, pl. 19, figs. 1-5; Clark and Rowe 1971: 144 (distribution), 161 (key); Liao and Clark 1995: 378, fig. 222; Rowe and Gates 1995: 176.

**Materials:** NMNS-1866092, 3 specimens, Tungshiao, 20 Dec. 1992; NMNS-2328057, 4 specimens, Wangkung, 13 Apr. 1996; NMNS-2328056, 2 specimens, Potsailiao; NMNS-2690086, 8 specimens, Hsiangshan, 23 Apr. 1994.

**Description:** Test medium in size, t.l./t.w./t.h./l.s. = 52.3/53.5/6.8/1 mm, rounded to pentagonal. Petaloid area distinctly raised towards apex. Oral side almost flat. Margin not thick, t.h./t.h.m. = 7/2 mm. Petaloid area up to 2/3 of aboral surface; frontal one longest, posterior petals shortest; frontal petal/anterior petal/posterior petal = 19/15/12 mm. All petals open distally. Interporiferous zones convex, poriferous zones sunken. Ambulacrum wide; interambulacrum narrow, about 1/3 width of ambulacrum. Interambulacrum slightly concave. Apical system more or less convex, with a central poriferous madreporite and 4 genital pores. Furrows connecting respiratory podial pores shallow, inconspicuous. Periproct at aboral side, near test edge, with short groove extending from anus to test margin. Ambulacral grooves extending from mouth to test margin and up to apical system. Tubercles on ambulacra of both oral and aboral surface in oblique series. Tubercles on interambulacra larger, sparser than those on ambulacra. Color in life dull gray or dark grayish brown; dry specimens grayish.

**Habitat:** This species is the most common sea urchin on the western coast of Taiwan. It is a littoral form, commonly collected on sandy or muddy substrate. In recent years, the population density of this species has dramatically decreased paralleling the

industrialization of the coast.

**Distribution:** Bay of Bengal, S. China, the Philippines, East Indies to New Britain, and northern Australia, 0-57 m (Liao and Clark 1995).

### Family Laganidae A. Agassiz

See: Clark and Courtman-Stock 1976: 241; Liao and Clark 1995: 383; Rowe and Gates 1995: 224.

Test sometimes >10 cm long but commonly ca. 4 cm, markedly flattened, usually discoidal, outline circular, oval, or angular, not perforated by slots. Petals well developed, pores usually conjugate. Plates of petals all alike, running across 1/2 the width of the petal. Genital pores 4 or 5. Simple ambulacral grooves present, not reaching the margin. Aboral miliary spines ending in a crown-like expansion.

#### *Peronella lesueuri* (Valenciennes) (Figs. 21, 22)

*Laganum lesueuri* Valenciennes, in L. Agassiz 1841: 116, pl. 24, figs. 3-6 (type localities: Australia and the Philippines).

*Peronella lesueuri* Chang and Wu, 1957: 48-49, pl. 19, fig. 6; Chang et al. 1964: 94; Clark and Rowe 1971: 144 (distribution), 162 (key), pl. 25, fig. 5; Liao and Clark 1995: 387-388, fig. 227; Rowe and Gates 1995: 225-226.

**Materials:** NMNS-2328060, 1 specimen, Hsiangshan, 7 Apr. 1990; NMNS-2328061, Kushan, 23 Dec. 1985; NMNS-2690087, 1 specimen, Pescadore Is., 11 Sept. 1994.

**Description:** Test medium to large, t.l./t.w./t.h. = 78/75/8.0 mm, with thin but not sharp edge. Test flat, elliptical, slightly longer than wide. Petaloid area occupying about 1/2 or more of test. Petals narrow, closed distally; frontal petal slightly longer than others. Petaloid area slightly raised towards apex. Oral surface almost flat. Margin thin, t.h./t.h.m. = 8/4 mm. Width of ambulacrum almost 6 times that of interambulacrum. Apical system slightly anterior, with central poriferous madreporite and 4 genital pores. Under microscope, furrows connecting respiratory podial pores conspicuous; a transverse series of 6-8 fine tubercles between consecutive pore-pairs. On oral side, ambulacral furrows short, about 1/3 of radius. Periproct on oral side, near posterior edge (inferomarginal), circular in outline, densely covered with fine spines. Primary tubercles and fine secondary tubercles uniformly cover aboral and oral surfaces; primary tubercles with sunken areoles. Primary tubercles on oral side larger than those on aboral side. Primary spines forming velvet coat. Color in life ranging from rose to Indian or brownish red; dry specimens light brown or light yellow.

**Habitat:** Individuals were trawled from sandy



substrates at 20-40 m off western Taiwan. A few individuals were collected near the low tide line.

*Distribution:* West coast of India to S. China, Japan, the Philippines, East Indies, and northern Australia, 0-70 m (Liao and Clark 1995).

#### Family Astriclypeidae Stefanini

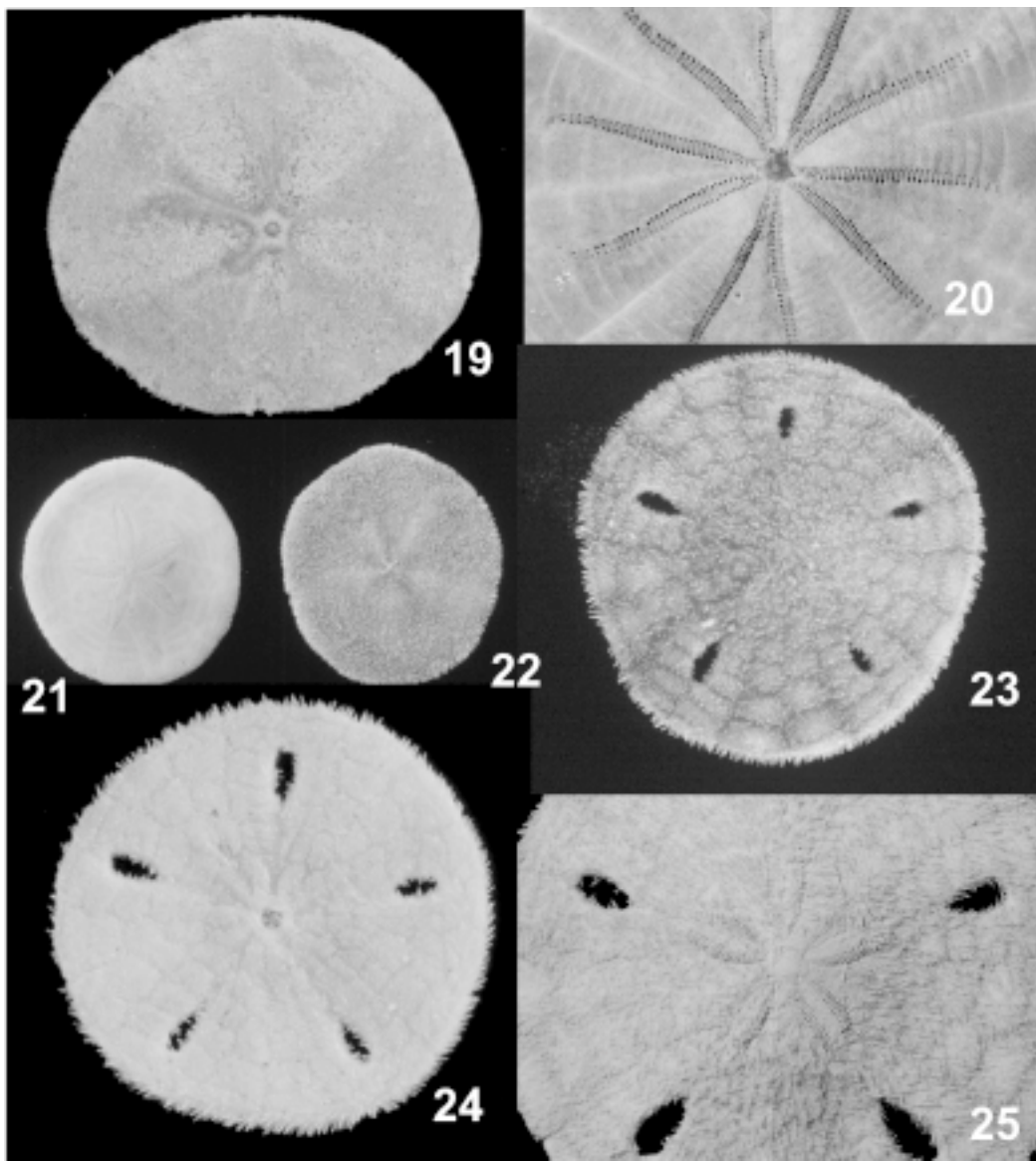
See: Shigei 1986: 127; Liao and Clark 1995: 389; Rowe and Gates 1995: 184.

Test large, usually >10 cm in length, always flattened, with thin and sharp edge. Circular in outline, but slightly truncated posteriorly. Internal

skeletal supports well developed. Oral side flat. Lunules 2 or 5 in number, one in each ambulacrum. Petals small but well defined. Interambulacra about as wide as ambulacra at ambitus. Apical system subcentral, with 4 genital pores. Periproct on oral side. Oral ambulacral furrow (food groove) bifurcating just outside the primordial plates.

#### *Astriclypeus manni* Verrill (Figs. 23-25)

*Astriclypeus manni* Verrill, 1867: 311 (type locality: southern Japan); Chang and Wu 1957: 55, pl. 22, figs. 1, 2; Chang



**Figs. 19, 20.** *Arachnoides placenta* (Linnaeus). Fig. 19 (x 1). Fig. 20 (x 16).

**Figs. 21, 22.** *Peronella lesueuri* (Valenciennes) (x 0.4).

**Figs. 23-25.** *Astriclypeus manni* Verrill. Figs. 23, 24 (x 2). Fig. 25 (x 4).



1964: 96; Clark and Rowe 1971: 144 (distribution), 162 (key); Shigei 1986: 128-129, pl. 29, fig. 1, pl. 97, figs. 1, 2, pl. 98, fig. 1; Liao and Clark 1995: 389, fig. 228.

**Material:** NMNS-2270020, 4 specimens (t.l. = 26, 26, 16, 15 mm), Wanlitung, 12 Apr. 1986.

**Description:** Rounded in outline, slightly truncated posteriorly, t.l./t.w./t.h./l.s. = 26/27/3/0.5 mm. Oral surface flat. Five elongate lunules in 5 ambulacra. Petaloid shorter than 1/2 test length. All petals similar in size. Petals narrowing distally, but not closed at distal end. Pore-zones broad, inner pores not very regular in arrangement; pore-series truncated at distal end; pore-pairs conjugate with deep, sharply limited, fine furrow. Oral ambulacral furrows divided near peristome; two main branches passing along sides of each lunule. Peristomial end of ambulacral furrows with conspicuous keel. Primary spines more or less club-shaped. Apical system central, with 4 genital pores; hydropores distributed over prominent, pentagonal apical disk. Periproct small, convex, covered with small plates, situated about midway between peristome and posterior margin. Adults in life brownish; juveniles purplish. Alcohol-preserved specimens and denuded tests whitish.

**Habitat:** Four specimens (t.l. = 26, 26, 16, 15 mm) were collected from 8 m in sandy substrate of a reef area of southern Taiwan.

**Distribution:** Cambodia, S. China, and S. Japan, ranging from shore to ca. 40 m (Liao and Clark 1995).

### ***Echinodiscus auritus* Leske**

(Figs. 26, 27)

*Echinodiscus auritus* Leske, 1778: 138 (type locality: unknown); Chang and Wu 1957: 54, pl. 21, figs. 1, 2; Chang et al. 1964: 96; Clark and Rowe 1971: 144 (key), 162 (distribution); Liao and Clark 1995: 390-391, fig. 229; Rowe and Gates 1995: 184.

**Materials:** NMNS-2015012, 3 specimens, Chungyun, 16 Sept. 1994; NMNS-2270019, 10 specimens (t.l. = 14-34 mm), Wanlitung, 12 Apr. 1986.

**Description:** Test thin, anterior rounded, posterior broad; the greatest width located on posterior end, t.l./t.w./t.h./l.s. = 52/57/3.7/0.5 mm. Petals small, closed distally, slightly raised towards apex. Petaloid area occupies < 1/2 the test. Oral side almost flat. Margin thin, t.h./t.h.m. = 3.7/1.1 mm. Frontal petal slightly longer than others. Two open slits in posterior ambulacra. Width of ambulacrum almost equal to that of interambulacrum. Apical system with central poriferous madreporite and 4 genital pores. Furrows connecting respiratory podial pores conspicuous; a transverse series of 6-10 tubercles

between consecutive pore-pairs. Poriferous zone as wide as interporiferous zone. Periproct on oral side, about 2/3 between peristome and posterior edge. Oral ambulacral furrows bifurcating into well-developed lateral branches, extending almost to test edge. Tubercles uniform on test surface. Primary spines 0.5-1 mm in length, forming velvet coat. Color in life of small individuals red-violet; large individuals dark purplish.

**Habitat:** Specimens were trawled from sandy substrate of western Taiwan. This species is an in-shore deposit feeder at 0-50 m depth. Ten specimens (t.l. = 14-34 mm) were collected from 8 m depth in sandy substrate in the same reef area as were found juvenile *Astriclypeus manni* in southern Taiwan.

**Distribution:** East Africa and most of the tropical Indian Ocean, except the Maldives, to S. China, S. Japan, the Philippines, East Indies, and northern Australia (Liao and Clark 1995).

### **Family Dendroasteridae Lambert**

See: Liao and Clark 1995: 392.

Test often moderate or large, but small in the species represented. Petals well defined, the anterior one more open than the paired petals. Without lunules. Oral ambulacral furrow usually bifurcating or trifurcating, but rudimentary in the small species represented. Apical system variable in position, four genital pores. Periproct near the edge of aboral side in the species represented. Aboral miliary spines terminating in bags.

### ***Sinaechinocyamus mai* (Wang)**

(Figs. 28-30)

*Taiwanaster mai* Wang, 1984: 135-139, pl. 1, figs. 1-3, pl. 2, figs. 1-6, pl. 3, figs. 1, 3, 4, pl. 4, figs. 1-4, pl. 5, figs. 1-4 (type locality: western Taiwan); Mooi 1989: 44.

*Sinaechinocyamus planus* Liao and Li, 1985: 152-153, pl. 1, fig. 3 (not *S. planus*); Liao and Clark 1995: 392-393, fig. 231c, d, pl. 22, fig. 4.

**Materials:** NMNS-2328054, 10 specimens, Tungshiao, 15 Dec. 1993; NMNS-2690088, 35 specimens, Szutsaohu, 7 Sept. 1994.

**Description:** Test small, thin, rigid, kite shaped to blunt rhombic in outline; t.l./t.w./t.h. = 9.4/9.7/1.9 mm. Petaloid area not raised distinctly towards apex, but aboral surface raised slightly. Oral side almost flat. Mouth at center of oral side. Margin not thick, t.h./t.h.m. = 2.3/0.5 mm. Petaloid area biased slightly toward the front, occupying about 1/2 the aboral surface. All petals opening distally; anterior one not open wider than others. Anterior petal longer than

frontal and posterior petals. Nine to 12 pore pairs. Under microscope, petals slightly sunken, interambulacra slightly raised. Apical system convex, with 4 conspicuous genital pores and central poriferous madreporite. No evidence of ambulacral grooves. Periproct at aboral side, near test edge. Primary tubercles uniform, with areole. Secondary tubercles without areoles, scattered among primary tubercles. Numerous small hyaline tubercles located among primary and secondary tubercles. Primary spines less than 0.5 mm, velvet-like. Color light green in life; dry specimens grayish, denuded test whitish.

*Habitat:* This is a littoral species, collected on sandy substrate of western Taiwan.

*Distribution:* Only recorded from southern China and western Taiwan.

#### Family Palaeopneustidae A. Agassiz

See: Shigei 1986: 135

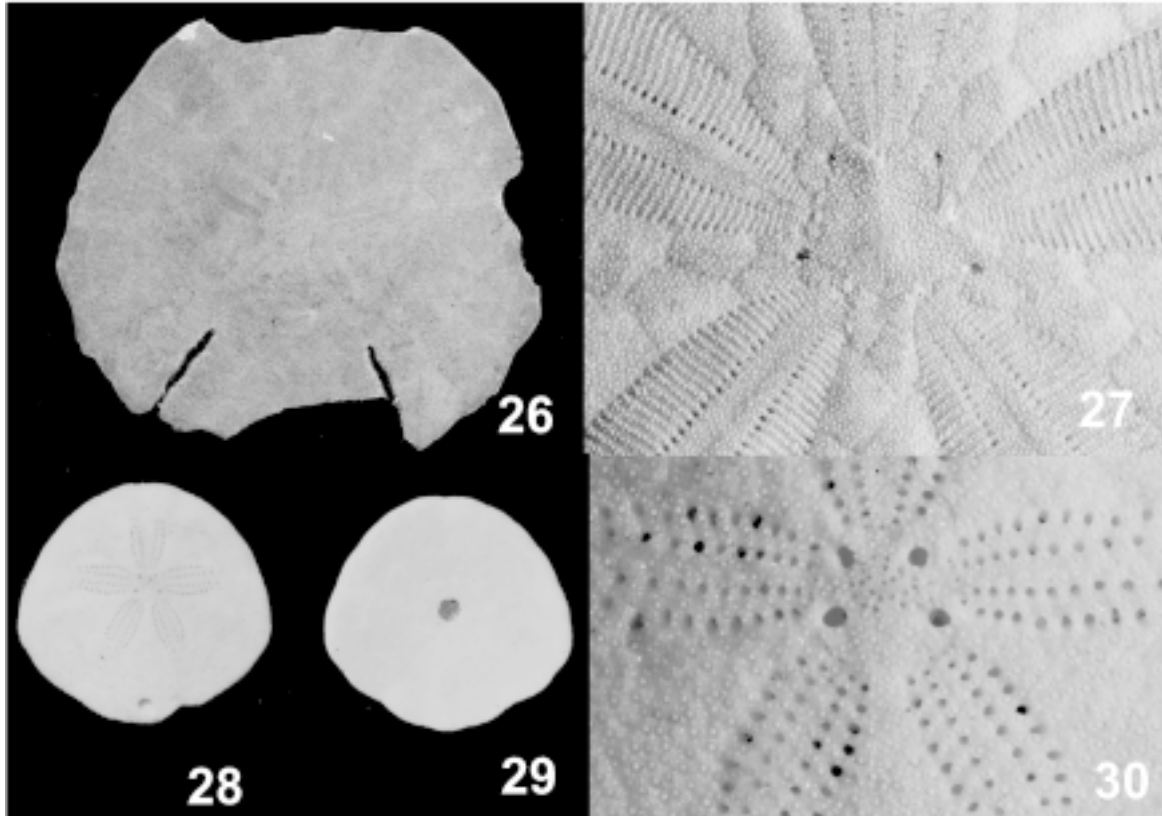
Ambulacra subpetaloid, flush with test, or not at all petaloid. Fascioles variable or lacking. Apical system ethmolytic. Primary spines present or absent (Shigei 1986).

#### *Linopneustes* sp.

(Figs. 31-34)

*Materials:* NMNS-2804012, 1 specimen, 9 Feb. 1998; NMNS-2804013, 1 specimen, 7 May 1998; NMNS-3166005, 1 specimen, 27 May 1999; Tungkang.

*Description:* Test large, fragile; t.l./t.w./t.h./l.s. = 137/109/51/17 mm. Outline from above ovate, arched on aboral side, flattened on oral side, slightly hemispherical. Indistinct frontal notch continuing to oral side forming distinct short notch at lowest part of test. In profile, posterior part rising a little more steeply than anterior part; posterior end obliquely truncate. Ambulacra except frontal, petaloid. Anterior and posterior petals long, flush with test, reaching 3/4 of aboral surface. Pore-series nearly parallel, subequal. Interporiferous zone broad, covered with 3-5 primary large tubercles and numerous secondary tubercles. Pores not conjugate; space between consecutive pore-pairs somewhat depressed. Pore-pairs in frontal ambulacrum small, provided with peripodium. Phyllodes short, not well developed. Posterior ambulacra on oral surface broad, naked.



**Figs. 26, 27.** *Echinodiscus auritus* Leske. Fig. 26 (x 0.8). Fig. 27 (x 16).

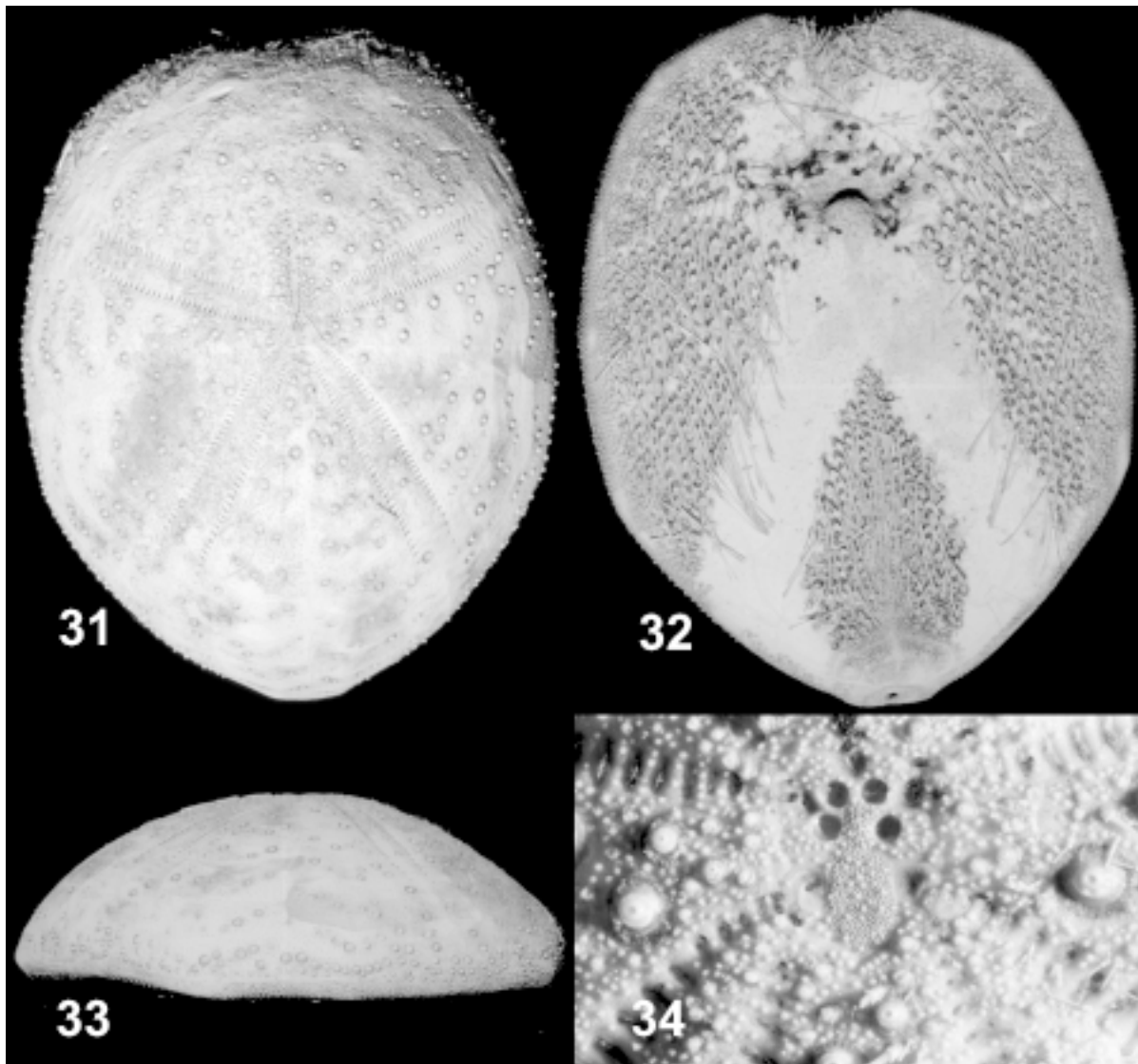
**Figs. 28-30.** *Sinaechinocyamus mai* (Wang). Figs. 28, 29 (x 8). Fig. 30 (x 20).

Apical system slightly anterior, with 4 genital pores; poriferous madreporite conspicuously elongated posteriorly. Peristome sunken. Periproct at oblique truncate of posterior end, covered by numerous plates. Oral surface with dense primary spines, but primary spines sparse on aboral surface. Shaft of primary spines slightly thorny under microscope; slightly curved at base. Large primary tubercles and secondary tubercles perforated. With sparsely tridentate pedicellariae. Without peripetalous fasciole, but with fine marginal fasciole on test margin. Subanal fasciole well developed. Alcohol-preserved specimens light brown.

*Habitat:* Three individuals were collected from 200-250 m sandy substrate in southern Taiwan. This

species is a deposit feeder with fine sand in the gut.

*Remarks:* This species is similar to *Linopneustes murrayi* (A. Agassiz) from Japan, but several characters distinguish it from *L. murrayi*. This species is larger and longer but lower than *L. murrayi*. This species has numerous large primary spines and tubercles on the aboral surface, while *L. murrayi* has few primary spines and tubercles. In addition, *L. murrayi* has tridentate, triphyllous, and large rostrate pedicellariae, while only sparsely tridentate pedicellariae are found in *Linopneustes* sp. In profile, the anterior part of *L. murrayi* rises more steeply than the posterior part, whereas in *Linopneustes* sp., the posterior part rises slightly more steeply than the anterior part.



Figs. 31-34. *Linopneustes* sp. Figs. 31, 32 (x 0.7). Fig. 33 (x 0.5). Fig. 34 (x 16).

This species is probably a new species. However, as it has not been compared with other species of *Linopneustes*, I am reluctant to describe it as a new species at this time.

### Family Spatangidae Gray

See: Gray 1825: 430; Shigei 1986: 149; Liao and Clark 1995: 394; Rowe and Gates 1995: 243.

With subanal fasciole, but without other fascioles. Apical system ethmolytic, with 3 or 4 genital pores. Large primary spines usually present, of various lengths. Spatangids distinguished from members of other spatangoid families by a subanal fasciole.

#### *Pseudomaretia alta* (A. Agassiz)

(Figs. 35, 36)

*Maretia alta* A. Agassiz, 1863: 360 (type locality: S. Japan).

*Pseudomaretia alta* Chang and Wu, 1957: 56-58, pl. 22, figs. 3-6; Clark and Rowe 1971: 146 (distribution), 165 (key); Shigei 1986: 155-156, pl. 33, figs. 1, 2, pl. 109, figs. 5, 6, pl. 110, figs. 1-4; Liao and Clark 1995: 396-397, fig. 232.

*Material*: NMNS-2572052, 11 specimens, Wanlitung, 12 Mar. 1997.

*Description*: Test small to medium, fragile, arched aborally, oval in outline, and narrowing posteriorly; t.l./t.w./t.h./l.s. = 28/22/14/9 mm. Frontal ambulacrum slightly grooved, nearly flush with test, anterior end very slightly notched. Posterior interambulacrum not keeled. Posterior end concave, forming roof over periproct. In profile, aboral side rising gradually towards apical system, then slightly sloping down; posterior end obliquely truncated. Anterior and posterior petals long, reaching near test margin, open slightly at distal ends. Anterior petals slightly shorter than posterior. Pore-pairs conjugated by inconspicuous shallow groove; a transverse series of 4-6 fine tubercles between consecutive pore-pairs. Very fine pores on frontal ambulacrum. Sternal system narrow, elevated, keeled posteriorly; dense primary tubercles on elevated and keeled posterior. Labrum inconspicuous, not protruding. Subanal fasciole keeled, well developed, heart shaped. Apical system slightly anterior, with 3 conspicuous genital pores. Periproct large, situated in deep hole on upper part of posterior end of test. Spines on aboral side short, dense; spines on oral side large, sparse. Few spines around peristome and anterior part of sternal system. Two to 3 large spines on antero-lateral sides of test; when denuded, two to 3 large tubercles visible. A tuft of longest spines, up to 9 mm, extending from subanal region. Tubercles on aboral side small, dense; tubercles on

oral side large but sparse especially those around sternal system and edge of test. Color light red in life; when captured, with purplish secretion; dry specimens light purple; denuded test white.

*Habitat*: Individuals were collected at 7 m depth from sandy substrate of reef area. This species is an inshore deposit feeder at 2-204 m depth (Liao and Clark 1995).

*Distribution*: Islands of the western Indian Ocean and Maldives to S. China, southern Japan, southern Taiwan, the Philippines, and East Indies (Shigei 1986, Liao and Clark 1995).

### Family Schizasteridae Lambert

See: Clark and Courtman-Stock 1976: 247-248; Shigei 1986: 142; Liao and Clark 1995: 403-404; Rowe and Gates 1995: 239.

Moderate or large size, usually heart shaped with frontal depression. Paired ambulacra aborally marked, petaloid sunken. Posterior pair of petals much shorter than anterior. Usually possessing peripetalous and latero-anal fascioles, but lacking marginal fasciole and sub-anal fasciole. Apical system ethmophract or ethmolytic with 2 to 4 genital pores. Large primary spines and tubercles fairly uniform. Periproct oval, situated on posterior end, aligned vertically or just visible from below. Peristome markedly anterior, semilunar with well-developed labrum.

#### *Schizaster lacunosus* (Linnaeus)

(Figs. 37, 38)

*Echinus lacunosus* Linnaeus, 1758: 665 (type locality: Indian Ocean).

*Schizaster lacunosus* Clark and Rowe, 1971: 140, 166; Clark and Courtman-Stock 1976: 248; Guille 1986: 48-49; Shigei 1986: 145-147, pl. 31, fig. 3, pl. 104, figs. 1-9; Imaoka et al. 1990: 126; Liao and Clark 1995: 408-409, fig. 238; Rowe and Gates 1995: 241.

*Materials*: NMNS-2690082, 1 specimen, Nanwang, 1 June 1993; NMNS-2690083, 1 specimen, Tahsi, 9 Dec. 1996.

*Description*: Test medium in size, fragile, heart shaped, high, especially posteriorly; t.l./t.w./t.h. = 78/72/59 mm. Outline from above heart shaped, with distinct frontal notch; posterior slightly narrow, posterior end pointed. Frontal ambulacrum deeply grooved. Posterior interambulacrum distinctly raised, keeled, projecting above periproct. Below periproct, test slightly concave. Petals deeply sunken, not broad but narrowing proximally. Anterior petals more than 2 times longer than posterior, slightly curved at both ends. Inner and outer pores elongate; outer pore-series on lateral part of elevated

walls. Under microscope, several fine granules in a transverse series situated between consecutive pore-pairs of anterior and posterior petals; interporiferous zone with few granules. Pores of frontal ambulacrum small, arranged in longitudinal series; elevated granule always situated between 2 pores; interporiferous zone with dense tubercles and fine granules. Phyllodes long. Ambulacra between phyllodes and anterior petals nearly naked. Posterior ambulacrum on oral side narrow, well tuberculated. Peripetalous fasciole well developed throughout entire length, close to petals, and anteriorly across frontal ambulacrum. Latero-anal fasciole beginning from an angle of peripetalous fasciole, running posterolaterally on posterior part of test, becoming more or less asymmetrical in subanal region. Apical system with 2 large genital pores and 2 additional small pores. Periproct large, oval, covered by 15-20 small plates. Aboral side with fine, uniform tubercles. Tubercles on anterior part larger. Tubercles on oral surface large, sparse. Denuded test whitish.

**Habitat:** A naked test was collected from a sandy substrate at 3 m depth in a reef area of northern Taiwan. One individual was trawled from about 100 m sandy substrate of northeastern Taiwan. This species is an inshore deposit feeder at 5-90 m depth.

**Distribution:** Japanese Sea, East China Sea, the Philippines, NE. Australia, and E. Africa.

### Family Brissidae Gray

See: Clark and Courtman-Stock 1976: 249; Shigei 1986: 170; Liao and Clark 1995: 409-410; Rowe and Gates 1995: 186.

Moderate or large size, ovate, more or less high. Paired ambulacra aborally marked petaloid but not deeply sunken, frontal ambulacrum not petaloid. Both peripetalous and entirely separate subanal fascioles present, latter with anal branches in some, but lacking internal fasciole. Apical system compact, central or slightly anterior, with 2-4 genital pores. Periproct longitudinal oval, on truncated posterior face of test. Peristome semilunar with a well-developed labrum, markedly anterior.

### *Brissus latecarinatus* (Leske)

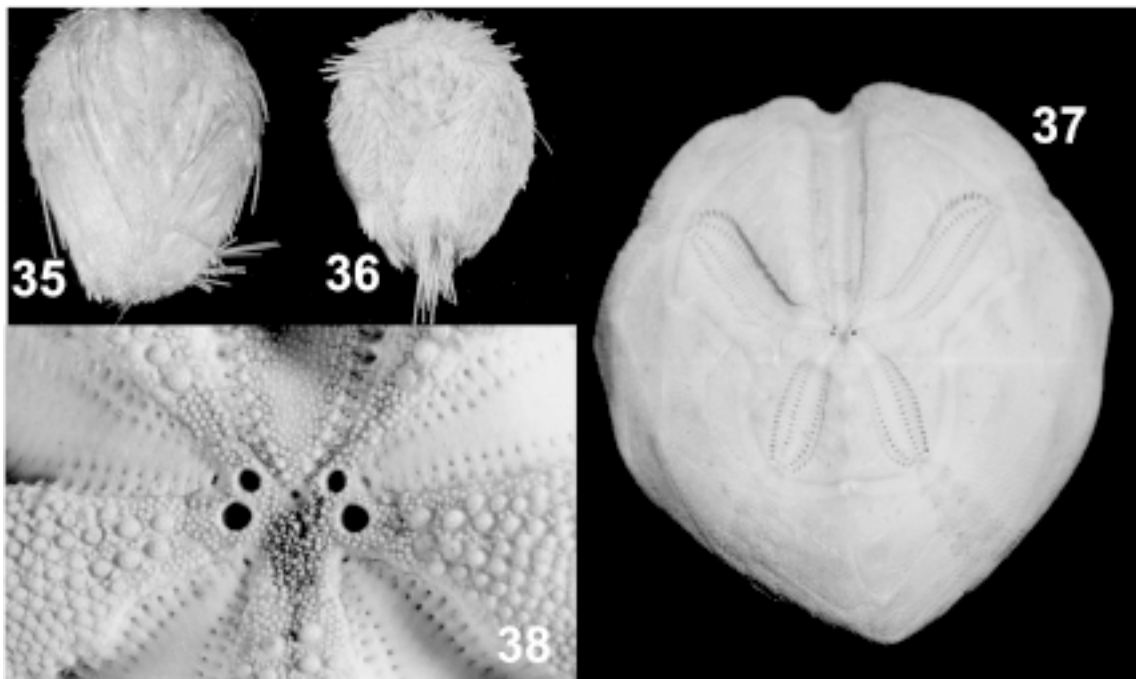
(Figs. 38-41)

*Spatangus brissus latecarinatus* Leske, 1778: 185, pl. 48 (4-5) (type locality: unknown).

*Brissus latecarinatus* Clark and Rowe, 1971: 146 (distribution), 165 (key), pl. 25, fig. 16; Shigei 1986: 179-180, pl. 36, fig. 1, pl. 119, figs. 1-4, pl. 120, fig. 1; Liao and Clark 1995: 412-413, fig. 239; Rowe and Gates 1995: 187-188.

**Material:** NMNS-3193001, 2 specimens, Nanwang, 24 Nov. 1998.

**Description:** Test fragile, medium in size, t.l./t.w./t.h. = 53/40/30 mm. Outline from above elliptical,



**Figs. 35, 36.** *Pseudomaretia alta* (A. Agassiz) (x 1.2).

**Figs. 37, 38.** *Schizaster lacunosus* (Linnaeus). Fig. 37 (x 1). Fig. 38 (x 16).



without distinct frontal notch; posterior slightly narrow, posterior end pointed. Frontal ambulacrum groove flat, inconspicuous. Posterior interambulacrum distinctly raised and keeled, projecting above periproct. Posterior end obliquely truncate, sloping conspicuously towards oral side. Lateral sides tumid. Petals sunken, narrowing proximally. Posterior petals longer than anterior. Anterior and posterior petals slightly undulating. Inner and outer pores elliptical; outer pore-series more narrow than inner. Ridges between consecutive pore-pairs low, each with regular, conspicuous series of small tubercles. Interporiferous zones narrow, width almost equal to diameter of adjoining pores. Phyllodes long, well developed. Sternal system broad. Labrum broad, thickened, upturned. Peripetalous fasciole well developed, but without anal fasciole. Subanal fasciole reniform. Apical system anterior at about 1/3 test length from anterior end, with 4 genital pores. Periproct longitudinally oval. Aboral tubercles smaller than oral. Tubercles on anterior part larger,

coarser. Denuded test white.

*Habitat:* Several naked tests were collected from sandy substrate at 3 m depth from reef area. This species is an inshore deposit feeder from the intertidal zone to 45 m deep (Shigei 1986).

*Distribution:* Widely distributed over the Indo-West Pacific, from Madagascar, Mauritius, and the Red Sea to Hawaii, the Marquesas Is. and the Tuamotu Is.

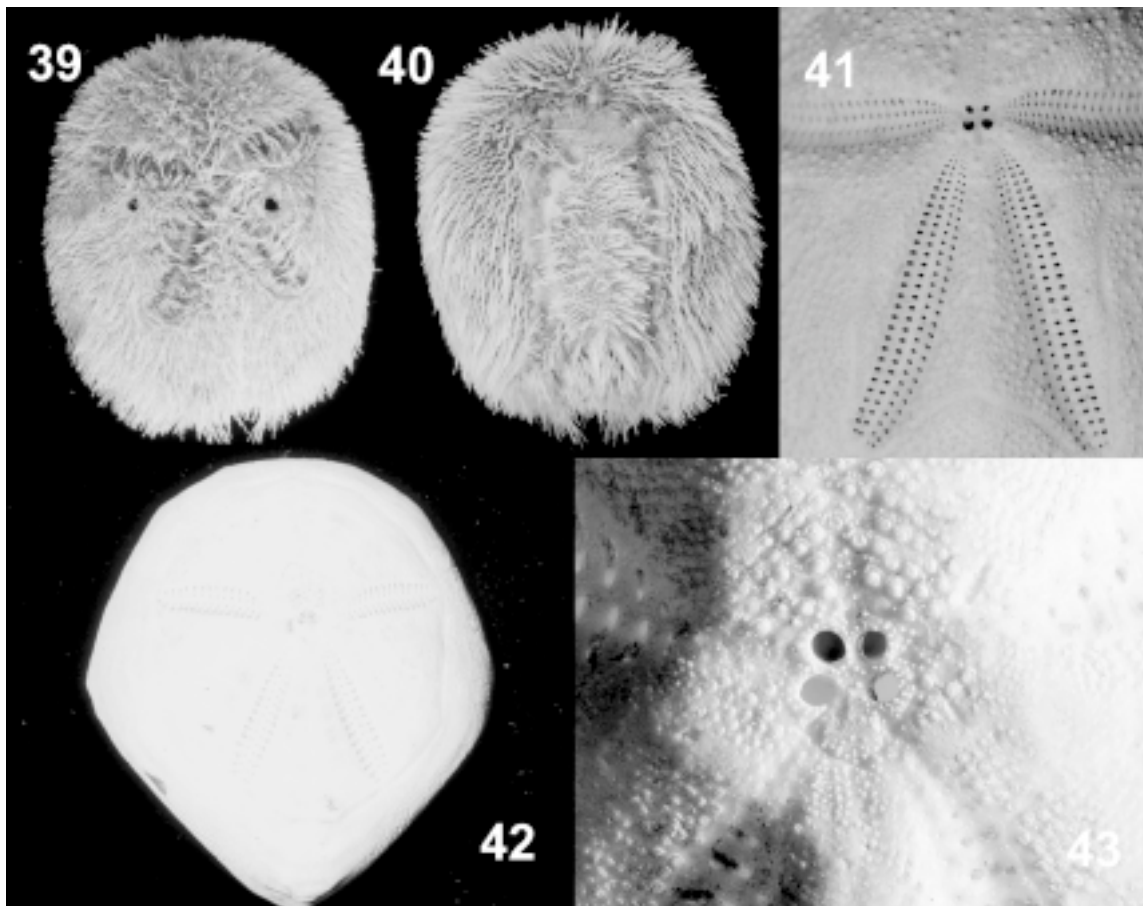
***Rhynobrissus pyramidalis* A. Agassiz**  
(Figs. 42, 43)

*Rhynobrissus pyramidalis* Agassiz, 1872: 58 (type locality: Linguin, China Sea); Clark and Rowe 1971: 146 (distribution), 166 (key); Liao and Clark 1995: 415-416, fig. 241; Rowe and Gate 1995: 191.

*Rhynobrissus pyramidalis* Chang and Wu, 1957: 65, pl. 25, figs. 3-6; Chang et al. 1964: 101.

*Material:* NMNS-2328067, 2 specimens, Pot-sailiao, 14 Sept. 1995.

*Description:* Test moderate, arched aborally, t.l./



**Figs. 39-41.** *Brissus latecarinatus* (Leske). Figs. 39, 40 (x 1). Fig. 41 (x 12).  
**Figs. 42, 43.** *Rhynobrissus pyramidalis* A. Agassiz. Fig. 42 (x 1). Fig. 43 (x 16).

t.w./t.h. = 49/44/30 mm. Oval in outline from above, narrowing posteriorly. Frontal ambulacrum not grooved, inconspicuous, anterior end without notch. Posterior interambulacrum not keeled. In profile, aboral side rising gradually towards middle posterior interambulacrum, then sloping slightly down to vertical truncated posterior face of test. Petals open distally, enclosed by peripetalous fasciole. Anterior petals shorter than posterior. Anterior and posterior petals slightly sunken. Pore-pairs conjugated by inconspicuous shallow groove, without conspicuous tubercles between consecutive pore-pairs. Very fine pores on frontal ambulacrum. Sternal system narrow, elevated, keeled in central longitudinal line, with dense large tubercles. Phyllodes short, broad. Labrum conspicuous, protruding. Anal fasciole conspicuous, blunt triangular or diamond shaped. Subanal fasciole broad, well developed, heart shaped. Apical system in center of aboral surface, with 4 conspicuous genital pores. Periproct small, longitudinal oval, protruding on upper side of vertical truncated posterior face of test; subperiproct slightly concave. Tubercles on aboral surface small, dense, while those on oral surface large, sparse. Denuded test whitish.

*Habitat:* Two denuded tests were trawled from sandy substrate at 20 m depth. This species is an inshore deposit feeder at 0-20 m depth.

*Distribution:* Madras, Singapore, the Gulf of Siam (Thailand), Hainan I. (S. China), and Australia (Liao and Clark 1995, Rowe and Gate 1995).

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## 臺灣產歪形海膽(棘皮動物門：海膽綱)及六種新記錄種

趙世民<sup>1</sup>

本文回顧臺灣產歪形海膽之研究，共整理 11 科 19 種有效種，並描述 6 種新記錄：卵豆海膽 *Fibularia ovulum* Lamarck (Fibulariidae 豆海膽科)、曼氏孔楯海膽 *Astriclypeus manni* Verrill (Astriclypeidae 星楯海膽科)、*Linopneustes* sp. (Palaeopneustidae 古心形海膽科)、凹裂星海膽 *Schizaster lacunosus* (Linnaeus) (Schizasteridae 裂星海膽科)、脊背壺海膽 *Brissus latecarinatus* (Leske)、吻壺海膽 *Rhynobrissus pyramidalis* A. Agassiz (Brissidae 壺海膽科)。本文包括 14 種的描述、棲地、地理分布及標本照。

**關鍵詞**：海膽，歪形海膽，棘皮動物，臺灣，分類。

<sup>1</sup> 國立自然科學博物館