



# HOKKAIDO UNIVERSITY

Title	Contributions to the Classification of the Sea-stars of Japan. : II. Forcipulata, with the Note on the Relationships between the Skeletal Structure and Respiratory Organs of the Sea-stars (With 11 Plates and 115 textfigures)
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**Contributions to the Classification of the Sea-stars of  
Japan. II. Forcipulata, with the Note on the Rela-  
tionships between the Skeletal Structure and  
Respiratory Organs of the Sea-stars<sup>1)</sup>**

By

**Ryoji Hayashi**

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(With 11 plates and 115 textfigures)

It is the second report of the writer's investigation on the sea-stars of Japan, undertaken under the guidance of Prof. Tohru Uchida and contains the following 41 forms belonging to the three families, Brisingidae, Zoroasteridae and Asteroiidae. These families are all included in the order Forcipulata. From Japanese waters 18 species of Forcipulata have previously been reported. They all belong to the family Asteroiidae, except Sladen's two species of Brisingidae. The species newly recorded are marked with asterisk.

**Family Brisingidae**

- \* *Odinia pacifica* forma *sagamiana* n. forma
- \* *Odinia austini* forma *japonica* n. forma
- \* *Parabrisinga pellucida* n. sp.
- Brisingella armillata* (SLADEN)
- \* *Freyellaster fecundus* forma *ochotensis* n. forma
- \* *Freyellaster intermedius* n. sp.
- Freyella pennata* SLADEN

**Family Zoroasteridae**

- \* *Zoroaster orientalis* n. sp.
- \* *Zoroaster orientalis* n. sp. forma *gracilis* n. forma
- \* *Zoroaster ophiactis* FISHER
- \* *Zoroaster microporus* FISHER
- \* *Cnemidaster wyvillii* SLADEN

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1) Contributions from the Akkeshi Marine Biological Station, No. 38.

**Family Asteroidea**

## Subfamily Pedicellasterinae

*Pedicellaster magister orientalis* FISHER\* *Pedicellaster magister esoensis* n. subsp.*Plazaster borealis* (UCHIDA)

## Subfamily Labidiasterinae

*Coronaster sakuranus* (DÖDERLEIN)

## Subfamily Coscinasterinae

*Sclerasterias satsumana* (DÖDERLEIN)*Coscinasterias acutispina* (STIMPSON)*Distolasterias stichantha* (SLADEN)*Distolasterias nipon* (DÖDERLEIN)\* *Distolasterias elegans* DJAKONOV*Lethasterias fusca* DJAKONOV\* *Lethasterias nanimensis chelifera* VERRILL

## Subfamily Pycnopodiinae

*Lysastrosoma anthosticta* FISHER

## Subfamily Asteroidea

*Aphelasterias japonica* (BELL)*Aphelasterias japonica* forma *torquata* (SLADEN)*Asterias amurensis* LÜTKEN*Asterias amurensis versicolor* SLADEN\* *Evasterias troschelii* forma *alveolata* VERRILL\* *Evasterias echinosoma* FISHER\* *Evasterias echinosoma* forma *robusta* n. forma\* *Leptasterias ochotensis* (BRANDT)*Leptasterias ochotensis similispinis* (CLARK)\* *Leptasterias orientalis aniwaensis* n. subsp.\* *Leptasterias pulchella* n. sp.\* *Leptasterias pulchella* n. sp. forma *tugaruensis* n. forma\* *Leptasterias hylodes* FISHER*Leptasterias alaskensis* forma *alaskensis* (VERRILL)<sup>1)</sup>*Leptasterias alaskensis asiatica* FISHER*Leptasterias camtschatica* (BRANDT)

Before going further, the writer must express his cordial thanks to Prof. Tohru Uchida for his kind guidance.

1) The species has not been recorded from Japanese waters.

## Systematic

## Order FORCIPULATA PERRIER

## Suborder BRISINGINA FISHER

## Family Brisingidae G. O. SARS

## Key to Japanese genera of Brisingidae

- a<sup>1</sup>. Dorsal surface of disc and genital region of ray provided with numerous conspicuous papulae; two gonads to each ray; genital region of ray with transverse skeletal arches or costae and intercostal plates; rays with regularly spaced transverse lateral combs of seven conspicuous slender spines; adambulacral plates higher than long, each with a prominent subambulacral spine, frequently truncate or more or less spatulate in proximal part of ray; first three to seven or eight pairs of adambulacral plates united in each interradius and above them the marginal plates similarly united; a syzygy at least between the first and second adambulacral plates . . . . .

*Odinia* PERRIER

- a<sup>2</sup>. No papulae either on disc and rays, proximal dorsal skeleton forming independent costae or continuous covering of thin plates; disc plates small, each bearing one to several small spinelets; lateral spines single, never forming a vertical comb of conspicuous spines.

- b<sup>1</sup>. First and second adambulacral plates as well as the upper part of second and third ambulacral plates united by syzygy.

- c<sup>1</sup>. Dorsal skeleton of ray in the form of independent spaced costae composed of elongated, more or less compressed, overlapping plates, projecting well above the level of the intervening integument; intercostal areas without immersed spineless plates.

- d<sup>1</sup>. Gonads numerous in a series along either side of ray; costae numerous; a number of intercostal prickles; first pair of adambulacral plates a little separated, above them, first marginal plates closely united by their lateral faces; proximal adambulacral plates each with a modified tipped subambulacral spine . . . . . *Parabrisinga* n. gen.

- d<sup>2</sup>. Gonads two to each ray, one on each side; subambulacral spines delicate, acicular; first adambulacral plates not joined but separated; the first pair of marginal plates not closely united their lateral faces, but by the adoral ends. . . . . *Brisingella* FISHER

- c<sup>2</sup>. Dorsal skeleton of genital region of ray composed of uniformly spiniferous plates, not forming independent costae; gonads in series; first pair of adambulacral plates united; above them a closely united pair of first marginal plates . . . . . *Freyellaster* FISHER

- b<sup>2</sup>. No syzygy between first and second adambulacral plates nor between

the upper part of second and third ambulacral plates; no marginal plates directly above the first pair of adambulacral plates which not united except sometimes by the proximal ends; outer ends of mouth plates project dorsally behind the first pair of adambulacrals; dorsal skeleton of ray composed of a uniform armor of thin spiniferous more or less overlapping plates as in *Freyellaster* ..... *Freyella* PERRIER

### Genus *Odinia* PERRIER

*Odinia*: PERRIER, 1885, p. 9. Type, *O. semicoronata* PERRIER.

The genus has not previously been recorded in Japanese waters. Two forms of *Odinia* are described in this paper.

*Diagnosis.* Rays numerous; disc elevated above the level of arm base; disc plates thin, loosely imbricated or isolated; disc and genital region of ray with numerous conspicuous papulae; genital region with transverse skeletal arches with spines; intercostal region with thin plates, spineless or spiniferous; rays with regular transverse lateral comb of seven conspicuous slender spines; adambulacral plates higher than long, with single prominent subambulacral spines frequently with truncate or spatulate tips; mouth plates broad, fan-shaped; first three to seven or eight pairs of adambulacral plates united in each interradius, above them similarly the marginals joined; a syzygy between first and second adambulacral plates.

#### Key Japanese species of *Odinia*

Complete costae about 10; lateral combs with 3 or 4 long slender spines; suboral spines present or absent.

- a<sup>1</sup>. Disc plates very loosely imbricated; combined width of oral margin of mouth plates about same as long as the median sutural length; first 4 pairs of adambulacral plates united in interradius; median costal spines fairly developed proximally; suboral spines present ..... *sagamiana*
- a<sup>2</sup>. Disc plates rather isolated; combined width of oral margin of mouth plates broader than the median sutural length; first 7 or 8 adambulacral plates united in interradius; median costal spines rudimentary; suboral spines absent ..... *japonica*

#### *Odinia pacifica* forma *sagamiana* n. forma<sup>1)</sup>

(Pl. XII, figs. 1 & 2)

The present species has an intermediate appearance between

1) The form is labeled by late Prof. S. Goto as *Odinia sagamiana* n. sp.

two species, *pacifica* and *penichra*, and more closely related to the former. The measurements are given below.

Rays in number	R	r	Locality	Depth	Collection
17	166 mm	16 mm	Misaki (Sengenzuka)	450 fms	S. Goto
16	195 mm	15 mm	Misaki (Okinose)	300-400 fms	S. Goto

*Diagnosis.* Rays 16 to 17; disc plates irregular, very loosely imbricated, each with 1 to 3 spinelets; 10-13 complete costae; pro-

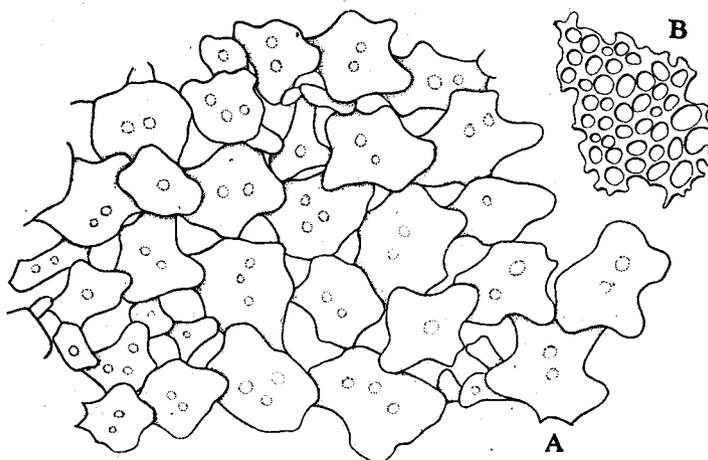


Fig. 1. *Odinia pacifica* forma *sagamiana*: (A) Skeletal structure of disc, 12 $\times$ ; (B) perforated spineless plate, 120 $\times$ .

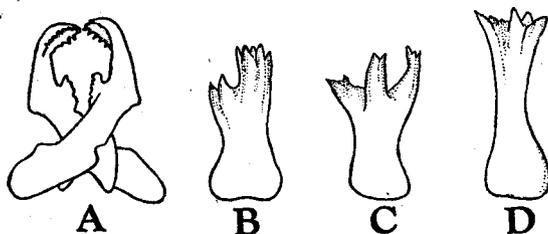


Fig. 2. *Odinia pacifica* forma *sagamiana*: (A) crossed pedicellaria on disc, 180 $\times$ ; (B)-(D) disc spines, 25 $\times$ .

ximal ones rather inconspicuous, irregular, each with about 10 slender spines; a number of intercostal spines in genital inflation; 3 or 4 prominent spines in a lateral comb; adambulacral plates each with

a perpendicular subambulacral spine and an aboral furrow spinelet, often 2 or 3; mouth plates each with 4-5 spines and 1 or 2 suboral; combined width of oral margin of mouth plates about same as long as the median sutural length; 4 pairs of postoral adambulacral plates united.

*Description.* Disc small, circular, convex, flat-topped, with round outline. Plates slightly swollen, irregular shaped, very loosely imbricated, each bearing 1 to 3 spinelets with several minute pointed tips. Scattered among them numerous minute crossed pedicellariae and these spinelets also bear several pedicellariae on their sides. Papulae conspicuous, uniformly distributed, generally one to each area.

Rays long and slender, fairly narrow at base, prominently swollen into the genital inflation just beyond the base. After the genital region the ray becomes slender, gradually tapering. Complete costae extend about one-thirds the length of ray, 10-13 in number, then the median portion becomes rudimentary and disappearing. Those on the proximal genital inflation are rather irregular, not conspicuous. Costae with spaced conspicuous slender spines, about 10 in number, of which 2 or 3 on each side of ray being conspicuously longer than the median. In the distal half portion of ray the median spines disappear and only 3 or 4 prominent sharply pointed lateral spines persist. In the genital region the innermost lateral spines are shorter than the adambulacral spines, but are much longer in the distal portion of ray. Distally the innermost spine of the lateral transverse comb is the longest, about 5-6 mm long, and the 4th or 5th, if present, are considerably short. These spines are each sheathed in a thin skin beset with numerous minute crossed pedicellariae. Intercostal areas paved with small thin, loosely imbricated plates, and a number of them in the midradial portion of the genital inflation have a small spine similar to the median costal spines in size and form. With reduction of costae, these plates become thin and discontinuous, and then disappear, and ambulacral ridge clearly visible through the thin dorsal integument. Though invisible by naked eye, there are observed numerous microscopic perforated plates in the integument, which are probably the rudiments of the plates. Papulae and minute crossed pedicellariae uniformly distributed in the proximal portion of ray, gradually decreasing in number distad, and the pedicellariae have a tendency to arrange in transverse bands.

Adamulacral plates fairly prominent, a little higher than long, each bearing a large perpendicular subambulacral spine, those in the genital region being the longest, about 3.5 mm long, decreasing in length distad. The spines are compressed at the distal half, the tip being truncate or shallowly grooved at the outer part. The outer side of spines is covered with a mebrane beset with numerous minute crossed pedicellariae, but the inner side is devoid of the organ. At the aboral end of each plate, facing furrow, is found a small spinelet with several crossed pedicellariae; occasionally 2 or 3 spinelets pre-

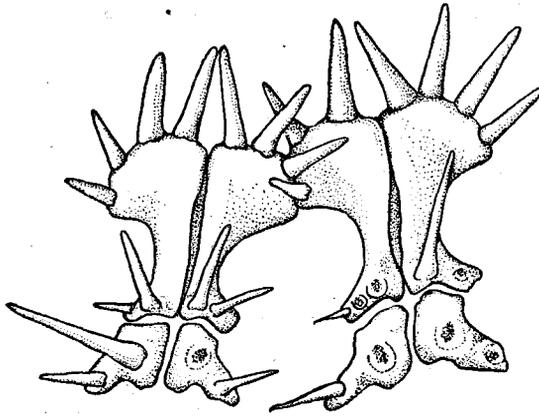


Fig. 3. *Odinia pacifica* forma *sagamiana*: Mouth plates and first adambulacral plates, the pedicellariae not shown, 8 $\times$ .

sent in the proximal portion of ray, arranged one over another. It must be noted that in newly regenerated rays (about 30 mm long) the furrow spinelets are entirely lacking. Mouth plates deeply excavated at furrow margin, each with an expanded curved oral margin and a less expanded margin adjacent to first adambulacral plate. The combined width of the oral margin of the plates is about same as long as the median sutural length, and the lateral oral expansion tends to fuse with that of the opposite plate. On the oral free margin of plate are 3 subequal bluntly pointed oral spines and 1 or 2 smaller spines on the lateral process. At the aboral end of plate exists a single suboral spine, but occasionally double which subsimilar to or a trifle longer than the oral spines on the lateral process. Aboral furrow spinelets mostly present. These spines bear each a small tuft of minute crossed pedicellariae at the tip. First 3 or 4 pairs of

adambulacral plates are united in each interradius, and above them the marginals are similarly joined.

Madreporite rather small, situated on the rounded margin of disc.

Gonads two to each ray, not in series. The colour in life is beautiful orange according to the label in the bottle.

*Locality.* Misaki, 300–450 fathoms.

*Remarks.* The present form resembles *O. penichra* from the Philippine Sea, but differs in having less conspicuous costae; a considerably stout suboral spine and furrow spinelets; more often two or three spines in a disc plate than one; adambulacral furrow spinelets more developed, sometimes 2 or 3 spinelets found. On the other hand the species more closely resembles *O. pacifica* from the Hawaiian Islands, but differs in having disc spinelets similar to those of *O. penichra*, and oral spinelets a trifle more longer and stouter and furrow spinelets more developed.

*Odinia austini* forma *japonica* n. forma

(Pl. XII, figs. 3 & 4)

*Diagnosis.* Rays 17 to 19, very long and slender; disc plates small, spaced, each with 1 to 3 spinelets; complete costae about 10; median costal spines poorly developed; 3 or 4 prominent spines in a lateral comb; no intercostal spines; adambulacral plates each with a subambulacral spine and an aboral furrow spinelet; mouth plates each with 3 or 4 oral spines; suboral spines absent, but if present, very rudimentary; aboral furrow spinelets absent; oral margin of united pair of mouth plates wider than the median sutural length; first 7 or 8 adambulacral plates united in interradius.

*Description.* The measurements are as follows:

Rays in number	R	r	Locality	Depth	Collection
18	415 mm	25 mm	Misaki	350 fms	S. Goto
18	390 mm	24 mm	Misaki	—	S. Goto
19	—	26 mm	Misaki	—	S. Goto
17	—	27 mm	Suruga Bay	200 M	Soyômaru

Disc circular, elevated above the level of arm base, flat-topped. Plates small, isolated, mostly roundish or elliptical in contour, each bearing 1 to 3 very minute spinelets, about 0.2 to 0.4 mm long. Rays

very long and slender, rather narrow at base, inflated into genital region, then gradually tapering to the tip. Pedicellariae and papulae numerous, the former more or less forming transverse bands. Costae rather poor, about 10 completed, about 5–7 mm apart, then the median portion becoming rudimentary. In some rays costae alternately placed, not meeting at the midradial portion, except the proximal 2 or 3 costae. Intercostal areas paved with thin irregular shaped spineless plates, but occasionally those on the median portion of ray become large and are arranged transversely showing somewhat costal appearances. The plates are reduced distad and ambulacral ridge visible through the thin integument. Costal spines long and slender, sharply pointed; the median spines are poorly developed, and even in complete

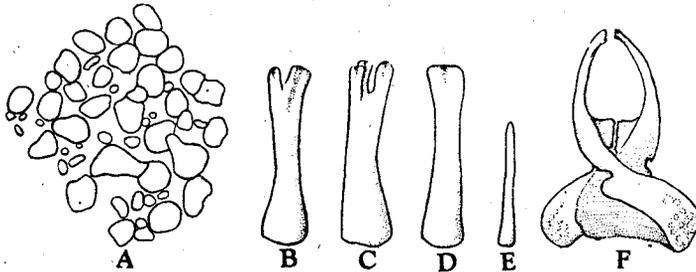


Fig. 4. *Odinia austini* forma *japonica*: (A) disc plates, 5 $\times$ ; (B)–(C) proximal subambulacral spines, 5 $\times$ ; (D) disc spine, 55 $\times$ ; (E) disc spine, 55 $\times$ ; (F) crossed pedicellaria on disc, 120 $\times$ .

costae the occurrence of the spines are quite aberrant. Four lateral spines on each side of ray are usually prominent, forming a lateral comb; those in genital region of ray shorter than in the middle or distal portions; those adjacent to adambulacral plates generally a little shorter than the second ones; the second or the third longest and the fourth a little shorter than or subequal to the first. In the middle of ray the first spines of lateral combs measure about 8–9 mm in length, the second 11–12 mm, the third 13–19 mm, the fourth about 8 mm. In the distal portion of ray the 3 lateral spines are subequal, about 10 mm long, and when the fourth spines be present, they are a little shorter. In the proximal portion of ray, the first spines measure about 6 mm, the second 6–6.5 mm, the third 4–5 mm, the fourth about 4 mm. These spines are heavily covered with a thin integument crowded with numerous crossed pedicellariae.

Adambulacral plates prominent, higher than long, but longer than high in the very distal portion of ray. Subambulacral spines single,

stout, those at the genital region being longest, about 5 mm long. The tips are compressed, truncated and grooved at the outer side, and occasionally bi- or trifid. The spines decrease in size distad, the distal ones being very small, acicular, about 1–1.5 mm long, though the adjacent costal spines being about 10 mm long. The outer side of spines is covered with numerous minute crossed pedicellariae. At the aboral end of each plate is a single small furrow spinelet with several pedicellariae near the tip, but on 3 postoral adambulacral plates and those near the arm tip the spinelets are usually absent. Mouth plates much excavated at furrow margin, each with an expanded curved oral margin and a less expanded margin adjacent to

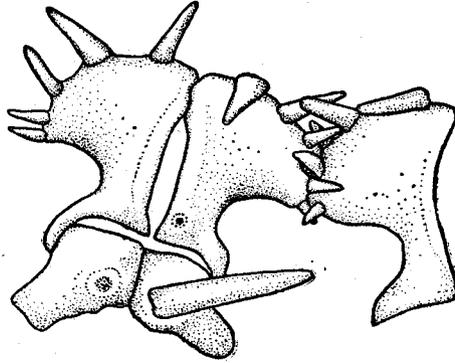


Fig. 5. *Odinia austtini* forma *japonica*: Mouth plates and first adambulacral plates, the pedicellariae not shown. 8x.

the first adambulacral plate. The oral lateral expansions opposite are not fused, and the combined width is wider than the median sutural length of plates. The plates bear 5 or 4 short oral spines, the median 3 mostly bearing crossed pedicellariae. Suboral spines usually absent, but in some specimens the spines often occur at random, though being short and small. Aboral furrow spines of mouth plates usually absent. Seven or 8 postoral adambulacral plates are joined together in each interradius and above them the marginal plates are similarly united.

Madreporite small, situated on the rounded margin of disc.

Gonads two to each ray, not in a series.

*Localities.* Misaki and Suruga Bay, 200 meters to 350 fathoms.

*Anatomical note.* Stomach much folded, subcircular, the pyloric portion being more or less subpentagonal. Pyloric caeca in pair about

45 mm long in a ray (400 mm); the median cavity is not much spacious, tube-like in form, with divergent caeca. The dorsal side of stomach is sharply constricted near the centre and communicated with a rather spacious rectal sac opening to anus. Tiedemann's bodies, two in each interradius, except the madreporic region, where the organ absent. Polian vesicles absent. Stone canal running along the adjacent ambulacral ridge, opening into the ring canal at the radius. Membraneous septum present in each interradius, except the madreporic interradius, where the septum covers the space sur-

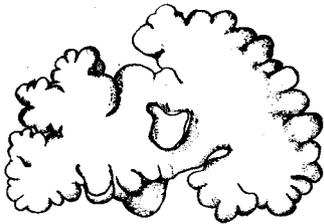


Fig. 6. *Odinia austini* forma *japonica*: Rectal sac, 3 $\times$ .

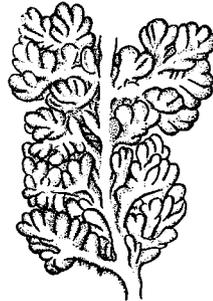


Fig. 7. *Odinia austini* forma *japonica*: A portion of hepatic caecum, 5 $\times$ .

rounded by the stone canal, the adjacent ambulacral ridge and the margin of peristome, and containing the axial organ.

*Remarks.* In general appearance the present species closely resembles *Odinia austini* Koehler, but differs in having adambulacral furrow spinelets and occasionally suboral spinelets with pedicellariae. Pedicellariae on disc not rare as described for *austini*. The furrow spinelets, however, may possibly be gradually formed with growth, as was observed in *O. pacifica* forma *sagamiana*. If so, it is considerably doubtful whether the characteristic is really reliable in the identification of *Odinia*, especially in such a case that the specimens to compare are much different in size as in the present case. The writer, however, has not the material enough to discuss about the matter, so he reported his specimens as a forma of *austini*. The present species differs from *O. pacifica* and forma *sagamiana* in having longer rays; isolated disc plates; in lacking intercostal spines; in the form of mouth plates and the armature; in having 7 or 8

united pairs of postoral adambulacral plates instead of 3 or 4. The mouth plates differ also from those of *O. clarki* and *O. penichra* in form and armature.

*Parabrisinga* n. gen.

*Diagnosis.* In general appearance, resembling two genera, *Craterobrisinga* and *Brisinga*, but differing in having separated interradiial (first) adambulacral plates, though the marginal plates being closely united by their lateral faces. Rays 12, very long and slender, R about 33 r. Costae numerous; genital region extended; a syzygy between first and second adambulacral plates and between the upper parts of second and third ambulacral plates; adambulacral plates with single subambulacral spines, the proximal ones being modified at the tip; single furrow spinelets; lateral spines long and slender.

Type, *Parabrisinga pellucida* n. sp.

*Remarks.* The present species is related to the following four genera, *Brisinga*, *Craterobrisinga*, *Astrostephane* and *Brisingella*, in the dorsal skeleton of ray which forms spaced costae composed of elongated, more or less compressed, overlapping plates projecting well above the level of the intervening integument, and bearing small spinelets; in the lack of intercostal spineless immersed plates. In having numerous lobes of gonads in a series along either side of ray, the genus is related to the two genera, *Brisinga* and *Craterobrisinga*, especially more closely related to the latter in having proximal subambulacral spines with modified, truncated tip. The present genus, however, distinctly differs from the two genera in the feature of adambulacral plates in interradius; the first pair of adambulacrals are not joined, but isolated, though above them the marginal plates are closely united by their lateral faces. In having such separate adambulacral plates the genus is related to *Brisingella*, but differs in the structure of the marginal plates which do not form inverted Y-shape; further more in having extended gonads. The structure of first interradiial adambulacral plates and the marginals seems not to depend upon the number of rays; in species of *Craterobrisinga* and *Astrostephane* having fewer rays than 12 (less than in *Parabrisinga*), the first adambulacral plates are not separated and also *C. albertii* with 9 rays (less than in *Brisingella*) has not separated first ad-

ambulacral plates or inverted Y-shaped marginals as might be expected if the structure is due to the number of rays alone. On the other hand, *Craterobrisinga* is separated from *Brisinga* in having crowded adambulacral armature and subambulacral spines of proximal plates with modified tips. But there is an aberrant form, such as *C. evermanni*, in which the modified tip of proximal adambulacral spines is not so heavy as in typical form, nor is the adambulacral armature so crowded. The present Japanese form has a similar adambulacral armature to that of *C. evermanni*. The writer, therefore, doubts if the adambulacral feature is fully a reliable generic character. It is probable that the two genera is united into the genus, *Brisinga*, and further the writer's *Parabrisinga* will be also reduced to the genus, when *Brisinga* includes forms having the separated first adambulacral interradial plates as in *Brisingella*.

*Parabrisinga pellucida* n. sp.

(Pl. XIII, Figs. 1 & 2)

Three specimens in a bottle were examined. The measurements are as follows:

Rays in number	Disc in diameter	Rays in length	Locality	Depth	Collection
12	23 mm	—	Probably Misaki	350 fms	Bashford Dean, 1905
12	24 mm	—	"	"	"
12	22 mm	345-370 mm	"	"	"

*Diagnosis.* Resembling in general appearance *Craterobrisinga evermanni*, but differing in the structure of the first interradial adambulacral plates. Disc plates small, isolated, with single spinelets, no pedicellariae on disc. Rays 12, very long and slender; costae numerous; very small costal spinelets; lateral spines long and delicate; adambulacral plates each with a long subambulacral spine and a furrow spinelet (distally absent); mouth plates each with 1 or 2 oral spinelets, a suboral and an aboral furrow spinelet. R about 33r.

*Description.* Disc rather small, slightly elevated above the base of rays; dorsal surface subplane, covered with small acicular, skin-covered spinelets, 0.7-1 mm long, spaced about 0.5 mm or less. Dorsal plates small, roundish, each with a single spinelet on the boss. There is no pedicellaria among spinelets.

Rays long and slender; genital regions not conspicuously inflated. Dorsal integument thin, translucent. Costae prominent, narrow, composed of overlapping oblong slightly compressed plates forming elevated arches; 26 to 29 in number, about 4 mm apart; generally opposite to every alternate adambulacral plates. The costae begin

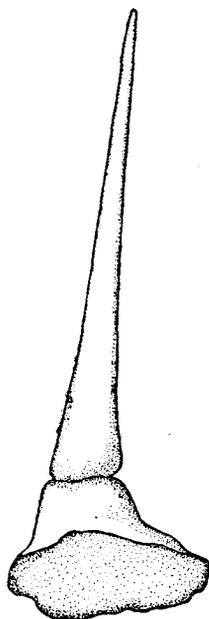


Fig. 8. *Parabrisinga pellucida*: Disc plate and spine, 80 $\times$ .



Fig. 9. *Parabrisinga pellucida*: Crossed pedicellaria, 400 $\times$ .

nearly at the base of ray, the first 2 or 3 being inconspicuous, sometimes more crowded. In the proximal portion of ray the costae are occasionally incomplete. The ridges are thickly covered with minute crossed pedicellariae, apparently free from prickles or spinelets. Similar narrow saccular transverse bands of crossed pedicellariae occur also in intercostal areas, one for each. These bands are observed throughout all the length of ray, even after costae disappearing. Lateral spines corresponding to alternate adambulacral plates, long, slender and tapering, about 6 mm long in the proximal portion of ray, about 12–15 mm long in the middle, about 10 mm long in the distal, where adambulacral spines about 2 mm long and furrow spine-

lets absent. These spines are sheathed in thin membrane beset with numerous crossed pedicellariae.

Ambulacral furrow rather wide, shallow. Adambulacral plates shorter than broad at base, then becoming longer than broad distad.

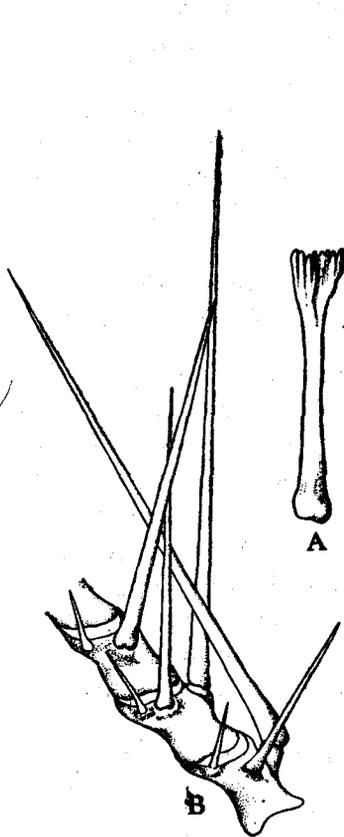


Fig. 10. *Parabrisinga pellucida*: (A) proximal adambulacral spine, 5 $\times$ ; (B) adambulacral plates in the middle portion of ray, the pedicellariae not shown, 5 $\times$ .

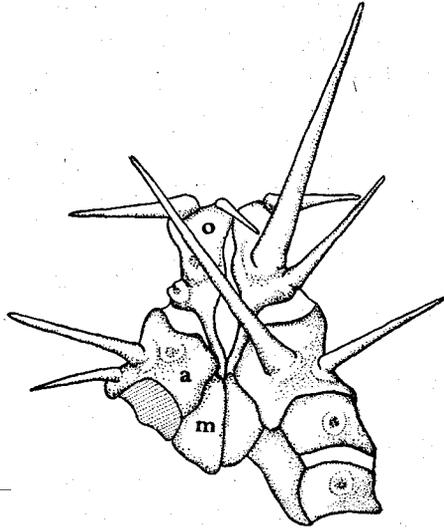


Fig. 11. *Parabrisinga pellucida*: Ventral view of mouth plates, adambulacral plates and marginal plates, 7 $\times$ ; a adambulacral plate, m marginal plate, o mouth plate.

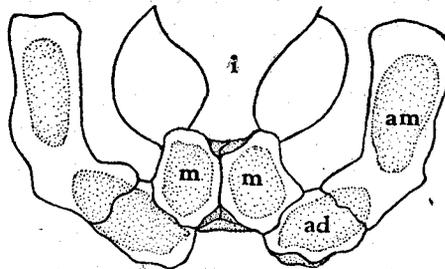


Fig. 12. *Parabrisinga pellucida*: Lateral view of plates of interbranchial angle after removal of rays, 7 $\times$ ; ad adambulacral plate, am ambulacral plate, i interradianal plate, m marginal plate.

Armature more or less related to that of *C. evermannii* of Hawaiian Is., consisting of 2 spines in an oblique transverse series along the aboral margin of plate. The inner, furrow spinelets, are much slender

and acute, sheathed in membrane with minute pedicellariae, about 2 mm long at the base of genital region, then reducing distad in size; beyond the middle portion of ray they are of irregular occurrence, and apparently entirely absent in the distal one-thirds the length of ray. Subambulacral spines articulated to small tubercles, situated more or less near the aboral end of plates, long and tapered, 5-7 mm long in the proximal portion of ray, 4-2 mm long in the distal. The subambulacral spines on the plates with lateral spines are slightly shorter than those on the alternate plates without lateral spines. About 10 proximal subambulacral spines, about 6 mm long, stout, with truncate modified tip. Mouth plates deeply excavated on the side toward furrow, each with an oral spine at the adoral furrow corner, about 2 mm long and occasionally with a shorter second spine on the middle of the oral margin. Suboral spines single, stout, tapering, about 4-5 mm long and furrow spines single, about 2-2.5 mm, situated near the furrow margin behind the suboral spine. First adambulacral plate usually with 1 subambulacral spine and 2 furrow spinelets. All these spines bear numerous minute crossed pedicellariae attached to a thin investment expanded into a flap at tip. The first pair of adambulacral plates are separated by the prolongation of combined mouth plates, and the interradial first marginal plates closely united by their lateral faces. The first and second adambulacral plates are well as the upper part of the second and third ambulacral plates are united by non-muscular symphysis.

Madreporite roundish, tubercular, situated near the margin of disc.

Numerous lobes of gonad extend in a series on either side of ray, reaching about one-thirds the length of ray.

*Locality.* Probably Misaki, 350 fathoms.

#### Genus *Brisingella* FISHER

*Brisingella*: FISHER, 1917, p. 427; . . . ., 1919, p. 523; . . . . 1928, p. 12.

Type, *Brisinga fragilis* FISHER.

From Japanese waters only one species, *B. armillata* (Sladen)<sup>1)</sup> has previously been recorded. The writer will add one more species, *B. pannychia* Fisher, as a Japanese member of the genus.

1) Fisher ('19, '28) briefly pointed out that Sladen's *armillata* probably belongs to *Brisingella*.

**Diagnosis.** Differing from typical *Brisinga* in having only one gonad on each side of ray; in having first interradial adambulacral plates separated by the outer ends of combined mouth plates; the marginals joined only by the adoral ends, forming an inverted Y-shaped structure with interradial plate. Rays mostly 10 in number, slender, easily deciduous; a syzygy between first and second adambulacral plates and also between the upper part of second and third ambulacral plates; adambulacral plates longer than broad, with few or no furrow spinelets and one sharp slender subambulacral spine. Mouth plates small, the oral margin being not much expanded. Tube-feet in two ranks, with single ampulla.

**Key to Japanese species of *Brisingella***

- a1. Costae numerous, about 30 or more; integument of ray without spinelets; mouth plates usually with furrow spinelets ..... *pannychia*  
 a2. Costae less than 15; a few prickles in integument of ray; mouth plates without furrow spinelets ..... *armillata*

***Brisingella pannychia* FISHER**

(Pl. XIII, figs. 3, 4, 5, 6)

*Brisingella pannychia*: FISHER, 1928, p. 18, pl. 8, figs. 4, 4a.

The writer examined a single specimen of typical *Brisingella* resembling two species, *B. fragilis* (Fisher) from the Hawaiian and Philippine Islands and *B. pannychia* Fisher from Bering Sea. The armature of adambulacral and mouth plates is more related to that of *B. fragilis*, rather than in *B. pannychia*, while in the condition of disc spinelets and in the lack of intercostal arches the Japanese specimen agrees with *B. pannychia*. According to Fisher ('28) the disc spinelets in *pannychia* are fully twice as long as those in *fragilis* and much less numerous, thus the identification. The Japanese *pannychia* seems to be a more related form to *fragilis* than in *pannychia* of Bering Sea.

**Diagnosis.** Disc rather small, rays 10; R 195 mm, r 10 mm, R=19.5r. Costal region long, with numerous widely spaced costae. Disc spinelets isolated, longer and less numerous than in *fragilis*, longer and more numerous than in *pusilla*; adambulacral armature consisting of 1 long subambulacral spine and 1 or 2 furrow spinelets; mouth plates each with 2 (3) oral spinelets and 1 or 2 aboral furrow spinelets and 1 suboral.

*Description.* Disc 20 mm in diameter, rays 10 in number, 195 mm in length. Disc depressed, the dorsal surface being as same as the level of arm base. Disc plates small, roundish, spaced about the length of the spinelets (0.45–0.5 mm long). Disc spinelets single, delicate, ending 2 or 3 minute points, and covered with a thin membrane. Around the base are scattered a few minute crossed pedicellariae.

Rays long and slender, narrow at the base, about 5 mm in width; gradually expanding in genital region, the widest part being about 7.5 mm wide at about 40 mm apart from disc, the outer part very gradually tapering to the tip. Integument of ray thin, subtranslucent.

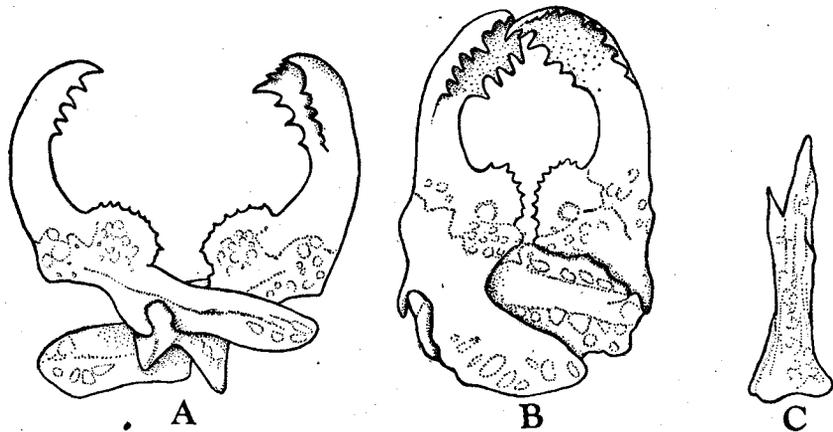


Fig. 13. *Brisingella pannychia*: (A) and (B) crossed pedicellariae, 600 $\times$ ; (C) dorsal spine, 70 $\times$ .

Costate prominent, narrow, composed of elongated overlapping plates, projecting well above the level of the intervening integument; about 30 in number, extending to the proximal two-thirds of ray, spaced 3–6 mm in each. Costae bearing small, spaced sharp spinelets, 0.8–0.9 mm long, 1 or 2 for a plate, 15–18 spinelets on each proximal costa. Costae each correspond to every alternate adambulacral plates, occasionally to every third plates, and are invested with a saccular membrane closely crowded with minute crossed pedicellariae. Similar arches of pedicellariae parallel to costae observed in intercostal areas, generally 1 to each area, frequently 2 or 3 according to the size of areas. In the distal half of ray, in which costae are completely disappeared, the succular bands of crossed pedicellariae

may be regularly observed at the positions corresponding to costae and the interval. Lateral spines long and slender, corresponding to each costa, about 9 mm long at the 11th costa corresponding to the 22nd adambulacral plate. The spines are membrane-covered, thickly beset with minute crossed pedicellariae.

Ambulacral furrow wide and shallow; adambulacral plates longer than broad. The armature is composed of 1 short, slender, acute adoral furrow spinelet, about 1.3 mm long proximally and 1 much longer and stouter subambulacral spine located more or less aborally, about 6.5–7 mm long proximally, where the lateral spines

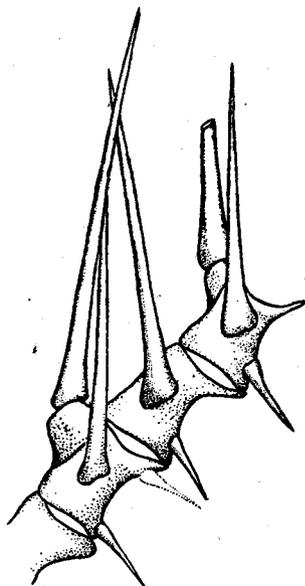


Fig. 14. *Brisingella pannychia*: The 19th to 22nd adambulacral plates, the pedicellariae not shown, 7 $\times$ .

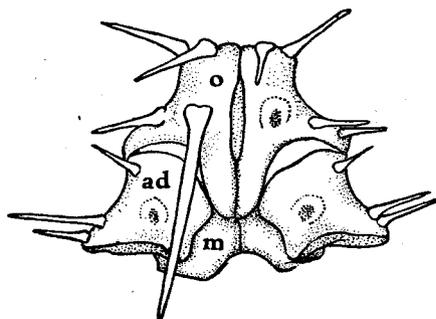


Fig. 15. *Brisingella pannychia*: Ventral view of mouth plates and adambulacral plates and marginal plates, 8 $\times$ ; ad adambulacral plate, m marginal plate, o mouth plate.

are about 9 mm long. The armature differs from that of Fisher's *pannychia* in the absence of aboral furrow spinelets, but the furrow spinelets seem to be variable in number: In the writer's specimen the spinelets are not usually single; in the proximal portion of rays often 2 spinelets (aboral and adoral) occur, rarely even 3 (2 adoral and 1 aboral); in a ray the 2 furrow spinelets are observed in the

greater part of ray, except the distal portion. These spines are membrane-sheathed, beset with numerous crossed pedicellariae. Mouth plates similar in form generally to those of *fragilis*, *pannychia* and *pusilla*, not deeply excavated on the furrow side, not expanded in the adoral furrow corner, but the aboral furrow corner is much extended toward furrow. The adoral margin of united pair of plates is nearly straight, not forming a curved expanded margin. Armature consisting of 2 short, slender oral spines situated nearer the furrow than the median suture, rarely 3 as in *fragilis*. Aboral furrow spinelets mostly 2 as in *fragilis*, but often 1 as in *pannychia*. Suboral spines single, long and considerably stout, about 3.5 mm long. These spines are sheathed in membrane with numerous pedicellariae. There is a syzygy between the first and second adambulacral plates and between the upper part of second and third ambulacral plates. First adambulacral plates not joined, but separate; first marginal plates united only by their inner (adoral) ends, forming an inverted Y-shaped structure with the interradial plate. Tube-feet in 2 ranks, with single ampullae.

Madreporite roundish, slightly tubercular, situated near the margin of disc.

*Locality.* Cape Tonin, off eastern coast of southern end of Saghalien Island, in Okhotsk Sea (Albatross, 1906, Station 5019); 192 fathoms; bottom character brown mud, black sand, pebbles.

*Distribution.* Known from Bering Sea and the locality above stated.

### *Brisingella armillata* (SLADEN)

*Brisinga armillata*: SLADEN, 1889, p. 1889, p. 608, pl. 110, figs. 1-3.

No specimens are represented in the collections at the writer's hand. The present species seems to be a member of *Brisingella*, but being unfortunate, Sladen ('89) does not give the description of the gonads and the skeletal structure of interradial angle.

*Diagnosis.* Rays 7 in number; R 240 mm, r 9 mm, R>26r, breadth of arm base 4.5 mm. Disc small, subdepressed, covered with exceedingly delicate semitransparent membrane, the plates being isolated, each with a minute spinelet. Rays covered with thin translucent membrane; in genital region present costae crowded with minute pedicellariae; a few isolated spicules may be found in intercostal areas. Lateral spines single, conspicuous, on every second

and third adambulacral plates, encased in a delicate membranous sheath crowded with minute crossed pedicellariae. Adambulacral armature composed of 2 furrow spinelets (aboral and adoral) with a few relatively large pedicellariae; and a perpendicular subambulacral spine crowded with minute pedicellariae. Mouth plates each with 2 oral spines and a suboral spine crowded with pedicellariae.

*Distribution.* Known from off coast of Japan, south of Kawatsu, 1875 fathoms; character of bottom blue mud.

### Genus *Freyellaster* FISHER

*Freyella*: FISHER, 1917, p. 428.

*Freyellaster*: FISHER, 1918, p. 104; . . . ., 1928, p. 21. Type, *Freyella fecundus* FISHER.

The genus has not yet been recorded in Japan. Two new form of the genus will be reported in the paper.

*Diagnosis.* Brisingidae with numerous serial gonads along either side of ray; plates of genital region thin, spiniferous, forming a continuous covering; not segregated in independent skeletal arches separated by an interval without plates; no papulae; first pair of adambulacral plates as well as the marginals closely joined together, 4 in all; a syzygy between first and second adambulacral plates and between second and third ambulacral plates; primary apical plates not conspicuous.

#### Key to Japanese species of *Freyellaster*

- a<sup>1</sup>. No prominent dorsal spines on rays; lateral spines opposite to alternate adambulacral plates; modified subambulacral spine with truncate, circular flaring tip . . . . . *fecundus* forma *ochotensis*
- a<sup>2</sup>. Prominent dorsal spines on rays; lateral spines opposite to each adambulacral plate; modified subambulacral spine with truncate, compressed broad tip with 2-5 knobs; 2 sorts of pedicellaria, major and minor . . . . . *intermedius*

#### *Freyellaster fecundus* forma *ochotensis* n. forma

(Pl. XIII, figs. 7, 8, 9, 10)

A single 16-rayed specimen was examined in a badly condition. All rays are separated from disc, no rays complete; the longest ray 160+mm in length, disc 30 mm in diameter.

*Diagnosis.* Resembling *F. fecundus* Fisher, differing in having more numerous rays (13 in the type) and adambulacral plates with adoral furrow spinelets as well as the aborals.

*Description.* Disc integument tight, crowded with uniform, solitary small sharp spinelets encased in membrane, about 0.6–0.7 mm long. Plates small, roundish, isolated, about 0.2–0.3 mm in diameter; no pedicellariae among them. No rays complete; dorsal integument rather thin, the delicate plates covering the extensive genital region being invisible, except in dry condition. These plates are thin, irregular in contour, various in size, loosely overlapped by the edge; those in the midradial portion of ray are more closely crowded than on the

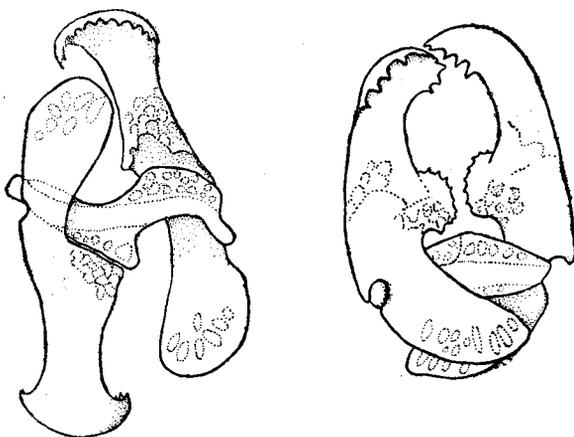


Fig. 16. *Freyellaster secundus* forma *ochotensis*: Crossed pedicellariae, 400 $\times$ .

sides of ray. Extending upward from lateral plates a few plates are stouter than the others, sometimes reaching half way to the median radial line. These plates are armed with small acicular spinelets sheathed in thin membrane giving them a blunt appearance, 1 to 3 to a plate. The spinelets are slightly shorter and more widely spaced than in those on disc. Saccular bands of minute pedicellariae inconspicuous on genital region, though scattered in the lateral side of ray; but then after they become conspicuous, each arising upward from lateral plates and between them, and the integument is semi-transparent, without spinelets. Genital regions not conspicuously inflated, gonads numerous, in a series along either side of ray.

Lateral spines long and slender, sheathed in membrane beset with numerous minute pedicellariae, about 12 mm long in the middle of genital region. These spines are articulated on small lateral plates partly fused to the lateral face of alternate adambulacral plates, but often on every third plates.

Ambulacral furrow relatively wide, adambulacral plates about as long as wide. The armature consists of a transverse series of spines on the aboral margin of plate; 2 or 3 furrow spinelets and 1 subambulacral near the base of ray. The innermost furrow spinelets measure

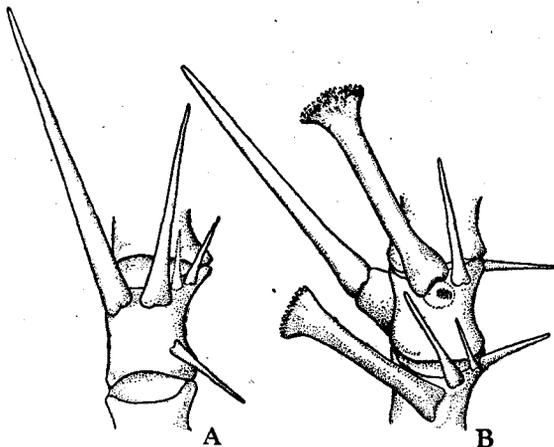


Fig. 17. *Freyellaster fecundus* forma *ochotensis*: (A) the 19th to 21st adambulacral plates, the pedicellariae not shown, 5 $\times$ ; (B) the 9th to 11th adambulacral plates, 5 $\times$ .

2–2.5 mm in length and the subambulacral about 4 mm, and when 3 furrow spines occur, the middle is shorter than the innermost. Proximal subambulacral spines, about 13 in number, about 5–6 mm long, have each a circular truncate, flaring tip with numerous minute points. A little apart from the base of genital region, there are usually adoral furrow spinelets similar to the aboral, so the armature is composed of 2 (3) aboral furrow spinelets, 1 adoral furrow spinelet and 1 long, tapering subambulacral spine (10–11 mm long). Mouth plates small, excavated on side toward furrow; the adoral and aboral furrow corner of plate being expanded laterally. The armature consists of 3 or 4 oral spines on the curved oral margin of plate, the innermost being the shortest, the rest graduated in size outerward; and a furrow spine

at the aboral lateral end of plate; 2 much heavier longer pointed spines on the ventral surface of plate, near the aboral end of plate, the inner (suboral spine) being stouter than the outer (second furrow spine). These aboral 3 spines are arranged in an oblique transverse series. The spines of mouth plate are all sheathed in membrane with numerous minute pedicellariae. First pair of adambulacral plates

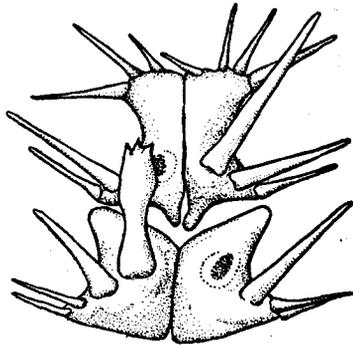


Fig. 18. *Freyellaster fecundus* forma *ochotensis*: Ventral view of adambulacral plates and mouth plates, the pedicellariae not shown, 7x.

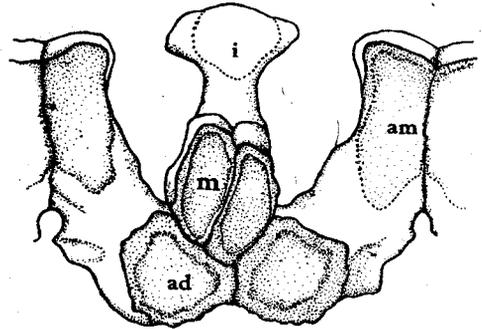


Fig. 19. *Freyellaster fecundus* forma *ochotensis*: Lateral view of plates of interbranchial angle after removal of rays, 8x; ad adambulacral plate, am ambulacral plate, i interradial plate, m marginal plate.

united by their lateral faces as well as the marginal plates immediately above them. An account of bad preservation of material, the writer could not well observe the nonmuscular symphysis between the first and second adambulacral plates and between the second and third ambulacral plates.

Madreporite suboval, situated near the margin of disc.

*Locality.* Okhotsk Sea, 440 fathoms; character of bottom black sand and gravel (Albatross, 1906, Station 5029).

#### *Freyellaster intermedius* n. sp.

(Pl. XIV, figs. 1, 2)

The present species generally resembles *Freyellaster spatulifera* Fisher from Macassar Strait, but differing in having conspicuous spines on the dorsal surface of ray. In this point the species is related to *F. echinata* (Sladen) from the Philippine Islands. The Japanese

form appears to be an intermediate from between *spatulifera* and *eechinata*, both above mentioned. A single specimen was examined; disc 25 mm in diameter, rays 14 in number, none completed, the longest being 80+mm long.

*Diagnosis.* *Freyellaster* having rather crowded thick ray-plates with a cluster of 2-7 spinelets and a prominent spine on many of them; disc spinelets solitary; about 20 proximal subambulacral spines with broad, truncate, compressed tip with 2-5 knobs; 2 aboral furrow spinelets proximally, but 3 spinelets in outer genital region, 2 of which aborally, the 1 adorally; lateral spines opposite to each ambulacral plate.

*Description.* Disc circular, flattened, slightly elevated above from the base of ray. Disc covered with a rather thick integument, crowded with subequal small, delicate, acicular, isolated spinelets sheathed in mebrane giving them an blunt appearance, about 0.3-0.5 mm long. Those around the anal aperture and on disc margin are slightly coarser. Among them are scattered no pedicellariae. Disc plates very small, granuliform.

The integument of ray is rather thin; rays slightly inflated in the genital region; gonads arranged in a series along either side of

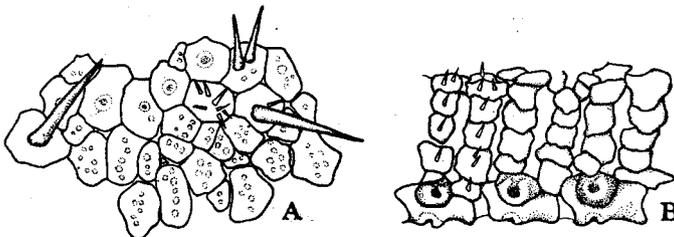


Fig. 20. *Freyellaster intermedius*: (A) dorsal view of skeletal structure of ray at the genital region, 5 $\times$ ; (B) lateral view of skeletal structure at the middle of ray, 5 $\times$ .

ray. The region is paved with rather large irregular, suboval, subtriangular, subhexagonal and subsquarish plates, each with a cluster of 2-7 small membrane-sheathed spinelets slightly longer than disc spinelets; no pedicellariae. The majority of them have a long slender, tapering spine articulated on the central tubercular eminence of plate, 2.5-4 mm long, except the arm base and ventral sides. The spines are each covered with a membrane invested with numerous minute

pedicellariae. In the ventrolateral portion of ray adjacent to adambulacral plates, these plates are imbricated a trifle more loosely than in the dorsal region and have a tendency to be arranged more or less in parallel transverse series, each corresponding to each lateral plate and interposing them; in the distal half portion of genital region, the plates show an appearance of low arches, but never forming independent arches. The spinelets of the arch are also arranged more or less in a transverse series. These arches are each furnished with a conspicuous transverse saccular band of minute crossed pedi-

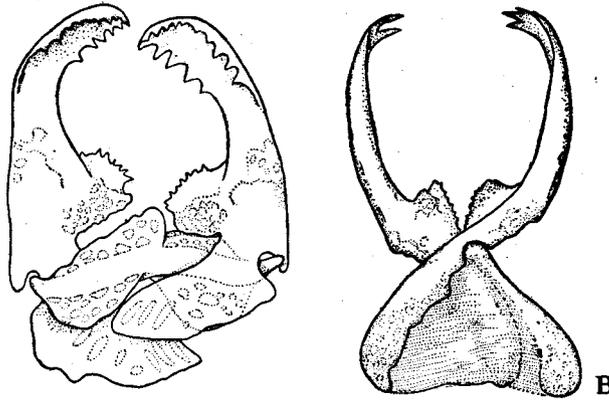


Fig. 21. *Freyellaster intermedius*: (A) minor pedicellaria, 450 $\times$ ; (B) major pedicellaria, 120 $\times$ .

cellariae. Lateral spines long and slender, beginning at the 7th or 8th adambulacral plates, opposite to each adambulacral plate, not to alternate adambulacrals as in *echinata*. The spines are each covered with a thin membrane beset with numerous minute crossed pedicellariae and about 13 mm long at the distal end of genital region.

Adambulacral plates wider than long proximally, then becoming longer than wide. At the basal portion of ray the armature consists of 3 spines along the aboral margin of plate. The innermost (aboral furrow spinelet) is shorter and smaller than the middle (second furrow spinelets) having a group of slender jawed major pedicellariae near the tip. The outermost spine (subambulacral spine) is perpendicular, much longer and stouter, and the first spines, about 20 2.5–4 mm long, except the ar mbase and ventral sides. The spines tips are broad, compressed, truncated, with 2–5 knobs. These spines

are membrane-sheathed, with numerous major and minor pedicellariae. In the distal half portion of genital region the subambulacral spines become long and tapering, about 12 mm long, and there is an adoral furrow spinelet with major pedicellariae in each plate as in *spatulifera*; thus the armature is composed of a subambulacral spine, 2 aboral furrow spinelets and 1 adoral furrow spinelet. These spines are invested in membrane, the aboral inner furrow spinelets being

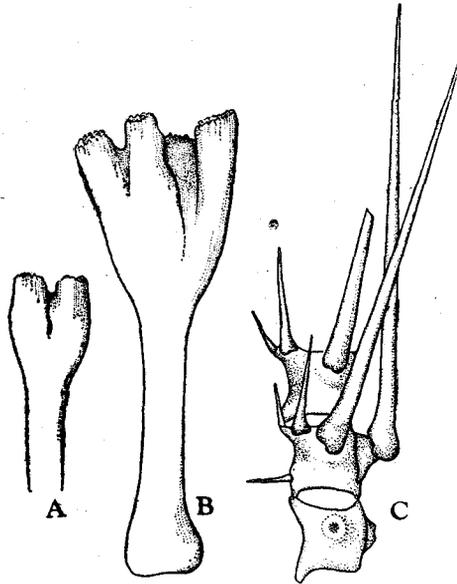


Fig. 22. *Freyellaster intermedius*: (A) and (B) proximal adambulacral spines, 12 $\times$ ; (C) adambulacral plates beyond genital region, 5 $\times$ .

mostly free from pedicellariae. In the distal half portion of genital region the major pedicellariae on subambulacral spines are much fewer than in the basal half, but the minor pedicellariae are more numerous than in lateral spines. Mouth plates small, each armed with 2 (3) oral spines and 1 aboral furrow spinelet and 1 suboral spine (about 6 mm) with a sublanceolate flattened tip. These spines are heavily invested with major crossed pedicellariae.

The first 3 adambulacral plates are united by their lateral faces, and directly above them the marginal plates are similarly joined; a nonmuscular symphysis between the first and second adambulacral plates and between the second and third ambulacral plates.

Madreporite situated near the margin of disc.

*Locality.* Albatross, 1906, Station 5084; Omaesaki 918 fathoms; character of bottom green mud, fine sand, Globigerina.

### Genus *Freyella* PERRIER

*Freyella*: FISHER, 1928, p. 24. Type, *Freyella spinosa* Perrier.

*Freyellidea*: FISHER, 1917, p. 429. Type, *Freyellidea microplax* FISHER.

The following diagnosis of the genus is given by Fisher ('28).

*Diagnosis.* Differing from *Freyellaster* Fisher in having only two gonads to each ray; in having a normal muscular symphysis between the first and second adambulacral plates; deficient in marginal plates entirely in the interbrachial angles; and in having the first adambulacral plates either joined, with tissue between or else separated nearly or quite to their proximal ends. A pair of very inconspicuous plates is attached to the lower end of the interradiial plate and the plates apparently look to be a portion of the interradiial plate. They really the extreme outer end of the mouth plates. They have the appearance of being separate plates because the inner end of the first pair of adambulacral plates nearly or entirely segregates them from the actinal or spine-bearing surface of the mouth plates. In those genera which have marginal plates in the interradius, this dorsal part of the mouth plate is entirely hidden by the marginals. Proximal subambulacral spines usually with modified tips.

### *Freyella pennata* SLADEN

*Freyella pennata*: SLADEN, 1889, p. 618, pl. 101, figs. 1-4.

The present species is not represented in the collections in the writer's hand. The species has not been examined, except the Sladen's description. So there is no way to determine whether this Challenger species belongs really to *Freyella* without knowing the disposition of gonads and skeletal structure of interbrachial angles; these characters not found in Sladen's description.

*Diagnosis.* Rays 10 in number; R 200-240 mm, r 11 mm, R 20r; breadth of ray at base 6 mm. Disc small, elevated above the level of arm base; rays delicate; disc and genital regions paved with thin and very delicate plates with 2-4 small spinelets, 0.6-0.7 mm long.

covered with a fleshy membrane; beyond the genital region the membrane becomes thin, translucent. The membrane is furnished with elongated saccular bands with minute pedicellariae. Lateral spines single, long and slender, situated on alternate adambulacral plates, covered with membrane beset with minute pedicellariae. Single large perpendicular subambulacral spines sheathed in membrane with minute pedicellariae; furrow spinelets 1 or 2 at the aboral end of plate, with 2 or 6 pedicellariae; mouth plates shield-shaped with a well-rounded margin adorally and subparallel sides; 3 or 4 oral spines; 1 suboral spine; 1 or 2 aboral furrow spinelets.

*Locality.* Off coast of Japan, south of Kawatsu, 1875 fathoms; character of bottom blue mud.

### Suborder ASTERIADINA FISHER

#### Family Zoroasteridae SLADEN

##### Key to Japanese genera of Zoroasteridae

Disc small, rays long, 5 in number; lateral plates forming regular longitudinal and transverse series; adradial plates present; adambulacral plates of 2 sorts, prominent and nonprominent.

- a<sup>1</sup>. Plates all covered with papilliform skin-covered spinelets; most of them with an enlarged spine; superambulacral plates absent .....

*Zoroaster* THOMPSON

- a<sup>2</sup>. Dorsal surface devoid of spines or any conspicuous armature, covered with a smooth tough membrane in sharp contrast to the ventrolateral areas with squamiform fleshy spinelets and enlarged spines; superambulacral plates present, the first being conspicuously enlarged into a buttress which connects upper end of first ambulacral plate with the body wall in interradial angle ..... *Cnemidaster* SLADEN

#### Genus *Zoroaster* WYVILLE THOMSON

*Zoroaster*: THOMPSON, 1873, p. 154. Type, *Zoroaster fulgens* THOMPSON; CLARK, 1920, p. 100; FISHER, 1928, p. 33.

*Diagnosis.* Zoroasteridae lacking superambulacral plates, with long slender ray; adradial plates overlapped by the lobes of carinal and superomarginal plates; 2 marginal series of 4-lobed to hexagonal plates; 5 or 6 ventrolateral series, the upper 3 or 4 being subsimilar to the marginals; adradial and marginal and ventrolateral plates forming regular transverse rows; most of the plates with a central spine; papular areas small, in the junction of 4 plates; pedicellariae

usually present on dorsal and ventral plates; 2 kinds of adambulacral plates, prominent and nonprominent, with 1 or 2 transverse rows of spines, the 1 or 2 (3) bearing pedicellariae; tube-feet more or less in 4 rows proximally, with prominent double ampullae; Polian vesicles absent; gonads 2 to a ray, attached at a little distance from inter-radial angle, on level with marginal plates.

**Key to Japanese species of *Zoroaster***

- a<sup>1</sup>. Carinal, marginal and ventrolateral plates all with central spine; spinelets papilliform.
- b<sup>1</sup>. Prominent adambulacral plates with 5 spines in a series; nonprominent ones with 4 or 5 spines; 5 series of ventrolateral plates; pedicellariae conspicuous; spinelets hirsutus ..... *ophiactis*
- b<sup>2</sup>. Subambulacral spines in 2 transverse rows; spinelets small; pedicellariae conspicuous or not.
- c<sup>1</sup>. 6 series of ventrolateral plates; pedicellariae not conspicuous; central spines on carinal plates small, or in tuft of enlarged spinelets; prominent adambulacral plates with 7-8 spines, nonprominent plates with 5-7 spines; R. 12.3 to 14 r ..... *orientalis*
- c<sup>2</sup>. 5 series of ventrolaterals; pedicellariae conspicuous; papular areas smaller; rays longer and slenderer; prominent adambulacral plates with 6-7 spines, nonprominent ones with 4-6 spines; R 11.6 to 17.2 r ..... *orientalis* forma *gracilis*
- a<sup>2</sup>. No central spines on carinal and superomarginal plates; spinelets granuliform; pedicellariae not conspicuous; papulae very small; inferomarginal and ventrolateral plates with central spine; 5 series of ventrolateral plates; subambulacral spines in 2 transverse rows ..... *microporus*

***Zoroaster orientalis* n. sp.**

(Pl. XIX, figs. 1 & 2)

Six specimens were examined, which have reduced adradial plates and many ventrolateral plates and complex adambulacral armature. The Japanese form is probably a new form of *Zoroaster*, closely related to *Z. carinatus philippinensis* Fisher, differing from the latter in having more numerous ventrolateral plates; 5 or 6 series instead of 4 as described for *philippinensis*; in marginal plates with a central spine not unusually; in having fewer adambulacral spines in 2 transverse rows. On the other hand, the form differs from *Z. angulatus* in having more numerous ventrolateral plates and more numerous adambulacral spines and in the central spines on carinal plates. From the Japanese form of *Z. ophiactis* it differs in having

less prominent central spines in tufts and shorter spinelets and smaller dorsal pedicellariae and in the armature of adambulacral plates.

*Diagnosis.* Belonging to *carinatus*-group, marginal and ventrolateral plates with a slender central spine; carinal plates with a small central spine or with a tuft of several enlarged spinelets; 5 (6) series of ventrolateral plates; prominent adambulacral plates with 7 spines in 2 transverse rows, the inner 2 with pedicellariae. R 12.3 to 14r.

The measurements of Omaesaki specimens are as follows:

R	r	R:r	Width in arm base	Locality	Depth	Character of bottom	Collection	Station
130 mm	10 mm	13	11 mm	off Omaesaki	475 fms	pebbles	Albatross 1906	5079
148 mm	12 mm	12.3	12 mm	"	"	"	"	"
154 mm	11 mm	14	12 mm	"	"	"	"	"
155 mm	12 mm	12.9	13 mm	"	"	"	"	"

*Description.* Disc flat-topped, elevated above the midradial ridge of ray; primary apical plates prominent. The disc is covered with small papilliform spinelets sheathed in membrane, about 0.5–0.6 mm long, smaller than in *philippinensis* in which the spinelets are 1 mm long. Papular areas small, each with a single papula, guarded by 2 or 3 small pedicellariae (0.6–0.7 mm long), about half as long as those in the Japanese form of *ophiactis*. Central spines on disc lost in the specimens, but if present, the spines not seem to be prominent judging from the protuberances on plates.

Rays long, very gradually tapering; carinal plates prominent, forming a conspicuous ridge, slightly wider than long, with 2 lobes on the either side. Adradial plates small, flat, sunken, overlapped by the lobes of carinal and superomarginal plates. Between the adradial and adambulacral plates are 8 longiseries of lateral plates, instead of 6 as described for *philippinensis*, but the 6th ventrolateral series are short and rudimentary. These plates are arranged in regular transverse rows, 9 of which corresponding to 5 carinal plates in the proximal portion of ray. Marginal plates wider than long, subhexagonal in form. The ventrolateral plates slightly increase in tumidity and decrease in width toward the furrow. All the plates are covered with small papilliform spinelets directed toward the

midradial line. The carinal plates are not furnished with a conspicuous central spine, but a small spine or 3 to 5 enlarged spinelets in tuft. Other plates, but adradial plates, all with a slender sharp, flattened central spine, increasing in size toward the furrow; those near adambulacral plates about twice or one and a half as long

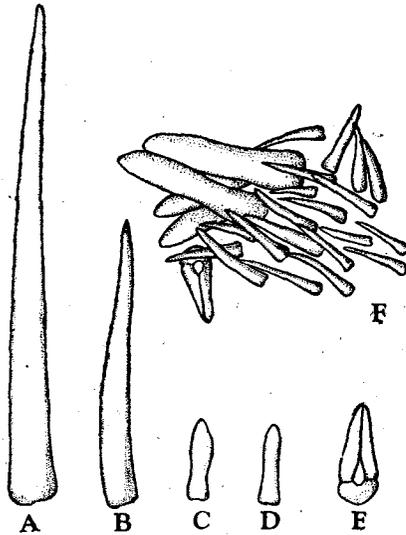


Fig. 23. *Zoroaster orientalis*: (A) central spine of ventrolateral plate near adambulacral plates, 17 $\times$ ; (B) superomarginal central spine, 17 $\times$ ; (C) and (D) disc spines, 17 $\times$ ; (E) disc pedicellaria, 17 $\times$ ; (F) carinal central spines and spinelets viewed from dorsolateral side, 17 $\times$ .

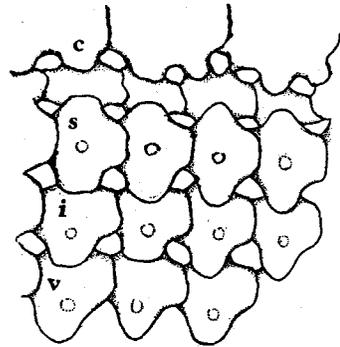


Fig. 24. *Zoroaster orientalis*: Skeletal structure in the proximal portion of ray, 5 $\times$ ; c carinal plate, s superomarginal plate, i inferomarginal plate, v ventrolateral plate.

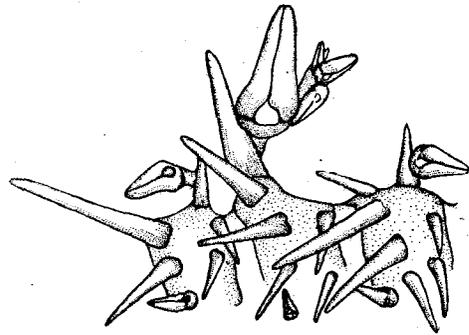


Fig. 25. *Zoroaster orientalis*: Adambulacral plates and armature in the proximal portion of ray, 12 $\times$ .

as the uppermost ones (about 2 mm long) and superomarginal plates occasionally with two spines. There are 8 series of small papular areas, each with a papula guarded by 2 or 3 small pedicellariae. Sometimes the pedicellariae occur on the transverse sutures between the carinal plates.

Prominent adambulacral plates with a transverse series of 5 or 6 spines; the innermost, deep in furrow, with a terminal sacculus beset with 4-6 small pedicellariae, and the spines occasionally bent toward the nerve cord. Above this are 4 or 5 slightly flattened spines in a transverse series; the lowermost, just above the true furrow spine, with a large pedicellaria as long as the spine, and very rarely the next also with a smaller pedicellaria. Along the adoral margin of the ventral surface of plate stand 2 spines forming an independent row. Alternate nonprominent adambulacral plates with 5 to 7 spines and spinelets in 2 transverse rows; these along the adoral margin of plates smaller than those on the aboral margin. The one on the adoral furrow corner has a medium-sized pedicellaria. Those on the aboral furrow corner are flattened, generally longest. On the outer end of plate stand small pedicellariae.

Madreporite conspicuous, convex, flat-topped.

*Locality.* Off Omaesaki, 475 fathoms, character of bottom pebbles (albatross, 1906, Station 5079); off Tyosi, 150 fathoms, character of bottom mud.

*Zoroaster orientalis forma gracilis n. forma*

(Pl. XVII, figs. 7, 8 & pl. XVIII, fig. 1)

*Diagnosis.* Differing from *orientalis* in having longer and slenderer rays; smaller papular areas; larger pedicellariae; usually a central spine on proximal carinal plates; fewer ventrolateral plates, 5 instead of 6; fewer adambulacral spines. R ranging from 11.6 to 17.2r.

The measurements are as follows:

R	r	R:r	Width in arm base	Locality	Depth	Character of bottom	Collec- tion	Station
70 mm	6 mm	11.6	6 mm	Kusakaki- jima, off Kagosima Bay	440 fms	Globigerina, Ooze	Albatross, 1906	4919
75 mm	6 mm	12.5	6 mm	"	"	"	"	"
95 mm	7.5 mm	12.5	8 mm	"	"	"	"	"
138 mm	8 mm	17.2	8 mm	"	"	"	"	4920

*Description.* Disc very small, rays long and slender; primary apical plates prominent. Disc uniformly covered with small spinelets

(0.6–0.7 mm long) ; papular areas small, each with a single pore, mostly guarded by 1 or 2 relatively large pedicellariae about 1.4 mm long. Carinal plates prominent, forming a ridge, having 2 lobes on

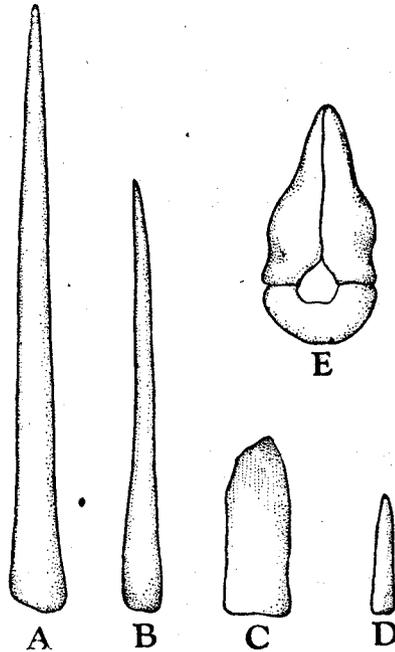


Fig. 26. *Zoroaster orientalis* forma *gracilis*: (A) central spine on ventrolateral plate adjacent adambulacral plates, 23 $\times$ ; (B) superomarginal central spine, 23 $\times$ ; (C) carinal central spine, 23 $\times$ ; (D) disc spine, 23 $\times$ ; (E) pedicellaria on disc, 23 $\times$ .

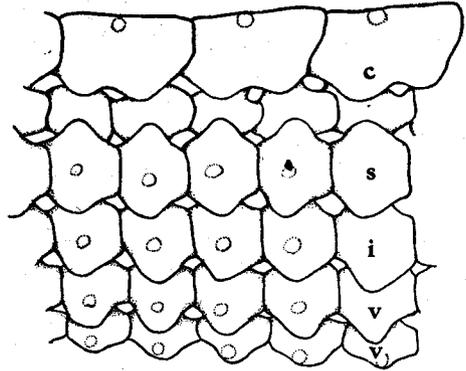


Fig. 27. *Zoroaster orientalis* forma *gracilis*: Skeletal structure of proximal portion of ray, 5 $\times$ ; c carinal plate, s superomarginal plate, i inferomarginal plate, v ventrolateral plate.

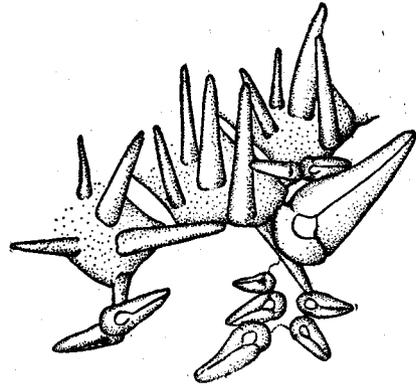


Fig. 28. *Zoroaster orientalis* forma *gracilis*: Adambulacral plates and armature in the proximal portion of ray, 17 $\times$ .

the either side, overlapping the adjacent adradial plates. Adradial plates small, flat, relatively sunken, 7 of which corresponding to 4 carinal plates in the proximal portion of ray. Between the adradial

series and adambulacral plates are 7 longiseries of lateral plates; 2 marginals and 5 ventrolaterals. Lateral plates hexagonal in form, slightly increasing in tumidity and decreasing in width toward furrow. Papular areas very small, each with a papula. There are 7 series of the areas on either side of carinal series in the proximal portion ray, though the 6th and 7th being rudimentary. Pedicellariae on rays slightly smaller than those on disc, standing generally at each lower end of plates, so the organ somewhat arranged in longitudinal and transverse series. These plates are all covered with small spinelets rather sparsely disposed, and except adradial plates, each bearing a slender slightly flattened sharp central spine increasing in length toward the furrow. Those on superomarginal plates measure about 2.3 mm in length and those near adambulacral plates about 3.5 mm. The central spines on carinal plates are robust, subconical in form, about 1 mm long. In the distal part of ray the spines are inconspicuous, but in the specimen (R 95 mm) the spines are conspicuous even in the distal part.

Prominent adambulacral plates with a vertical series of 5 spines; the one deep in furrow with 4 to 6 small pedicellariae and the next just above the furrow spine with a large pedicellaria as long as the spine. On the adoral furrow corner usually stands a spinelet similar to the outermost one of the adjacent series, but occasionally 2 spinelets present along the adoral margin of plate. Alternate nonprominent adambulacral plates with 5 (4-6) spines in 2 transverse rows; the spines of the aboral series are larger than those of the adoral. The one standing on the adoral furrow corner generally with 2 small pedicellariae and the innermost aboral spine long and stout. Tube-feet in 2 series.

Madreporite of medium size, circular in form, situated near the margin of disc.

*Locality.* Kusakakijima, off Kagoshima Bay, 440 fathoms (Albatross, 1906, Station 4919, 4920).

*Remarks.* The small specimens are closely related to the Japanese specimen of *Z. ophiactis*, but differing in having smaller papular areas, smaller spinelets and slightly slenderer rays. More important difference is found in the adambulacral armature composed of 2 series of spines. From *Z. angulatus* the present species seems to differ in having more numerous ventrolateral plates (5 instead of 3 or 4) and longer rays.

*Zoroaster ophiactis* FISHER

(Pl. XV, fig. 3)

*Zoroaster ophiactis*: FISHER, 1916, p. 29; . . . ., 1919, p. 473, pl. 135, figs. 2, 2a-b, pl. 136, fig. 1, pl. 139, fig. 3.

The specimens examined are closely related to *Z. ophiactis* Fisher. They are probably a form of the present species, though very difficult for identification of this puzzling group only from the description. On the other hand, the Japanese form resembles *Z. spinulosus*, but differs in having a little longer spinelets, larger papular pedicellariae, the 5th ventrolateral plates and a trifle more numerous adambulacral spines. From *ophiurus* Fisher it differs in having more pronounced adradial plates, a little more numerous adambulacral spines and the 5th ventrolateral plates. The Japanese form is related to *Z. magnificus* and *hirsutus* Ludwig in respect to adradial plates; but differs from *magnificus* in having more numerous series of ventrolateral plates and shorter rays, and in lacking peculiar pedicellariae; and from *hirsutus* in larger papular pedicellariae and the presence of the 5th ventrolateral plates and a little more numerous adambulacral spines.

*Diagnosis* *Zoroaster* having central spines on the disc and carinal and lateral plates; adradial plates not much reduced; prominent adambulacral plates with a series of 5 spines, the inner 2 bearing pedicellariae. Disc small, rays long, R about 12.5 to 14.3 r.

The measurements are as follows:

R	r	R:r	Width in arm base	Locality	Depth	Character of bottom	Collection	Station
75 mm	6 mm	12.5	6.5 mm	Off Omaesaki	918 fms	Green mud, fine sand, Globigerina	Albatross, 1906	5084
86 mm	6 mm	14.3	7 mm	"	"	"	"	"
100 mm	8 mm	12.5	8 mm	"	"	"	"	"

*Description.* Disc small, fairly elevated; primary plates conspicuous, notched by papulae, covered with slender rather long hirsutus spinelets, about 0.7 mm to 1 mm long, and a pedicellaria (about 1.5 mm long) is generally found near each papular area. The primary plates have each a robust conical central spine, about 1.5 mm long.

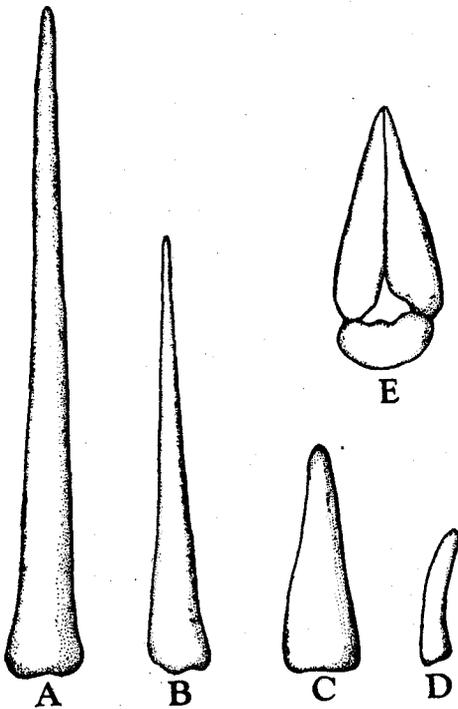
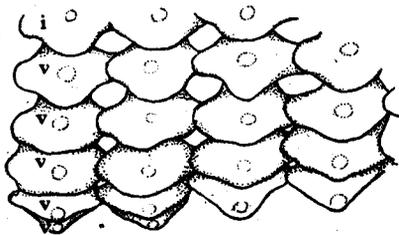


Fig. 29. *Zoroaster ophiactis*: (A) central spine on ventrolateral plate adjacent to adambulacral plates, 23 $\times$ ; (B) superomarginal central spine, 23 $\times$ ; (C) carinal central spine, 23 $\times$ ; (D) dorsal spinelet, 23 $\times$ ; (E) dorsal pedicellaria, 23 $\times$ .



( Fig. 31. *Zoroaster ophiactis*: Skeletal structure in the proximal portion of ray, 7 $\times$ ; i inferomarginal plate, v ventrolateral plate.

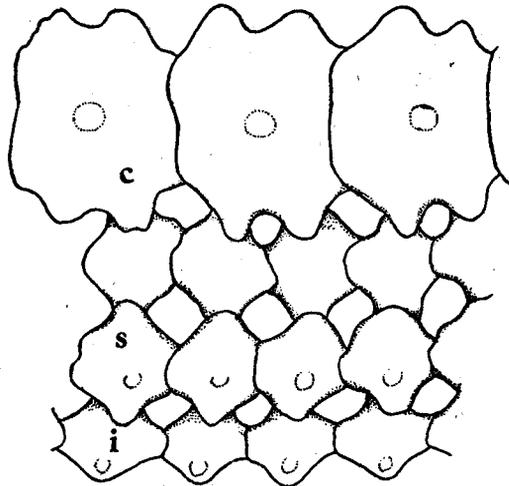


Fig. 30. *Zoroaster ophiactis*: Skeletal structure in the proximal portion of ray, 7 $\times$ ; c carinal plate, s superomarginal plate, i inferomarginal plate.

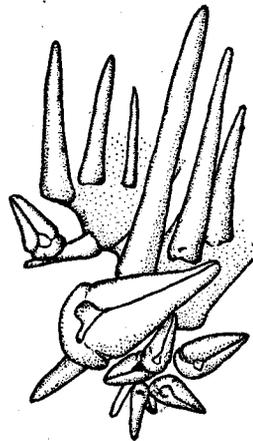


Fig. 32. *Zoroaster ophiactis*: Adambulacral plates and armature in the proximal portion of ray, 20 $\times$ .

Rays long and slender. Carinal plates prominent, forming a conspicuous ridge, each with 2 lobes on the either side and a robust central spine. Adradial plates rather conspicuous, extending nearly to the tip, a little smaller than superomarginal plates. They are overlapped by the lobes of carinal and superomarginal plates. Between the series and adambulacral plates are 7 series of lateral plates; 2 marginals and 5 ventrolaterals. The 7th series does not extend beyond one-thirds the length of ray. They are also arranged in regular transverse rows, 2 rows corresponding to one carinal plate proximally, but the regularity is soon lost. These plates increase in tumidity toward the furrow, and the upper 3 plates are about subequal, having 4 obtuse lobes, by which they imbricated. They are covered with slightly spaced hirsute spinelets like those on disc and carinal plates, increasing in length toward the furrow, and each with a conspicuous slender sharp central spine. The central spines increase in length toward the furrow, those adjacent to adambulacral plates being one and a half as long as those on superomarginals measuring about 2.5 mm in length. Papular areas rather large, each with usually a single papula, but often double on the either side of carinal plates. The areas are generally guarded by a two-jawed pedicellaria, usually longer than the spinelets.

Prominent adambulacral plate armed with one spine with a terminal sacculus beset with about 10 small pedicellariae, which situated deep in furrow. Above it, is found a row of 4 (rarely 5) tapering spine along near the aboral margin of plate. The spine just above the true furrow spine is generally armed with a large pedicellaria, the third spine being longest. Occasionally the outermost spine stands near the adoral margin of plate; in such a case, the spines on the ventral surface of plate are arranged in an oblique series toward the outer adoral corner of plate. Alternate nonprominent adambulacral plates have a small spine generally with a pedicellaria on the adoral furrow corner and a group of 3 or 4 spines on the ventral surface of plate; the one near the aboral furrow corner is prominent. These aboral spines are often arranged in an oblique series.

Madreporite rather prominent, circular, convex, situated near the margin of disc, behind the interradial plate.

*Note on a small specimen (R 75 mm).* The carinal plates forming a ridge have a stout central spine; central spines on lateral plates

distinctly distinguishable from the spinelets. Four series of ventrolateral plates; the 4th series being short, the 3rd one reaching about two-thirds the length of ray. Prominent adambulacral plates with a transverse series of 5 spines, the innermost spine deep in furrow, with 2-4 pedicellariae, and the 2nd spine mostly wanting in the large pedicellaria. Nonprominent plates each with 1 adoral spine generally with a small pedicellaria and 3 aboral spines in a series.

*Locality.* Off Omaesaki 918 fathoms; character of bottom green mud, fine sand, Globigerina (Albatross, 1906, Station 5084).

*Distribution.* Known from the southern Luzon to Celebes and the locality above stated.

### *Zoroaster microporus* FISHER

(Pl. XV, fig. 2, pl. XVIII, fig. 5 & pl. XXII, fig. 6)

*Zoroaster microporus*: FISHER, 1916, p. 30; . . . ., 1919, p. 475, pl. 134, figs. 4, 4a, pl. 136, fig. 2, pl. 139, fig. 4.

The specimens examined are closely related to *Z. microporus* Fisher from Moluccas, but differing in having more numerous ventrolateral plates and tube-feet in 4 ranks. On the other hand they somewhat resemble *Z. adami* Koehler, but differing in having more numerous lateral plates and more complex adambulacral armature. These specimens are probably eligible a boreal form of *Z. microporus*.

The measurements are as follows:

R	r	R:r	Locality	Depth	Character of bottom	Collection	Station
67 mm	7 mm	9.5	Off Goto Is.	181 fms	Gray sand, broken shells, rock	Albatross, 1906	4891
90 mm	11 mm	8.1	—	—	—	Soyômaru, 1928	—
91 mm	10 mm	9.1	—	—	—	"	—
116 mm	11 mm	10.5	—	—	—	"	—

*Diagnosis.* *Zoroaster* having skeletal plates covered with granuliform spinelets; no trace of central spines on the disc and carinal and superomarginal plates; adradial series inconspicuous, but extending nearly the tip; 5 series of ventrolateral plates each with a central spine; prominent adambulacral plates each with an aboral series of 5 spines and 2 short slender spines in the adoral; the non-prominent plates with 5 spines in 2 series; tube-feet in 4 series.

*Description.* Disc small, swollen, the major portion being occupied by large primary apical plates and the secondaries, forming two circles around the central plate. These plates are uniformly covered with minute granuliform truncate skin-covered spinelets,

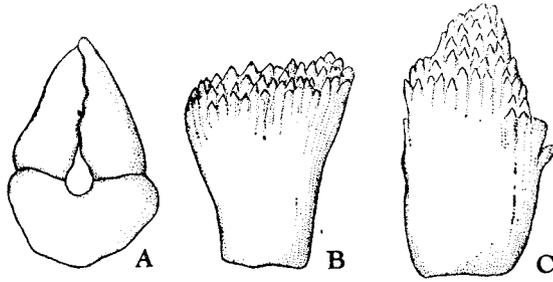


Fig. 33. *Zoroaster microporus*: (A) dorsal pedicellaria, 120X; (B) dorsal spine, 120X; (C) superomarginal spine, 120X.

about 0.2 to 0.3 mm long. The surface of plates is not smooth, but granular. Around the margin of plates are scattered small papulae and minute two jawed pedicellariae, slightly longer than the spinelets, 0.25–0.4 mm long. No large central spines. Papulae one to an area, pores very small.

Rays long and slender, gradually tapering. Carinal plates conspicuous, squarish or suboval in form, slightly wider than long

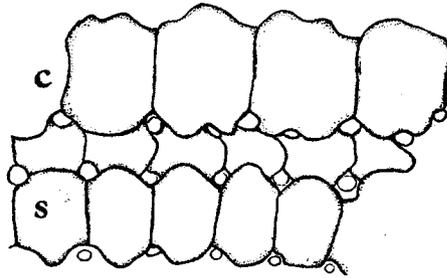


Fig. 34. *Zoroaster microporus*: Skeletal structure in the proximal portion of ray, 7X; c carinal plate, s superomarginal plate.

proximally. The arching transverse sutures are nearly straight, and the either side of the proximal several plates are shallowly notched in the middle for a small papula, and the four corners of plates are each slightly concaved for an adjacent small papular pore. The notches

soon disappear on account of the absence of the pore, while the corner pores persist regularly along ray. Between the carinal series and adambulacral plates are 8 longiseries of lateral plates; 1 adradial, 2 marginal and 5 lateral plates. These plates form very regular longitudinal and transverse rows; 6 carinal plates corresponding to 9 lateral plates proximally, 10 carinals to 12 laterals distally. Adradial plates small, flat, sunken, overlapped by carinal and superomarginal plates, but extending to the tip. Superomarginal plates elliptical, wider than long, larger than inferomarginals proximally but nearly subequal in the distal half of ray. These plates are uniformly covered with granuliform spinelets similar to those on disc, and those on superomarginals slightly flattened and tapering. No prominent central spines.

Ventrolateral plates (6 in all, including inferomarginal plates) very gradually decreasing in width toward furrow. They are each

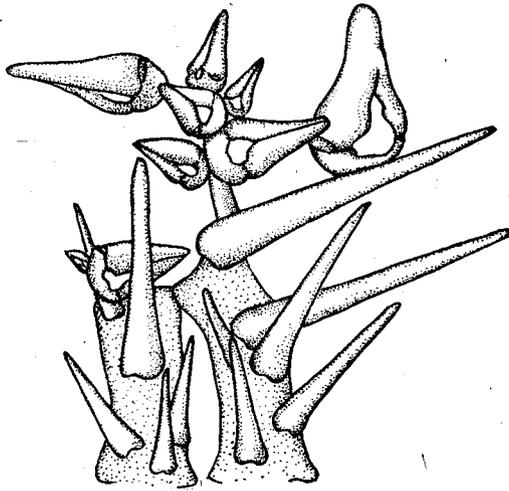


Fig. 35. *Zoroaster microporus*: Adambulacral plates and armature in the proximal portion of ray, 25 $\times$ .

armed with short rather pointed papilliform spinelets and a slender flattened tapering central spine. The central spines increase in length toward furrow, the uppermost spines being about 1.2–1.5 mm long and the lowermost about 2.5 mm long. Superomarginal plates not armed with the central spine near the end of ray. Very small papular areas are found at the junction of any 4 plates, except 2

series near adambulacrals where papular areas inconspicuous. Minute pedicellariae scattered in the sutures of plates, especially near papular areas.

Prominent adambulacral plates with 2 series of spines; 5 prominent spines in a transverse oblique series and 2 much shorter adoral spines. The innermost aboral spine, deep in furrow, is slender, bearing a saccular investment of 2-10 straight pedicellariae and the next spine long and stout, a little compressed, with a conspicuous pedicellaria in the middle, the jaws being often slightly curved. Alternate nonprominent adambulacral plates each with 5 (4) spines in 2 transverse rows, the innermost near the adoral margin of plate with 1 to 3 pedicellariae. Tube-feet in 4 series.

Madreporite small, circular, situated about the middle of r, behind the primary interradial plate.

*Locality.* Off Goto Islands, 181 fathoms (albatross, 1906, Station 4891).

*Distribution.* Known from Amblan Id. (off Borneo), Molluccas, 700 fathoms and Japan.

#### Genus *Cnemidaster* SLADEN

*Cnemidaster*: SLADEN, 1889, p. 423. Type. *Cnemidaster wyvillii* SLADEN.

The genus which was based upon a single very immature specimen obtained at the depth of 800 fathoms in the Arafura Sea, includes the following 4 species, *wyvillii*, *zea*, *squamatus* and *nudus*. According to Fisher ('19) and Clark ('20) these 4 species are so closely related that it is exceedingly difficult to separate them properly and Clark remarks as follows "I think *nudus* is undoubtedly distinct from the East Indian forms, but the three are certainly very closely allied."

*Diagnosis.* Zoroasteridae having superambulacral plates, the first being enlarged, connecting the upper end of the first ambulacral plates with the body wall at interradial angle; lacking spines or any conspicuous armature on disc plates, carinals, adradials and marginals and sometimes one series of ventrolateral plates; these plates are covered with a smooth tough skin; 3 to 5 series of ventrolateral plates; first superomarginal plates much larger than the second, subsimilar in size to first carinal plates; ventrolaterals each with squamiform spinelets and a central spine, but the latter not usually; papular areas

very small, each with a single pore; conspicuous pedicellariae on disc present or absent; adambulacral plates of 2 sorts, prominent and non-prominent; subambulacral spines in 2 series; tube-feet in 4 series, with double ampullae; Polian vesicles absent.

***Cnemidaster wyvillii* SLADEN**

(Pl. XV, figs. 4, 5)

*Cnemidaster wyvillii*: SLADEN, 1889, p. 424, pl. 67, figs. 3, 4, pl. 68, figs. 3, 4; FISHER, 1919, p. 480, pl. 134 figs. 3, 3a, pl. 138.

The writer examined 2 specimens of *Cnemidaster*, quite identical to the East Indian form, though there are pedicellariae on dorsal surface, but according to Fisher the organ seems to appear comparatively late as well as granules and spines, so he identified the Japanese specimens with the present species.

*Diagnosis.* Disc plates, carinal, adradial and marginal series of plates (one series of ventrolaterals proximally) covered with skin; oblong granuliform spinelets, papulae and pedicellariae around the plates; carinal ridge not much prominent; adradial series reaching one-fifths of ray; ventrolaterals in 4 or 5 series, covered with squamiform spinelets, 2 to 6 to a plate; a central spine on many of them; on the outer third of ray marginals also with one or more appressed spinelets or granules. Adambulacral plates of 2 sorts; the prominent with generally 5 spines in 2 transverse series.

The measurements are as follows:

R	r	Locality	Depth	Character of bottom	Collection	Station
64 mm	8 mm	Sionomisaki	712 fms	brown mud, pebbles, Foraminifera	Albatross, 1906	4975
55 mm	7 mm	Omaesaki	662 fms	Green mud, fine sand, Globigerina	Albatross, 1906	5082

*Description.* Whole body covered with a rather thick integument. Disc rather small, flat-topped, elevated above the base of rays, the major portion being occupied by conspicuous primary apical plates and secondary radial plates. The surface of plates is slightly swollen, indented for papulae. Oblong granuliform spinelets and fairly large papulae observed around the margin. Rays evenly arched, gradually tapering to the tip, without a well marked carinal

ridge; plates arranged in very regular series. Carinal plates slightly convex, proximally a trifle more wider than long, distally longer than wide, with granuliform spinelets along the sutural line of plates. Near the arm base is a short nearly hidden series of small adradial plates reaching one-fifths the ray, where double series of papular areas occur between carinal and superomarginal series, one papula in an area. On the either side of carinal series are 7 series of lateral plates arranged in very regular longitudinal and transverse series; both marginal plates and the proximal half of the next (first series of ventrolateral plates) are smoothly skin-covered, but all ventrolateral series are spiniferous in the specimen (R 55 mm). Superomarginal plates wider than long, slightly smaller than the carinals, 57 in number in a ray (R 64 mm), while carinal plates 48. The first plates are much larger than the second, subsimilar to the first plates of carinal series. Papular areas rather poorly developed, interpolated between proximal carinal and supermarginal series and intermarginal area and also between inferomarginal and the following series. The inferomarginal plates and the adjacent ventrolaterals are subequal in size, longer than wide; the rest gradually increasing in tumidity toward furrow and decreasing in width. These plates are armed with slightly spaced, lanceolate, flat squamiform spinelets, 2-6 to a plate, and many of them, especially near furrow, with a sharp, flattened, central spine, about 2.5 mm long. The bare marginal plates are also armed with one or more small appressed spinelets or granules in the outer one-thirds ray.

Prominent adambulacral plates with a transverse series of 4 or 5 spines sheathed in rather thick membrane, the innermost rather deep in furrow being pointed, slightly flattened; the next 2 or 3 longer, compressed, tapering, slightly curved aborally and the outer 1 or 2 short, more or less leaf-like. The innermost spines usually bear each a large pedicellaria with spatulate jaws curved at the distal half, about 1.2 mm long, sometimes accompanied by a smaller one especially near the arm base. Along the adoral margin of plates are 2 (rarely 1) short, slender curved spinelets. Nonprominent adambulacral plates generally with 5 spines in 2 transverse series; the adoral 2 or 3 being slender, slightly compressed, tapered, often the outermost being squamiform and the innermost bears a pedicellaria; the aboral 2 or 3 being larger, flattened, squamiform. Occasionally there are 6 spines; 3 in adoral series and the other 3 in the aboral. In the

distal half of ray the plates are subequal, with a transverse series of 4 or 5 spines, the innermost spine being slender, with a pedicellaria near the tip, the outermost 2 mostly squamiform and 1 or 2 slender curved spinelets stand adorally on the outer side of the series. Tube-feet in 4 series. First superambulacral plates are enlarged, connecting the upper end of the first 2 ambulacral plates with the body wall

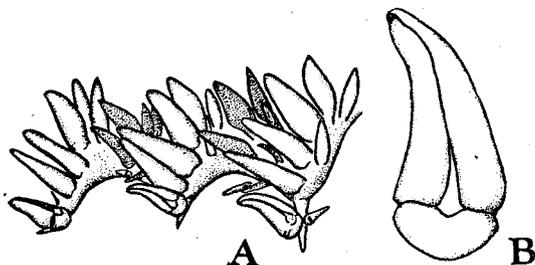


Fig. 36. *Cnemidaster wyvillii*: (A) adambulacral armature in the proximal portion of ray, 8 $\times$ ; (B) adambulacral pedicellaria, 25 $\times$ .

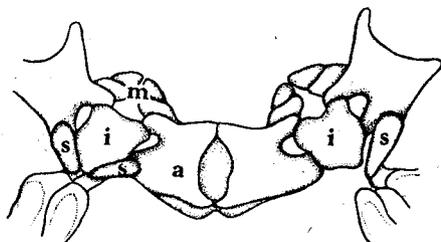


Fig. 37. *Cnemidaster wyvillii*: Skeletal structure of mouth region, 5 $\times$ ; a ambulacral plate, i interradial plate, m mouth plate, s superambulacral plate.

in interradial angle. Mouth plates small, sunken, armed with 2 or 3 oral spinelets, the inner being shorter, each with 3 or 4 pedicellariae; and 2 cylindrical long tapered suboral spines, the inner about two-thirds the length of the outer, about 2.5 mm long, without pedicellariae.

Madreporite small, roundish, located behind the primary interradial plate surrounded by granules.

*Locality.* Off Sionomisaki and Omaesaki, 662–712 fathoms (Albatross, 1906, Stations, 4875, 5082).

*Distribution.* Vicinity of Darvel Bay, Borneo; Gulf of Tomini, Celebes; Arafura Sea; 761–1.089 fathoms and the locality above mentioned.

### Family Asteroiidae GRAY, emended

The Japanese forms belong to the following five subfamilies; Pedicellasterinae, Labidiasterinae, Coscinasterinae, Asteroiinae and Pycnopodiinae.

#### Subfamily Pedicellasterinae FISHER

*Pedicellasterinae*: FISHER, 1918, p. 108; . . . ., 1923, p. 249; . . . ., 1928, p. 57.

In Japanese waters are found two genera, *Pedicellaster* and *Plazaster*, but the latter is apparently a quite isolated group of Pedicellasterinae, having a long adoral carina.

#### Genus *Pedicellaster* SARS

*Pedicellaster*: SARS, 1861, p. 77. Type, *p. typicus* SARS; FISHER, 1923, p. 251; . . . ., 1928, p. 58.

*Diagnosis.* Crossed pedicellariae of two kinds; the major with slender jaws having usually 4 curved prominent terminal teeth. Dorsal skeleton irregular open meshed, carinal plates in series; marginal and ventrolateral plates well developed in regular transverse series; the number of plates in series decreasing in the middle of ray, then increasing again; spinelets uniformly small; postoral first adambulacral plates widely separated interradially; furrow narrow; tube-feet biserial with a large ampulla to each; gonads opening laterally at a slight distance from disc.

*Remarks.* The writer examined specimens of *Pedicellaster* from Korea and Hokkaido. The Korean specimens are undoubtedly referable to *P. magister orientalis* Fisher and those of Hokkaido (*esoensis* in this paper) are probably a new form of *magister*. Fisher ('28) remarks in his monograph as follows:

*Orientalis* "is well marked on account of pedicellarian characters alone." Regarding the pedicellarian characters the following facts are found among the related three forms: The major pedicellariae are larger in *magister* than in *magister orientalis*, while the teeth in the median vertical series and the furrow pedicellariae are less numerous in the former than in the latter, and *esoensis* stands intermediate between the two species as shown below.

Species	Number of vertical teeth in major pedicellariae	Major pedicellariae in length	Furrow pedicellariae
<i>magister</i>	2 ( 3 )	0.45-0.55 mm	rare
<i>esoensis</i>	3 (2-5)	0.4 -0.5 mm	abundant
<i>orientalis</i>	4 (3-5)	0.36-0.4 mm	very abundant

According to Fisher ('28), the lobes of dorsal plates of *orientalis* are broader than those of *magister*, but the specimens of *orientalis* examined by the present writer have a trifle more slender lobes than in *esoensis*. On the other hand, the both Japanese forms have slightly more developed ventrolateral plates than in *magister*, but it must be noted that in *orientalis* the 4-lobed ventrolateral plates are connected transversely by secondary oblong spiniferous plates in the proximal half of ray, which are not described by Fisher; accordingly the dorsolateral areas are narrower than in *esoensis*. The character is seemingly constant for *orientalis*.

#### *Pedicellaster magister orientalis* FISHER

(Pl. XVI, figs. 1, 2)

*Pedicellaster magister orientalis*: FISHER, 1928, p. 66, pl. 16, fig. 5, pl. 27, figs. 1, 1a-1c, 5, pl. 28, fig. 3, pl. 34, fig. 5.

**Diagnosis.** Similar to *Pedicellaster magister*, but differing in the following points: Major pedicellariae slightly smaller, with 4 (3-5) teeth in the median vertical series; small ovoid pedicellariae numerous on mouth plates; ventrolateral plates fewer in each transverse series, but interpolated by oblong secondary plates. Disc small, rays slender, very gradually tapering, bluntly pointed, R 45 mm, r 6 mm.

**Description.** Fifteen specimens were examined. The surface of body shows a soft downy appearance, covered by small, spaced, sheathed spinelets, interspersed with very numerous small crossed pedicellariae (0.23-0.25 mm long). These spinelets are about 0.5 to 0.7 mm long, with 2 to 5 terminal points; 1 to 5 spinelets on a carinal plate, generally 1 on a dorsolateral. Papulae not easily recognized owing to the presence of spinelets and pedicellariae, 1 or 2 in an area. Major pedicellariae smaller than in *magister* and *esoensis*, about 0.36 to 0.4 mm long, with mostly 4 teeth in the median vertical series, but range 3 to 5. The marginal region is covered with the

minor and major crossed pedicellariae, but the ventral region with the major only. Dorsal skeleton irregularly open meshed, composed of 3- or 4-lobed plates and the oblong connective ossicles; the carinals being 4-lobed, distinguishable from the dorsolaterals by the regular

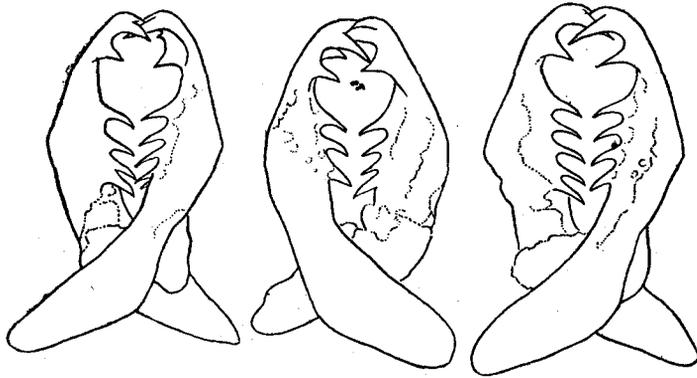


Fig. 38. *Pedicellaster magister orientalis*: Major pedicellariae, 120 $\times$ .

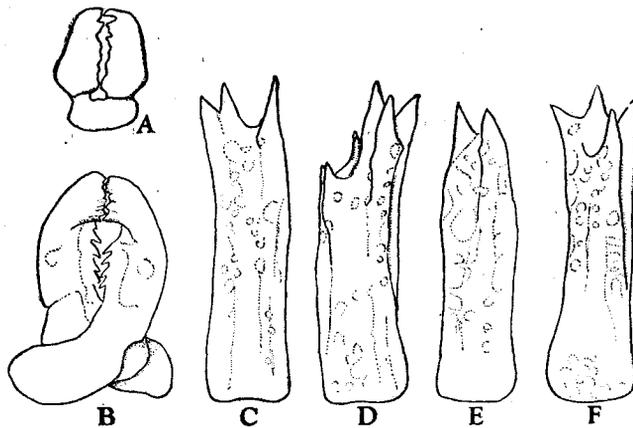


Fig. 39. *Pedicellaster magister orientalis*: (A) straight pedicellaria in furrow, 60 $\times$ ; (B) minor pedicellaria, 120 $\times$ ; (C)–(F) dorsal spinelets, 60 $\times$ .

arrangement. The lobes of plates are much slenderer than in *esoensis*.

Marginal and ventrolateral plates 4-lobed, arranged in transverse series, showing *magister*-type: in a transverse series proxim-

ally, 3 in the middle of ray, then again increasing 5 to 7, then gradually decreasing toward the tip. It is noticeable that the 4-lobed plates are connected by oblong spiniferous secondary plates in transverse series in the proximal portion of ray. Ventrolateral plates each with a single spinelet.

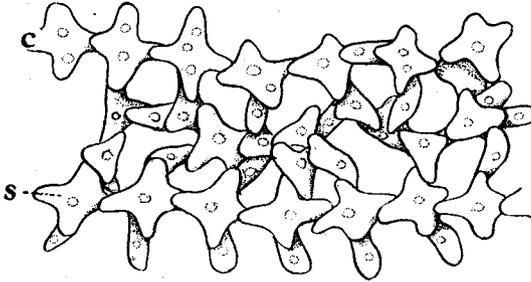


Fig. 40. *Pedicellaster magister orientalis*: Skeletal structure in the proximal portion of ray, 7 $\times$ ; c carinal plate, s superomarginal plate.

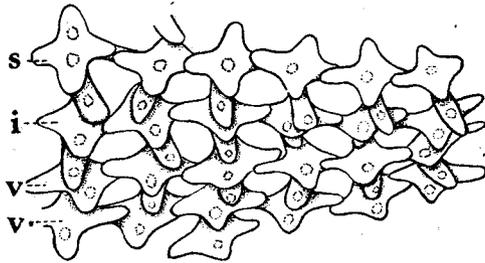


Fig. 41. *Pedicellaster magister orientalis*: Skeletal structure in the proximal portion of ray, 7 $\times$ ; i inferomarginal plate, s superomarginal plate, v ventrolateral plate.

Adambulacral plates with 2 slender spines in 2 longiseries. Along furrow edges are small straight pedicellariae. Mouth plates with 5 spines in a curved series, the outer 2 being in pair. The plates are armed with numerous straight pedicellariae.

Madreporite small, situated slightly nearer the margin of disc than the centre.

*Localities.* Off Matusima, Korea, 93 to 184 fathoms, character of bottom green mud (Albatross, 1906, Stations 4862, 4861, 4859);

off Dogo Island, 116 fathoms, character of bottom green mud, gray sand, *Globigerina* (Station 4844).

*Distribution.* Southern part of the Japan Sea.

*Pedicellaster magister esoensis* n. subsp.

(Pl. XVI, fig. 7 & pl. XX, fig. 2)

*Diagnosis.* Resembling *P. magister orientalis* but differing in having stouter skeleton; slightly larger major crossed pedicellariae with 3(2-5) vertical teeth; spinelets a trifle more delicate; ventrolateral secondary plates absent. R 56 mm, r 10 mm.

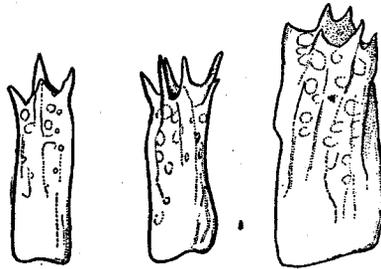


Fig. 42. *Pedicellaster magister esoensis*: Dorsal spines, 60 $\times$ .

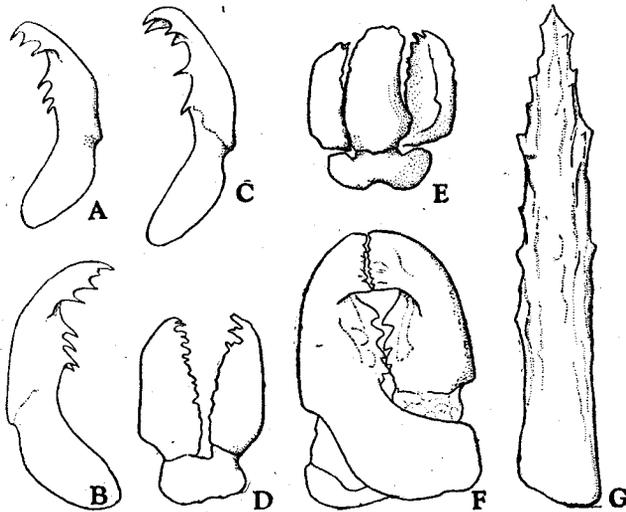


Fig. 43. *Pedicellaster magister esoensis*: (A)-(C) jaw of major crossed pedicellaria, 60 $\times$ ; (D)-(E) straight pedicellariae on mouth plate, 60 $\times$ ; (F) minor crossed pedicellaria, 120 $\times$ ; (G) adambulacral spine, 35 $\times$ .

*Description.* Three specimens were examined. Rays swollen at the base, gradually tapering. Entire surface of body covered with small uniform spinelets in pulpy sheath. The spinelets are small and delicate, with 3 to several hyaline terminal points, 0.4 to 0.6 mm long, 1 to 4 to a plate according to the size, mostly 3 or 4, rarely 5 to a carinal plate. Among the spinelets are disposed numerous minor crossed pedicellariae appearing small pulpy papillae, about 0.26 to 0.3 mm long. Marginal region covered with minor and major pedicellariae, the latter being very abundant in ventrolateral region, so closely placed as to be united with one another by the investing

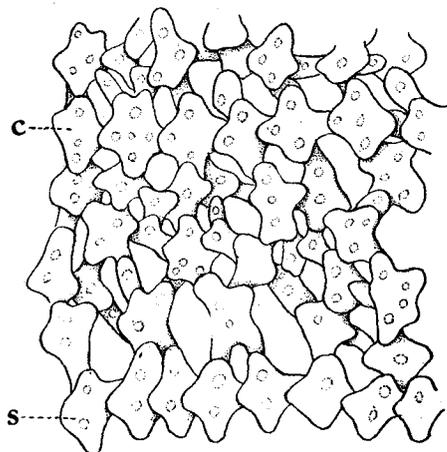


Fig. 44. *Pedicellaster magister esoensis*: Skeletal structure in the proximal portion of ray, 7 $\times$ ; c carinal plate, s superomarginal plate.

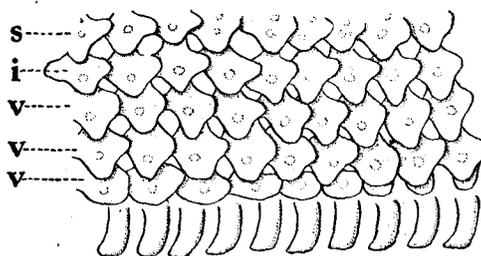


Fig. 45. *Pedicellaster magister esoensis*: Skeletal structure in the middle portion of ray, 7 $\times$ ; i inferomarginal plate, s superomarginal plate, v ventrolateral plate.

sheaths, about 0.4–0.5 mm long, with 3(2–5) teeth in the vertical series. No spines are conspicuous except the double rows of ambulacral spines. Carinal plates 4-lobed, in a series, distinguishable from dorsolaterals by the reason of the regularity. The dorsolaterals form irregular meshes, composed of 3 to 5 irregular lobed plates and the oblong connective ossicles. The lobes are much obtuser than in *orientalis*.

Marginal and ventrolateral plates 4-lobed, regularly arranged in transverse series; 5 plates in a transverse series proximally, 3 at the middle of ray, then increasing to 4 or 5 again. These plates bear

each a single spinelet, but the superomarginals mostly with 2, and the inferomarginals often with 2 proximally.

Adambulacral spines thickly sheathed in membrane, 2 for each plate, slender and tapering, about 1.5 to 2 mm long. Mouth plates with 4 to 6 slender spines in a curved series, increasing slightly in length from the inner to the outer; when 5 spines present, the outer 2 being in pair and when 6 present, the outer 4 in 2 pairs. Along furrow edges are small oval blunt straight pedicellariae, generally one to a plate and mouth plates with several of them.

Madreporite circular small, situated in the outer half of r.

*Locality.* Off Urakawa, Hokkaido, 175 fathoms, character of bottom fine black sand, brown mud, broken shells (Albatross, 1906, Station 5038).

#### Genus *Plazaster* FISHER

*Plazaster*: FISHER, 1941, p. 449. Type, *Labidiaster borealis* UCHIDA.

The present curious sea-star, *Labidiaster borealis*, has been only one species of the *Labidiaster* in the northern hemisphere. Recently Fischer ('41), comparing the species with Antarctic species of *Labidiaster*, pointed out as follows; "This species is not a *Labidiaster* and nor does it appear to be closely enough allied to be included in the *Labidiaster*." He described this very isolated group as a new genus, *Plazaster*, remaking "Possibly the best disposition of *Plazaster* is to be regarded it as polybranchiate offshoot of the Pedicellasterinae, differing principally in having a long adoral carina."

*Diagnosis.* Rays 22 to 39; skeleton forming irregular meshes of numerous small plates, each with a small acicular spinelet; superomarginal plates undiscernible; inferomarginals each with 1 or 2, rarely 3 spines, joined directly to adambulacrals, alternating with a small secondary spineless plate; adambulacrals with 2, 3, or 4 spines in a transverse series, without attached pedicellariae; integument thin; crossed pedicellariae encircling the base of spinelets, with jaws bearing two enlarged lateral teeth; straight pedicellariae in papular areas and in furrow; gonads 2 to each ray, opening dorsolaterally at about diameter of disc distant from arm base; a membraneous interradial septum with strong dorsoventral pillar of plates from odontophre.

*Plazaster borealis* (UCHIDA)

(Pl. XVI, figs. 3, 4)

*Labidiaster borealis*: UCHIDA, 1928, p. 800, fig. 9, pl. 33, figs. 1, 2.*Plazaster borealis*: FISHER, 1941, p. 449, pls. 66, 68, 69.

*Diagnosis.* Disc circular; rays long, flexible, numerous more than 20, cylindrical in section. Dorsal plates small, forming irregular meshes; spines, one for a plate, small, acicular, surrounded by several small crossed pedicellariae. Superomarginal plates undiscernible; inferomarginals joined directly to adambulacrals, alternating with secondary spineless plates, each bearing 1 or 2 rarely 3 spines. Adambulacral spines 3(2-4) arranged in a transverse series, without attached pedicellariae. Crossed pedicellariae with jaws expanded distally bearing 2 enlarged lateral teeth; straight pedicellariae various in size, found on dorsal surface, especially in furrow. Mouth plates each with 2 oral spines and 1 or 2 suboral. Adoral carina composed of first 7 to 9 pairs of adambulacral plates.

The measurements and the number of rays are as follows:

Rays in number	Longest ray	Diameter of disc	Depth	Locality
34	87 mm	30 mm	Shore	Hakodate, Hokkaido
33	53 mm	28 mm	"	Wakumoto, Hokkaido
37	160 mm	58 mm	"	Teuri, Id., Hokkaido
33	58 mm	24 mm	"	"
33	70 mm	27 mm	"	"
33	114 mm	47 mm	"	"
32	210 mm	64 mm	"	Osyoro, Hokkaido
35	65 mm	23 mm	"	Hatinohe, Honsyu
39	114 mm	45 mm	44 fms	Tugaru Strait
37	110 mm	38 mm	"	"
31	81 mm	27 mm	Shore	Onagawa, Honsyu

*Description.* Disc rather swollen, circular in outline, Rays long, cylindrical in section, constricted at base, widest about the middle, then gradually tapering, variable in number, 31 to 39 (22 to 35 in Uchida's examples). Dorsal skeleton forming irregular meshes composed of numerous small rod-like and 3- or 4-lobed plates, the skeletal nodes each with a small, slender sharp spinelet surrounded by 3 to 6

crossed pedicellariae. The jaws are expanded distally, bearing an enlarged lateral terminal tooth on each. The meshes on rays are more open on disc. These spinelets are not arranged in any regular series, and there are no remarkable size differences between those

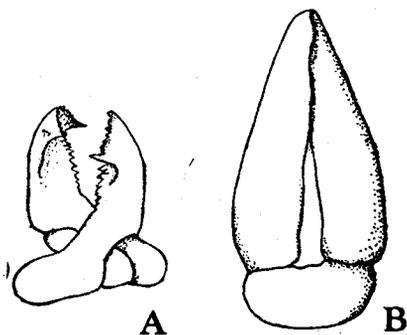


Fig. 46. *Plazaster borealis*: (A) crossed pedicellaria, 100 $\times$ ; (B) straight pedicellaria, 50 $\times$ .

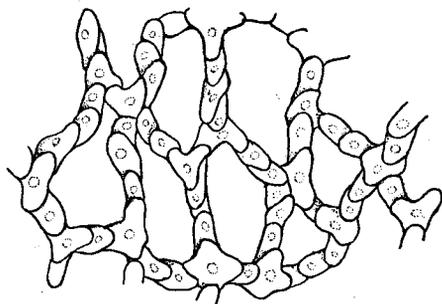


Fig. 47. *Plazaster borealis*: Skeletal structure in the proximal midradial portion of ray, 20 $\times$ .

on disc and rays. Papular areas each with several papulae and rather large straight pedicellariae, mostly 1 or 2 in an area. The marginal papular areas adjacent to adambulacral plates are exceedingly large, transversely elongated, subquardate in form.

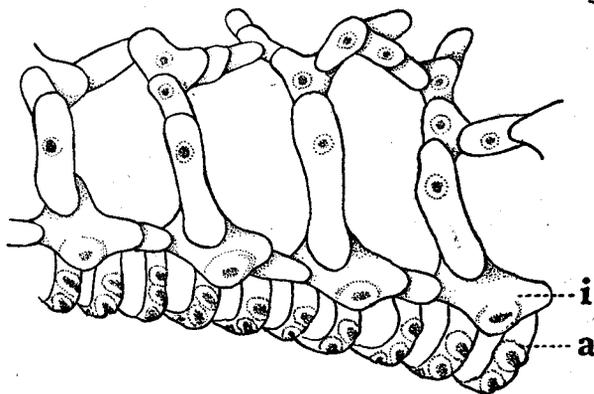


Fig. 48. *Plazaster borealis*: Skeletal structure in the middle portion of ray, 20 $\times$ ; a adambulacral plate, i inferomarginal plate.

Marginal plates poorly developed: Superomarginal series undiscernible, and the inferomarginal series is directly joined to

adambulacral plates, composed of spiniferous 4-lobed plates and secondary spineless elliptical plates between them. Inferomarginal spines 1 to each plate, but often 2, rarely 3 proximally, much longer than general dorsal spinelets, bearing basally 1 or 2 lanceolate pedicellariae, but beyond the middle of ray there is a circle of crossed pedicellariae around the spine.

Adambulacral plates short and rather broad, each with 3 subequal pointed spines arranged in an oblique transverse series, larger than the inferomarginals; no attached pedicellariae. These spines are variable in number with growth; in large specimens 4 spines occur

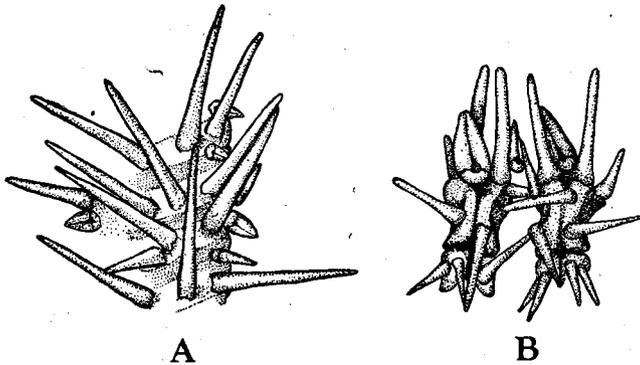


Fig. 49. *Plazaster borealis*: (A) adambulacral plates and armature, 7 $\times$ ; (B) mouth plates, 7 $\times$ .

proximally, but generally 3 in the greater part of rays; but 2 in small specimens. Straight pedicellariae various in size occur in furrow. Mouth plates each with 2 oral spines and 1 or 2 long and stout suboral spines and 2 to 4 straight pedicellariae. The inner oral spines are about twice as large as the outer, the tip being flattened. Adoral carina composed of 7 to 9 pairs of postoral adambulacral plates. Membraneous interradial septa with strong dorsoventral pillar of plates from odontophore.

Gonads 2 to each ray, consisting of a bunch of branched slender lobes, attached to dorsolateral body wall in approximately the diameter of disc distant from the base of ray.

Madreporite roundish, rather small, situated about midway between the centre of disc and the margin.

*Localities.* Onagawa, Hatinohe, Cape Tsiuka (Albatross, 1906, Station 4807), and Osyoro, Hakodate, Wakumoto, Teuri Island in Hokkaido.

*Distribution.* Hokkaido and northern Honsyu and Korean Sea.

*Anatomical note.* The present species has very numerous rays, but the digestive system resembles that of 5 rayed Asterids. The cardiac stomach is very large, but somewhat appears to have 5 cardiac pouches each retracted by a pair of muscles attached to the ambulacral plates and the pyloric stomach also subpentagonal in form. Near the centre of the pyloric stomach is located the rectal sac opening to the anus by a sharp constriction. The pyloric caeca in each ray open into the stomach by a short common duct. Polian vesicles absent; Tiedeman's bodies less than the number of rays, 11 in number in a 32 rayed specimen, occurring at random in pair or solitary in inter-radius. Tube-feet each with a single ampulla.

#### Subfamily Labidiasterinae VERRILL, emended

*Labidiasterinae:* VERRILL, 1914, p. 26; FISHER, 1919, p. 492; . . . ., 1923, p. 249; . . . ., 1928, p. 88.

#### Genus *Coronaster* PERRIER, emended

*Coronaster:* PERRIER, 1885, p. 13; . . . ., 1894, p. 92, pl. 8; FISHER, 1919, p. 494. Type, *Coronaster parfaiti* PERRIER.

*Stolasterias* (subgenus) part: SLADEN, 1889, p. 584.

*Heterasterias:* VERRILL, 1914, p. 46. Type, *Asterias* (*Stolasterias*) *volsellata* SLADEN.

*Diagnosis.* Disc small, rays long, slender, numerous, 8-11 in number. Dorsal skeleton widely meshed, consisting of slender lobed plates joined by oblong connecting ossicles; carinal and 2 marginal series regular; at each node of skeletal meshes is a single sharp spine with a heavy globular wreath of abundant pedicellariae; papulae in tufts; ventrolateral plates absent; adambulacral plates small, rather separated, and 1 to 3 slender spines, generally 2, without attached pedicellariae; mouth plates excavated toward furrow; tube-feet in quadriserries. Straight pedicellariae large, numerous, hand-shaped.

#### *Coronaster sakuranus* (DÖDERLEIN)

(Pl. XIV, figs. 3, 4, 5, 6, 7)

*Asterias volsatella* SLADEN var. *sakurana*: DÖDERLEIN, 1902, p. 332.

Döderlein's species, *Asterias volsatella* var. *sakurana*, from Kagosima Bay is certainly included in *Coronaster* judging from his description. The writer examined a ten-rayed *Coronaster* obtained from the same locality. The specimen agrees in all essential particulars with *C. sakuranus* and also with *C. haliceps* Fisher from the Philippine Islands; only differing in the spinulation of mouth plates; 2 oral spines unequal in length, and the suboral spines are located more or less nearer to the aboral end of plate than the middle; exceptionally 3 oral spines exist. These differences are not so important enough to distinguish the two allied species. *C. haliceps* Fisher will probably be a synonym of *C. sakuranus* (Döderlein) by the priority of nomenclature.

*Diagnosis.* Disc small, circular, slightly swollen; rays long and slender, 8-10. Dorsal skeleton forming wide meshes; carinal and 2

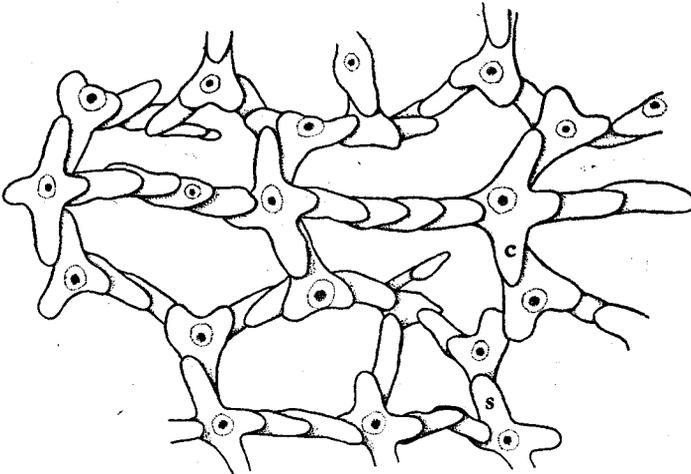


Fig. 50. *Coronaster sakuranus*: Skeletal structure in the proximal portion of ray, 5 $\times$ ; c carinal plate, s superomarginal plate.

marginal series regular. Spines on skeletal nodes solitary, slender and acute, surrounded by a heavy globular sheath covered with small crossed pedicellariae. Large hand-shaped unguiculated pedicellariae scattered all over the surface; small straight pedicellariae numerous, the ends of jaws being crossed. Adambulacral plates diplacanthid, without attached pedicellariae.

*Description.* The specimen examined measures 182 mm in R, 13 mm in r. Rays 10 in number, long and slender, more or less

narrowed near the base. Dorsal integument thin, membranous. Dorsal skeleton of disc and rays form large squarish or subpentagonal or somewhat irregular meshes. Carinal series regular, composed of slender-lobed cruciform plates at each skeletal node and the oblong connective plates, generally 3 or 4 in each interval. Dorsolateral skeleton consists of 3-lobed Y-shaped plates at each skeletal node, and

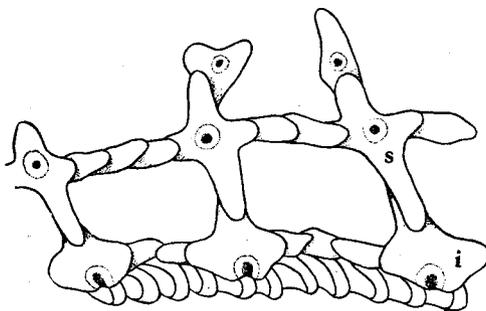


Fig. 51. *Coronaster sakuranus*: Skeletal structure in the proximal portion of ray, 5 $\times$ ; i inferomarginal plate, s superomarginal plate.

the oblong connective plates. The spines are slender and acute, about 3–3.5 mm long, 1 on each principal plate, sometimes on the connective plates of carinal series.

Superomarginal plates cruciform, the lower lobes being elongated, overlapping to those of inferomarginal plates; each with a single spine similar to dorsal one. These plates are joined by 2 or 3 intermediate oblong plates. Inferomarginal plates, adjacent to adambulacral plates, corresponding to superomarginals in position, each connected by 2 or 3 oblong intermediate plates. Inferomarginal spines slender and acicular, 1 for each plate, but longer and stouter than dorsal and superomarginal ones, measuring about 4–5.2 mm in length. Intermarginal papular areas very regular, large, quadrate in form.

These spines are encircled by a conspicuous globose bouquet of small crossed pedicellariae borne upon the heavy sheath, the tip of spines being a little protruded from the cushion. Crossed pedicellariae with 2 enlarged terminal lateral teeth on each jaw, the one being a little smaller than the other, and a double row of 12–13 small lateral teeth. Large 5- or 6-clawed unguiculate pedicellariae scattered all

over the surface, especially on disc and in marginal and ventrolateral areas. Small straight pedicellariae found in papular areas; papulae occurring in tufts, 2 or 3 in an area, about 4 to 7 for each tuft.

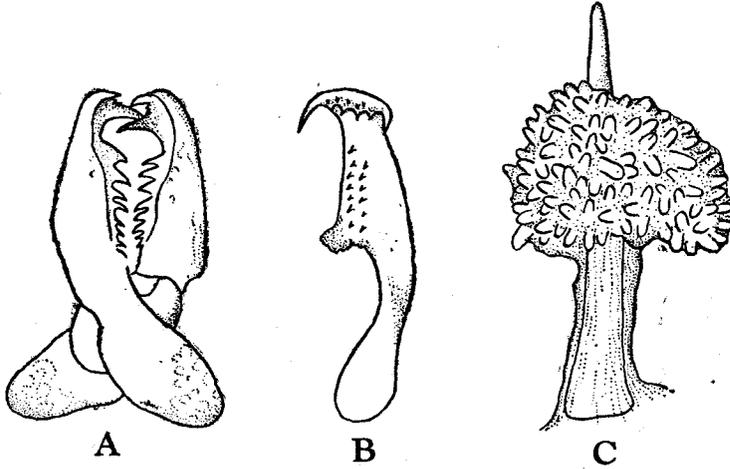


Fig. 52. *Coronaster sakuranus*; (A) crossed pedicellaria, 160 $\times$ ; (B) jaw of crossed pedicellaria, 160 $\times$ ; (C) dorsal spine, 20 $\times$ .

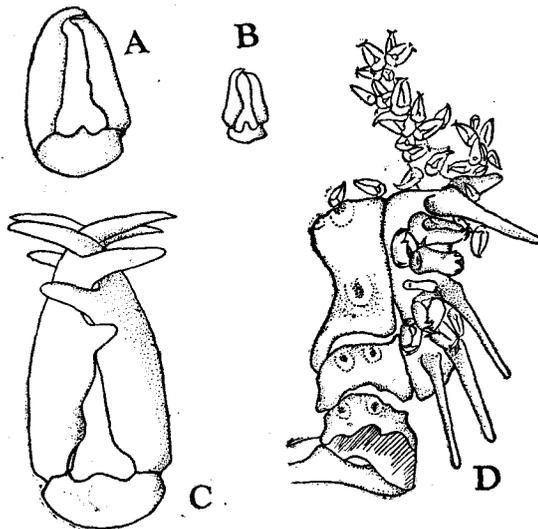


Fig. 53. *Coronaster sakuranus*; (A) and (B) straight pedicellariae in furrow, 20 $\times$ ; (C) straight pedicellaria on mouth plate, 20 $\times$ ; (D) mouth plates and adambulacral plates, 7 $\times$ .

Adambulacral plates small, band-like, separated by an interval which is slightly wider than their length. Spines double, about 2.4–2.8 mm long, slender and tapered, without attached pedicellariae, the inner being slightly shorter than the outer. Along furrow face are scattered small pedunculate straight pedicellariae, the jaw tips being crossed.

Mouth plates large, excavated toward furrow for the first tube-feet. On the middle of the ventral surface of plate, a little nearer the aboral end stands a stout cylindrical blunt suboral spine, the base being more or less compressed, about 3.5 mm long. Oral spines 2, not subequal as in *C. halicepus*; the inner is similar to the suboral spine in size and form, but the base more compressed; the outer at the adoral furrow corner of plate is much compressed, stouter than the inner, but smaller, about half as long as the inner. One of mouth plates has exceptionally 3 oral spines, the middle being similar to the inner in form, but a little shorter. At the base of the outer spine there is a slender streamer of small pedicellariae, but often the inner spine also with the streamer. Many straight pedicellariae, various in size, are found on the surface of plates. Tube-feet in 4 series.

Madreporite rather large, situated nearer the margin of disc than the centre.

*Locality.* Okikojima, Kagosima Bay, 39 fathoms, character of bottom brown sand, broken shells, pebbles (Albatross, 1906, Station 4946).

*Distribution.* Only known from Kagosima Bay.

### Subfamily Coscinasterinae FISHER

*Coscinasterinae:* FISHER, 1923, p. 249; . . . ., 1928, p. 93.

#### Key to Japanese genera of Coscinasterinae

- a<sup>1</sup>. Only the outer one of the 2 inferomarginal spines carries a cluster of crossed pedicellariae.
- b<sup>1</sup>. Adambulacral plates diplacanthid; rays pentagonal in section, 5 in number; outer inferomarginal spines connected in longiseries by a continuous web confined the base; skeleton regular; dorsolateral and ventrolateral plates in a series; straight pedicellariae slender, lanceolate . . . . . *Sclerasterias* PERRIER
- b<sup>2</sup>. Adambulacral plates diplacanthid; a series of spiniferous ventrolateral plates; large straight pedicellariae with dentate jaws; rays fissiparous,

7 to 12; skin covering skeleton not unusually thick and tough; crossed pedicellariae with prominent lateral tooth to terminal lip .....

**Coscinasterias VERRILL**

c<sup>1</sup>. All carinal plates 4-lobed; carinal and superomarginal plates alternately or all spiniferous; adoral carina consisting of first 2 or 3 pairs of postoral adambulacral plates.. **Subgen. Stolasterias SLADEN**

a<sup>2</sup>. The inner as well as the outer inferomarginal spines carries a cluster of crossed pedicellariae; adambulacral plates diplacanthid; carinal and superomarginal plates directly imbricated in series, regularly spiniferous; a series of spineless ventrolateral plates.

b<sup>1</sup>. Crossed pedicellariae with 2 enlarged terminal teeth on each jaw; straight pedicellariae lanceolate, but spatulate or unguiculate ones sometimes present; dorsolateral plates in 2 or 3 regular or irregular series on each side of ray; odontophore with single pit on the outer margin ..... **Distolasterias PERRIER**

b<sup>2</sup>. Crossed pedicellariae without enlarged terminal teeth; straight pedicellariae relatively large, spatulate or unguiculate; dorsolateral plates very numerous, small, crowded, arranged irregularly; spines ornately fluted; odontophore with 1 or 2 pits on the outer margin .....

**Lethasterias FISHER**

**Genus Sclerasterias PERRIER emended**

*Sclerasterias*: FISHER, 1928, p. 105 (with synonymy). Type, *Sclerasterias guernei* PERRIER.

*Diagnosis.* Disc small; rays pentagonal in section; skeletal series regular. Superomarginal plates large, with a broad decending lobe; the surface with a circumscribed area of tiny hyaline protuberances. Carinal and superomarginal plates alternately spineless, but often irregular. Inferomarginal plates with 2 spines, the outer series of spines being united by a web. Dorsolateral and ventrolateral plates separately in a series, the spines present or absent, if present, single. Dorsal and superomarginal spines encircled by a wreath of crossed pedicellariae and the outer inferomarginal spines by a half wreath; inner inferomarginal and ventrolateral spines lacking the organ. Crossed pedicellariae bearing a terminal enlarged lateral tooth on the outer face of each jaw. Straight pedicellariae not spatulate or dentate. Mouth plates not sunken; adambulacral plates diplacanthid.

***Sclerasterias satsumana* (DÖDERLEIN)**

(Pl. XIV, figs. 8, 9; 10, 11)

*Asterias satsumana*: DÖDERLEIN, 1902, p. 334.

The present species was reported by Döderlein ('02) from Kagosima Bay, about 20 meter in depth. Three small Goto's specimens were examined by the present writer, which are labeled as *Asterias satsumana* Döderlein. So far as the writer examined, the species is undoubtedly a form of *Sclerasterias*. The measurements are as follows:

R	r	Locality	Collection
13-18 mm	4 mm	Off Yamakawa, Kagosima Bay	S. Goto, 1886
15-37 mm	4 mm	"	"
25 mm	4 mm	Okikosima, Kagosima Bay	Albatross, 1906, St. 4946

*Diagnosis.* Disc small, rays 5, unequal in length, constricted at base, nearly pentagonal in section; intermarginal areas wide and about vertical. Spines in fairly regular series: Carinal plates each with 1 spine; dorsolateral spines, 1 for a plate, in a series. Superomarginal plates alternately spiniferous; inferomarginals each with 2 compressed truncate spines; proximal ventrolaterals with a spine, but entirely absent in small specimen. Mouth plates with 2 oral and 1 suboral spines; one pair of contiguous postoral adambulacral plates; adambulacral spines, 2 for each plate, subequal, truncate, compressed, without attached pedicellariae. Crossed pedicellariae in conspicuous circumspinal wreath absent from inner inferomarginal and ventrolateral spines. Straight pedicellariae not numerous, small, lanceolate.

*Description.* Disc small, rays long, unequal in length, constricted at base, nearly pentagonal in section; dorsolateral surface steeply

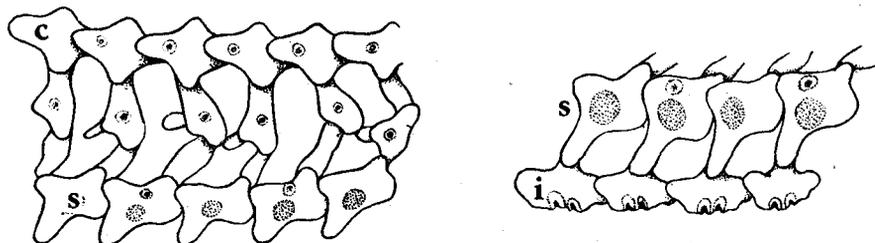


Fig. 54. *Sclerasterias satsumana*: Skeletal structure in the proximal portion of ray, 7x; c carinal plate, i inferomarginal plate, s superomarginal plate.

sloping; intermarginal areas wide, vertical. Carinal plates 4-lobed, directly imbricating in a regular longiseries, bearing a small pointed spine in each. Dorsolateral plates transversely elongated, rod-like

or subtriangular in form, by which carinal plates connected to superomarginals; the longitudinal connecting ossicles poorly developed. Dorsolateral spines, one for a plate, arranged in a longiseries, but somewhat irregularly in the proximal portion of ray in the large specimen. These spines are wreathed with small crossed pedicellariae with a terminal enlarged lateral tooth characteristic to the genus. Papular areas with 1 to 5 papulae in an area, according to the size.

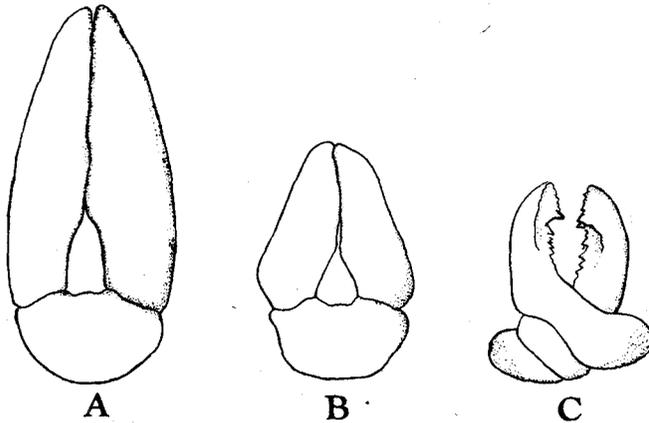


Fig. 55. *Sclerasterias satsumana*: (A) and (B) straight pedicellariae, 50 $\times$ ; (C) crossed pedicellaria, 110 $\times$ .

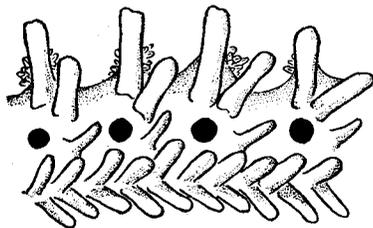


Fig. 56. *Sclerasterias satsumana*: Inferomarginal, ventrolateral and adambulacral spines in the proximal portion of ray, 8 $\times$ .

Superomarginal plates 4-lobed, arranged in a conspicuous longiseries, loosely imbricated, with a large decending lobe overlapping to each inferomarginal plate and a circular hyaline pebbled area. Superomarginal spines occur alternately, forming a regular series along the outer border of plates, but in the distal portion of ray most

of plates armed with a spine. These spines are similar to the carinal, with a wreath of crossed pedicellariae. Inferomarginal plates smaller than the superomarginals, each with 2 compressed, truncate spines; the outer spines are half wreathed by crossed pedicellariae and between them is found a well marked web; the inner spines a little shorter than the outer, lacking pedicellariae.

Ventrolateral plates small, opposite to each inferomarginal plate, reaching the distal portion of ray, each with a spine without attached pedicellariae. The spines are similar to inner inferomarginal spines in form, but shorter and smaller. Papular areas each with a large papula in an area, but in small specimens both the spines and papulae are absent, as in the distal portion of ray of the large specimen.

Adambulacral spines 2 in each plate, subequal, flattened and truncated, free from pedicellariae. Mouth region not sunken; plates each armed with 2 oral spines, the inner being larger, similar to general adambulacral spines in size and form, and the outer shorter and slenderer, about half as large as the inner. Following mouth plates is present a pair of joined adambulacral plates each with 2 spines. Straight pedicellariae small, lanceolate, toothless, located on adambulacral plates and intermarginal area, but never numerous, few on dorsal surface. Tube-feet biserial, somewhat showing quadriserial arrangement.

Madreporite rather large, circular, slightly convex, situated slightly nearer the margin of disc than the centre.

*Localities.* Off Yamakawa, Kagosima Bay; Okikojima, Kagosima Bay, 39 fathoms, character of bottom brown sand, broken shells, pebbles.

*Distribution.* Known only from Kagosima Bay.

*Remarks.* The present species is closely related to *S. heteropaes* Fisher distributed in Half Moon Bay to San Diego, Calif., 27 to 85 fathoms, but seemingly differs in having more developed spinulation; almost all carinal plates spiniferous; distal superomarginal spines not regularly on alternate plates, but on each; dorsolateral and ventrolateral spines more developed; mouth plates with a pair of contiguous postoral adambulacral plates; adambulacral spines not slender, tapering, but truncated and compressed.

### Genus *Coscinasterias* VERRILL

*Coscinasterias*: VERRILL, 1867, p. 248. Type, *C. muricata* VERRILL (rel. *Asterias calamaria* GRAY).

*Coscinasterias acutispina* (STIMPSON)

(Pl. XIV, figs. 14, 15)

*Asterias calamaria* var. *japonica*: DÖDERLEIN, 1902, p. 332.

*Coscinasterias acutispina*: HAYASHI, 1938, p. 66.

*Diagnosis.* Rays narrow, numerous 7 to 10, fissiparous, very gradually tapering to blunt tips, subpentagonal in section. Carinal plates 4-lobed, in a regular series, alternately spiniferous, occasionally all plates spiniferous proximally. Dorsolateral spines in a series or more or less irregularly. Superomarginal plates with pebbling areas, alternately spiniferous. Inferomarginal plates with 2 spines in each, the outer with a cluster of crossed pedicellariae. Adambulacral plates monacanthid, without attached pedicellariae.

*Description.* The following description is based upon a 7-rayed specimen (R 45 mm, r 8 mm).

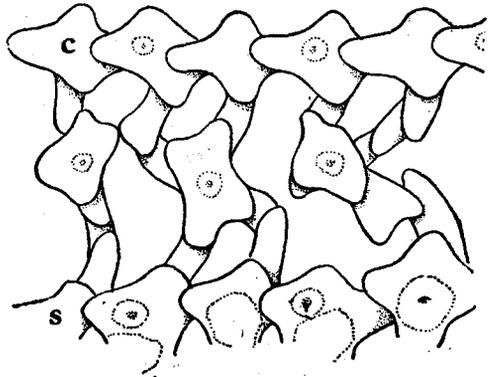


Fig. 57. *Coscinasterias acutispina*: Skeletal structure in the proximal portion of ray, 7 $\times$ ; c carinal plate, s' superomarginal plate.

Dorsal skeleton open meshed, carinal plates 4-lobed, arranged in a regular longiseries, with an acute spine on alternate plates, about 1.3–1.6 mm long, but in specimens each with a spine proximally rarely accompanying an accessory spine. Dorsolateral skeleton composed of 3- or 4-lobed plates and oblong secondaries; spines 1 to a plate, arranged in a longiseries; in specimens the series of spines is more or less irregular in the proximal portion of ray. Papular areas large, each with 1 or 2 groups of papulae consisting of 3 to 7 papulae,

according to size. These spines are each provided with a collar of crossed pedicellariae measuring 0.3 to 0.35 mm in length, the terminal tooth being not conspicuously prominent.

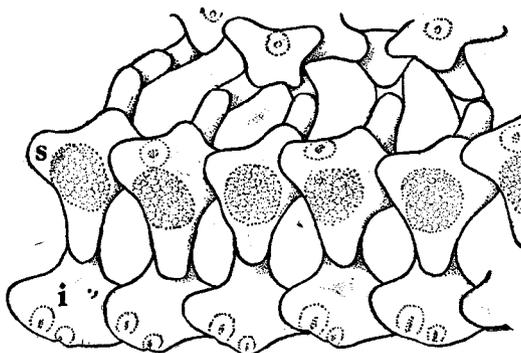


Fig. 58. *Coscinasterias acutispina*: Skeletal structure in the proximal portion of ray; i inferomarginal plate, s superomarginal plate.

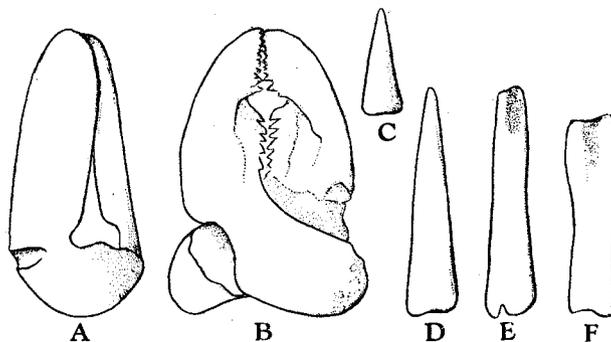


Fig. 59. *Coscinasterias acutispina*: (A) straight pedicellaria on mouth plate, 35 $\times$ ; (B) crossed pedicellaria, 120 $\times$ ; (C) dorsal spine, 12 $\times$ ; (D) superomarginal spine, 12 $\times$ ; (E) inferomarginal spine, 12 $\times$ ; (F) inferomarginal spine, 12 $\times$ .

Marginal plates arranged in very regular longiseries. Superomarginal plate 4-lobed, the lower lobe being elongated, overlapping the upper lobe of the inferomarginal, with a subcircular pebbling area. The spines occur on alternate plates, with pointed or slightly compressed tips, a little longer than the dorsolaterals, with a collar of crossed pedicellariae. Inferomarginal plates each with double flattened truncate spines in a slightly oblique row, the outer with a cluster

of crossed pedicellariae on the outer side; in specimens 3 spines rarely occur, the outermost spine alone with the cluster. Intermarginal papular areas each with 5 to 7 papulae in an group.

Ventrolateral plates poorly developed, opposite to each inferomarginal plate in position, extending two-thirds the length of ray, each with an acute small slender spine. The series is considerably variable in specimens, sometimes absent or spineless.

Adambulacral plates each with a slender flattened, truncate or blunt spine without attached pedicellariae. Mouth plates rather large, each with 2 flattened oral spines, the outer being about half as large as the inner, and a suboral spine, but not usually. Numerous straight pedicellariae, various in size, scattered on mouth plates, in inter-brachial channels and along the furrow, the large one measuring about 1 mm in length. Adoral carina composed of 3 or 2 postoral plates each with a single spine.

Madreporite circular, variable in number from 2 to 4, situated about the middle of r.

*Localities.* Ogasawara Islands, Kakeroma (Amaiôshima) and Tomioka, Yenosima, Kominato and Toyama Bay.

*Distribution.* The Ogasawara Islands and Amaiôshima and Kyusyu and southern Honsyu.

### Genus *Distolasterias* PERRIER

*Distolasterias*: PERRIER, 1896, p. 34. Type, *Asterias* (*Stolasterias*) *stichantha* SLADEN; FISHER, 1928, p. 102.

*Diagnosis.* Differing from *Sclerasterias* in having a cluster of crossed pedicellariae on the inner as well as on the outer of the 2 inferomarginal spines; in lacking inferomarginal web; dorsolateral skeleton not restricted to a single series; crossed pedicellariae with 2 enlarged terminal teeth on each jaw, instead of one. Dorsolateral skeleton composed of 4- or 5-lobed primary plates and the secondary ones, various in size and form; carinal plates with 4 lobes, directly imbricated in a regular series; spines generally 1 or 2 for a plate, but in specimens more spines occur; dorsal and superomarginal spines with thick circlets of crossed pedicellariae. Marginal series regular, superomarginal plates monacanthid; inferomarginal plates diplacanthid, the spines with a cluster of crossed pedicellariae, often mingled with small lanceolate straight pedicellariae; adambulacral

plates diplacanthid, no pedicellariae attached. Papulae in groups, 1 or 2 in an area; straight pedicellariae various in size and form, slender lanceolate, dentate, spatulate or unguiculated; lanceolate straight pedicellatae usually in furrow. Odontophore with a single pit on the outer margin.

**Key to Japanese species of *Distolasterias***

- a<sup>1</sup>. Dorsal skeleton widely open meshed; dorsolateral spines well spaced, arranged in regular series, 1 to a plate, slender, tapering; large unguiculate straight pedicellariae scattered on dorsal, marginal and ventrolateral regions; no slender jawed lanceolate straight pedicellariae, except in furrow; crossed pedicellariae smaller than in *nipon*, having less prominent terminal fangs. . . . . *stichantha*
- a<sup>2</sup>. Dorsal skeleton more closely meshed than in *stichantha*; dorsolateral spines more numerous, not arranged in definite series, short and stout, pointed, or bluntly pointed, subtruncate, truncate, compressed or grooved at tip, sometimes bi- or trifold; small lanceolate straight pedicellariae numerous, scattered all over the surface including furrow; large unguiculate straight pedicellariae generally absent.
- b<sup>1</sup>. Crossed pedicellariae with prominent terminal fangs; dorsal spines 1 or 2 for a plate, pedicellariae-groups of marginal spines mingled with small lanceolate straight pedicellariae . . . . . *nipon*
- b<sup>2</sup>. Dorsal spines much more numerous and stouter, 1 to 7 for a plate; crossed pedicellariae with less prominent terminal fangs; small lanceolate straight pedicellariae more numerous . . . . . *elegans*

***Distolasterias stichantha* (SLADEN)**

(Pl. XVI, fig. 6 & pl. XX, fig. 1)

*Asterias (Stolasterias) stichantha*: SLADEN, 1889, p. 586, pl. 106, figs. 1-4.

*Diagnosis.* Differing from *D. nipon* in having small crossed pedicellariae with less prominent terminal fangs; a large number of unguiculate straight pedicellariae; in having more open skeletal meshes and fewer well spaced dorsal spines; spines slender and tapering. Rays long and stout, gradually tapering; R about 8r (Sladen's type specimen  $R > 9r$ ). Dorsolateral spines well spaced, arranged in regular series, surrounded by thick wreaths of crossed pedicellariae. Marginal spines long and tapering; superomarginals, 1 for a plate, with circlets of crossed pedicellariae; inferomarginals 2 for a plate, with half wreath of crossed pedicellariae. Adambulacral plates diplacanthid. Straight pedicellariae lanceolate, unguiculate or spatulate.

*Description.* A single specimen of Goto's collection was examined, measuring 105 mm in R, 13 mm in r. Dorsal skeleton composed of 4-lobed carinal plates, transversely elongated dorsolateral

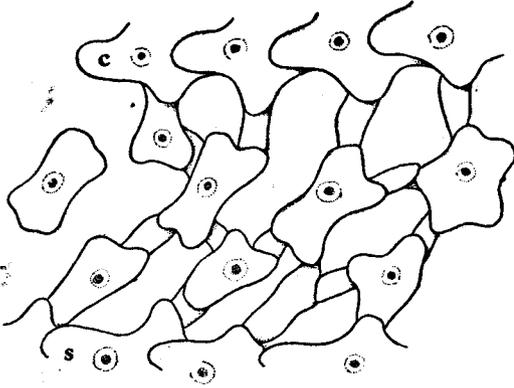


Fig. 60. *Distolasterias stichantha*: Skeletal structure in the proximal portion of ray, 5 $\times$ ; c carinal plate, s superomarginal plate.

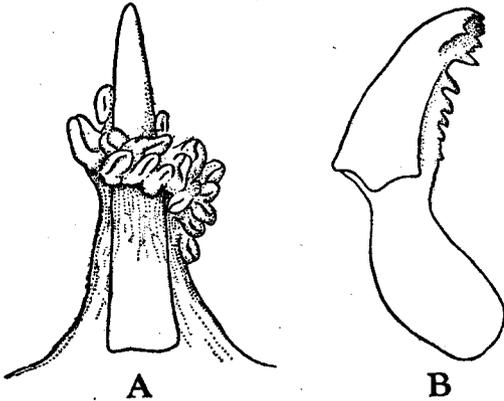


Fig. 61. *Distolasterias stichantha*: (A) dorsal spine, 20 $\times$ ; (B) jaw of crossed pedicellaria, 120 $\times$ .

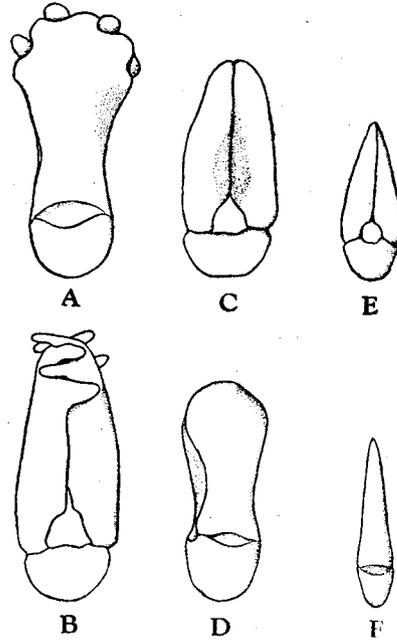


Fig. 62. *Distolasterias stichantha*: (A) ventrolateral straight pedicellaria, 15 $\times$ ; (B) lateral view of the same, 15 $\times$ ; (C) ventrolateral straight pedicellaria, 15 $\times$ ; (D) lateral view of the same, 15 $\times$ ; (E) straight pedicellaria in furrow, 15 $\times$ ; (F) lateral view of the same, 15 $\times$ .

plates with irregular 3, 4 or 5 lobes, and the connecting oblong plates. Carinal plates in a regular longiseries, directly imbricated, each bearing a slender tapering cylindrical spine, about 2.5 mm long. The primary dorsolateral plates are each provided with a single spine

similar to the carinals, arranged in 2 longiseries on each side of ray, though more or less irregular in arrangement. These spines are surrounded by thick wreaths of crossed pedicellariae, about 0.4 mm long. The terminal fangs are not so prominent as in *D. nipon*. Papulae in groups, generally 1 or 2 in an area, each with 3 to 5 papulae. Prominent unguiculate or spatulate straight pedicellariae scattered all over the surface. Small slender jawed lanceolate ones as is found in *D. nipon* are few on the surface.

Marginal plates arranged in regular series; superomarginal spines, one for a plate, slender and tapering, a little longer than the dorsolaterals, each with a thick collar of crossed pedicellariae; inferomarginal spines, two for a plate, subsimilar in length to superomarginals, half wreathed with crossed pedicellariae. Intermarginal papular areas contain 3 to 5 papulae in each. Ventrolateral plates small, spinless, extending to the distal portion of ray.

Adambulacral plates diplacanthid; spines subequal, about 3 mm long, slender and tapering, without attached pedicellariae. Mouth plates not sunken, each with 2 oral spines and 1 suboral. In the furrow are found numerous slender straight pedicellariae, variable in size. First adambulacral plates joined, each with a single spine.

Madreporite rather large, circular, situated about midway between the centre of disc and the margin.

Colour in alcohol bleached bluish gray.

*Locality.* Wakudogake, Misaki, 350 fathoms.

*Distribution.* Only known from Japan; off Tokyo and Misaki, 345 to 350 fathoms.

#### *Distolasterias nipon* (DÖDERLEIN)

*Asterias nipon:* DÖDERLEIN, 1902, p. 334; Uchida, 1928, p. 798, pl. 33, figs. 3, 4.

*Distolasterias nipon:* FISHER, 1928, p. 103, pl. 43, fig. 5, pl. 60, figs. 2, 2a, pl. 81, fig. 8.

*Diagnosis.* Differing from *D. stichantha* in having more closely meshed skeleton and stouter and more numerous dorsolateral spines not arranged in definite series; in having numerous small lanceolate straight pedicellariae on body surface including furrow and larger crossed pedicellariae with more prominent terminal fangs; in lacking large unguiculated straight pedicellariae. Rays 5, long and stout, R about 8r. Dorsal spines, 1 or 2 for a plate, thick, bluntly pointed,

subtruncate or compressed at the tip, sometimes with grooves or bi- or trifold; superomarginal spines single; inferomarginals double; in the pedicellariae-group often mingled small lanceolate straight pedicellariae; adambulacral plates diplacanthid; no attached pedicellariae.

*Description.* The description is based upon a specimen measuring 185 mm in R, 25 mm in r.

Dorsal skeleton irregular reticulum, composed of 4-lobed carinal plates and 3 to 6 irregularly lobed dorsolaterals and the intermediate

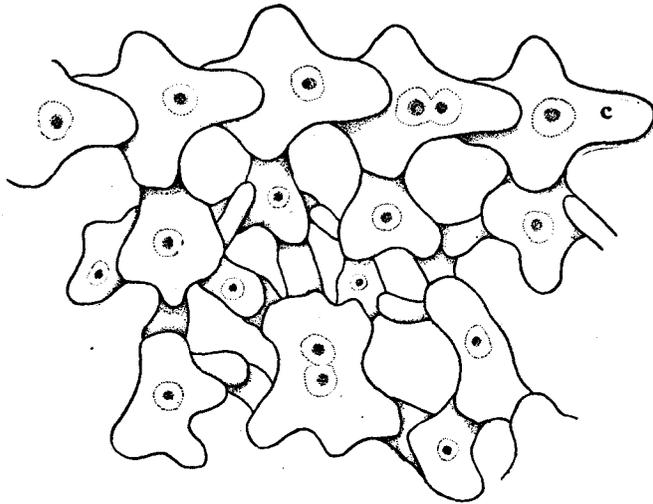


Fig. 63. *Distolasterias nipon*: Skeletal structure in the middle of ray, 5 $\times$ ; c carinal plate.

plates. The carinal plates are directly imbricated, forming a regular series. Carinal spines, generally 1 (2) for each plate, stout but short, various in form; conical, bluntly pointed, subtruncate, occasionally compressed, with grooves, or bi- or trifold at the tip, about 3 mm long proximally. Dorsolateral spines, 1 or 2 for a plate, stout, generally bluntly pointed, conical in form, considerably various in size, slightly increasing in length toward furrow, the large ones measuring about 5 mm in length. These spines are thickly encircled by characteristic crossed pedicellariae, about 0.5 mm long, with 2 prominent terminal teeth in each jaw. Papulae in groups, 1 or 2, rarely 3 in an area, each bearing 7 to 18 papulae. Small lanceolate straight pedicellariae 0.5 to 0.7 mm long, scattered among the spines.

Marginal plates directly imbricated, arranged in regular longiseries. Supermarginal spines single, in a regular series, surrounded by thick crossed pedicellariae often mingled with a number of small

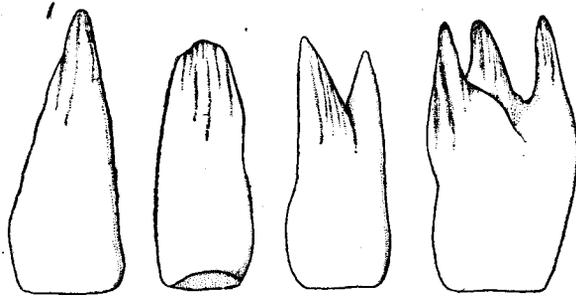


Fig. 64. *Distolasterias nipon* : carinal spines, 12 $\times$ .

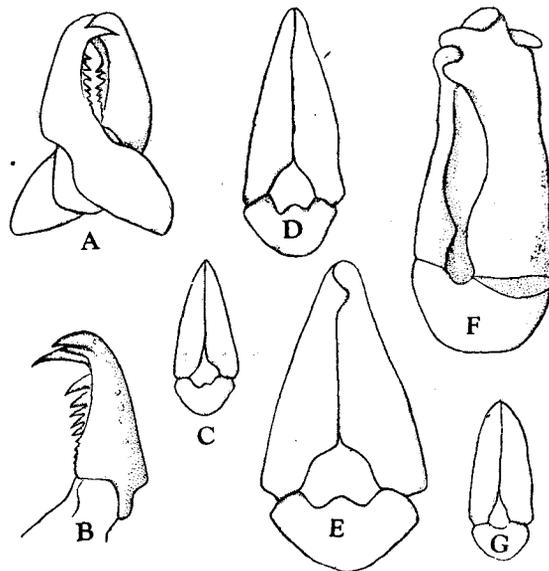


Fig. 65. *Distolasterias nipon* : (A) crossed pedicellaria, 55 $\times$  ; (B) jaw of crossed pedicellaria, 80 $\times$  ; (C) straight pedicellaria in furrow, 30 $\times$  ; (D) and (E) ventrolateral straight pedicellariae, 30 $\times$  ; (F) ventrolateral straight pedicellaria in Muroran specimen, 25 $\times$  ; (G) dorsal straight pedicellaria, 30 $\times$ .

straight pedicellariae; inferomarginal spines double, in 2 longiseries, each with a basal tuft of crossed pedicellariae mingled with straight ones. These spines are longer and stouter than the dorsolaterals,

6-7 mm long proximally, various in form, subtruncate, bluntly pointed or compressed at the tip, or gouge shaped.

Ventrolateral plates small, spineless, wedged in between the inferomarginals and adambulacrals, corresponding in position to the inferomarginals, reaching the distal portion of ray. Papular areas each with 4 to 6 papulae in an area, the straight pedicellariae being larger than on dorsal surface, measuring 1 to 1.5 mm long, with dentate jaws, but not expanded terminally as in those of *stichantha*. In a specimen (R 185 mm) obtained from Muroran exceptionally large unguiculate straight pedicellariae are found in the ventrolateral areas, but not numerous.

Adambulacrals plates each armed with 2 slender long spines, about 5 mm long, without attached pedicellariae. In the furrow scattered numerous lanceolate straight pedicellariae similar to the dorsolaterals. Mouth plates each with 2 oral spines, the inner being subtruncated, about as long as the plate, about 2-2.2 mm long; the outer on furrow corner of plate quite small. Suboral spines single, long and stout, about 3.5 mm long, located near the aboral end of plate. Adoral carina consisted of 4 pairs of postoral adambulacrals plates bearing solitary spines, the first plates being about half as long as the mouth plate.

Madreporite large, convex, circular, situated at the middle of r.

The dorsal integument of dried or alcoholic specimens is blackish, and the spines and their encircling cushion of pedicellariae are yellowish white in a sharp contrast.

*Localities.* Muroran, Osyoro, Usu and Hidaka in Hokkaido; off Yamagata Prefecture; off Matsushima (Korea), 150 fathoms (Albatross, 1906, Station 4868); off Kinkasan, 107 to 129 fathoms (Stations 5047, 5048).

*Distribution.* From Peter the Great Bay southward to Korea and Hongkong.

### *Distolasterias elegans* DJAKONOV

(Pl. XV, fig. 1, pl. XVII, fig. 6)

*Distolasterias elegans:* DJAKONOV, 1931, p. 67, figs. 1, 2.

Six specimens of *Distolasterias* were examined, ranging from 92 mm to 300 mm in R, which are referable to the present species.

*Diagnosis.* Resembling *D. nipon*, but differing in having more numerous and stouter dorsal spines; crossed pedicellariae with

slightly less prominent terminal fangs; small lanceolate straight pedicellariae more numerous; colour in life pale brown.

The measurement are as follows:

R	r	R:r	Locality	Depth	Collection
92 mm	14 mm	6.5	Tomari Bay, Kunasiri Id.	11-14 m.	J. Tokita, 1941
160 mm	23 mm	6.9	"	"	"
220 mm	28 mm	7.8	"	"	"
300 mm	35 mm	8.5	"	"	"
250 mm	42 mm	6.8	Akkesi	—	M. Iwasa, 1934
290 mm	37 mm	6.7	"	—	"

*Description.* Skeletal structure resembles that of *nipon*; carinal plates 4-lobed, directly imbricated in a regular longiseries; the dorsolaterals each with 3 to 6 irregular lobes joined by the intermediate plates being various in size and form. Carinal spines, 1 to 7 to each plate, short, stout, truncate, occasionally with grooves at the distal half, about 2-3 mm long, but 1 to each plate in small specimens. Dorsolateral spines similar to the carinals, increasing in length toward furrow, measuring 3-4.5 mm long, the tip being grooved,

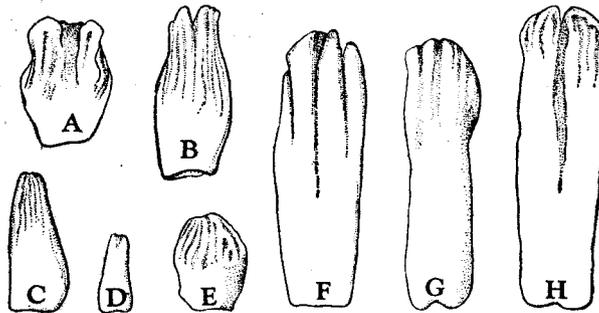


Fig. 66. *Distolasterias elegans*: (A)-(E) dorsal spines, 5 $\times$ ; (F) superomarginal spine, 5 $\times$ ; (G) and (H) inferomarginal spines, 5 $\times$ .

truncated or bluntly pointed, 1 to 3 for a plate. These spines are thickly wreathed by crossed pedicellariae with 2 enlarged lateral terminal teeth on each jaw, but the one being slightly larger than the other, measuring 0.43 to 0.52 mm in length. Papulae in groups, 1 or 2 in an area, 10 to 20 or more papulae in a group. Numerous small slender jawed lanceolate straight pedicellariae scattered among spines.

Superomarginal plates 4-lobed, directly imbricated in a regular series, each with a single long stout spine (often 2 or 3 proximally). The spines are surrounded by crossed pedicellariae. Inferomarginal plates generally with 2 stout spines, a little larger than the supero-

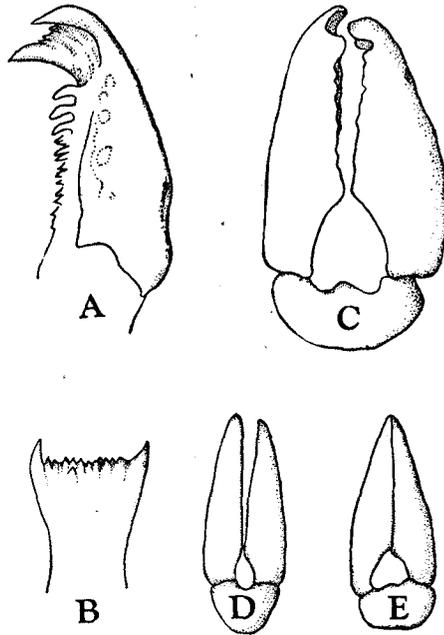


Fig. 67. *Distolasterias elegans*: (A) and (B) jaw of crossed pedicellariae, 110 $\times$ ; (C) ventrolateral straight pedicellaria, 25 $\times$ ; (D) dorsal straight pedicellaria, 55 $\times$ ; (E) straight pedicellaria in furrow, 25 $\times$ .

marginals, 7-8 mm long proximally, mostly gouge shaped, with a basal tuft of crossed pedicellariae; intermarginal papular areas each with about 20 papulae.

Ventrolateral plates in a series, spineless, corresponding to inferomarginals in position, reaching the distal portion of ray. Papular areas with 10 to 15 papulae in an area; straight pedicellariae larger than on dorsal surface, the large ones being dentate as in *nipon*.

Adambulacral plates diplacanthid, the spines being a little stouter than in *nipon*, slightly flattened; the outer longer and stouter than the inner, having a shallow groove on the outer side, about 6 mm

long; no attached pedicellariae. Numerous lanceolate straight pedicellariae scattered in furrow. Mouth plates each with 2 oral spines, the inner one being short, but stout, about 3 mm long, with compressed truncated extremity, the outer much smaller. Suboral spines single, about 5.5 mm long. Adoral carina composed of first 4 pairs of adambulacral plates.

Madreporite prominent, convex, circular, situated about the middle of r.

The colour in life and alcohol is pale brown, without patterns.

*Locality.* Akkesi and Tomari Bay, Kunasiri Island, Kurile Islands.

*Distribution.* Castery Bay and the localities above stated.

### Genus *Lethasterias* FISHER

*Lethasterias*: FISHER, 1923, p. 258. Type, *Asterias nanimensis* VERRILL.

*Diagnosis.* Dorsal skeleton very numerous, irregularly meshed; carinal plates 4-lobed, directly imbricated, all spiniferous; dorsal and superomarginal spines with thick wreaths of crossed pedicellariae

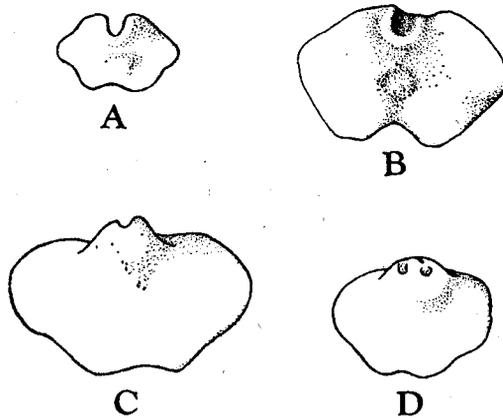


Fig. 68. Odontophores, 7 $\times$ : (A) *Lethasterias fusca*; (B) *Distolasterias elegans*; (C) *Distolasterias nipon*; (D) *Lethasterias nanimensis chelifera*.

without enlarged terminal teeth; inferomarginal spines double, each with a half-wreath of crossed pedicellariae; a series of spineless ventrolateral plates; adambulacral plates diplacanthid; mouth plates

not deeply sunken; adoral carina consisting of 2 pairs of postoral adambulacrals; large unguiculate straight pedicellariae present; odontophore with 1 or 2 pits.

*Remarks.* Fisher ('28) pointed out that *Lethasterias* has a very characteristic odontophore with 2 pits on the outer margin, but in *L. fusca* examined by the writer the odontophore has a single pit, though in *L. nanimensis chelifera* the pits are double. The writer doubts if the odontophore is reliably characteristic to separate *Lethasterias* from *Distolasterias*. *Lethasterias* may be distinguishable from *Distolasterias* in having very numerous, dorsolateral plates and spines, both irregularly arranged and in crossed pedicellariae without conspicuously enlarged terminal tooth on each side of the jaw.

#### Key to Japanese species of *Lethasterias*

- a<sup>1</sup>. Prominent unguiculate straight pedicellariae numerous, scattered all over the surface; circumspinal wreaths of crossed pedicellariae heavy, often touching one another; dorsal spines black tipped, stone-drill shaped, with 3 to 8 channels; odontophore with 2 pits ..... *nanimensis chelifera*
- a<sup>2</sup>. Prominent unguiculate straight pedicellariae not abundant, absent on dorsal and marginal surfaces; the wreath of crossed pedicellariae never touching one another; dorsal spines with finely striated; odontophore with a pit ...  
*fusca*

#### *Lethasterias fusca* DJAKONOV

(Pl. XXII, figs. 3, 4)

*Lethasterias fusca*: DJAKONOV, 1931, p. 79, figs. 5-7.

*Diagnosis.* Rays 5, long, swollen. Dorsal plates numerous, irregularly meshed; each generally with 1 small, obtuse to clavate spine with a finely fluted tip, having thick wreath of crossed pedicellariae, but the wreaths never so heavy as in *chelifera*; carinal and superomarginal plates 4-lobed, strongly imbricated; inferomarginal spines double, each with a half-wreath of crossed pedicellariae; ventrolateral plates spineless, in a series; adambulacrals plates diplacanthid; first 2 pairs of adambulacrals plates in contact each other at the interradius; odontophore with a single pit on the outer margin; large unguiculate straight pedicellariae absent on dorsal surface.

*Description.* The following description is based upon a specimen measuring 72 mm in R, 10 mm in r.

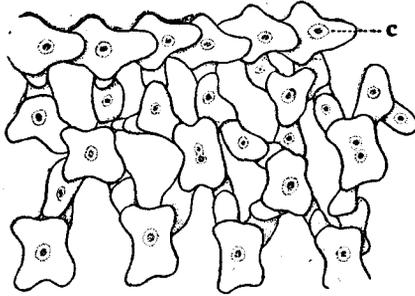


Fig. 69. *Lethasterias fusca*: Skeletal structure in the middle portion of ray, 5 $\times$ ; c carinal plate.

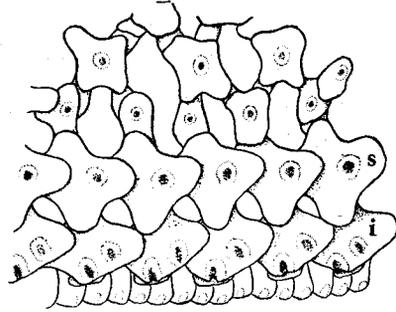


Fig. 70. *Lethasterias fusca*: Skeletal structure in the middle portion of ray, 5 $\times$ ; s supermarginal plate, i inferomarginal plate.

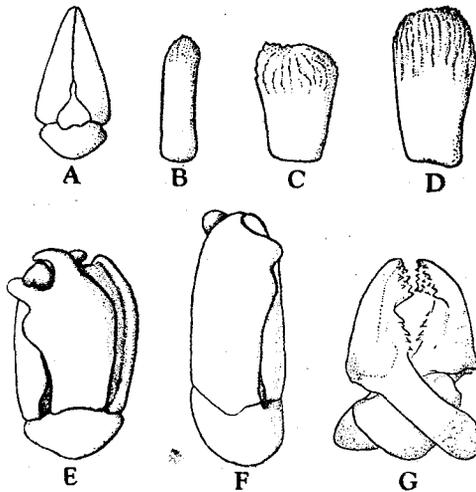


Fig. 71. *Lethasterias fusca*: (A) straight pedicellaria in furrow, 30 $\times$ ; (B)–(D) dorsal spines, 20 $\times$ ; (E) and (F) ventrolateral straight pedicellariae, 20 $\times$ ; (G) dorsal crossed pedicellaria, 120 $\times$ .

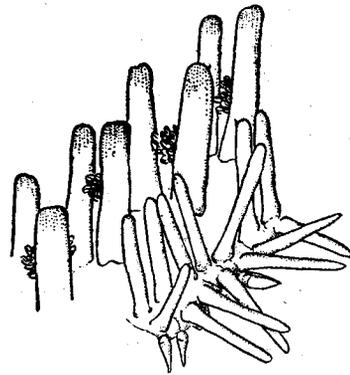


Fig. 72. *Lethasterias fusca*: Inferomarginal and adambulacral spines, 7 $\times$ .

Dorsal skeleton composed of subquadrate 4-lobed and subtriangular primary plates and oblong secondaries; carinal plates arranged in a regular longiseries, directly imbricated. Dorsal spines generally 1 to a plate but rarely 2, obtuse to clavate, finely fluted at

the tip, about 0.8 to 1.2 mm long. These spines are thickly wreathed with crossed pedicellariae lacking enlarged terminal fangs, about 0.21–0.23 mm long. The wreaths are not so heavy as in *nanimensis*, never touching one another. Dorsolateral spines without well defined order in arrangement. Papular areas with 1 to 10 papulae in an area.

Marginal plates arranged in regular longiseries; the superomarginal situated low on the side of ray. Superomarginal plates 4-lobed, directly imbricated, each with a spine longer and stouter than the dorsolaterals, thickly wreathed with crossed pedicellariae. These spines are truncate and a little compressed at the tip, mostly with a shallow groove on the outer side, measuring 1.6–2 mm in length. Inferomarginal spines, 2 to a plate, similar to the superomarginals, but a little longer and stouter, each with a half wreath of crossed pedicellariae on the outer side. Intermarginal papulae 1 to 3 in an area.

Ventrolateral plates small, spineless, corresponding to inferomarginal plates in position, reaching the distal portion of ray. Papular areas with 1 to 3 papulae in an area.

Adambulacral plates with 2 long and slender spines without attached pedicellariae, the tips being flattened; the outer slightly longer and stouter than the inner. Mouth plates each with 2 oral spines and 1 long suboral spine; adoral carina composed of first 2 pairs of adambulacral plates, each with a single spine.

In the furrow are scattered numerous small, generally lanceolate straight pedicellariae, various in size. Large unguiculate straight pedicellariae occur on mouth plates and ventrolateral regions, especially in the interbrachial portions, but rarely in intermarginal portions. The pedicellariae rarely have 3 jaws. In the dorsal and marginal portions the straight pedicellariae are few or absent.

Madreporite circular, situated about the middle of r. The colour of alcoholic specimens is uniformly black or with yellowish brown irregular patterns on rays.

*Localities.* Three specimens collected by Dr. M. Iwasa from Muroran, 1 specimen collected by Dr. T. Hikita from Usu; 1 specimen collected by Dr. S. Goto from Hokkaido.

*Distribution.* Northern Japan Sea and Tartary Gulf and southern Pacific coast of Hokkaido.

***Lethasterias nanimensis chelifera* (VERRILL)**

(Pl. XV, fig. 6 &amp; pl. XXI, fig. 2)

*Distolasterias chelifera*: VERRILL, 1914, p. 185, pl. 81, figs. 1, 1a-1b, pl. 110, figs. 1, 2.*Lethasterias nanimensis chelifera*: FISHER, 1928, p. 134, pl. 60, figs. 4, 4a-4e, pl. 61, figs. 1, 1a-1g, pl. 62, figs. 1, 1a, 2, 2a, pl. 63, pl. 64, fig. 2.

*Description.* The following description is based upon a specimen measuring 110 mm in R, 12 mm in r.

Skeletal structure similar to that of *L. fusca*; carinal plates 4-lobed, directly imbricated in a regular longiseries; dorsolateral skeleton composed of irregular 3- to 5-lobed primary plates and oblong secondaries. Dorsal spines tipped black, 1 to a plate, obtuse to clavate, stone-drill shaped, with 3 to 8 unequal channels, 1.2-1.5 mm

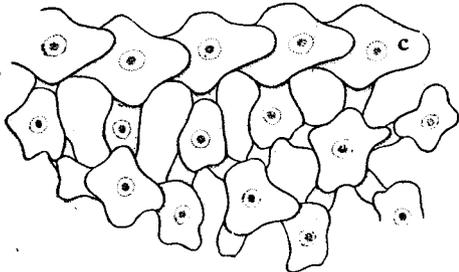


Fig. 73. *Lethasterias nanimensis chelifera*: Skeletal structure in the proximal portion of ray, 5x; c carinal plate.

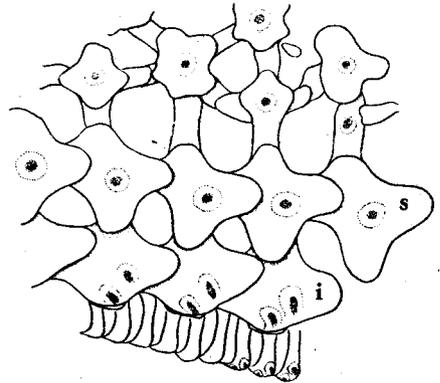


Fig. 74. *Lethasterias nanimensis chelifera*: Skeletal structure in the proximal portion of ray, 5x; s superomarginal plate, i inferomarginal plate.

long. The spines are thickly wreathed with crossed pedicellariae measuring about 0.3 to 0.33 mm in length. The circumspinal wreaths of crossed pedicellariae frequently touch one another and the grooves or channels of spine tips are much more conspicuous than in *L. fusca*. The pedicellariae are larger than those of *fusca*. Papulae filling the spaces between the wreaths of crossed pedicellariae, 3 to 5 in an area.

Marginal plates 4-lobed, arranged in regular longiseries; superomarginal plates situated low on the side of ray, each with a single stone-drill shaped spine thickly encircled with crossed pedicellariae, the spines being slightly larger than or subsimilar to the adjacent dorsolateral spines. Inferomarginal spines, 2 to a plate, a little heavier than the superomarginals, having truncate, terminally flat-

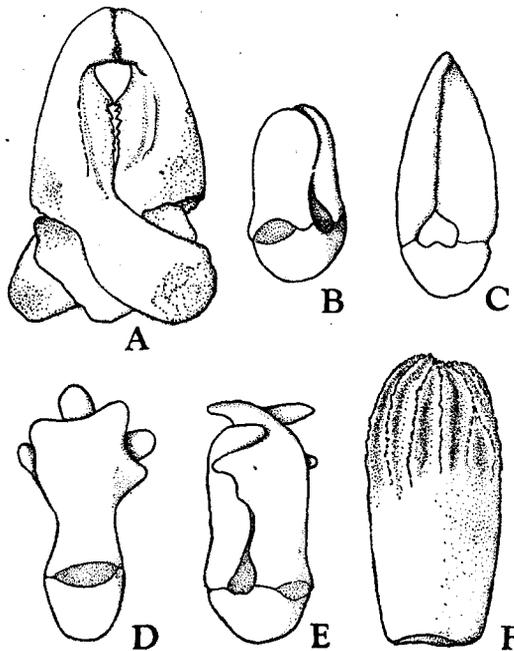


Fig. 75. *Lethasterias nanimensis chelifera*: (A) crossed pedicellaria, 110 $\times$ ; (B) dorsal straight pedicellaria, 25 $\times$ ; (C) straight pedicellaria in furrow, 35 $\times$ ; (D) and (E) dorsal straight pedicellariae, 25 $\times$ ; (F) dorsal spine, 25 $\times$ .

tened striated tip with a shallow groove, each with a cluster of crossed pedicellariae on the outer side. Intermarginal papular areas with 2 or 3 papulae in an area. In the distal portion of ray the areas become narrow, and the circumspinal wreaths of crossed pedicellariae of both marginal plates are touched.

Ventrolateral plates small, spineless, opposite to each inferomarginal plate, extending the middle of ray. The series is less developed than in *fusca*.

A large number of prominent unguiculate straight pedicellariae are scattered all over the surface and the large ones are found in ventrolateral portions, measuring 1.3 mm in length, beside these, small spatulate straight pedicellariae found in dorsal surface.

Adambulacral plates each with 2 long slender, bluntly pointed spines; in furrow scattered numerous small lanceolate straight pedicellariae, various in size. Mouth plates each with 2 oral spines, the inner being much longer and stouter than the outer, with terminally flattened tip; suboral spines single, long and slender. Odontophore with 2 pits on the outer border.

Madreporite circular, situated about the middle of r.

The colour in a dry specimen is blackish gray in the dorsal side, the ventral side a little paler.

*Localities.* Tartary Gulf, 38 fathoms, green mud (Albatross, 1906, Station 5004); Tartary Gulf, 35 fathoms, fine gray sand, green mud (Station 5003); off Bomasirisima, 142 fathoms, gray mud, sand, gravel (Station 4993); vicinity of Cape Patience, 75 fathoms, sand, pebbles (Station 5023); Aniwa Bay 42 fathoms, green mud (Station 5012); Rakuma, Saghalien.

*Distribution.* From Saghalien to Bering Strait thence to Gulf of Alaska and southward to Hokkaido.

### Subfamily Pycnopodiinae VERRILL

*Pycnopodiinae:* VERRILL, 1914, p. 197.

### Genus *Lysastrosoma* FISHER

*Lysastrosoma:* FISHER, 1922, p. 590; . . . ., 1924, p. 1; . . . ., 1928, p. 148.

Type, *Lysastrosoma anthosticta* FISHER.

*Diagnosis.* Rays 5, soft and weak; dorsal skeleton reduced to isolated small spiniferous plates interspersed with vestigial perforated spineless platelets. Marginal skeleton poorly developed; superomarginals monacanthid, alternately spineless; inferomarginals diplacanthid, discontinuous; sometimes the marginals are each connected by 1 or 2 small intermediate ossicles. Dorsal and marginal spines each encircled by a thick sheath expanded distally, bearing numerous crossed pedicellariae with a conspicuous enlarged lateral terminal tooth; 2 inferomarginals in a common sheath. Adambulacral spines

single, without attached pedicellariae. Mouth plates prominent, with a pair of enlarged postoral adambulacral plates.

***Lysastrosoma anthosticta* FISHER**

(Pl. XIV, figs. 12, 13)

*Lysastrosoma anthosticta*: FISHER, 1922, p. 591, figs. 1, 2; . . . ., 1924, p. 2, 5 figs., pls. 1, 2; . . . ., 1928, p. 149, pl. 73, fig. 1, 1a-1j, pl. 75.

*Diagnosis.* Differing from closely related species, *L. demiora* Clark, in having weaker skeleton; fewer dorsal isolated plates, more numerous vestigial perforated platelets; much weaker marginal intermediate ossicles; and smaller first adambulacral plates.

*Description.* R 71 mm, r 9 mm, breadth of arm base 10 mm; R ranging from 5.8 to 11.3r.

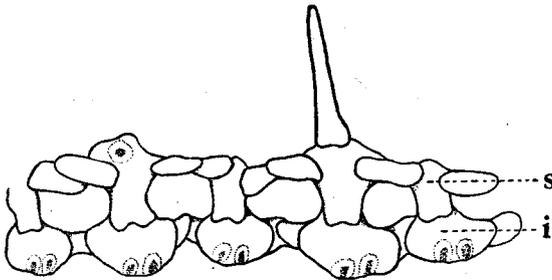


Fig. 76. *Lysastrosoma anthosticta*: Marginal plates in the proximal portion of ray, 7 $\times$ ; s superomarginal plate, i inferomarginal plate.

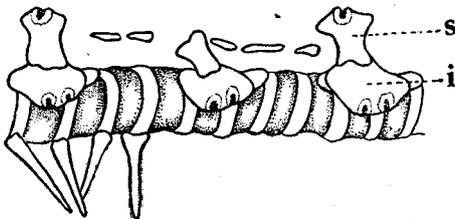


Fig. 77. *Lysastrosoma anthosticta*: Marginal and adambulacral plates in the proximal portion of ray, 7 $\times$ ; s superomarginal plate, i inferomarginal plate.

Due to the absence of dorsal connecting skeleton, whole the body is soft and flabby; even in the marginal and ambulacral plates the articulation is rather loose, so the measurements in life may be varia-

ble in the conditions. Dorsal skeleton composed of small isolated plates, each bearing a slender acicular spine, about 0.8 mm to 1.2 mm in length, thickly beset with crossed pedicellariae. These spines are not in any regular series; crossed pedicellariae with an enlarged lateral tooth on one side of each jaw. Numerous papulae and small slender to broadly lanceolate straight pedicellariae scattered all over the surface, measuring 0.2 to 0.4 mm in length. Perforated vestigial platelets immersed in integument, roundish or elliptical in contour, about 0.1 mm in diameter.

Alternate superomarginal plates spineless, much smaller than the spiniferous plates. The large superomarginals each carry a long slender spine in a thick sheath crowded with pedicellariae 2.5 mm to 3 mm long; the tip of spine is entirely hidden by or a little protruded.

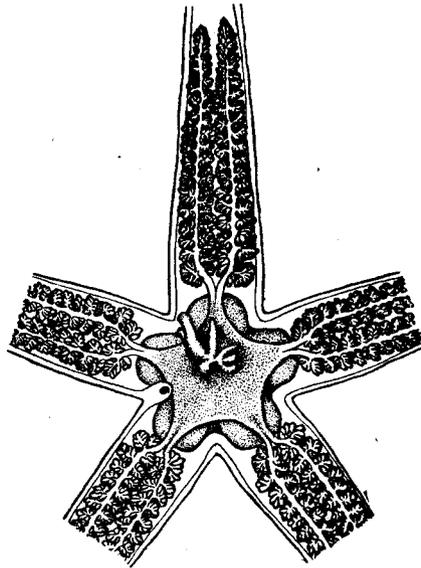


Fig. 78. *Lysastrosoma anthosticta*: Dorsal view of digestive organs, about natural size.

from the cushion of crossed pedicellariae. In the proximal portion of ray these plates are connected by small intermediate ossicles, but the ossicles entirely disappear at the distal portion of ray, and the marginal plates become rudimentary. Inferomarginal plates also disconnected, except at arm base, each bearing 2 subequal bluntly pointed

spines subsimilar to the superomarginals, the 2 spines being involved in a single sheath with crossed pedicellariae. Ventrolateral plates absent.

Adambulacral plates small, thin, each with a single slender spine being devoid of attached pedicellariae. Small straight pedicellariae occur in furrow. Ambulacral furrow wide; tube-feet in 4 ranks. Mouth plates prominent, each provided with 2 or 3 flattened, truncate oral spines and a long suboral spine at the outer end of plate. The oral spines bear a group of small straight pedicellariae. Following the mouth plates the first pair of adambulacral plates are enlarged and joined, the second being separated.

Madreporite circular, situated near the edge of the disc.

*Localities.* Muroran, Akkesi in Hokkaido and Onagawa, Honsyu.

*Distribution.* Hokkaido and northern Honsyu.

*Anatomical note.* The internal structure is not reduced, similar to that the *Asterias*. Body brownish purple; spines reddish brown. Peristome circular, colourless. Stomach colourless; cardiac stomach thin, loosely separated from pentagonal pyloric one. Hepatic caeca reaching  $2/3$  of ray, without spacious median cavity, the casca in pair opening into the pyloric stomach by a common duct. Rectal sac greenish brown, lobular. Tiedeman's bodies, 2 in each interradius, except the madreporic one where only one body occurs. Polian vesicles absent. Tube-feet each with a single ampulla.

### Subfamily Asteriinae (VERRILL)

*Asteriinae:* VERRILL, 1914, p. 42; FISHER, 1923, p. 250; . . . ., 1298, p. 57; . . ., 1930, p. 2.

#### Key to Japanese genera of Asteriinae

- a<sup>1</sup>. Adambulacral spines provided with cluster of straight or straight and crossed pedicellariae.
- b<sup>1</sup>. Gonads opening dorsally, adambulacrals mixed monacanthid and diplacanthid, or diplacanthid, or mixed diplacanthid and triplacanthid.
  - c<sup>1</sup>. A single series of ventrolateral plates, spineless or with a small spine; inferomarginal plates strictly ventral in position, the superomarginals defining the ambitus of ray; furrow spines of alternate adambulacrals more or less toward furrow . . . . . *Asterias* LINNÉ
  - c<sup>2</sup>. 3 to 6 prominent series of ventrolateral plates, each bearing 1 or 2 stout spines; inferomarginal plates lateral in position; furrow spines of alternate adambulacral plates often somewhat toward furrow . . . . . *Evasterias* VERRILL

- b<sup>2</sup>. Gonads opening ventrally; adambulacrals monacanthid, diplacanthid or mixed monacanthid and diplacanthid, 1 or 2 series of spiniferous ventrolateral plates; dorsal skeleton more or less open; spines small, often having an appearance of being arranged in longiseries ..... *Leptasterias* VERRILL
- a<sup>2</sup>. Adambulacrals devoid of attached pedicellariae; gonads opening just above superomarginals at a distance from interbrachial angle; ventrolateral plates absent; adambulacrals diplacanthid; marginal plates each with a transverse comb of 3 or 4 spines ..... *Aphelasterias* FISHER

### Genus *Aphelasterias* FISHER

*Aphelasterias*: FISHER, 1923, p. 602. Type, *Asterias japonica* BELL.

*Diagnosis.* Dorsal skeleton closely meshed, papular areas small; numerous, imbricated; carinal plates in a regular longiseries. Dorsal spines in small groups, carrying small crossed pedicellariae. Marginal plates regular, larger than dorsolaterals, each bearing a transverse comb of 3 or 4 bluntly pointed or compressed spines, each with a tuft of crossed pedicellariae. Intermarginal spines present in the fully adult specimens. Ventrolateral plates absent. Adambulacrals plates diplacanthid; no adambulacrals spine pedicellariae. Straight pedicellariae small, lanceolate or dentate, variable in size. Gonads open just above superomarginals at a distance from interbrachial angle.

#### Key to Japanese species of *Aphelasterias*

- a<sup>1</sup>. Dorsal spines small, subtruncated; marginal spines, especially inferomarginals, stout, truncate and compressed; straight pedicellariae small, not numerous, only in furrow ..... *japonica*
- a<sup>2</sup>. Dorsal spines much longer and tapering; marginals not compressed, but slender and bluntly pointed; straight pedicellariae numerous in furrow, the large being dentate ..... *torquata*

### *Aphelasterias japonica* (BELL)

(Pl. XXI, fig. 1 & pl. XXII, fig. 5)

*Asterias japonica*: BELL, 1881, p. 515, pl. 48, figs. 6, 6a-b; DÖERLEIN, 1902, p. 335.

*Aphelasterias japonica*: FISHER, 1930, p. 205.

*Diagnosis.* Rays 5, constricted at base. Dorsal plates numerous, closely meshed: papular areas small. Carinal plates in a regular series,

each with 5 to 9 spinelets; dorsolaterals with 1 to 7 spinelets. Marginal series regular; 3 or 4 inferomarginal spines in a transverse comb, stout, broad, truncate and compressed; intermarginal plates present proximally; adambulacral plates diplacanthid; straight pedicellariae small, not numerous, only in furrow.

*Description.* The description based upon a specimen (R 110 mm, r 12 mm) is as follows:

Dorsal skeleton closely meshed; 4-lobed carinal plates arranged in a regular longiseries, each with 5 to 9 small spinelets with subtruncate or bluntly pointed tips, about 0.7 to 0.9 mm long. Dorsolateral plates irregular in form, arranged somewhat in irregular

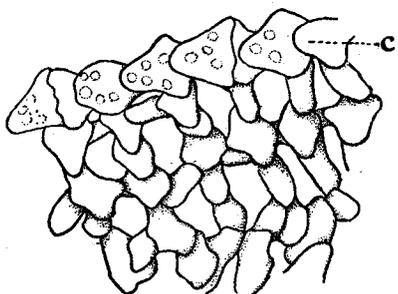


Fig. 79. *Aphelasterias japonica*: Skeletal structure in the middle portion of ray, 7 $\times$ ; c carinal plate.

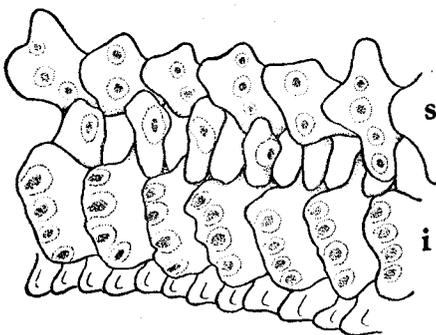


Fig. 80. *Aphelasterias japonica*: Skeletal structure in the proximal portion of ray, 7 $\times$ ; s superomarginal plate, i inferomarginal plate.

transverse series, each bearing 1 to 7 spinelets, 1–1.5 mm long, increasing in length lateralward. These spinelets are each beset with a circlet of small crossed pedicellariae, about 0.2 mm long. Papular areas small, mostly with 2 to 4 (1 to 6) papulae in an area; no straight pedicellariae.

Marginal plates in 2 regular rows, directly imbricated. Superomarginal plates each with 2 to 4 spines in an oblique transverse row, with slightly curved extremity being bluntly pointed or compressed. They are slightly stouter than the adjacent dorsolaterals, about 1.7–2 mm long, the spinal crossed pedicellariae being in a circlet or in a tuft on the outer side. Inferomarginal plates each with a prominent transverse comb of 4 or 5 compressed, broad, truncated spines bearing

a group of crossed pedicellariae on the outer side. These spines are much stouter than the superomarginals, about 2.5 mm long and 1 mm wide. In the proximal portion of ray is a series of intermarginal

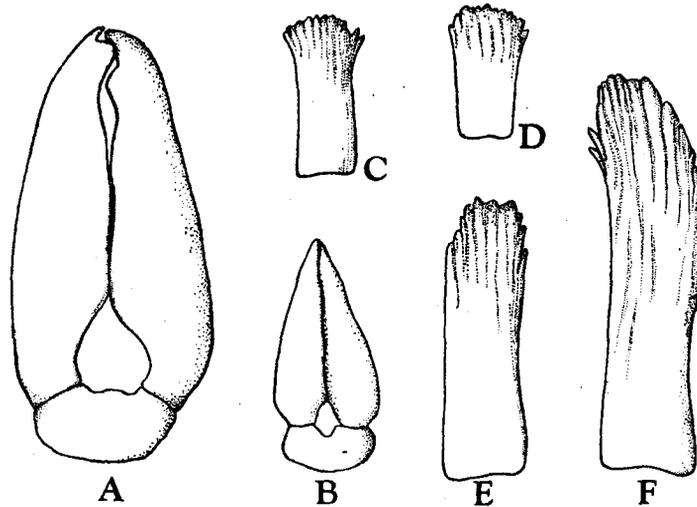


Fig. 81. *Aphelasterias japonica*: (A) and (B) straight pedicellariae in furrow, 55 $\times$ ; (C)-(E) dorsal spines, 25 $\times$ ; (F) superomarginal spine, 25 $\times$ .

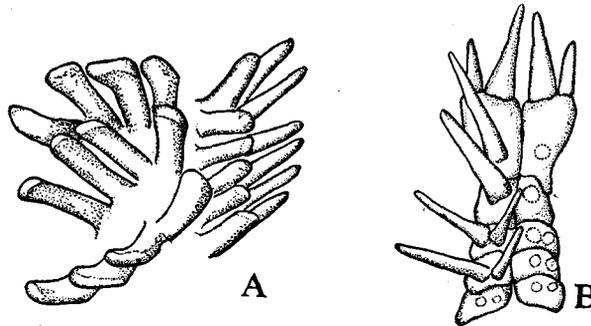


Fig. 82. *Aphelasterias japonica*: (A) adambulacral and intermarginal spines in the middle portion of ray, 7 $\times$ ; (B) mouth plates and adambulacral plates, 7 $\times$ .

plates, mostly each with a single spinelet. Intermarginal papular areas each containing 1 to 3 papulae.

Adambulacral spines double, the outer being a little stouter than the inner, with truncated compressed tip, the inner bluntly pointed.

Small lanceolate straight pedicellariae occur in furrow, but not numerous, variable in size. Adoral carina composed of first 3 pairs of adambulacral plates, the first plates being not conspicuously larger than the rest and each with a single spine. Mouth plates each armed with 2 or 3 large oral spines and 1 suboral.

Madreporite circular, swollen, situated nearer the margin of disc than the centre.

Colour in life reddish brown, occasionally with darker transverse patterns in rays.

*Localities.* Osyoro, Muroran, Nemuro in Hokkaido; Aniwa Bay and Busse Lake in Saghalien; Mutsu Bay, Toyama Bay and Tokyo Bay.

*Distribution.* From Saghalien to southward to Tokyo and Toyama Bays.

***Aphelasterias japonica* forma *torquata* (SLADEN)**

(Pl. XXII, figs., 1, 2)

*Asterias torquata*: SLADEN, 1889, p. 570, pl. 102, figs. 1-4.

*Aphelasterias japonica* forma *torquata*: FISHER, 1930, p. 205.

*Diagnosis.* Differing from *A. japonica* in having much longer and slender spines on dorsal and marginal plates; furrow pedicellariae a little more numerous, the large being dentate.

*Description.* Skeletal structure closely similar to that of *A. japonica*. Papular areas each with 2-6 papulae. Carinal spines, 2 to 4 to a plate, longer than those of *japonica*, 1-1.6 mm long; dorso-lateral spines, 1 to 3 for a plate, slender and tapering. The dorso-laterals are about 2 mm long, beset with crossed pedicellariae, and the small protuberances of plate for spines are a little more prominent than in *japonica*. Superomarginal spines also slender and tapering, 2.5-2.7 mm long, 3 or 4 for a plate, arranged in an oblique transverse row; inferomarginal spines, 3 or 4 to a plate, long and slender, slightly flattened, not so broad and stout as in *japonica*, about 3 mm in length. Ventrolateral plates absent.

Adambulacral spines double, long and slender, the outer being a little larger than the inner. Adoral carina composed of first 2 pairs of adambulacral plates; mouth plates with 2 or 3 oral spines, the innermost being longer and stouter than the others. Suboral

spines single. A large number of lanceolate straight pedicellariae are found in furrow, the large being dentate.

Madreporite circular, swollen, situated nearer the margin of disc than the centre.

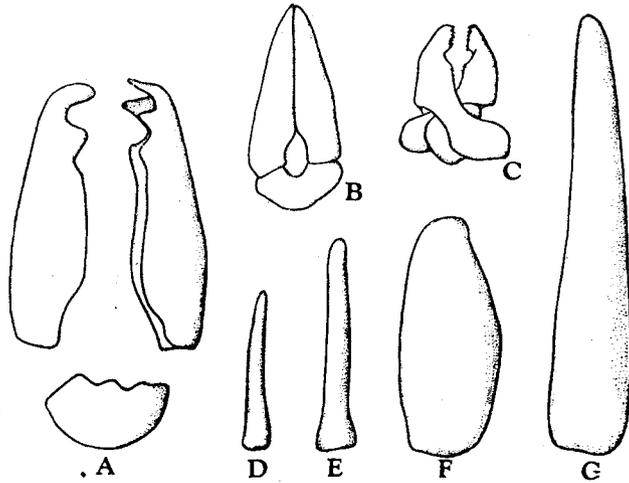


Fig. 83. *Aphelasterias japonica* forma *torquata*: (A) and (B) straight pedicellariae in furrow, 40 $\times$ ; (C) crossed pedicellaria, 80 $\times$ ; (D) and (E) dorsal spines, 17 $\times$ ; (F) inferomarginal spine of *A. japonica*, 17 $\times$ ; (G) inferomarginal spine of *torquata*, 17 $\times$ .

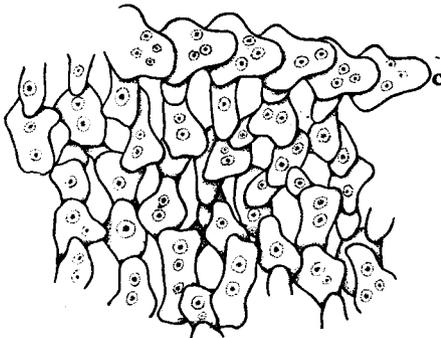


Fig. 84. *Aphelasterias japonica* forma *torquata*: Skeletal structure in the proximal portion of ray, 5 $\times$ ; c carinal plate.

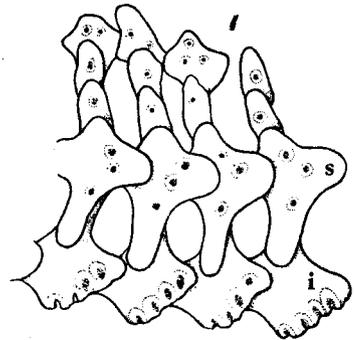


Fig. 85. *Aphelasterias japonica* forma *torquata*: Skeletal structure in the proximal portion of ray, 5 $\times$ ; s superomarginal plate, i inferomarginal plate.

The measurements are as follows:

Station	R	r	R:r	Locality	Depth	Character of bottom	Collection
4807	103 mm	11 mm	9.3	Tugaru Strait	44 fms	Shells, coarse gravel	Albatross, 1906
4807	120 mm	13 mm	9.2	"	"	"	"

*Locality.* Tugaru Strait.

*Distribution.* Off Yokohama to Tugaru Strait, 5 to 47 fathoms.

### Genus *Asterias* LINNEAUS

*Asterias*: LINNÉ, 1758, p. 66; FISHER, 1930, p. 5. Type, *Asterias rubens* LINNEAUS.

### *Asterias amurensis* LÜTKEN

*Asterias*: LINNÉ, 1758, p. 66; FISHER, 1930, p. 5. Type, *Asterias rubens* pl. 7; HAYASHI, 1936, p. 5, pls. 1, 2.

*Asterias rollestoni*: BELL, 1881, p. 151; DÖDERLEIN, 1902, p. 333; UCHIDA, 1928, p. 797, pl. 31, figs. 2, 3.

*Allasterias forficulosa*: VERRILL, 1914, p. 194, pl. 83, figs. 3-3c, pl. 84, fig. 1.

*Asterias amurensis rollestoni*: FISHER, 1930, p. 205.

*Asteracanthion rubens* var. *migrata*: SLADEN, 1879, p. 432.

*Allasterias migrata*: VERRILL, 1940, p. 373.

*Asterias amurensis migrata*: FISHER, 1930, p. 205.

*Diagnosis.* Rays 5, very rarely 6; dorsal side low arched; ventral side flattened, superomarginal plates defining the ambitus; broad at the base, tapering rapidly to a blunt point; dorsal spines small, the carinal in a wavy line; superomarginal spines 6 to 9, variable with growth and in locality; inferomarginal spines usually 2 through the life; adambulacral spines 3 and 2 alternating proximally, the furrow spines alternately in position toward furrow.

*Description.* The writer ('36) described the species in his another paper, with the note on the variations. The following description is based upon a specimen (R 180 mm, r 47 mm, arm base 51 mm) obtained from Akkesi Bay.

Dorsal spines small, robust outlining papular areas, the tips being compressed or slightly grooved, 1 to 1.5 mm long. The carinal series is represented by an indistinct wavy line. Dorsolateral spines in irregular longiseries. Papulae numerous, increasing with growth. Superomarginal plates defining the ambitus of ray, each with 6 to 9

spines forming a dense cheveude-frise on the very angular margin of ray. These spines are spatulate or gouge-shaped, 2 or 3 times heavier than the dorsolaterals, about 2.5 to 3 mm long. They are variable in number and form with growth and in localities. Ventrolateral side flattened, with double rows of inferomarginal spines, separated from the superomarginals by a conspicuous channel and from the adambulacral plates by a little narrower channel, both channels densely covered with papulae. A short series of intermarginal spines is found. Inferomarginal spines, 3 to 4.7 mm long, spatulate or gouge-shaped, broader at the tip than the base. Ventrolateral plates rudimentary, without spine.

Adambulacral spines much longer than the inferomarginals, 4.5 to 5.5 mm long. Furrow spines tapering or blunt, situated on alternate plates. Proximally 2 subambulacral spines present, single distally, the tips being compressed or grooved on the outer side. The adambulacral formula is 3,2,3,2,—2,2,2,2,—2,1,2,1,—. The subambulacral spines increase in number and variable in form with growth. The new spines occur first in the proximal portion of ray at the outer side of the old spines, thus the arrangement and form of spines show those of junior stages of the sea-star gradually toward the tip. Mouth plates small, sunken, each with 2 spines. Adoral carina composed of first 6 pairs of adambulacral plates with 2 spines. Furrow spines appear first on the 7th or 8th plates.

Madreporite circular, large, situated about the middle of r.

Pedicellariae very abundant: Small ovate to lanceolate straight pedicellariae scattered over the dorsal surface, on superomarginal, intergarginal and inferomarginal plates and the base of the spines, and on the adambulacral and mouth plates and the spines. Furrow spines each with a cluster of 9 to 13 straight pedicellariae. Those on ventral side are about twice as large as the dorsal ones; in the intermarginal channel, the straight pedicellariae measure about 0.9 to 1.2 mm in length, while the dorsals are about 0.3 to 0.5 mm long. Crossed pedicellariae present on the dorsal and ventral sides forming usually a single circle around the dorsal spine, ranging from 0.24 to 0.27 mm in length. The pedicellariae form clusters on the upper and outer side of all marginal and subambulacral spines, but not on the alternate furrow spines bearing straight pedicellariae only.

Madreporite large, circular, situated slightly nearer the centre of disc than the margin.

*Localities.* Akkesi, Muroran, Osyoro, Hakodate; Busse Lake, Saghalien; off Kinkasan, 82 fathoms, Miyazu Bay, Tango, Toyama Bay, Sirahama, Kii, off Yamagata Prefecture, Tomari Bay, Kunasiri Kurile Islands.

*Distribution.* Widely distributed in the North Pacific regions and Japan.

*Asterias amurensis versicolor* SLADEN

(Pl. XX, figs. 5, 6)

*Asterias versicolor:* SLADEN, 1889, p. 573, pl. 104, figs. 1-4.

The writer ('36) formerly suggested that the species is probably a variety of *A. amurensis*. Recently he examined two specimens of the species. It is closely related to the *rollestoni*-form of *amurensis*, but the spinulation is apparently distinct from *amurensis* and the pedicellariae are smaller.

*Diagnosis.* Resembling *rollestoni*-form of *amurensis*, but differing in having a little stouter skeleton and fewer spines, carinal and superomarginal plates each with usually a single spine forming regular longiseries, pedicellariae smaller and slenderer. R 62 mm, r 17mm.

*Description.* General form similar to that of *amurensis*; carinal spines arranged in a regular longiseries, small, but robust, truncate, 1-1.2 mm long. Dorsolateral spines widely spaced, slightly larger than the carinals, arranged in 2 irregular longiseries. Small slender straight pedicellariae uniformly scattered on the dorsal surface, 0.2 to 0.35 mm long. Crossed pedicellariae small, arranged in a circle around the base of spines, about 0.2-0.22 mm long. Papulae numerous.

Dorsal skeleton irregular open meshed, carinal plates in a regular longiseries, each with a spine. The skeleton is a little stouter than in *rollestoni*-form. The colour in a dry specimen is dark brown mottled with pale yellow, each dorsal spine in the centre of the yellowish zones.

Superomarginals each with usually a spine, longer and stouter than the dorsolaterals, about 1.7-2 mm long, bearing a cluster of crossed pedicellariae (about 0.2 mm long) at the base. Inferomarginal plates with 2 stout robust spines in double rows, the series

being separated from the superomarginal series by a channel with a series of spineless intermarginal plates reaching two-thirds the length of ray and from adambulacral series by a channel with a series of spineless ventrolateral plates reaching the middle of ray. The intermarginal channel is slightly broader than the ventrolateral. Small straight pedicellariae with slender jaws scattered in the both channels; those in intermarginal channel being larger than the ventrolaterals.

Adambulacral spines 1 and 2 regularly in alternate position; furrow spines cylindrical, bluntly pointed, with several slender straight pedicellariae; subambulacral spines with flattened truncate tip proximally, indicating a shallow groove on the outer side, each with 1 or 2 straight pedicellariae only or mixed with 1 to 3 crossed pedicellariae. Mouth plates with 2 cylindrical spines, the inner about two-thirds the length of the outer.

Madreporite circular, conspicuous, situated nearer than the centre of disc and the margin.

*Localities.* Toyama Bay and Daityosima (Inland Sea).

*Distribution.* Southern regions of Japan.

### Genus *Evasterias* VERRILL

*Evasterias*: VERRILL, 1914, pp. 51, 151. Type, *Asterias troschelii* STIMPSON; FISHER, 1930, p. 139.

*Diagnosis.* Differing from *Asterias* in having numerous ventrolateral plates, each with 1 or 2 spines, arranged in 3 to 6 longiseries; between these series are present series of papular areas. Dorsal skeleton robust, irregularly meshed, composed of 3 or 4 irregularly lobed primary plates and elliptical or elongated secondaries; carinal plates 4-lobed, arranged in an irregular series; spines short, various in form. Inferomarginal plates rather lateral in position, similar to the adjacent ventrolaterals in size and form; adambulacral plates monacanthid, diplacanthid or irregularly mixed diplacanthid and triplacanthid, the spines carrying prominent clusters of crossed and straight pedicellariae; adoral carina composed of first 3 to 5 pairs of adambulacral plates; straight pedicellariae toothless or unguiculated; crossed pedicellariae without enlarged terminal fangs; gonads open dorsally, close to the interradial line.

Key to Japanese species of *Evasterias*

- a<sup>1</sup>. Dorsal spines small, crowded, forming irregular reticular patterns; inferomarginal plates low on the side of ray; 4 series of ventrolateral plates; adambulacral plates diplacanthid; dorsal straight pedicellariae few; ventral straight pedicellariae not dentate ..... *alveolata*
- a<sup>2</sup>. Dorsal spines isolated; inferomarginal plates high at side of ray; straight pedicellariae unguiculated.
- b<sup>1</sup>. Dorsal straight pedicellariae small, lanceolate; 4 to 6 series of ventrolateral plates; adambulacral plates diplacanthid and triplacanthid ....  
*echinosoma*
- b<sup>2</sup>. Dorsal spines more widely spaced; dorsal straight pedicellariae not lanceolate, but very prominent, unguiculated; 3 series of ventrolaterals; adambulacral plates monacanthid ..... *robusta*

*Evasterias troschelii* forma *alveolata* VERRILL

(Pl. XVI, fig. 5 &amp; pl. XX, figs. 3, 4)

*Evasterias troschelii* var. *alveolata*; VERRILL, 1914, p. 162, fig. 1.*Evasterias troschelii* forma *alveolata*; FISHER, 1930, p. 144, pl. 58; figs. 2, 2a-2c, 7a, 7b, pl. 59, figs. 1, 1a, pl. 61, figs. 2, 3, pls. 62, 63, pl. 66, fig. 1.

The specimens examined are closely related to the present species, but differ in having much more developed spinulation. The Japanese specimens may be a multispined form of the variant species.

*Diagnosis.* Differing from *E. echinosoma* in having much more numerous, smaller dorsal spines forming irregular reticular patterns; in having more numerous spines on marginal and ventrolateral plates; fewer ventrolateral plates; in lacking dentate large straight pedicellariae; small lanceolate straight pedicellariae on dorsal surface few or absent; inferomarginal plates lower on the side of ray; adambulacral plates monacanthid and diplacanthid or diplacanthid.

*Description.* The following description is based upon a specimen measuring 135 mm in R, 28 mm in r.

Disc large; rays 5, broad at the base, gradually tapering. Dorsal skeleton irregularly meshed, composed of 4 or 5 irregularly lobed, subtriangular and irregular shaped principal plates and the oblong intermediate plates, carinal series not well marked. Dorsal spines crowded, forming very evident reticular patterns; small, but rather robust, cylindrical, obtuse to truncate, clavate or capitate, with finely striated tips, about 0.7 mm long. Ten to 20 or more spines pack on each large plates and 3 to 10 on smaller somewhat transversely elong-

ated plates, carinal spines not heavier than dorsolaterals. These spines are encircled by small crossed pedicellariae, about 0.21 to 0.24 mm long. The spaces between the spine-groups are filled with

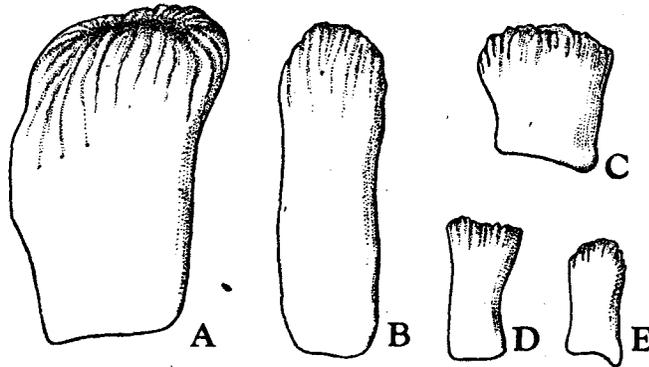


Fig. 86. *Evasterias troscheli* forma *alveolata*: (A) and (B) ventrolateral spines, 25 $\times$ ; (C)-(E) dorsal spines, 25 $\times$ .

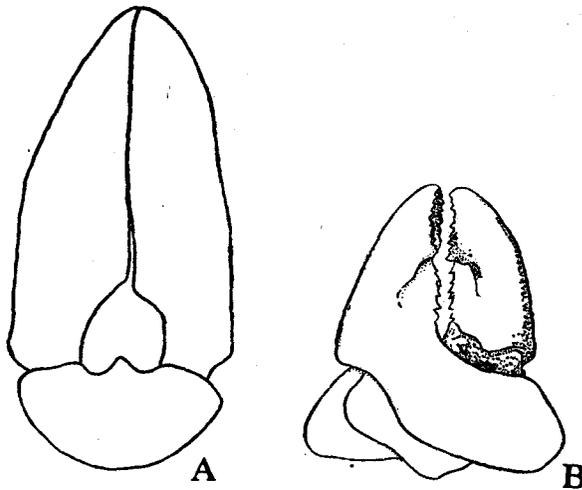


Fig. 87. *Evasterias troscheli* forma *alveolata*: (A) adambulacral straight pedicellaria, 70 $\times$ ; (B) crossed pedicellaria, 160 $\times$ .

abundant papulae and minute spinelets and isolated crossed pedicellariae; dorsal straight pedicellariae seemingly absent, but when present, very minute.

Marginal plates distinct, lozenge form to 4-lobed, closely imbricated; superomarginal plates much larger than the inferomarginals, forming the lateral margin of ray, curve up at interradius to the level of madreporite. Intermarginal channel fairly broad; there is a series of rod-like spineless intermarginal plates reaching the middle of ray, but in small specimens the series absent. Superomarginal spines not single, but in groups, 5 to 8 to a plate, similar to dorsal spines in form, but slightly larger. Inferomarginal spines similar to superomarginals, but fewer, 3 to 5 for a plate.

Ventrolateral plates arranged in 4 series (4 even in small specimens) closely imbricated, each with generally 2 or 3 spines with crossed pedicellariae on the outer side. These spines are longer and stouter than the marginals, the tips being truncate or obtuse, often slightly flattened, but in the proximal portion of ray the spinulation of the uppermost ventrolateral plates is similar to that of marginal plates. There is a short series of connecting plates in the proximal portion of ray between inferomarginal plates and the next ventrolaterals, but the series is absent in small specimens.

Adambulacral plates usually diplacanthid, the outer spines being stouter than the inner, each with a cluster of crossed pedicellariae and large straight ones. Mouth plates each with 2 rather short, stout oral spines, the inner being much longer and stouter than the outer. Suboral spines single, long. Adoral carina composed of 6 or 7 pairs of postoral adambulacral plates, the adoral 2 or 3 plates each with a single long spine. In small specimens the adoral carina is composed of first 3 pairs of adambulacral plates.

Straight pedicellariae small, lanceolate, few on dorsal surface, but fairly abundant on intermarginal and ventrolateral surfaces and in furrow, 0.45 to 1 mm in length.

Madreporite circular, situated about midway between the centre of disc and the margin.

*Locality.* Busse Lake, Saghalien.

*Distribution.* North Pacific regions.

*Evasterias echinosoma* FISHER

(Pl. XVIII, fig. 2 & pl. XIX, fig. 6)

*Evasterias echinosoma:* FISHER, 1926, p. 2, pls. 1, 2; . . . ., 1930, p. 152, pl. 59, figs. 2, 2a-2h, pls. 67-69.

*Diagnosis.* Rays 5, long and stout, the dorsal side being swollen and convex, the ventral subflattened. Dorsal spines well spaced, generally 1 to a plate, nearly uniform in size. Supermarginal plates generally monacanthid, dorsal in position; inferomarginals or the uppermost ventrolaterals demarcating the margin of ray, ventrolaterals in 4 or 5 (6) longiseries, generally monacanthid often diplacanthid; adambulacrals triplacanthid or diplacanthid and triplacanthid. Two sorts of straight pedicellariae; the small lanceolate obtuse or acute, the larger denticulated.

*Description.* Twelve specimens were examined. The description based upon a specimen (R 143–160 mm, 25 mm in r, 27 mm in breadth of arm base) is given below.

Rays 5, long and stout, very gradually tapering, the dorsal surface being convex and swollen and the ventral subflattened. Dorsal skeleton irregularly meshed, composed of 3- or 4-lobed large primary plates with irregular outline and smaller secondaries; carinal plates

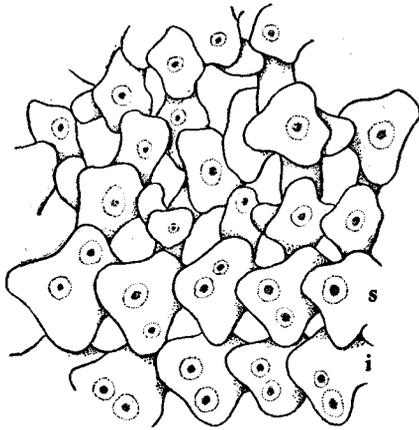


Fig. 88. *Evasterias echinosoma*: Skeletal structure in the proximal portion of ray, 5 $\times$ ; s supermarginal plate, i inferomarginal plate.

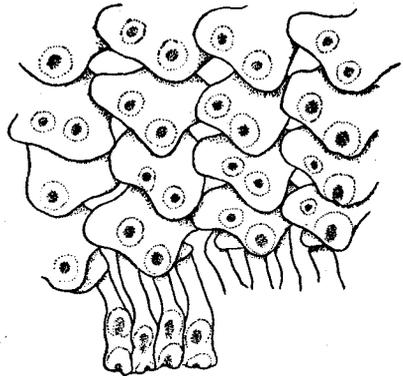


Fig. 89. *Evasterias echinosoma*: Ventrolateral plates and adambulacrals in the proximal portion of ray, 5 $\times$ .

4-lobed, arranged in a longiseries, though somewhat irregular. Dorsal spines well spaced, robust, subconical, generally 1 to a plate (but often 2), nearly uniform in size, about 1.5–2 mm long; when 2 spines occur to a plate, the one is smaller. These spines are irregularly

arranged, but somewhat in longiseries proximally, each thickly wreathed with small crossed pedicellariae without enlarged terminal fangs, about 0.3 mm in length. All the spaces between the circumspinal wreaths of crossed pedicellariae appear to be occupied with numerous papulae, straight pedicellariae and isolated crossed pedicellariae. Straight pedicellariae on dorsolateral surface lanceolate, obtuse or acute, having a tendency to increase in size toward the furrow; the large ones on marginal and ventrolateral regions are denticulated; those in the furrow small, elongated triangular in form.

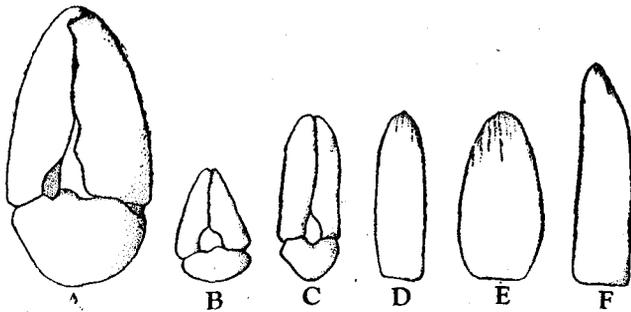


Fig. 90. *Evasterias echinosoma*: (A) ventrolateral straight pedicellaria, 25 $\times$ ; (B) straight pedicellaria in furrow, 25 $\times$ ; (C) dorsal straight pedicellaria, 25 $\times$ ; (D) and (E) dorsal spines, 12 $\times$ ; (F) ventrolateral spine, 12 $\times$ .

Marginal plates 4-lobed, arranged in 2 regular longiseries, similar in size and form to the neighbouring ventrolateral ones. Superomarginal plates dorsal in position, so the inferomarginals defining the lateral margin of ray. These spines occur generally 1 to a plate, but often 2 or 3 proximally, each thickly wreathed with crossed pedicellariae. They are slightly longer and stouter and more tapered than the dorsolateral spines.

Ventrolateral plates arranged in regular 5 longiseries, gradually diminishing in size toward the furrow; the innermost series extending a little beyond 1/3 of ray, the second about the middle. Thus, in 2/3 the ray there are 3 series of the plates. These plates have each 1 or 2 spines, thickly wreathed with crossed pedicellariae, but mostly half-wreathed in the inner spines.

Adambulacral plates triplacanthid in the proximal portion of ray, then triplacanthid and diplacanthid and mostly diplacanthid in

the distal portion of ray. The spines are bluntly pointed, a little longer than the adjacent ventrolaterals, each with a tuft of small crossed pedicellariae and large straight ones. The innermost alternate spines are located deep in furrow. When 3 spines present, the outermost one is shorter and slenderer than the inner. Mouth plates not sunken, each armed with 2 flattened oral spines with a number of straight pedicellariae at the base, the outer (upper) being much smaller than the inner (lower). Suboral spines single, beset with crossed pedicellariae and straight ones. Adoral carina composed of first 4 pairs of adambulacral plates, each with a single spine with pedicellariae near the tip.

Madreporite large, subplane, situated a little nearer the centre of disc than the margin.

*Localities.* Three specimens from Aniwa Bay (Albatross, 1906, Station 5005, 5007, 5010); 2 specimens from Bomasirisima, Rebun Island (Albatross, 1906, Station 4994); 4 specimens from Busse Lake (Goto's collection); 3 specimens from Rakuma (S. Sato's collection); depth ranging from 21 to 190 fathoms.

*Distribution.* Southern Bering Sea, from Bristol Bay to Unalaska; the coast of Asia from Avatka Bay, Kamchatka to Okhotsk Sea and northern Japan Sea.

*Evasterias echinosoma forma robusta n. forma*

(Pl. XVIII, figs. 3, 4)

A single specimen of *Evasterias* was examined, measuring 80 mm in R, 16 mm in r. It resemble *E. echinosoma*, but comparing with *echinosoma*, though approximately similar in size, it has a different appearance. The specimen has more robust skeleton and broader rays. The dorsal spines are fewer, more well spaced, much stouter and adambulacral plates monacanthid. It seems to be probably a new member of *echinosoma*-group. It is separated from *E. troschelii* in having inferomarginal plates defining the margin of ray; in having robust, uniformly large, widely spaced, fewer dorsal spines and a large number of prominent unguiculate straight pedicellariae scattered all over the surface.

*Diagnosis.* Differing from *E. echinosoma* in having much more widely spaced dorsal spines; a large number of prominent straight pedicellariae on dorsal and ventral surface; fewer papulae; small

lanceolate straight pedicellariae apparently absent on dorsal surface. Rays 5, broad at base; dorsal spines widely spaced, generally uniform in size; marginal plates monacanthid, inferomarginal plates high at the side of ray; ventrolateral plates monacanthid, forming 3 series; adambulacral plates monacanthid; a large number of unguiculated straight pedicellariae scattered all over the surface.

*Description.* Dorsal skeleton irregularly meshed, composed of 3- to 5-lobed principal plates and elongated secondaries; carinal plates 4-lobed, directly imbricated, arranged in an irregular line. Carinal spines 1 (2) for a plate, considerably stout, subconical in form, 2-2.5 mm long; dorsolaterals generally 1, often 2 for a plate, a little smaller than the carinals, arranged somewhat in 2 longiseries. These spines

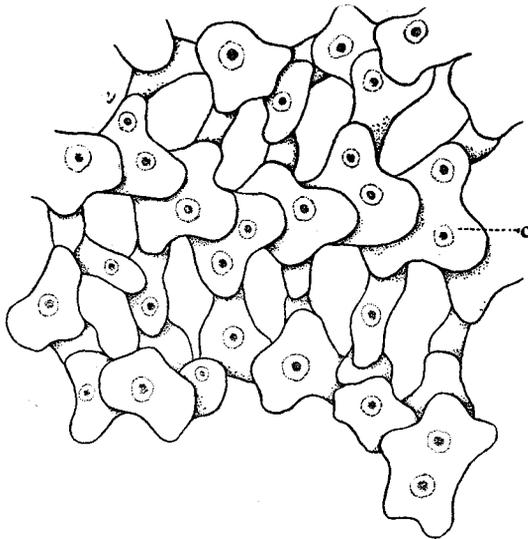


Fig. 91. *Evasterias echinosoma forma robusta*: Skeletal structure in the middle portion of ray, 5 $\times$ ; c carinal plate.

are much more widely spaced than in *echinosoma* and thickly wreathed with small crossed pedicellariae lacking enlarged terminal teeth, 0.32-0.35 mm long. Papulae not numerous, 5 to 8 in an area, arranged in a lineal series or in a group. A large number of prominent unguiculated straight pedicellariae measuring 3-4 mm in length are scattered on dorsal side and small lanceolate straight pedicellariae seemingly absent.

Marginal plates conspicuous, forming 2 regular series, the inferomarginals defining the lateral margin of ray. These plates are 4-lobed, each with a single spine thickly wreathed with crossed pedicellariae. The spines are a little longer and stouter than the dorso-laterals. Intermarginal papular areas with 5 to 7 papulae in an area and large unguiculated straight pedicellariae scattered in the areas.

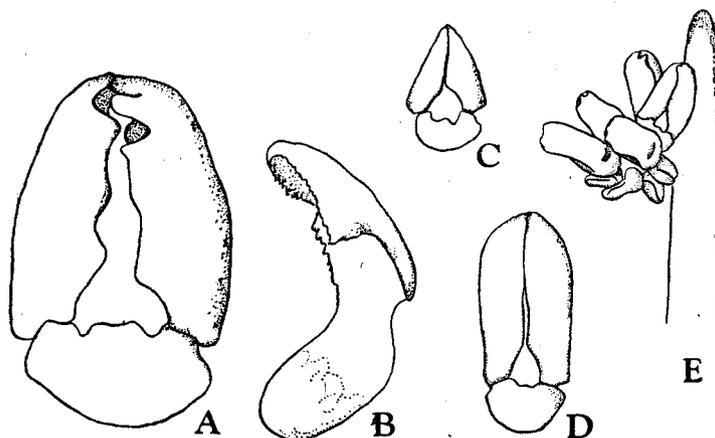


Fig. 92. *Evasterias echinosoma* forma *robusta*: (A) dorsal straight pedicellaria, 40 $\times$ ; (B) jaw of crossed pedicellaria, 110 $\times$ ; (C) straight pedicellaria in furrow, 40 $\times$ ; (D) dorsal straight pedicellaria, 40 $\times$ ; (E) adambulacral spine, 20 $\times$ .

Ventrolateral plates corresponding in position to inferomarginals, arranged in 3 regular series; the uppermost just below inferomarginals reaching arm tip; the middle nearly to the tip; the lowermost about the middle of ray. They are each separated by a series of papular areas containing 1 to 5 pores in each, and large unguiculated straight pedicellariae found in the areas. Ventrolateral spines, about 3.5 mm long, 1 to a plate, gradually decreasing in size toward the furrow, each with a half-wreath of crossed pedicellariae on the outer side.

Adambulacral plates monacanthid; spines alternately facing to the furrow, the inner being slenderer than the outer; each with a cluster of straight and crossed pedicellariae on the outer side. Numerous straight pedicellariae various in size, located in the furrow. Mouth plates each armed with 2 oral spines and 1 stout suboral spine the inner oral spines being much larger than the outer. Adoral carina

composed of first 3 pairs of adambulacral plates bearing solitary spines.

Madreporite circular, situated about midway between the centre of disc and the margin.

*Locality.* Cape Patience, Sayhalien, 75 fathoms, character of bottom sand and pebbles (Albatross, 1906, Station 5023).

### Genus *Leptasterias* VERRILL

*Leptasterias*: VERRILL, 1886, p. 350. Type, *Asteracanthion mülleri* SARS; VERRILL, 1914, p. 116; FISHER, 1930, p. 23.

#### Key to Japanese species and subgenera of *Leptasterias*

- a<sup>1</sup>. Rays 5; size small, symmetry pentamerous . . . . **Subgen. *Leptasterias* VERRILL**
- b<sup>1</sup>. Straight pedicellariae all small, subtriangular in form.
- c<sup>1</sup>. Dorsal crossed pedicellariae not in thick wreaths.
- d<sup>1</sup>. Marginal plates connected in series by secondary plates in adult specimen; ventrolateral plates in 2 series (1 in typical form) . . . . . ***ochotensis***
- d<sup>2</sup>. No secondary marginal plates; ventrolateral plates in 2 series.. ***ochotensis similispinis***
- c<sup>2</sup>. Dorsal crossed pedicellariae in thick wreaths, similar in size to those of *orientalis*; dorsal spines uniformly large; ventrolateral plates in a series . . . . . ***orientalis aniwaensis***
- b<sup>2</sup>. Straight pedicellariae large, unguiculated.
- c<sup>1</sup>. Crossed pedicellariae not in thick wreaths; dorsal skeleton weak.
- d<sup>1</sup>. Straight pedicellariae abundant, scattered all over the surface, with narrow jaws; ventrolateral plates in 2 series . . . ***pulchella***
- d<sup>2</sup>. Straight pedicellariae few on dorsal surface; crossed pedicellariae larger; ventrolateral plates in a series, rays slenderer.. ***hylodes***
- c<sup>2</sup>. Crossed pedicellariae in thick wreaths; straight pedicellariae fewer, with slightly broader jaws; ventrolateral plates in 2 series . . . . . ***pulchella* forma *tugaruensis***
- a<sup>2</sup>. Rays 6; symmetry hexamerous; size small or large . . . . . **Subgen. *Hexasterias* FISHER**
- b<sup>1</sup>. Straight pedicellariae large, broad.
- c<sup>1</sup>. Dorsal spines without indication of longiseries, but in reticular patterns; ventrolateral plates in a series; straight pedicellariae broad, "stone hammer" shape . . . . . ***alaskensis***
- c<sup>2</sup>. Straight pedicellariae represented by narrower jawed ovoid ones... ***alaskensis asiatica***
- b<sup>2</sup>. Straight pedicellariae small, lanceolate or ovate; ventrolateral plates in 2 series . . . . . ***camtschatica***

***Leptasterias ochotensis* (BRANDT)**

(Pl. XIX, figs. 4, 5)

*Leptasterias ochotensis*: FISHER, 1930, p. 57, pls. 12, 27, 28.

Eleven specimens are examined, ranging from 15 mm to 28 mm in R, collected by Dr. S. Sato from Rakuma, the western coast of southern Saghalien. They are closely related to *L. ochotensis similispinis*, but differ in having secondary marginal ossicles, though being rudimentary. According to Fisher ('30) "They are present probably only in fully adult animals,<sup>1)</sup> since none are present in a specimen with R 27 mm". In this point, these specimens are more related to *ochotensis*, but the superomarginal spines are more numerous, 2 or 3 to a plate instead of generally 1.

**Diagnosis.** Dorsal spines small, spaced, cylindrical or clavate; carinal series differentiated; superomarginal plates di- or triplacanthid; inferomarginal and ventrolateral plates monacanthid; adambu-

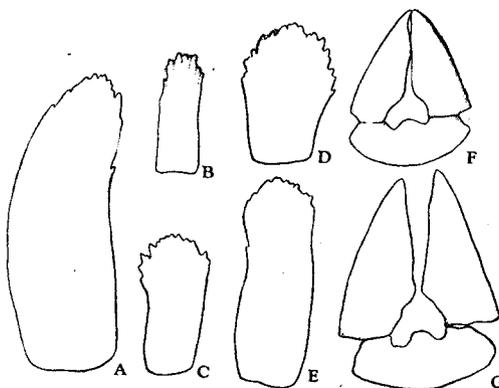


Fig. 93. *Leptasterias ochotensis*: (A) inferomarginal spine, 35X; (B)-(D) dorsal spines, 35X; (E) superomarginal spine, 35X; (F) dorsal straight pedicellaria, 80X; (G) ventral straight pedicellaria, 80X.

lacr plates mona- or diplacanthid; secondary marginal ossicles present. Straight pedicellariae small, subtriangular, distributed on dorsal and ventral sides.

**Description.** The description based upon the largest specimen

1) *Leptasterias ochotensis*.

(R 28 mm, r 6.5 mm) is given below.

Dorsal skeleton composed of 3 or 4 lobed primary plates and elongated secondaries; the carinals 4-lobed, directly imbricated in a longiseries. Dorsal spines small, cylindrical or clavate, with minutely thorny extremities, 1 to 3 to a plate, about 0.4–0.6 mm long, varying from 0.15 to 0.3 mm in breadth. These spines are encircled with a number of small crossed pedicellariae, about 0.18–0.2 mm in length. Papular areas with 1 to 3 papulae in an area. Straight pedicellariae

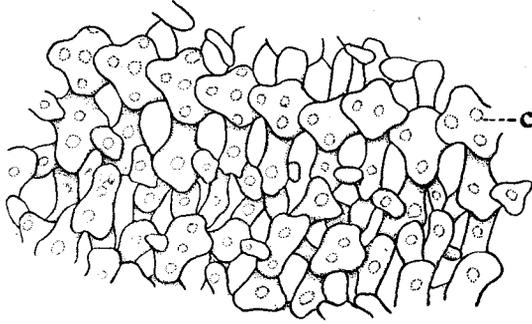


Fig. 94. *Leptasterias ochotensis*: Skeletal structure in the arm base, 7 $\times$ ; c carinal plate.

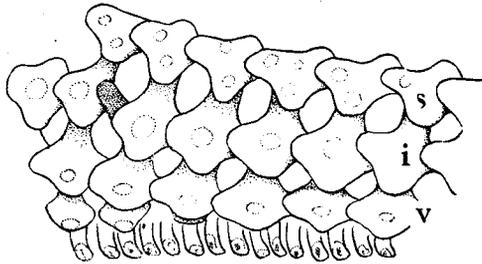


Fig. 95. *Leptasterias ochotensis*: Skeletal structure in the arm base, 7 $\times$ ; s superomarginal plate, i inferomarginal plate, v ventrolateral plate.

small, subtriangular in form, increasing in size toward the furrow ranging from 0.27 to 0.36 mm in length. They are not abundant on dorsal surface and the axial ones are not conspicuously larger than intermarginal and ventrolateral ones, about 0.35 mm long.

Superomarginal plates 4-lobed, directly imbricating, the series curving upward near the arm base, reaching the dorsal end of interbrachial sinus. Between inferomarginal plates are interpolated rod-

like ossicles near the arm base, but not well developed. Superomarginal spines generally 2 or 3 for a plate, about 0.7–0.8 mm, but in small specimens the spines are generally single. The spines are cylindrical, longer and stouter than the dorsolaterals, encircled by crossed pedicellariae, the tips being striated and rounded. Inferomarginal spines 1 to a plate, rarely 2, longer and stouter than the superomarginals, cylindrical, slightly tapering, about 1–1.1 mm long. Intermarginal papulae generally 1 to an area.

Ventrolateral plates in 2 series, the upper extending nearly to the tip, the lower being rudimentary, not reaching to one-thirds the length of ray, each with a single spine similar to inferomarginals, but those on the upper series larger than the inferomarginals and those of the lower series a little smaller. Inferomarginal and ventrolateral spines have each a cluster of crossed pedicellariae on the outer side, and papular areas mostly with a papula in an area.

Adambulacral plates diplacanthid and monacanthid alternately, but not very regularly. Often the diplacanthid only occur in the base of ray. The spines are cylindrical in form, with slightly tapered or rounded tips. These spines alternately set slightly back, the inner facing the furrow being slenderer than the outer, each with a cluster of about 10 crossed pedicellariae, about 0.2 mm long. Mouth plates each with 2 cylindrical tapering oral spines, the inner being longer than the outer, and 1 stouter suboral spine, each with mostly 1 to 4 small straight pedicellariae. First pair of postoral adambulacral plates forming adoral carina. Small straight pedicellariae scattered along furrow margin.

Madreporite circular, situated about midway between the centre of disc and the margin.

*Locality.* Rakuma, Saghalien.

*Distribution.* Okhotsk Sea and northern Japan Sea.

### *Leptasterias ochotensis similispinis* (CLARK)

(Pl. XVII, figs. 3, 4, 5 & pl. XIX, fig. 3)

*Asterias similispinis*: CLARK, 1908, p. 288.

*Leptasterias ochotensis similispinis*: FISHER, 1930, p. 59.

A good series of *Leptasterias* was collected from Nemuro, ranging from 9 mm to 40 mm in R and a large number of similar form

from Akkesi Bay. The largest specimen is obtained from Daikoku-jima, Akkesi, which measures 57 mm in R, 11 mm in r. They are probably referable to be *Asterias similispinis* Clark. Concerning the present species Fisher ('30) suggests under the name of *Leptasterias ochotensis similispinis* in his description of *L. ochotensis*, remarking as follows:

"H. L. Clark has described a very similar form, *Asterias similispinis*, from Taraku Island, near Nemuro, Hokkaido. I have examined one of the six original specimens (No. 1964, Mus. Comp. Zoöl.), the largest of which has R only 25 mm ( $R=5r$ ). In the available specimen (R 22 m) the secondary marginal ossicles are not present. Neither are they present in small *ochotensis*. The rays are a little robuster than in *ochotensis* of similar size and the straight pedicellariae average smaller but are of the same triangular shape. The gonads, although dried, indicate that the species is a *Leptasterias*."

Between the small specimens of the two *Leptasterias*, *ochotensis* and *similispinis*, there are seemingly no remarkable differences except the presence of secondary marginal plates. In the specimens in the writer's hand, the secondary ossicles are entirely absent, although much larger than the original specimens of Clark. The characteristic is to be regarded as a constant feature of *similispinis*, but in having small subtriangular straight pedicellariae the species may be regarded as a member of *ochotensis*-group.

*Diagnosis.* Closely related to *L. ochotensis* but differing in having no secondary marginal ossicles even in fully grown adult; in having 2 series of ventrolateral plates; straight pedicellariae near genital pores not conspicuous, nor crowded. Dorsal skeleton irregular open reticulum; marginal plates in 2 regular series; 2 series of ventrolateral plates. Dorsal spines small, spaced, cylindrical or clavate; 1 or 2 for a dorsolateral plate, 1 to 4 on each carinal plate. Marginal and ventrolateral spines longer and stouter than dorso-laterals, generally 1 to a plate, often 2. Adambulacral spines single, but often double proximally. Small subtriangular straight pedicellariae abundant on dorsal and ventral surfaces.

*Description.* The following description is based upon a Nemuro specimen (R 40 mm).

Dorsal skeleton irregular open meshed. Carinal plates in a longiseries, but not very regularly, composed of mostly 3- or 4-lobed plates directly imbricated, each with 1 to 4 small spines with striated

round tips, about 0.5 to 0.6 mm long. Dorsolateral skeleton composed of 3- or 4-lobed plates and the intermediate oblong plates, each bearing 1 or 2 spines similar to those of carinal series. These spines are

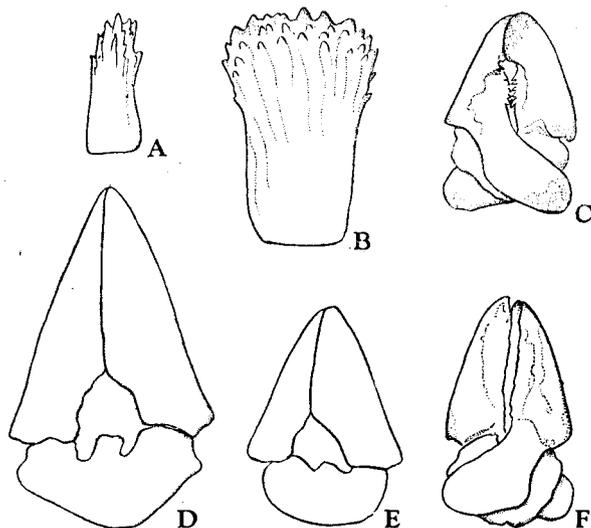


Fig. 96. *Leptasterias ochotensis similispinis* of Nemuro: (A) and (B) dorsal spines, 55 $\times$ ; (C) dorsal crossed pedicellaria, 120 $\times$ ; (D) interradiial straight pedicellaria, 120 $\times$ ; (E) dorsal straight pedicellaria, 120 $\times$ ; (F) adambulacral crossed pedicellaria, 120 $\times$ .

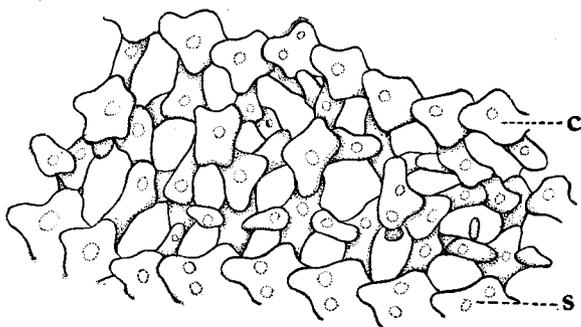


Fig. 97. *Leptasterias ochotensis similispinis* of Nemuro: Skeletal structure in the proximal portion of ray, 7 $\times$ ; c carinal plate, s superomarginal plate.

surrounded by 2 to 6 small crossed pedicellariae measuring 0.21 to 0.23 mm in length. Papular areas with 3 to 8 papulae in an area and

generally 1 or 2 small subtriangular straight pedicellariae, about 0.23 to 0.3 mm long.

Marginal plates in regular series in the lateral portion of ray, entirely lacking secondary intermediate plates; superomarginal plates 4-lobed, directly imbricated, each generally with a single spine but often double. These spines are longer and stouter than dorsal spines, about 1 mm long, slightly curved in the distal half and provided with a circle of crossed pedicellariae. When 2 spines present, the inner is usually slenderer than the outer. In small specimens the spines are generally single. Inferomarginal plates 4-lobed proximally, the spines generally 1 to a plate, often 2, being similar to the superomarginals, each bearing a group of crossed pedicellariae on the outer side. Intermarginal papular areas each contain 1 to 5 papulae and 1 to 3 straight pedicellariae.

Ventrolateral plates opposite to each marginal plate in position, extending nearly to the tip of ray; several proximal ones imbricated, then isolated one another. Near the base of ray is present a short second series of 4 or 5 plates. The spines are subequal to or slightly smaller than inferomarginal ones, each bearing a tuft of crossed pedicellariae on the outer side.

Adambulacral spines single, about 1.5 mm long, but proximally often 2 spines present; each with a cluster of 4 to 10 crossed pedicellariae on the outer side. The spines alternately set slightly back, the inner being a little slenderer than the outer. Mouth plates each with 2 oral spines, the inner being about 1.2 mm long, twice as large as the outer. Suboral spines single, about 1.5 mm long, with 1 to 4 straight pedicellariae. The first 2 pairs of postoral adambulacral plates form adoral carina. Straight pedicellariae near genital pores are neither so prominent nor crowded as in *ochotensis*, similar to the adjacent ventrolateral ones in size. Along the furrow margin are scattered small straight pedicellariae.

Madreporite circular, situated about the middle of r.

*Localities.* Nemuro and Akkesi, shore.

*Distribution.* Hokkaido.

*Note on Akkesi specimens.* There are 2 forms in Akkesi Bay, one smaller slender rayed form and the other similar to Nemuro form, but there are no essential differences between both the forms. The specimens obtained in front of the Akkesi Marine Biological Station are all small, the largest measuring 24 mm in R, 6 mm in r,

although they are fully adult. They live under stones on shore. The breeding season is in April, and the habit is very curious. The eggs are laid on the under surface of stone with gelatin-like substance as in Molluscan eggs. The eggs are very large, about 0.7 mm in dia-



Fig. 98. *Leptasterias ochotensis similispinis*: The specimen at the right side is protecting the egg-mass.

meter, and on the egg-mass a female specimen, probably the mother, is found, apparently protecting her eggs. Therefore, the species may have not the pelagic larval stages.

***Leptasterias orientalis aniwaensis* n. subsp.**

(Pl. XVII, fig. 1, 2)

The present species is somewhat an intermediate form between *orientalis* and *similispinis*; differing from *similispinis* in having a little slenderer tip of rays; more widely spaced dorsal spines of about uniformly large, with thicker wreaths of crossed pedicellariae; superomarginal and dorsal plates almost usually monacanthid; ventrolateral plates in a series. In having thick circumspinal wreaths of large crossed pedicellariae the form resembles *orientalis*, but differing in having only subtriangular toothless straight pedicellariae. From *ochotensis* it differs in lacking secondary marginal plates and in dorsal spinulation.

*Diagnosis.* Rays gradually tapering; dorsal spines well spaced, uniformly large, bluntly pointed with rather thick wreaths of crossed

pedicellariae; carinal series discernible; superomarginal and ventrolateral plates each with a single spine; ventrolateral plates in a single series; adambulacral plates with 1 or 2 spines alternately.

*Description.* The following description is based upon a specimen measuring 43 mm in R, 9 mm in r.

Dorsal surface of disc and rays beset with small cylindrical minutely thorny, slightly pointed or bluntly pointed spines, measuring 0.7 to 1 mm in length, 0.3 to 0.4 mm in width. These spines are fairly well spaced and encircled by thick wreaths of crossed pedicellariae, 0.26–0.3 mm long. Among them are scattered characteristic small subtriangular straight pedicellariae, about 0.4 mm (0.13 to 0.5 mm) long. Carinal series of spines distinct as a lineal arrangement. Dorsal skeleton irregular open reticulum, the primary plates being 3- or 4-lobed, connected by elongate intermediate plates. Papular areas contain 1 to 3 papulae in an area.

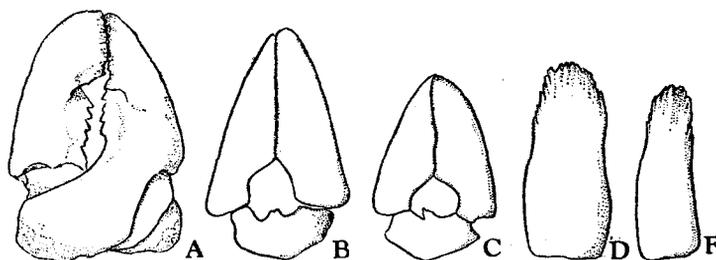


Fig. 99. *Leptasterias orientalis aniwaeensis*: (A) crossed pedicellaria, 120 $\times$ ; (B) interradial straight pedicellaria, 60 $\times$ ; (C) dorsal straight pedicellaria, 60 $\times$ ; (D) and (E) dorsal spines, 30 $\times$ .

Marginal plates arranged in regular longiseries; superomarginal series turning upward near the base of ray, the plates being 4-lobed, directly imbricated without secondary ossicles. Superomarginal spines usually single, but very rarely double, cylindrical, slightly tapered, about 1.2–1.5 mm long. Inferomarginal plates directly imbricated, each with usually a spine but very rarely double proximally, stouter than superomarginal spines, 1.2–2 mm long. Small crossed pedicellariae occur in circles around the superomarginal spines and in clusters on the outer side of the inferomarginal spines. Inter-marginal papular areas contain mostly 2 papulae in an area.

Ventrolateral plates in a series extending about one-thirds the length of ray, the spines being single, similar to inferomarginal spines, but a little slenderer and shorter. Ventrolateral papular areas with mostly a single papula in an area. Axial straight pedicellariae, not conspicuously larger than the neighbours, about 0.5–0.52 mm long, but up to ten in number in each crowd.

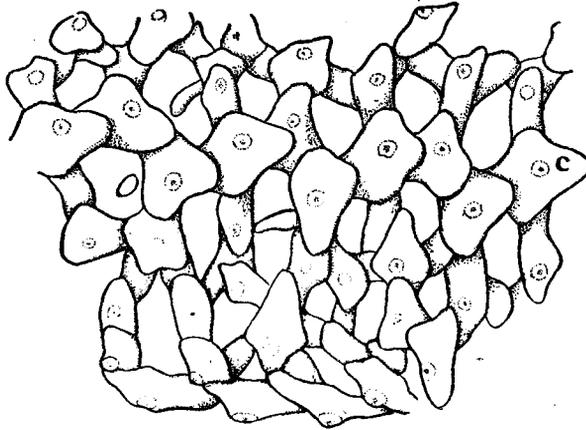


Fig. 100. *Leptasterias orientalis aniwaensis*: Skeletal structure in the proximal portion of ray, 7 $\times$ ; c carinal plate.

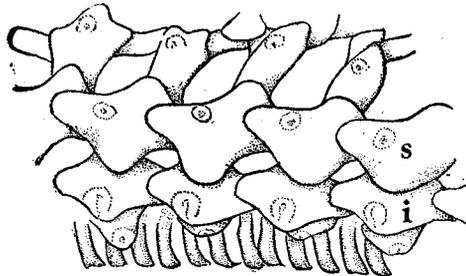


Fig. 101. *Leptasterias orientalis aniwaensis*: Skeletal structure in the proximal portion of ray, 7 $\times$ ; s superomarginal plate, i inferomarginal plate.

Adambulacral spines cylindrical, 1 or 2 for a plate in a fairly regular alternation, except the proximal portion of ray, where adoral 7 to 8 plates each with a single spine. The inner spines are slightly slenderer than the outer, about 1.7 mm long proximally. These spines are beset with a cluster of 1 or more crossed pedicellariae (about

0.3 mm long), not so numerous as in *orientalis* and *similispinis*, often appearing to be absent and beside them accompanying straight pedicellariae proximally (about 0.35 to 0.5 mm long). Mouth plates with 2 oral spines, the inner long and stout, the outer being much smaller. Suboral spines single, but occasionally double, with in addition a little shorter spine behind the former. These spines each bear 1 to 3 straight pedicellariae, different in size. Numerous small subtriangular straight pedicellariae scattered on the furrow margin.

Madreporite circular, situated about midway between the centre of disc and the margin.

*Locality.* Aniwa Bay, 40-43 fathoms, character of bottom green mud, fine gray sand (Albatross, 1906, Stations 5006, 5007, 5008).

### *Leptasterias pulchella* n. sp.

(Pl. XXI, figs. 7, 8)

The present form has been pointed out by Fisher ('30) as an underscribed race related to *orientalis*. The writer could not examine typical *orientalis* to compare, but it differs from Fisher's *orientalis* (not typical) of Japanese waters in greater abundance of unguiculated straight pedicellariae with narrower jaws; circumspinal crossed pedicellariae less prominent; crossed pedicellariae slightly smaller; dorsal skeleton more delicate; adambulacral pedicellariae much fewer. On the other hand, the present form is related to *L. hylodes* distributing in Alaska and the Aleutian Islands in the form of straight pedicellariae, though differing in the following points; unguiculate straight pedicellariae similar in form much more numerous; ventrolateral plates more developed; intermarginal spines absent.

*Description.* The following description is based upon a specimen (R 27 mm, r 6 mm).

Rays not obtuse, but tapering. Spines numerous, very small, uniform in size, slender and tapering, about 0.7 mm long. These spinelets are generally 1 to a plate, pretty uniformly spaced, each with a circle of 3 to 6 small crossed pedicellariae, about 0.19 to 0.21 mm long. Carinal series not discernible from the other. Among these spinelets are uniformly scattered a large number of unguiculated straight pedicellariae, much stouter than the spinelets, 0.7 to 0.9 mm long. Skeletal reticulum composed of mostly 4(3-5) lobed plates

and the intermediate plates. Papular areas, irregular in form, mostly with a papula in an area.

Marginal plates with 4 slender lobes, regularly arranged, directly imbricated, each with a single spinelet similar to the dorsolaterals;

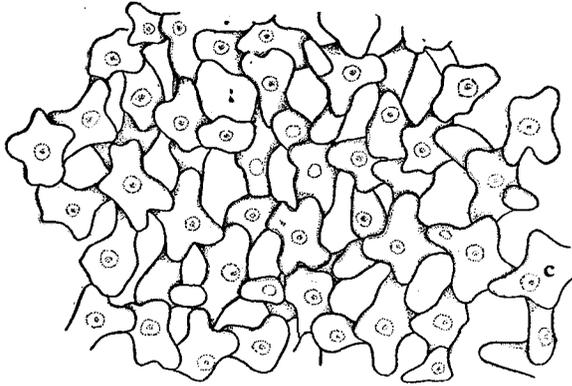


Fig. 102. *Leptasterias pulchella*: Skeletal structure in the proximal portion of ray, 12 $\times$ ; c carinal plate.

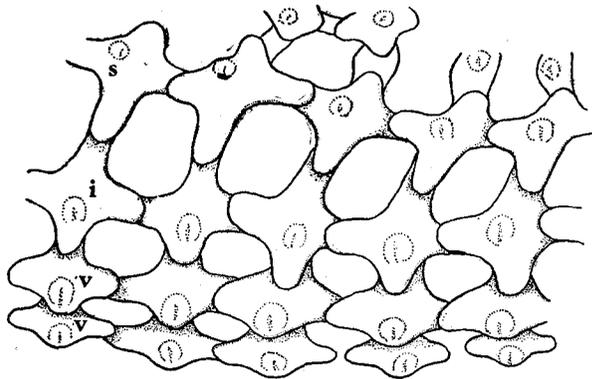


Fig. 103. *Leptasterias pulchella*: Skeletal structure in the proximal portion of ray, 12 $\times$ ; s superomarginal plate, i inferomarginal plate, v ventrolateral plate.

superomarginal spines encircled by crossed pedicellariae, inferomarginals with a tuft of the organ on the outer side. Intermarginal papular areas wide, squarish in form, containing a large papula in an area; intermarginal spines absent.

Ventrolateral plates regularly arranged in 2 series, the upper extending near the tip, the lower about the middle of ray. Papular areas each with a large papula. Spinelets single, similar to the infero-marginals.

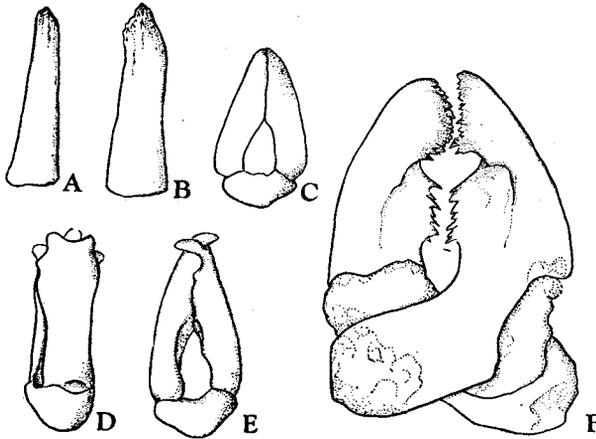


Fig. 104. *Leptasterias pulchella*: (A) and (B) dorsal spines, 35 $\times$ ; (C) straight pedicellaria in furrow, 60 $\times$ ; (D) and (E) dorsal straight pedicellariae, 35 $\times$ ; (F) dorsal crossed pedicellaria, 250 $\times$ .

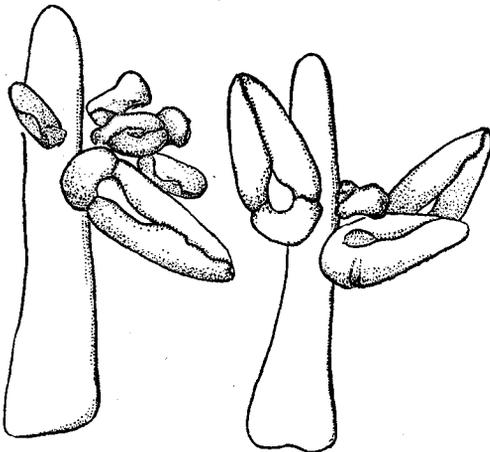


Fig. 105. *Leptasterias pulchella*: Adambulacral spines, 50 $\times$ .

Adambulacral spines slender, slightly tapered or bluntly pointed, 1 or 2 to a plate in fairly regular alternation in the greater part of ray, but in about 10 adoral plates the alternation irregular and adoral

3 plates generally with solitary spines. Adoral carina consists of a pair of plates in union. Mouth plates each with a bluntly tapering oral spine at the inner end, about 1 mm long and a stouter suboral spine; these spines carry 1 or 2 unguiculate straight pedicellariae. Adambulacral spines with 1 to 6 crossed pedicellariae accompanied with 1 to 3 large unguiculate straight pedicellariae, occasionally with straight pedicellariae only. Small straight pedicellariae numerous along the furrow margin, the large being somewhat dentate. Axial pedicellariae in a pair, not prominent but subsimilar to the neighbours in size.

Madreporite small, situated slightly nearer the centre of disc than the margin.

*Locality.* Off Kinkasan, 107 to 129 fathoms, character of bottom dark gray sand, broken shells, pebbles (Albatross, 1906, Station 5047, 5048).

*Leptasterias pulchella* forma *tugaruensis* n. forma

(Pl. XXI, figs. 5, 6)

Concerning the present form, Fisher ('30) remarks "They are probably examples of small race, living in the cold water of the Japan Sea, intermediate between *orientalis* and an undescribed race<sup>1)</sup> found in the warmer waters off the east coast of Hondo (Station 5047)" and "the crossed pedicellariae are smaller and the straight pedicellariae are much slenderer, with more delicate teeth (resembling the slenderest type of *hylodes*)". The examples examined by the present writer differ from his *pulchella* (Fisher's undescribed race of Hondo) in having much fewer, broader straight pedicellariae; dorsal skeleton stouter; the spines a little longer and stouter, with thicker wreaths of crossed pedicellariae. The writer will describe them here as a form of *pulchella*.

*Description.* The following description is based upon a specimen measuring 29 mm in R, 6 mm in r.

Rays gradually tapering. Dorsal surface of disc and rays covered with isolated slender tapering or bluntly pointed spinelets (about 1 mm long) thickly wreathed with crossed pedicellariae (0.21–0.22 mm long). Dorsal skeleton a little stouter than in *pulchella*, composed of 3 to 5 irregularly lobed plates and oblong intermediate ones.

1) *Leptasterias pulchella* in this paper.

Papular areas with mostly 1 or 2 papulae in an area. Straight pedicellariae rare on dorsal surface.

Marginal plates 4 lobed, arranged in the lateral position of ray, each with a single slender tapering spine; superomarginals a little

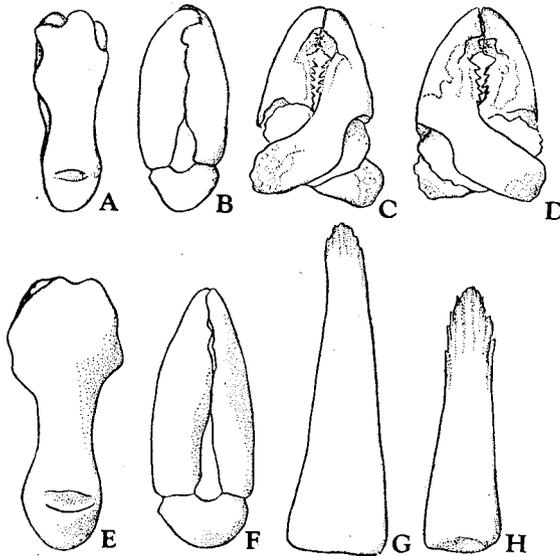


Fig. 106. *Leptasterias pulchella* forma *tugaruensis*: (A) and (B) ventrolateral straight pedicellariae, 35 $\times$ ; (C) adambulacral crossed pedicellaria, 120 $\times$ ; (D) dorsal crossed pedicellaria, 120 $\times$ ; (E) and (F) interradial straight pedicellariae, 35 $\times$ ; (G) superomarginal spine, 35 $\times$ ; (H) dorsal spine, 35 $\times$ .

longer than the dorsolateral, thickly encircled by crossed pedicellariae, about 1.2 mm long proximally, the inferomarginals about 1.4 mm long, with a thick cluster of crossed pedicellariae on the outer side.

Ventrolateral plates in 2 series, the upper one extending about three-fourths the length of ray, the lower to the one-fourths, each plate with a single spine subsimilar to the inferomarginals, generally with a thick cluster of crossed pedicellariae on the outer side. Ventrolateral straight pedicellariae not numerous, the axial ones measuring 0.07 mm to 0.95 mm in length, with a little broader jaws than in *pulchella*.

Adambulacral spines cylindrical, 1 or 2 to a plate in a fairly regular alternation, each with a thick cluster of crossed pedicellariae,

beside them appending with 1 or 2 straight pedicellariae. Proximal 7 to 8 plates with a single spine. Mouth plates with 2 cylindrical blunt spines; the oral one about half as long as the suboral, each with a cluster of crossed pedicellariae accompanying straight ones.

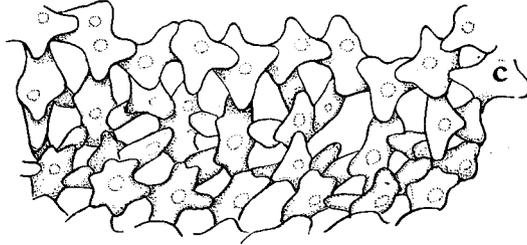


Fig. 107. *Leptasterias pulchella* forma *tugaruensis*: Skeletal structure in the proximal portion of ray. 7×; c carinal plate.

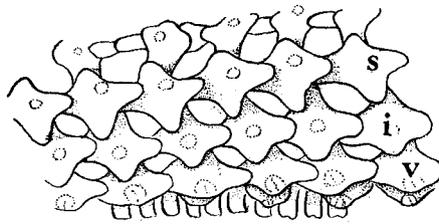


Fig. 108. *Leptasterias pulchella* forma *tugaruensis*: Skeletal structure in the proximal portion of ray, 7×; s superomarginal plate, i inferomarginal plate, v ventrolateral plate.

Madreporite circular, situated about the middle of r.

*Locality.* Cape Tsiuka, 44 to 47 fathoms, character of bottom shells, coarse gravel (Albatross, 1906, Stations 4807, 4808).

### *Leptasterias hylodes* FISHER

(Pl. XXI, fig. 9)

*Leptasterias hylodes*: FISHER, 1930, p. 35, pl. 10, figs. 5-11; pl. 17, pl. 18, figs. 1-3.

Three specimens were examined, resembling *L. pulchella*, but differing in having slenderer rays and ventrolateral plates in a series, the unguiculate straight pedicellariae much fewer. They are closely

related to *L. hylodes* Fisher in southern Bering Sea, but the crossed pedicellariae being slightly larger. They are probably an Asiatic form of the species.

*Description.* The description is based upon a specimen measuring 29 mm in R, 5.5 mm in r.

Rays slender, gently tapering. Dorsal spines uniform, slender and tapering, about 0.6 to 1 mm long. Carinal spines not distinguishable from the neighbours. Skeletal structure subsimilar to that of *pulchella*. Circumspinal crossed pedicellariae not so thick as in *orientalis*, but in a circle, measuring about 0.26 to 0.28 mm in length. Concerning the size, they are subsimilar to those of *orientalis*. Large unguiculate straight pedicellariae absent on dorsal side. Papulae 1 or 2 in an area.

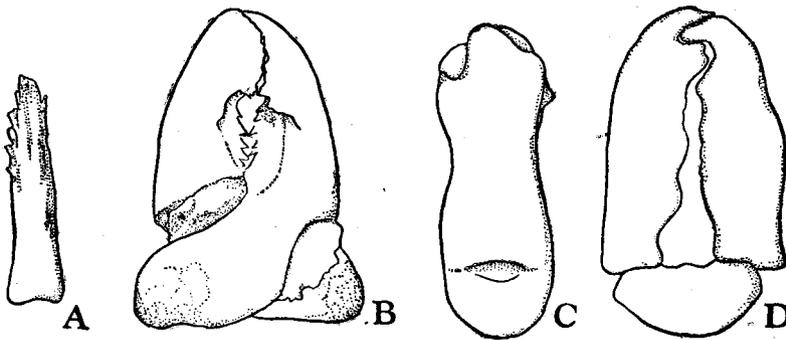


Fig. 109. *Leptasterias hylodes*: (A) dorsal spine, 50 $\times$ ; (B) crossed pedicellaria, 160 $\times$ ; (C) ventrolateral straight pedicellaria, 50 $\times$ ; (D) interradial straight pedicellaria, 50 $\times$ .

Marginal plates on the lateral margin of ray, with 4 slender lobes, directly imbricated. Superomarginal spines 1 to a plate, slender and tapered, longer than the dorsolaterals, about 1–1.1 mm long. Beside them the proximal superomarginal plates bear solitary short small spinelets on the lower lobes, and the spinelets show an appearance of a short series of intermarginal spinelets. These spines are wreathed with crossed pedicellariae. Intermarginal papular areas squarish in form proximally, each with 1 to 3 papulae.

Ventrolateral plates in a series, reaching three-fourths the length of ray; spines single, each with a cluster of crossed pedicellariae on the outer side. Large unguiculate straight pedicellariae found in the

intermarginal and ventrolateral areas, but not so numerous as in *pulchella*. The axial ones in a pair, about 0.9–1 mm long. Ventrolateral papular areas with a single papula in an area.

Adambulacral spines slender, cylindrical, tapered, 1 or 2 for a plate alternately, each with a cluster of 2 to 5 crossed pedicellariae. Proximal 7 or 8 plates each armed with a single spine, and straight pedicellariae present on the spines. Mouth plates each with 2 spines, the oral one being about half as large as the suboral, which similar to the following adambulacral spines, each with 1 to 4 crossed and straight pedicellariae. Adoral carina composed of 2 pairs of postoral adambulacral plates.

Madreporite circular, situated slightly nearer the margin of disc than the centre.

*Locality.* Cape Tonin, Saghalien, 100 fathoms, character of bottom brown mud, broken shells, pebbles (Albattoss, 1906, Station 5018).

### *Leptasterias alaskensis* forma *alaskensis* (VERRILL)

(Pl. XIX, fig. 7, pl. XXI, fig. 12, pl. XXII, fig. 7)

*Asterias epichlora* var. *alaskensis*: VERRILL, 1909, p. 549.

*Leptasterias epichlora* (part): VERRILL, 1914, p. 132.

*Leptasterias epichlora alaskensis*: VERRILL, 1914, p. 136, pl. 28, figs. 1, 2, pl. 85, figs. 1–1d.

*Leptasterias alaskensis* forma *alaskensis*: FISHER, 1930, p. 125, pl. 48, figs. 2, 2a–2f, pl. 56.

The present species is not represented in Japanese waters. The specimens examined are obtained from Unalaska and Atka Islands.

*Diagnosis.* Rays 6. Differing from *L. camtschatica* in the irregular arrangement of dorsal spines, usually in a reticular pattern, without indication of longiseries; in the size and form of straight pedicellariae; in having more open irregular dorsal skeleton; dorsal area broader, the superomarginal plates ventral in position; in worse development of ventrolateral plates.

*Description.* Rays gradually tapering, with obtuse tip; R 45 mm, r 16 mm, arm base 18 mm in breadth. Dorsal skeleton in very irregular open reticulum, the plates being irregular in contour. Carinal series irregular, sometimes not marked off from dorsolateral plates. Spines irregularly arranged in single series surrounding papular

areas. These spines are unequal, small, but robust, capitate or subcapitate with round or truncate, straited extremity; frequently a little larger spines (2 to 4 or 5) grouped, especially in carinal region. Papulae conspicuous, numerous among spines and pedicellariae, variable in number according to age and size, 1 to 5 or more in an area. Characteristic large bivalved pedicellariae scattered in dorsal papular areas, mostly 1 to an area; abundant on plates and papular areas in marginal and ventrolateral regions, the jaws being a little longer than

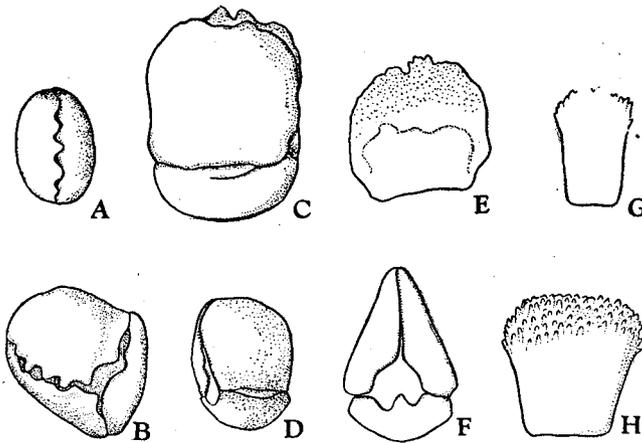


Fig. 110. *Leptasterias alaskensis* forma *alaskensis*: (A)-(D) straight pedicellariae, 30 $\times$ ; (E) jaw of straight pedicellaria, 30 $\times$ ; (F) straight pedicellaria in furrow, 55 $\times$ ; (G) and (H) dorsal spines, 30 $\times$ .

broad or slightly broader than long, with edge of the jaw denticulated. The largest ones occur on the ventrolateral side of arm base, measuring about 1 mm or more in length. Rarely the pedicellariae bear 3 jaws. In small specimen (R 14 mm) the pedicellariae rarely occur in the marginal portions of ray, but seemingly absent. Small crossed pedicellariae, 0.2-0.23 mm long, scattered among dorsal and superomarginal spines and forming clusters on the outer sides of inferomarginal and adambulacral spines.

Superomarginal plates in a series, with obtuse 4 lobes, directly imbricated, each with 2(1-3) cylindrical, subcapitate or subtuncate spines, generally slightly longer and thicker than the dorsolaterals. Inferomarginal plates slightly smaller than the superomarginals; no

intermarginal plates, but occasionally small oblong spineless plates interpolated between both the marginals in the proximal portion of ray of large broad rayed specimens; intermarginal papular areas each containing 2 to 6 papulae. Inferomarginal spines generally double, a little longer and stouter than the superomarginals.

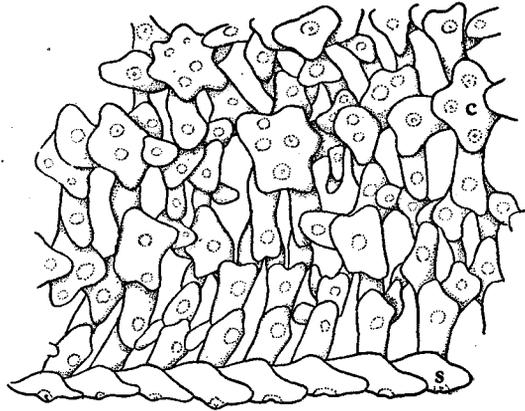


Fig. 111. *Leptasterias alaskensis* forma *alaskensis*: Skeletal structure in the proximal portion of ray, 5 $\times$ ; c carinal plate, s superomarginal plate.

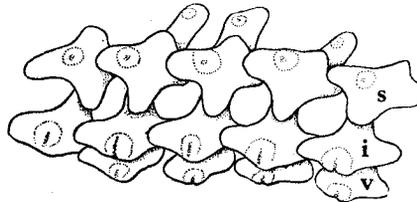


Fig. 112. *Leptasterias alaskensis* forma *alaskensis*: Skeletal structure in the proximal portion of ray, 5 $\times$ ; s superomarginal plate, i inferomarginal plate, v ventrolateral plate.

Ventrolateral plates in a series, extending about the middle of ray or a short distance beyond; spines solitary; cylindrical with rounded tip, subequal to or slenderer than the inferomarginals; the distal plates thin, spineless. Ventrolateral papular areas with 1 to 2 papulae in an area. In small specimen (R 20 mm more or less) the series is rudimentary, wanting spines.

Adambulacral spines alternate 1 and 2 fairly regularly, but in specimens solitary; the inner spines are usually slenderer than the outer. Adoral carina composed of 2 or 3 pairs of postoral adambulacral plates. Mouth plates small, each with 2 oral and 1 suboral spines, the outer oral spines being smaller, about one-half as long as the inner.

Madreporite circular, situated in the middle of r.

*Note on specimens from Atka Is.* The specimens are characterized by prominent small groups of dorsal spines and by greater ranges of size. Large specimens have slightly slenderer and longer rays and larger papular areas. Superomarginal plates each with mostly a single spine in the proximal portion of ray; 2 rarely 3 in the distal half. Proximal inferomarginal spines usually single, but double distally. Ventrolateral spines absent in small specimen (R 30 mm); in large specimen (R 40 mm) the spines are in a short series. The characteristic bivalved pedicellariae are variable in number; in small specimens seemingly absent, but in the large specimens the typical ones rather abundant. Adambulacral spines alternate 1 and 2 regularly, but occasionally single.

*Locality.* Unalaska and Atka Islands, shore.

*Distribution.* Kodiak westward to Attu Islands.

#### *Leptasterias alaskensis asiatica* FISHER

*Leptasterias alaskensis asiatica:* FISHER, 1930, p. 131, pl. 48, fig. 1, 1a-1d, pl. 57, figs. 3, 4, 5.

The present species is not represented in the collections at the writer's hand.

*Diagnosis.* Similar to *L. alaskensis* but the broad bivalved pedicellariae represented by narrow-jawed ovoid ones. Dorsal spines numerous, of rather uniform length, robust, subcapitate, arranged in a reticular pattern. R 55 mm, r 15 mm.  $R=3.7r$ ; breadth of ray at base 15 mm.

*Distribution.* Known from Shimushir (Kurile Is.), Bering Island, Medni Island (Commander Islands).

#### *Leptasterias camtschatica* (BRANDT)

(Pl. XXI, figs. 3, 4)

*Leptasterias camtschatica:* FISHER, 1930, p. 91, pl. 42, figs. 1, 1a-1d, pl. 49, fig. 1.

**Diagnosis.** Rays 6; differing from *alaskensis* in having much developed ventrolateral plates in 2 series; in the more regular arrangement of dorsolateral spines and papular areas; in size and form of straight pedicellariae which are small, compressed, lanceolate or ovate.

**Description.** Four specimens were examined, ranging from 25 mm to 27 mm in R. The description based upon a specimen (R 27 mm, r 7 mm) is as follows:

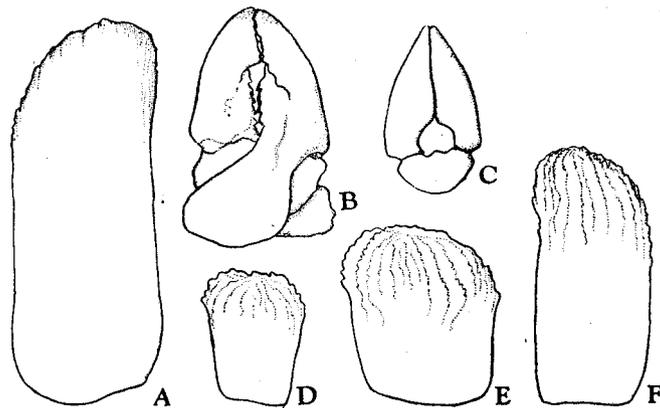


Fig. 113. *Leptasterias camtschatica*: (A) inferomarginal spine, 35 $\times$ ; (B) dorsal crossed pedicellaria, 120 $\times$ ; (C) ventrolateral straight pedicellaria, 65 $\times$ ; (D) and (E) dorsal spine, 35 $\times$ ; (F) superomarginal spine, 35 $\times$ .

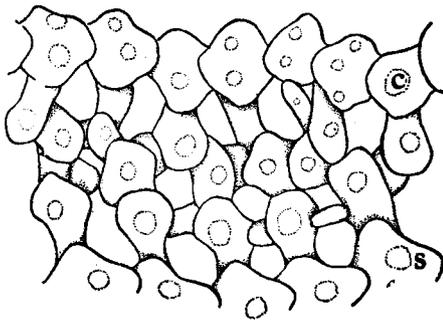


Fig. 114. *Leptasterias camtschatica*: Skeletal structure in the proximal portion of ray, 7 $\times$ ; c carinal plate, s superomarginal plate.

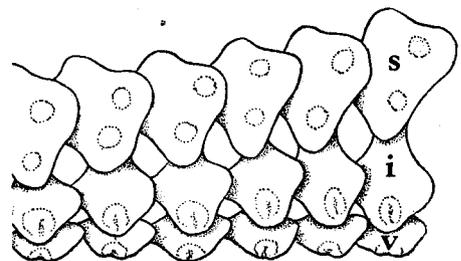


Fig. 115. *Leptasterias camtschatica*: Skeletal structure in the proximal portion of ray, 7 $\times$ ; s superomarginal plate, i inferomarginal plate, v ventrolateral plate.

Dorsal spines small, short, fairly robust, with striated capitate tips, about 0.4–0.7 mm long. Carinal spines 1 to 4 to a plate, dorsolaterals generally 1 to a plate. The carinal spines are subsimilar to the dorsolaterals, but distinguishable from the latter by their crowded arrangement. The dorsolateral spines are arranged more or less in longiseries. These spines are encircled by several crossed pedicellariae, 0.23 to 0.26 mm long. Skeletal meshes composed of irregular oblong, subelliptical, obtusely lobed plates and the connective; carinal plates with 4 very obtuse lobes, directly imbricated in a series. Papular areas more or less in 3 series between the carinal and superomarginal series, each containing 2 to 6 papulae. Small straight pedicellariae scattered in the areas.

Marginal plates 4-lobed, directly imbricated, forming regular longiseries on the lateral side of ray; the superomarginals are a little larger than the inferomarginals. Superomarginals spines capitate, striated, 2 for a plate (often 1 distally, rarely 3 proximally), arranged in 2 regular longiseries, a little larger than the dorsolaterals, about 0.7 to 0.9 mm long. The series bends upward at the base of ray. Inferomarginal spines cylindrical with round tip, heavier and longer than the superomarginals in the proximal portion of ray, but only a trifle more in the distal portion. Superomarginal spines with a circle of crossed pedicellariae; inferomarginals with a cluster of crossed pedicellariae on the outer side.

Ventrolateral plates in 2 series, the upper nearly along whole the length of ray, the lower about the one-thirds, each with a single spine similar to inferomarginals, but a little shorter. The spines bear a cluster of crossed pedicellariae on the outer side. Intermarginal and ventrolateral papular areas with generally 1 or 2 papulae in an area and small straight pedicellariae (0.3 to 0.4 mm long).

Adambulacral spines cylindrical, blunt, irregularly 1 or 2 for a plate, but single distally. Four proximal plates usually with solitary spines each with a cluster of crossed pedicellariae and small straight pedicellariae proximally. Mouth plates each with 2 slender oral spines and 1 longer suboral spine with several straight pedicellariae. The outer oral spines are shorter than the inner, occasionally absent. Along the furrow margin are found numerous small straight pedicellariae.

Madreporite circular, situated about the middle of r, slightly nearer the margin of disc.

*Locality.* Araitō, Kurile Islands.

*Distribution.* Commander Islands, Kamchotka and the Kurile Islands.

### Relationships between the skeletal structure and respiratory organs of sea-stars

The investigations concerning the respiratory organs of sea-stars are very meagre and only the papulae are known as external gills. In my study on the classification of Japanese sea-stars I found that the Polian vesicles and the ampullae of tube-feet have a remarkable correlation to the papular areas. I want to propose in the present paper that the two organs may be concerned to the respiratory function.

The following 114 species were used in the work.

#### Order FORCIPULATA

##### Fam. Brisingidae

- Odinia pacifica* forma *sagamiana* HAYASHI
- Odinia austini* forma *japonica* HAYASHI
- Brisingella pannychia* FISHER
- Freyllaster fecundus* forma *ochotensis* HAYASHI
- Freyllaster intermedius* HAYASHI
- Parabrisinga pellucida* HAYASHI

##### Fam. Zoroasteridae

- Zoroaster orientalis* HAYASHI
- Zoroaster orientalis* forma *gracilis* HAYASHI
- Zoroaster ophiactis* FISHER
- Zoroaster microporus* FISHER
- Cnemidaster wyvillii* SLADEN

##### Fam. Asteriidae

###### Subfam. Pedicellasterinae

- Pedicellaster magister orientalis* FISHER
- Pedicellaster magister esoensis* HAYASHI
- Plazaster borealis* (UCHIDA)

###### Subfam. Labidiasterinae

- Coronaster sakuranus* (DÖDERLEIN)

###### Subfam. Coscinasterinae

- Sclerasterias satsumana* (DÖDERLEIN)

*Coscinasterias acutispina* (STIMPSON)  
*Distolasterias nipon* (DÖDERLEIN)  
*Distolasterias elegans* DJAKONOV  
*Lethasterias fusca* DJAKONOV  
*Lethasterias nanimensis chelifera* VERRILL

## Subfam. Pycnopodiinae

*Lysastrosoma anthosticta* FISHER

## Subfam. Asteriinae

*Aphelasterias japonica* (BELL)  
*Aphelasterias japonica* forma *torquata* (SLADEN)  
*Asterias amurensis* LÜTKEN  
*Asterias amurensis versicolor* SLADEN  
*Evasterias trochelii* forma *alveolata* VERRILL  
*Evasterias echinosoma* FISHER  
*Leptasterias ochotensis* (BRANDT)  
*Leptasterias ochotensis similispinis* (CLARK)  
*Leptasterias orientalis aniwaensis* HAYASHI  
*Leptasterias pulchella* HAYASHI  
*Leptasterias pulchella* forma *tugaruensis* HAYASHI  
*Leptasterias allaskensis* forma *alaskensis* (VERRILL)  
*Leptasterias camtshatica* (BRANDT)

## Order SPINULOSA

## Fam. Asterinidae

*Asterina batheri* GOTO  
*Asterina pectinifera* (MÜLLER et TROSCHEL)  
*Asterina coronata* forma *japonica* HAYASHI  
*Asterina exigua* (LAMARK)

## Fam. Echinasteridae

*Echinaster luzonicus* (GRAY)  
*Henricia leviuscula* (STIMPSON)  
*Henricia leviuscula spiculifera* (CLARK)  
*Henricia reniessa* HAYASHI  
*Henricia reniessa* forma *tohokuensis* HAYASHI  
*Henricia regularis* HAYASHI  
*Henricia exigua* HAYASHI  
*Henricia densispina* SLADEN  
*Henricia saghaliensis* HAYASHI  
*Henricia kinkasana* HAYASHI  
*Henricia nipponica* UCHIDA  
*Henricia tumida* VERRILL  
*Henricia pacifica* HAYASHI  
*Henricia aspera* FISHER  
*Henricia Ohshimai* HAYASHI  
*Henricia Ohshimai* forma *acutispina* HAYASHI  
*Henricia pachyderma* HAYASHI  
*Henricia reticulata* HAYASHI

*Henricia irregularis* HAYASHI  
*Poraniopsis inflata* (FISHER)

**Fam. Acanthasteridae**

*Acanthaster planci* (LINNÉ)

**Fam. Mithrodiidae**

*Mithrodia clavigera* (LAMARK)

**Fam. Solasteridae**

*Solaster endeca* (LINNÉ)  
*Solaster stimpsoni* VERRILL  
*Solaster dawsoni* VERRILL  
*Solaster paxillatus* SLADEN...  
*Solaster borealis* (FISHER)  
*Solaster Uchidai* HAYASHI  
*Crossaster papposus* (LINNÉ)  
*Crossaster papposus* forma *japonica* FISHER

**Fam. Pterasteridae**

*Pteraster tessellatus* IVES  
*Pteraster uragaensis* HAYASHI  
*Pteraster obscurus* (PERRIER)  
*Diplopteraster multipes* (SARS)  
*Hymenaster glaucus* SLADEN

**Order PHANEROZONIA**

**Fam. Gonioplectinidae**

*Ctenodiscus crispatus* (RETZIUS)

**Fam. Astropectinidae**

*Leptychaster arcticus* (SARS)  
*Leptychaster anomalus* FISHER  
*Dipsacaster grandissimus* GOTO  
*Astropecten latespinosus* MEISSNER  
*Astropecten giselbrechti* DÖDERLEIN  
*Astropecten polyacanthus* MÜLLER et TROSCHEL  
*Astropecten kagoshimensis* LORIOL  
*Astropecten scoparius* VALENCIENNES

**Fam. Luidiidae**

*Luidia maculata* MÜLLER et TROSCHEL  
*Luidia quinaria* MARTENS  
*Luidia yesoensis* GOTO

**Fam. Archasteridae**

*Archaster typicus* MÜLLER et TROSCHEL

**Fam. Goniasteridae**

**Subfam. Pseudarchasterinae**

*Pseudarchaster parelii* (DÜBEN et KOREN)  
*Pseudarchaster pretiosus* (DÖDERLEIN)

## Subfam. Goniasterinae

- Mediaster brachatus* GOTO  
*Mediaster arcuatus* (SLADEN)  
*Ceramaster japonicus* (SLADEN)  
*Hippasteria imperialis* GOTO  
*Hippasteria nozawai* GOTO

## Fam. Oreasteridae

- Stellaster equestris* (RETZIUS)  
*Protoreaster nodosus* (LINNÉ)  
*Culcita novaeguineae* MÜLLER et TROSCHEL

## Fam. Asteropidae

- Asterope carinifera* (LAMARK)

## Fam. Linckiidae

- Fromia indica* PERRIER  
*Fromia indica* forma *andamanensis* KOEHLER  
*Fromia milleporella* (LAMARK)  
*Fromia monilis* PERRIER  
*Certonardoa semiregularis* (MÜLLER et TROSCHEL)  
*Nardoa frianti* KOEHLER  
*Nardoa tumulosa* FISHER  
*Nardoa tuberculata* GRAY  
*Nardoa tuberculata* forma *pauciforis* MARTENS  
*Nardoa tuberculata* forma *obtusa* PERRIER  
*Linckia multifora* LAMARK  
*Linckia laevigata* LINNÉ  
*Linckia diplax* (MÜLLER et TROSCHEL)  
*Linckia guildingii* GRAY  
*Ophidiaster granifera* LÜTKEN  
*Ophidiaster cribrarius* LÜTKEN

**Relations between the skeletal structure and the respiratory organs in the Forcipulata.** The Forcipulata have usually well developed papulae with the exception of some Brisingids. In Brisingidae the dorsal skeleton is exceedingly reduced. The plates of disc are usually thin, and isolated or very loosely imbricated. The skeleton of ray is generally found only in the proximal portion of ray. The Brisingids are divided into two groups, one lacking papulae, the other provided with them. The following fifteen genera belong to the first group.

*Hymenodiscus* PERRIER  
*Gymnobrisinga* STUDER  
*Astrocles* FISHER  
*Brisinga* ASBJØRSEN

*Craterobrisinga* FISHER  
*Parabrisinga* HAYASHI  
*Astrostephane* FISHER  
*Brisingella* FISHER

*Brisingaster* LORIOL  
*Stegnobrisinga* FISHER  
*Astrolirus* FISHER  
*Belegicella* LUDWIG

*Colposter* LUDWIG  
*Freyellaster* FISHER  
*Freyella* PERRIER

From the skeletal structure these fifteen genera are grouped into four. The first group includes the two genera, *Hymenodiscus* and *Gymnobrisinga*, in which the skeleton is most reduced and no visible skeleton is present on rays. The second group has isolated transverse skeletal arches on rays, which are composed of flattened or compressed overlapping plates. The following six genera belong to the group; *Astrocles*, *Brisinga*, *Craterobrisinga*, *Parabrisinga*, *Astrostephane* and *Brisingella*. The third group has spaced costae as in the second group above mentioned, but the integument between the costae is immersed with numerous fenestrated or thin embryonic plates. They are touched with each other or slightly overlapped or spaced. The three genera, *Brisingaster*, *Stegnobrisinga* and *Astrolirus*, belong to the group. The fourth group includes the four genera, *Belegicella*, *Colposter*, *Freyellaster* and *Freyella*. The skeleton of rays does not form independent costate, but is composed of uniform armor of thin, more or less overlapping plates.

In these genera the dorsal integument is exceedingly thin, generally translucent or semitranslucent, so the internal organs are visible by naked eye through the integument. It is surmised that the whole thin integument itself functions as a respiratory organ, and the absence of papulae is due to the presence of the very thin integument.

There are, however, two genera of Brisingidae having papulae, *Brisingenes* Fisher and *Odinia* Perrier. In *Brisingenes* the papulae occur on the disc margin in a single circle; two papulae to each ray, but none on rays. The skeleton of ray is similar in structure to that of *Brisinga*. The *Brisingenes*, therefore, is referable to the writer's second group with rudimentary papulae. In *Odinia* the papulae are conspicuous on the disc and proximal portion of rays. The skeleton of rays is composed of isolated skeletal arches and thin plates existing between them. The skeleton is reduced in the distal portion of rays, and the integument becomes thin, where the papulae are not conspicuous but rare. So far as the writer examined, the integument of *Odinia* is a trifle more tough than in the Brisingids wanting papulae.

The Brisingids have a reduced ampulla to each tube-foot. The ampulla is not a perfect vesicle, but is represented by a swollen membrane covering the ambulacral pore. The reduction of the ampullae is not probably due to their being a deep-sea animal, because the other deep-sea forms, Zoroasteridae, have very prominent double ampullae to each tube-foot. The reduction of the ampullae may be ascribed to the thinness of the integument, of which the whole surface functions as a respiratory organ. Because, in the other sea-stars as will be stated below, the ampullae of tube-feet decrease in number and in size in accordance with the increase of papular areas.

The deep-sea forms, Zoroasteridae, have well developed Phanerozonia skeleton composed of 4-lobed to hexagonal plates. The carinal plates form a ridge, and on either side of the carina is found a series of smaller adradial plates overlapped by the lobes of the carinal and superomarginal plates. The ventrolateral plates are arranged in three to six regular longiseries. The papular areas are very the small, isolated, one papula for each, but are distributed on both the dorsal and ventral surfaces. The Polian vesicles are absent, and the ampullae of tube-feet are very prominent, double in number. The double ampullae are much larger in size than those of the Spinulosa and Phanerozonia having Polian vesicles. The prominency of the ampullae of Zoroasteridae may be resulted from the absence of Polian vesicles and the smallness of papular areas: It is observed in the other sea-stars that occurrence of Polian vesicles and the number of the ampullae have a correlation to the reduction of papular areas: The sea-stars having reduced papular areas are provided with double ampullae to each tube-foot and also with Polian vesicles, and those lacking Polian vesicles have generally a single ampulla to each tube-foot and well developed papular areas. The Zoroasterids, however, lack the Polian vesicles, though they have such reduced papular areas as in the forms having the vesicles.

In *Pedicellaster* the skeletal structure shows an intermediate form between the pavement-type as in Zoroasteridae and the network type as in Asteroiidae. The dorsal skeleton forms an open irregular reticulum composed of cruciform or Y-form plates and the oblong connective. The ventrolateral plates are four-lobed, numerous in *P. magister*-group and are arranged in regular transverse series, but not in regular longiseries. The whole surface of body has a soft downy appearance and is covered with small, spaced sheathed spine-

lets which are interspersed with very numerous crossed pedicellariae of two kinds, minor and major. The papulae are, therefore, small and inconspicuous, not easily recognized, though one or two existing in an area. The ampullae of tube-feet are single but very prominent, somewhat showing a double appearance in alcoholic specimens. The ampullae are much larger than those of Asteriinae. The enlargement of the ampullae may be explained by the same reason as stated in Zoroasteridae.

*Evasterias*, a member of Asteriinae, has numerous series of ventrolateral plates as in *Pedicellaster*, though differing in appearance of body surface. The ventrolateral plates are not so delicate as in *Pedicellaster*, but are rather robust. They are arranged in regular longitudinal and transverse series. The dorsal skeleton forms an irregular mesh which is composed of three or four irregular lobed plates and the oblong connective. The pedicellariae are never so numerous as in *Pedicellaster*. The papulae are numerous, distributed all over the surface of body. The ampullae of tube-feet are single and are of medium size as in the other Asteriinae.

In Forcipulata having only one or two series of ventrolateral plates, the dorsal skeleton forms usually an open reticulum which is consisted of mostly three- or four-lobed plates and the oblong connective plates. The papulae are well developed in the skeletal meshes. The ampullae of tube-feet are of medium size and usually single. The following forms are included in the group; *Asterias*, *Leptasterias* of the Asteriinae and *Sclerasterias*, *Coscinasterias*, *Distolasterias* and *Lethasterias* belonging to the Coscinasterinae.

Forcipulata as *Coronaster*, *Plazaster*, *Lysastrosoma* and *Aphelasterias* are all devoid of the ventrolateral plates. The inferomarginal plates are located just external to the adambulacral plates. The skeleton of these forms is considerably diverse in structure, but the papulae are well developed, and the ampullae of tube-feet are of medium size, usually single. The dorsal skeleton of *Coronaster sakuranus* is composed of slender lobed cruciform or three-lobed plates and the oblong connective plates. The papular areas are very large, squarish or subpentagonal or somewhat irregular in form. The papulae are in tufts, two or three in an area, each tuft consisting of about four to seven papulae. The integument is membranous, but is much thicker than in Brisingids. The inferomarginal plates are each connected with by two or three oblong intermediate plates. The

structure of inferomarginal series resembles that of *Plazaster borealis*, an aberrant member of the Pedicellarinae, and also that of *Lysastrosoma anthosticta* of the Pycnopodiinae. *Lysastrosoma* has exceedingly reduced skeleton: The dorsal skeleton is reduced to isolated small spiniferous plates. The marginal plates are also poorly developed. The integument is very soft and membraneous on account of the absence of dorsal connecting skeleton. It is rather thick and is not so thin, nor translucent as in Brisingids. The Brisingids, as already stated, have reduced skeleton but no papulae, while *Lysastrosoma* has large numerous papulae. It is known that the occurrence of papulae is due to the thickness of the integument, not to the reduction of skeleton. In *Plazaster* the dorsal skeleton is not reduced as in *Lysastrosoma*, but forms irregular meshes consisting of numerous small plates. The inferomarginal plates are interpolated with small connective one. The papulae are well developed all over the surface of body. *Aphelasterias* lacks ventrolateral plates. The inferomarginal plates are each directly imbricated, without the intermediate plates between them. The dorsal plates are well developed and are rather imbricated. The papular areas are not wide, but the papulae are distributed all over the surface, one to six papulae to an area.

The Forcipulata already stated are grouped in three: The first group is "Asterid-type", in which the papular areas are well developed, and the ampullae of tube-feet are of medium size, usually single. The second group is "Zoroasterid-type", in which the papulae are poorly developed on account of the development of skeleton and the ampullae of tube-feet are very prominent and double. The third group is "Brisingid-type", in which the integument becomes very thin and translucent, and the papulae are present or absent, but are usually absent in the distal portion of ray, and the ampullae of tube-feet are reduced. *Pedicellaster* shows an intermediate form between the two types, Asterids and Zoroasterids. The ampullae of tube-feet seem to increase in size and number in correlation to the decrease of papular areas. In the sea-stars having reduced skeleton the occurrence of papulae is due to the thickness of the integument: When the integument is exceedingly thin, the papulae are not differentiated. In the Forcipulata the Polian vesicles are usually absent.

**Relations between the skeletal structure and respiratory organs in the Spinulosa.** Six families of the Spinulosa are known in Japanese

waters; Echinasteridae, Asterinidae, Mithrodiidae, Acanthasteridae, Solasteridae and Pterasteridae. These families are divided into two groups, one having Polian vesicles, the other lacking them. The latter group includes the two families, Echinasteridae and Pterasteridae.

In *Echinaster luzonicus* the dorsal skeleton consists of numerous small plates which form roundish irregular\* meshes. The ventrolateral plates are absent, and the inferomarginal plates are located just external to adambulacral plates. The integument covering the skeleton is rather thick and the papular areas are well developed, four to eight papulae to each area. *Henricia* species found in Japan are roughly grouped in three from the skeletal structure; the first group has thick, closely imbricated meshed skeleton. The marginal and ventrolateral plates are well defined, forming three regular longi-series. The following forms belong to the group; *leviuscula*, *leviuscula spiculifera*, *reniessa*, *tohokuensis*, *regularis*, *exigua*, *densispina*, *saghaliensis*, *kinkasana*, *nipponica* and *tumida*. The second group has reticulated open meshed skeleton and the marginal and ventrolateral plates are arranged in three regular series. The papular areas are a little more wider than those of the first group. The group includes the following forms; *pacifica*, *aspera*, *ohshimai*, *ohshimai forma acutispina* and *pachyderma*. The third group has inconspicuous marginal plates and the ventrolateral plates are more or less arranged irregularly. The skeletal meshes are open or close. The following two forms belong to the group; *reticulata* and *irregularis*. In these forms of *Henricia* the integument is generally thin, and the papulae are well developed, distributed all over the surface. In the two genera, *Echinaster* and *Henricia*, the Polian vesicles are usually absent, and the ampullae of tube-feet are of medium size, usually single.

There is an exceptional form of the Echinasteridae, in which the Polian vesicles are observed, though the ampullae of tube-feet are single as in *Echinaster*. It is *Poraniposis*, on which the writer ('40) already suggested that the form is probably a distinct group related to two families, Echinasteridae and Acanthasteridae, rather than as a member of Echinasteridae. The dorsal skeleton is ridged, forming a much wide reticulum. It is composed of three-, four- or five-lobed slightly raised tuberculated plates at each skeletal node, which are connected with by several oblong overlapping plates. The

dorsal side of body is low arched and the ventral side subflattened. The integument is rather thick and tough, and is beset with calcareous granules. The papular areas are very spacious and are distinctly separated by the skeletal ridge. Fifty or more papulae exist in each area, but the papulae are entirely absent in the ventral side of body. Therefore, the papular regions of *Poraniopsis* as the whole are more reduced than in the other Echinasterids, *Henricia* and *Echinaster*. The respiratory function of *Poraniopsis* may be disturbed by the reduction of papular areas and by the presence of thick integument containing calcareous granules. There are four Polian vesicles in *Poraniopsis*, one in each interradius, except the madreporic zone. The vesicles are absent in the other Echinasterids having well developed papular areas. The occurrence of Polian vesicles may have a compensatory correlation to the reduction of the respiratory regions.

In *Acanthaster planci* the body is covered with a thick integument containing calcareous granules. The skeleton forms a wide reticulum. The papular areas having numerous papulae are found universally on disc, but are restricted on rays only to the proximal portion. The ventral side of body is entirely devoid of them. Therefore, the papular areas are apparently more diminished than in *Poraniopsis*. The ampullae of tube-feet of the species are double, though in *Poraniopsis* they are single. The Polian vesicles are more numerous; one in each interradius except the madreporic interradius, where two vesicles usually occur.

The dorsal skeleton of Asterinidae does not form an open network, but is composed of large, crescentic or subcordate plates, sometimes accompanying small accessory ones. These plates are regularly arranged in V-shaped series with those of the adjacent rays. The papular areas are restricted on the dorsal side of body, except along the marginal portion, where papulae are absent. The ampullae of tube-feet are double, and the Polian vesicles are usually present, four in number.

The Solasteridae have double ampullae to each tube-foot and four Polian vesicles. The papular areas are poorly developed and are absent on the ventral side of body. In several forms as *Uchidai*, *Stimpsoni*, *endeca*, *paxillatus*, the dorsal skeleton is not open-meshed and is composed of three- or four-lobed imbricating plates. The papular areas are never wide, each containing one or two small papulae. In the forms as *borealis* and *dawsoni*, the skeletal meshes

are a little larger, by the presence of connecting ossicles in the skeleton; accordingly the papulae become numerous; each area with five to ten papulae in *dawsoni* and three or four in *borealis*. In *Crossaster* the skeletal meshes are more open, bearing one to ten papulae in an area.

In the Mithrodiidae the integument is very thick and is beset with numerous rough granules, tubercles and spinelets. The dorsal skeleton forms a wide reticulum making a low ridge. The papulae are abundant in the skeletal meshes, but are confined to the dorsal side of body and are absent on the ventral side. The tube-feet are provided with double ampullae to each. The Polian vesicles are five in number, one in each interradius, though they are four in the other Spinulosa families, Asterinidae and Solasteridae. The increase of number of the vesicles in Mithrodiidae will be explained to some extent, if the Polian vesicles are an organ which compensates the reduction of respiratory function on the body surface. It is because that by the presence of such thick integument beset with numerous calcareous granules, the respiratory function of Mithrodiidae may be more disturbed than in Asterinidae or Solasteridae which have not so thick integument and no calcareous substance in it. On the other hand, the occurrence of numerous Polian vesicles in *Acanthaster* will be similarly explained by the presence of thick integument and the smallness of papular areas.

Pterasteridae differ from the other sea-stars in having a nida-mental cavity conveying to the central osculum. The dorsal skeleton is composed of thin, slender lobed cruciform plates closely imbricated lobe by lobe. The integument covering the skeleton is very thin and translucent and there are no papulae. The Polian vesicles are absent. The supradorsal membrane is thick and spongy. The spiracula of the membrane are very numerous, and are sometimes in fine creases. However, when the supradorsal membrane is thin as in *Pteraster uragaensis*, the spiracula are not numerous but few and almost invisible. *Pteraster jordani* is also provided with few spiracula and with thin supradorsal membrane. The number of spiracula seems to be proportional to thickness of the membrane. The tube-feet of *Pteraster* are arranged in two rows and the ampullae are double. The skeleton of *Diplopteraster* is similar in structure to that of *Pteraster*, but the tube-feet are arranged in four rows and the ampullae are double. In the two genera just referred to, it is known

that the number of the ampullae is irrespective to the rows of tube-feet (two or four). *Hymenaster* has very thin translucent integument covering the skeleton which is composed of slender cruciform plates forming a regular net-work. The papulae are not differentiated and the Polian vesicles are absent.

In Spinulosa the following relations may be summarized: When the papular areas are well developed and distributed all over the surface, the ampullae of tube-feet are single and the Polian vesicles absent as in the Forcipulata, but when the papular areas are absent on the ventral side of body, the ampullae of tube-feet become double and the Polian vesicles occur. The occurrence of Polian vesicles and the number of which are correlated to the reduction of papular areas owing to the development of skeleton and also to the thickness of integument. The number of ampullae of tube-feet is independent of the arrangement of tube-feet, but the ampullae increase in number, from single to double, according to the decrease of papular areas. The spiracula of supradorsal membrane of Pterasteridae increase in number according as the membrane becomes thick.

**Relation between the skeletal structure and respiratory organs in the Phanerozonia.** The writer examined fourty forms belonging to eight families; Gonioplectinidae, Astropectinidae, Luidiidae, Archasteridae, Goniasteridae, Oreasteridae, Asteropidae and Linckiidae. They are divided in two groups, one lacking definite flat sucking discs of tube-feet, the other having them. The first group includes the following three families; Gonioplectinidae, Astropectinidae and Luidiidae. In the group the Polian vesicles are usually present and the ampullae of tube-feet are double, while in the second group the Polian vesicles are present or absent and the ampullae of tube-feet are also diverse in number, single or double. The occurrence of the vesicles and the number of the ampullae are not concerned in the terminal structures of tube-feet.

In the Phanerozonia having paxillae, the papulae are restricted to the dorsal surface of body. In *Ctenodiscus crispatus* the ventrolateral plates are very well developed and are imbricated, arranged in oblique transverse rows. The marginal and ventral sides of body are covered with a tumid membrane, while the dorsal side is covered with paxillae. The bases of paxillae are circular, closely set or rather isolated. The papulae are solitarily distributed between the paxillae. They are lacking on a circular area in the centre of disc

and on five narrow interradial and five midradial areas of rays. The tube-feet are of conical, without true sucking discs. The ampullae are single to each tube-foot. The Polian vesicles are six in number; one in each interradius, two in the madreporic interradius.

In *Astropecten* the marginal plates are very massive. The inferomarginal plates occupy almost all ventrolateral regions, leaving very small interradial areas. The ventrolateral plates never extend beyond the middle of ray. The dorsal side of body is covered with paxillae. The bases of paxillae are touched or isolated, and are surrounded by generally five or six papulae. The papulae are singly distributed and are usually absent in a narrower or wider midradial line and in the centre of disc. The tube-feet are of conical, without true sucking discs. The ampullae are double to each tube-foot. The Polian vesicles are six in number, one in each interradius, except the madreporic part, where two vesicles occur. In *Leptychaster* the bases of paxillae are irregularly lobed. Six papulae occur around each plate emerging between the irregular lobes by which plates touch. The papulae are absent in the centre of disc and along the median radial area of ray, where the paxillae mostly lack the lobes. The marginal plates are massive. The ventrolateral area of the genus are fairly larger than in *Astropecten* and the plates are arranged in series, the series adjacent to adambulacrals extending about half the length of ray or more. There are no ventral papulae. The tube-feet bear no sucking discs and the ampullae are double to each tube-foot. The Polian vesicles are six in number as in *Astropecten*. In *Dipsacaster* the ventrolateral areas are large, and the plates numerous. They are regularly arranged in oblique transverse rows corresponding to each adambulacal plate. The paxillae are well spaced. The papulae are very numerous and are distributed almost uniformly on the whole dorsal surface of body. They are relatively large and sometimes as many as four or five in an area enclosed by any four paxillae. The papular areas is more extensive than in the other forms of *Astropectinidae*, *Astropecten* and *Leptychaster*. The Polian vesicles are five in number, one in each interradius, though they are six in the two genera. The tube-feet have double ampullae to each as in *Astropecten*. In the three forms of *Astropectinidae* above mentioned, the Polian vesicles seem to increase in number as the papular areas diminish in size.

*Archaster typicus* has some resemblances to *Astropecten*, but is readily distinguished from the latter by the presence of a very well defined median radial series of paxillae. The dorsolateral paxillae are arranged in oblique transverse series. These plates are connected with by their lobes. The papulae are uniformly distributed on the dorsal surface of body, four to six or seven papulae around a paxilla. There are four Polian vesicles, one in each interradius, except the madreporic one. The tube-feet have sucking discs, and the ampullae are double to each tube-foot.

In *Luidia* the ventral interradiial area is very small, and the ventrolateral plates extend nearly to the tip of ray in a single series. The inferomarginal plates are very broad, forming the lateral borders of the rays, and the superomarginals are paxilliform, similar to the adjacent dorsolateral paxillae. The paxillae are comparatively large, closely set, and the bases of paxillae bear four lobes by which plates overlap regularly. Those on ray are arranged in longiseries, but the rows are more or less irregular in the distal part of ray. On the dorsal surface everywhere, the papulae are immersed between the plates, four in number around a plate. The papula is compound, resembling a decalcified low paxilla with distal portion subdivided into numerous papillae. The tube-feet have no sucking discs, and the ampullae are double to each tube-foot. The Polian vesicles occur one in each interradius, except the madreporic zone where the vesicles are absent.

In Goniasteridae the ventral side of body is devoid of papulae. The tube-feet have sucking discs and the ampullae are double to each tube-foot. The Polian vesicles are usually present, varying in number from four to six. The Polian vesicles seem to increase in number as the papular areas decrease in distribution. In *Pseudarchaster* the marginal plates are thick and low. The ventrolateral area is large, and the plates are numerous, arranged in rows running from ambulacrals to inferomarginals. The dorsal plates are paxilliform and are arranged in series parallel with the median radial line. They are provided with five or six distinct lobes by which plates touch or overlap one another. The papulae are uniformly distributed on the dorsal surface between paxillae, but are absent in the distal half of ray where the paxillae are arranged somewhat irregularly and are subhexagonal or oval in form. Six papulae occur around a paxilla. The tube-feet have sucking discs and the ampullae are double to each

tube-foot. The Polian vesicles are five in number, one in each inter-radius.

In *Mediaster* the ventral interradial area is spacious, extending far along rays. The dorsal plates are paxilliform, and the bases are connected with by internal radiating plates, mostly six to a plate. The papular areas are extensive, containing rather large papulae which are uniformly distributed on the dorsal surface. They are however absent in the apical parts of rays and in the restricted interradial areas. According to Fisher ('11) the papular area of *Mediaster aequalis* is more extensive than in *M. arcuatus*, and two or three papulae commonly occur in an area. The papular regions of the genus are more extensive than those of *Pseudarchaster*. The Polian vesicles of the genus are four in number, though they are five in *Pseudarchaster*.

In *Ceramaster japonicus* the dorsal surface is covered with fairly regular, spaced hexagonal to quadrate tabula crowned with a convex group of numerous polygonal granules. They are arranged in regular rows parallel with the median radial. These plates are slightly spaced and there are no internal connecting plates as in *Mediaster*. Those on the midradial portion of ray bear six short, broad lobes, but on either side of these the lobes are soon lost and the plates become circular. The papulae are separated from one another and four to six or even more papulae occur around a plate. They are considerably well distributed on the dorsal surface. In young specimens the papulae are restricted to the broad petaloid radial region of body. The Polian vesicles are five in number, one in each interradius. In *Hippasteria* the dorsal plates are closely set and very unequal in size. The larger ones are more or less round and slightly convex. The small are various in size and shape, filling up the spaces between the larger ones. The papulae are found singly between the plates, but not very numerous. The Polian vesicles are six in number, one in each interradius, except the madreporic inter-radius, where two vesicles occur.

The oreasteridae have a thick skeleton and lack ventral papulae. The tube-feet have well developed sucking discs, and the ampullae are double to each tube-foot. The Polian vesicles are usually present, four in number. In *Stellaster* the dorsal plates are round polygonal and are uniformly covered with fine granules showing apparently smooth to naked eye. The papulae are situated in the interspaces

between the corners of the dorsal plates. Three to five papulae are grouped on disc, but in the distal half of rays they occur solitarily. They are absent on the interradial lines. The Polian vesicles are four in number. *Protoreaster* has a well developed skeleton and plates which are arranged in relatively regular longi- and transverse rows. The whole body including spaces between plates is entirely covered with rounded or polygonal granules. Numerous papular pores are found in each inter-ossicular spaces. The individual pores are small but very distinct. The Polian vesicles are four in number. *Culecita* quite differs from *Oreasterids* in external appearances, but is quite similar to *Protoreaster* in internal structures. The whole body is entirely invested with coarse granules and spines. The papular areas are large, very irregular in form and distribution. They are mostly more or less circular or elliptical in outline. They contain numerous small but distinct papular pores. They are, in some specimens, somewhat larger than the nonporiferous areas. They extend to very near the ventral margin of body.

In *Asterope carinifera* the body is covered with smooth tough integument. The dorsal plates are loosely imbricated. The papular areas are distributed all over the dorsal surface, and two to five papulae exist in each area. The ventral side of body has no papulae. The tube-feet have double ampullae to each. Polian vesicles are four in number.

The *Phanerozonia* hitherto described all lack papulae on their ventral surface of body. The Polian vesicles are usually present, and the ampullae of tube-feet are double (single in *Ctenodiscus* alone). In some *Linckiidae*, however, the papular areas are found on both surfaces of body. The ampullae of tube-feet are variable in number, and Polian vesicles are present or absent. In *Fromia* the dorsal skeleton is composed of subcircular to elliptical, flat plates. They are thickly covered with fine granules. The papulae are very small and are singly distributed at the corners of plates. They are found on the ventral surface as well as the dorsal, but we must notice in the genus that the papular pores are very small. The tube-feet have sucking discs, and the ampullae are double. The Polian vesicles are present, four in number. In *Nardoa* the dorsal skeleton is consisted of numerous small plates which are diverse in size. The papular areas are rather large, never so reduced as in *Fromia*. The areas are however absent in the ventral surface of body. When the papulae

occur in the ventral surface, they are small and are restricted to the arm base. The tube-feet have double ampullae to each and the Polian vesicles are four in number.

*Linckia* is devoid of papulae on the ventral surface, though they are well developed on the dorsal. The tube-feet is provided with a single ampulla to each, and Polian vesicles are absent. So far as the writer's observation goes, it is an only exceptional case that Polian vesicles are absent and ampullae of tube-feet are single in spite of the presence of well developed skeleton causing the lack of ventral papulae.

In *Ophidiaster* the dorsal skeleton is composed of subcordate main plates and smaller connective ones. They are arranged in longitudinal and transverse series. The papular areas are relatively well developed on both surfaces of body. The ampullae of tube-feet are single, and the Polian vesicles are absent.

The relationships hitherto described by the present writer for the sea-stars of the three orders may be summarized as follows:

The papulae are usually observed in the sea-stars, except some of *Brisingidae* and *Pterasteridae*. In the sea-stars having reduced skeleton, the presence of papulae is correlated to the thickness of the integument, not to the reduction of skeleton: In the *Brisingids* lacking papulae the skeleton is very reduced and the integument is exceedingly thin, but *Lysastrosoma* has a rather thick integument, even if the skeleton is much reduced, and the papulae are well developed. It is, therefore, surmised that the absence of papulae in the *Brisingids* is due to the presence of the thin integument, of which the whole surface probably functions as a respiratory organ. The *Pterasterids* lack papulae, and the integument covering skeleton is very thin, but the supradorsal membrane has spiracula. The spiracula increase in number according as the membrane becomes thick. The respiratory functions of the sea-stars may be disturbed by the presence of skeleton and thick integument.

The writer observed that the ampullae of tube-feet are variable in number according to the reduction of papular areas (respiratory regions): In the sea-stars having exceedingly large respiratory regions as in *Brisingids*, the ampullae are reduced, not forming perfect vesicles, but are represented by swollen membranes covering the ambulacral pores: The Polian vesicles are absent in the group. But in the other sea-stars having papulae, the ampullae of tube-feet form usually perfect vesicles. In the case that they are single, the

papular areas are relatively well developed on both dorsal and ventral surfaces of body: The Polian vesicles are absent. The skeleton is mostly open-meshed as in the Asteriinae, Coscinasterinae, Labidiasterinae and Pedicellasterinae of the Forcipulata; *Echinaster* and *Henricia* of the Spinulosa; and *Ophidiaster* of the Phanerozonia. But in the group as in the Zoroasteridae of Forcipulata and *Fromia* of the Phanerozonia, the papular areas become very small owing to the presence of well developed skeleton. The papular areas contain only a single papula in each. In the two forms the tube-feet have double ampullae though the papulae exist on both dorsal and ventral surfaces of body. The ampullae of the Zoroasteridae are very prominent. Regarding the prominency of the ampullae we must notice that the Zoroasteridae lack Polian vesicles, though *Fromia* has them.

In the Asterinidae, Acanthasteridae, Mithrodiidae and Solasteridae of the Spinulosa and almost all the Phanerozonia examined, the papular areas are restricted on the dorsal surface of body alone and they are absent on the ventral surface owing to the presence of well developed skeleton or the thick integument. In these forms the ampullae of tube-feet are almost usually double. The Polian vesicles are present. There are however some exceptional cases: The two forms, *Poraniopsis* and *Ctenodiscus*, have a single ampulla to each tube-foot, though the papular areas are restricted to the dorsal surface. But they have Polian vesicles which are absent in the sea-stars having single ampullae of tube-feet. The two forms are probably regarded as the intermediate forms between the two groups above mentioned, one having Polian vesicles and double ampullae of tube-feet, the other having the single ampullae and lacking Polian vesicles.

It has been a general opinion that the ampullae of tube-feet regulate the circulation of sea-water in the tube-feet by their contraction and relaxation. But it is doubtful, because Brisingids have only rudimentary ampullae which are not likely adequate for the purposes. The ampullae are variable in number and size regardless to the presence or absence of sucking discs in tube-feet. So far as the writer observed, the ampullae may be rather regarded as a compensatory organ of papular areas (respiratory regions) in sea-stars, than as a locomotion organ.

The Polian vesicles are absent in all Forcipulata and some of the spinulosa and Phanerozonia. These forms have well developed papular areas on both dorsal and ventral surface of body. In the

sea-stars lacking the ventral papular areas, the Polian vesicles are almost usually present. The most of *Phanerozonia* and some of *Spinulosa* belong to the group. It is known that the occurrence of Polian vesicles is due to the reduction of papular areas. The vesicles are generally four in five-rayed sea-stars, but are variable in number, from four to six, as the papular areas become small. It means that the Polian vesicles may be a organ which compensates the reduction of respiratory function on body surface.

In comparison with the two forms, *Zoroaster* and *Fromia*, having similarly small papular areas owing to the presence of well developed skeleton, the *Zoroaster* has very prominent double ampullae to each tube-foot, while the double ampullae of *Fromia* are never so prominent but of medium size. The Polian vesicles are present in *Fromia*, but are absent in *Zoroaster*. The prominent ampullae of *Zoroaster*, therefore, may have a correlation to the absence of Polian vesicles and reduction of papular areas. The papular areas of *Pedicellaster* are much smaller than those of *Asteriidae*, and the ampullae of tube-feet of the former are much more prominent than those of the latter. The prominency of the ampullae of *Pedicellaster* may be due to the reduction of papular areas.

The function of the Polian vesicles has not been determined by any authors, but the writer wants to propose here that the vesicles and the ampullae of tube-feet are compensatory organs of papulae. If the papulae are called "external gills," both the organs may be called "internal gills."

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### Explanation of Plate XII

- Fig. 1. Ventral side of *Odinia pacifica* forma *sagamiana* n. forma. About  $2/3\times$ .  
 Fig. 2. Dorsal side of *Odinia pacifica* forma *sagamiana* n. forma. About  $2/3\times$ .  
 Fig. 3. Dorsal side of *Odinia austini* forma *japonica* n. forma. About  $1/2\times$ .  
 Fig. 4. Ventral side of *Odinia austini* forma *japonica* n. forma. About  $1/2\times$ .

### Explanation of Plate XIII

- Fig. 1. Dorsal side of *Parabrisinga pellucida* n. sp. About  $2/3\times$ .  
 Fig. 2. Ventral side of *Parabrisinga pellucida* n. sp. About  $2/3\times$ .  
 Fig. 3. Dorsal side of disc of *Brisingella pannychia* Fisher. About  $2/3\times$ .  
 Fig. 4. Ventral side of a ray of *Brisingella pannychia* Fisher. About  $2/3\times$ .  
 Fig. 5. Ventral side of disc of *Brisingella pannychia* Fisher. About  $2/3\times$ .  
 Fig. 6. Dorsal side of a ray of *Brisingella pannychia* Fisher. About  $2/3\times$ .  
 Fig. 7. Dorsal side of a ray of *Freyellaster fecundus* forma *ochotensis* n. forma. About  $2/3\times$ .  
 Fig. 8. A ray of *Freyellaster fecundus* forma *ochotensis* n. forma. About  $2/3\times$ .  
 Fig. 9. Ventral side of disc of *Freyellaster fecundus* forma *ochotensis* n. forma. About  $2/3\times$ .  
 Fig. 10. Dorsal side of disc of *Freyellaster fecundus* forma *ochotensis* n. forma. About  $2/3\times$ .

### Explanation of Plate XIV

- Fig. 1. Dorsal side of *Freyellaster intermedius* n. sp. About  $2/3\times$ .  
 Fig. 2. Ventral side of *Freyellaster intermedius* n. sp. About  $2/3\times$ .  
 Fig. 3. A portion of ray of *Coronaster sakuranus* (Döderlein), showing the skeletal structure. About  $2/3\times$ .  
 Fig. 4. A ray of *Coronaster sakuranus* (Döderlein). About  $2/3\times$ .  
 Fig. 5. A ray of *Coronaster sakuranus* (Döderlein). About  $2/3\times$ .  
 Fig. 6. Dorsal side of disc of *Coronaster sakuranus* (Döderlein). About  $2/3\times$ .  
 Fig. 7. Ventral side of disc of *Coronaster sakuranus* (Döderlein). About  $2/3\times$ .  
 Fig. 8. A ray of *Sclerasterias satsumana* (Döderlein), showing the skeletal structure. About natural size.  
 Fig. 9. Ventral side of *Sclerasterias satsumana* (Döderlein). About natural size.  
 Fig. 10. Dorsal side of *Sclerasterias satsumana* (Döderlein), a ray showing the skeletal structure. About natural size.  
 Fig. 11. Dorsal side of *Sclerasterias satsumana* (Döderlein). About natural size.  
 Fig. 12. Ventral side of *Lysastrosoma anthosticta* Fisher. About natural size.  
 Fig. 13. Dorsal side of *Lysastrosoma anthosticta* Fisher. About natural size.

- Fig. 14. Ventral side of *Coscinasterias acutispina* (Stimpson). About natural size.  
Fig. 15. Dorsal side of *Coscinasterias acutispina* (Stimpson). About natural size.

#### Explanation of Plate XV

- Fig. 1. Ventral side of *Distolasterias elegans* Djakonov. About  $1/2\times$ .  
Fig. 2. Dorsal side of *Zoroaster microporus* Fisher. About  $2/3\times$ .  
Fig. 3. Dorsal side of *Zoroaster ophiactis* Fisher. About  $2/3\times$ .  
Fig. 4. Ventral side of *Cnemidaster wyvillii* Sladen. About  $2/3\times$ .  
Fig. 5. Dorsal side of *Cnemidaster wyvillii* Sladen. About  $2/3\times$ .  
Fig. 6. Ventral side of *Lethasterias nanimensis chelifera* Verrill. About  $2/3\times$ .

#### Explanation of Plate XVI

- Fig. 1. Ventral side of *Pedicellaster magister orientalis* Fisher. About natural size.  
Fig. 2. Dorsal side of *Pedicellaster magister orientalis* Fisher. About natural size.  
Fig. 3. Dorsal side of *Plazaster borealis* (Uchida). About  $2/3\times$ .  
Fig. 4. Ventral side of *Plazaster borealis* (Uchida). About  $2/3\times$ .  
Fig. 5. Dorsal side of *Evasterias troschelii* forma *alveolata* Verrill. About natural size.  
Fig. 6. Dorsal side of *Distolasterias stichantha* (Sladen). About  $2/3\times$ .  
Fig. 7. Dorsal side of *Pedicellaster magister esoensis* n. subsp. About natural size.

#### Explanation of Plate XVII

- Fig. 1. Dorsal side of *Leptasterias aniwaensis* n. sp. About natural size.  
Fig. 2. Ventral side of *Leptasterias orientalis aniwaensis* n. sp. About natural size.  
Fig. 3. Dorsal side of *Leptasterias ochotensis similispinis* (Clark) of Akkesi Bay. About natural size.  
Fig. 4. Dorsal side of *Leptasterias ochotensis similispinis* (Clark) of Nemuro. About natural size.  
Fig. 5. Ventral side of *Leptasterias ochotensis similispinis* (Clark) of Nemuro. About natural size.  
Fig. 6. Dorsal side of *Distolasterias elegans* Djakonov. About  $1/3\times$ .  
Fig. 7. Dorsal side of *Zoroaster orientalis* forma *gracilis* n. forma. About  $2/3\times$ .  
Fig. 8. Ventral side of *Zoroaster orientalis* forma *gracilis* n. forma. About  $2/3\times$ .

#### Explanation of Plate XVIII

- Fig. 1. Dorsal side of *Zoroaster orientalis* forma *gracilis* n. forma. About  $2/3\times$ .

- Fig. 2. Dorsal side of *Evasterias echinosoma* Fisher. About  $1/2\times$ .  
 Fig. 3. Ventral side of *Evasterias echinosoma* forma *robusta*. About  $2/3\times$ .  
 Fig. 4. Dorsal side of *Evasterias echinosoma* forma *robusta*. About  $2/3\times$ .  
 Fig. 5. Ventral side of *Zoroaster microporus* Fisher. About  $2/3\times$ .

### Explanation of Plate XIX

- Fig. 1. Dorsal side of *Zoroaster orientalis* n. sp. About  $2/3\times$ .  
 Fig. 2. Ventral side of *Zoroaster orientalis* n. sp. About  $2/3\times$ .  
 Fig. 3. Ventral side of *Leptasterias ochotensis similispinis* (Clark) of Akkesi. About natural size.  
 Fig. 4. Ventral side of *Leptasterias ochotensis* (Brandt) of Rakuma. About natural size.  
 Fig. 5. Dorsal side of *Leptasterias ochotensis* (Brandt) of Rakuma. About natural size.  
 Fig. 6. Ventral side of *Evasterias echinosoma* Fisher. About  $1/2\times$ .  
 Fig. 7. Ventral side of *Leptasterias alaskensis* forma *alaskensis* (Verrill). About natural size.

### Explanation of Plate XX

- Fig. 1. Ventral side of *Distolasterias stichantha* (Sladen). About  $2/3\times$ .  
 Fig. 2. Ventral side of *Pedicellaster magister esoensis* n. subsp. About natural size.  
 Fig. 3. Ventral side of *Evasterias troschelii* forma *alveolata* Verrill. About  $1/2\times$ .  
 Fig. 4. Dorsal side of *Evasterias troschelii* forma *alveolata* Verrill. About  $1/2\times$ .  
 Fig. 5. Ventral side of *Asterias amurensis versicolor* Sladen. About natural size.  
 Fig. 6. Dorsal side of *Asterias amurensis versicolor* Sladen, a ray showing the skeletal structure. About natural size.

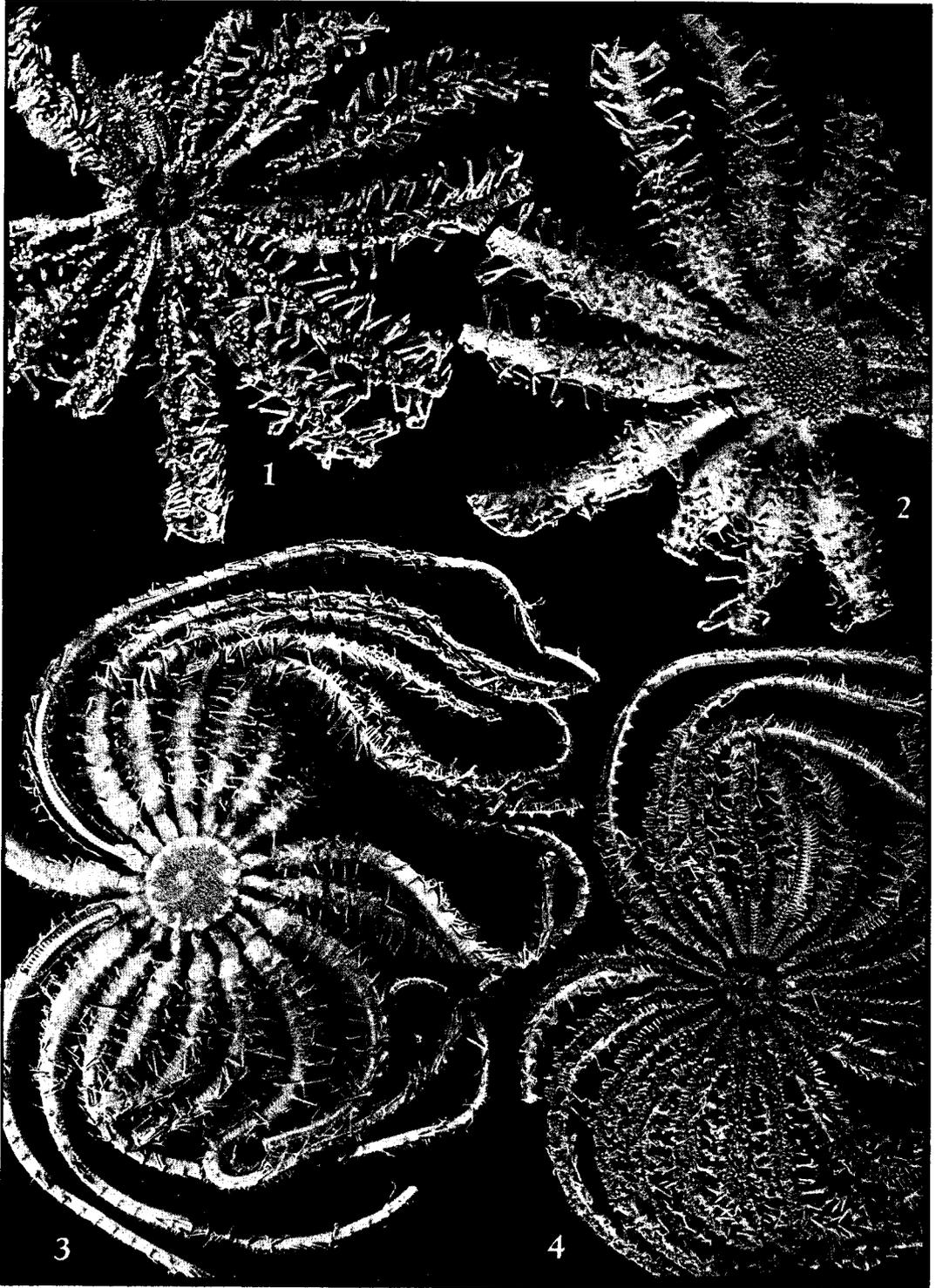
### Explanation of Plate XXI

- Fig. 1. Ventral side of *Aphelasterias japonica* (Bell). About natural size.  
 Fig. 2. Dorsal side of *Lethasterias nanimensis chelifera* Verrill. About  $2/3\times$ .  
 Fig. 3. Ventral side of *Leptasterias camtshatica* (Brandt). About natural size.  
 Fig. 4. Dorsal side of *Leptasterias camtshatica* (Brandt). About natural size.  
 Fig. 5. Ventral side of *Leptasterias pulchella* forma *tugaruensis* n. forma. About natural size.  
 Fig. 6. Dorsal side of *Leptasterias pulchella* forma *tugaruensis* n. forma. About natural size.  
 Fig. 7. Dorsal side of *Leptasterias pulchella* n. sp. About natural size.

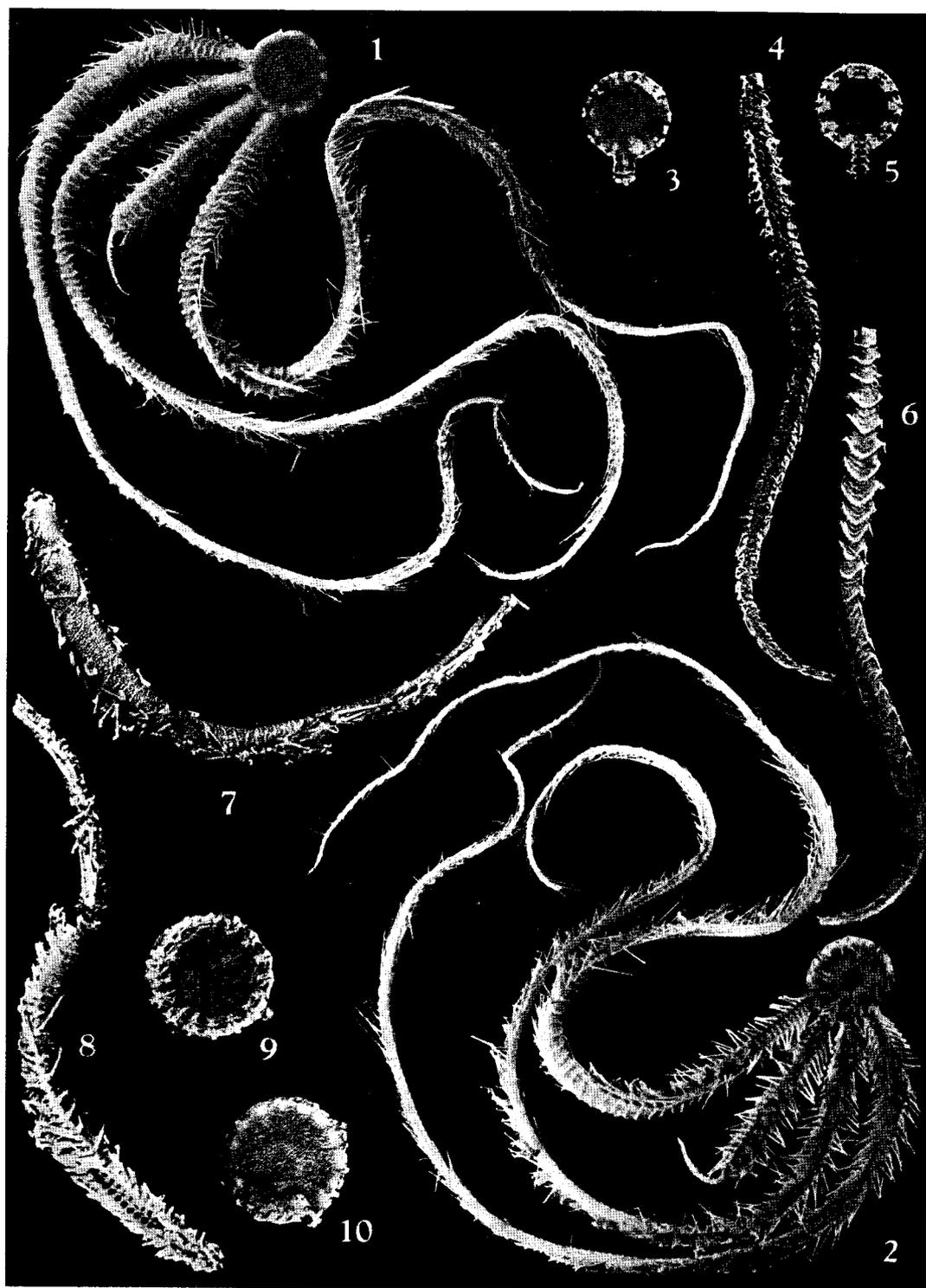
- Fig. 8. Ventral side of *Leptasterias pulchella* n. sp. About natural size.  
Fig. 9. Dorsal side of *Leptasterias hylodes* Fisher. About natural size.  
Fig. 10. Ventral side of *Leptasterias orientalis aniwaensis* showing the skeletal structure. About natural size.  
Fig. 11. Dorsal side of *Leptasterias orientalis aniwaensis* showing the skeletal structure. About natural size.  
Fig. 12. Dorsal side of *Leptasterias alaskensis* forma *alaskensis* (Verrill), showing the skeletal structure. About natural size.

### Explanation of Plate XXII

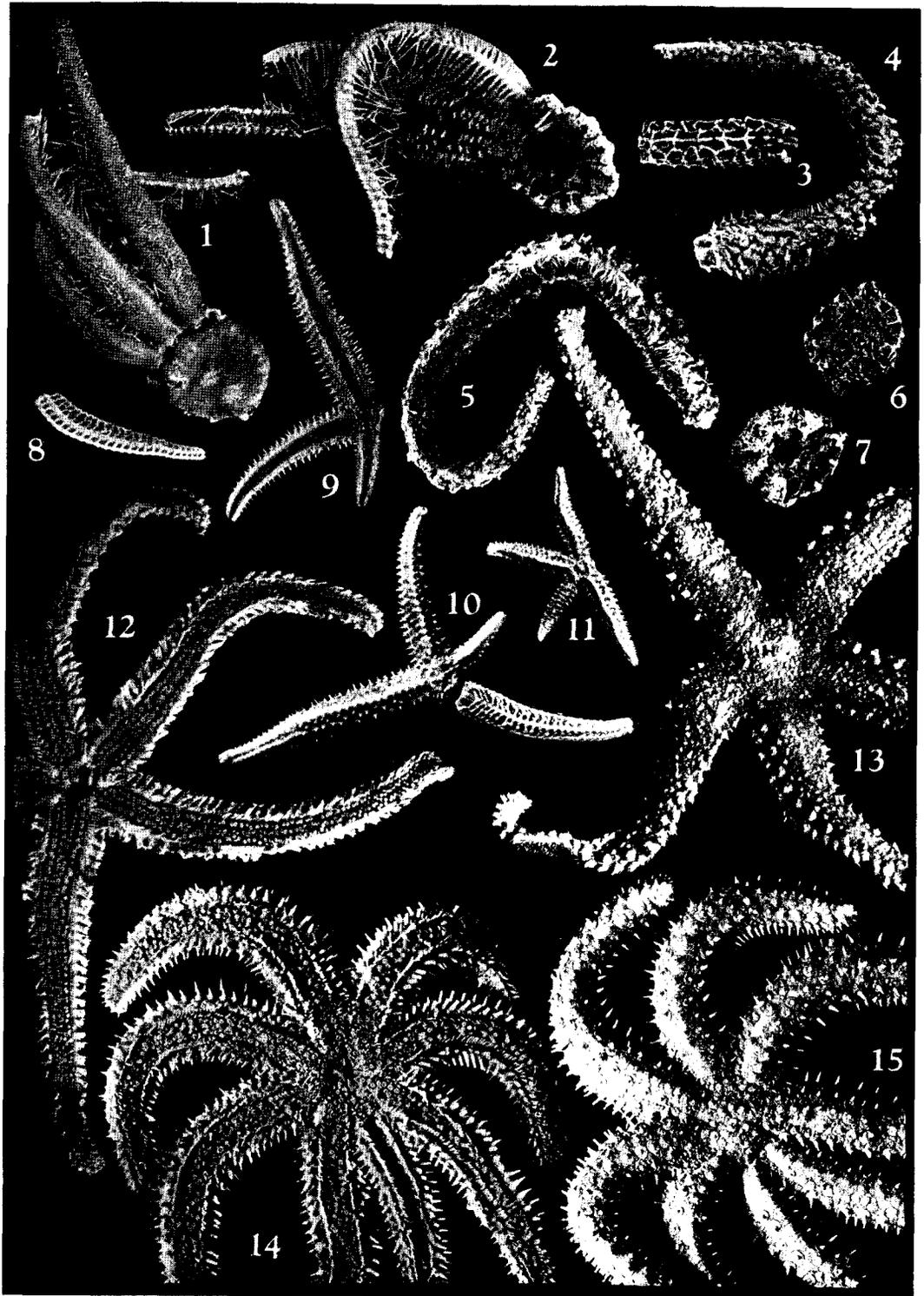
- Fig. 1. Dorsal side of *Aphelasterias japonica* forma *torquata* Sladen. About natural size.  
Fig. 2. Ventral side of *Aphelasterias japonica* forma *torquata* Sladen.  
Fig. 3. Ventral side of *Lethasterias fusca* Djakonov. About  $2/3\times$ .  
Fig. 4. Dorsal side of *Lethasterias fusca* Djakonov. About  $2/3\times$ .  
Fig. 5. Dorsal side of *Aphelasterias japonica* (Bell). About natural size.  
Fig. 6. Dorsal side of *Zoroaster microporus* Fisher. About  $2/3\times$ .  
Fig. 7. Dorsal side of *Leptasterias alaskensis* forma *alaskensis* (Verrill). About natural size.
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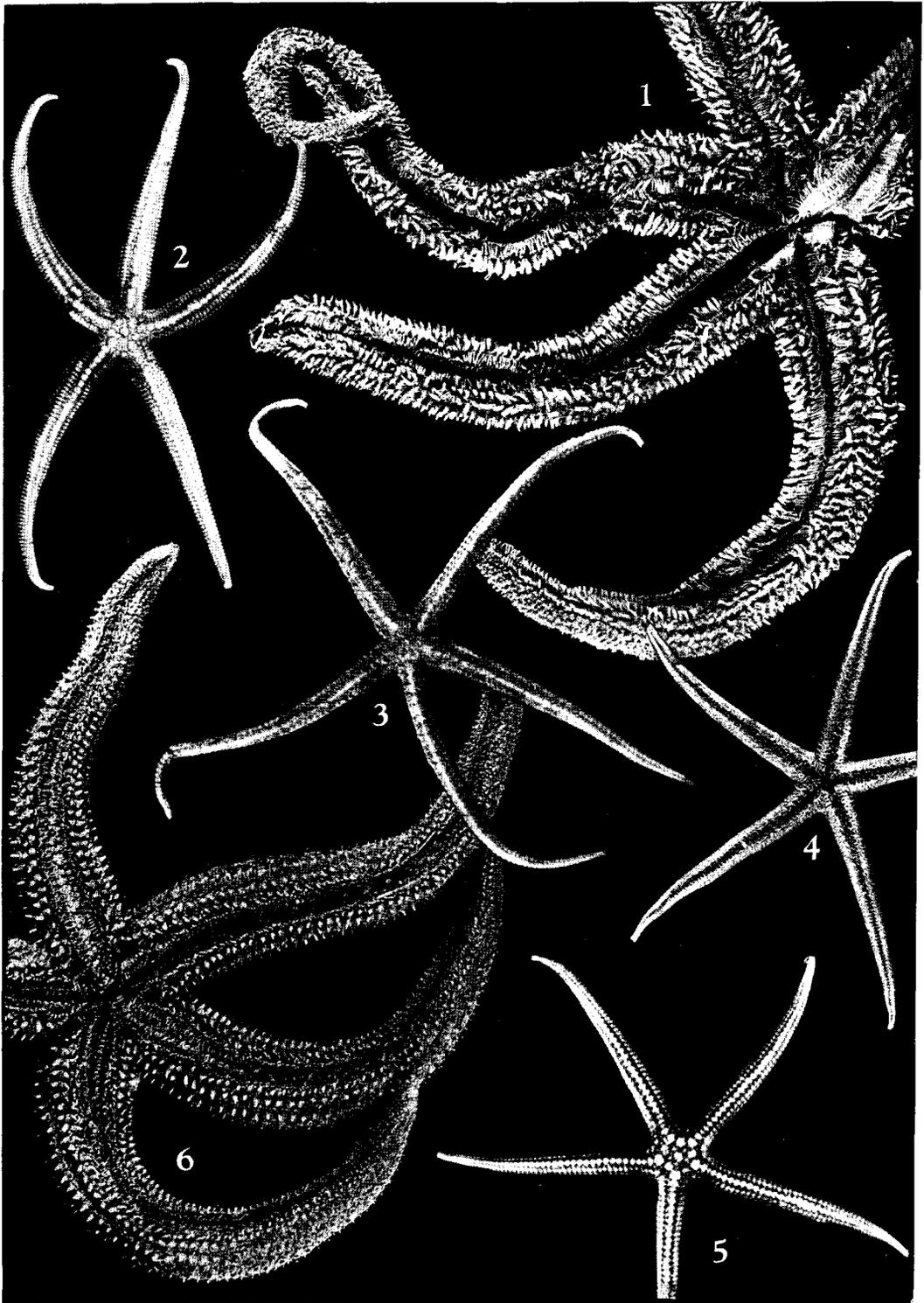
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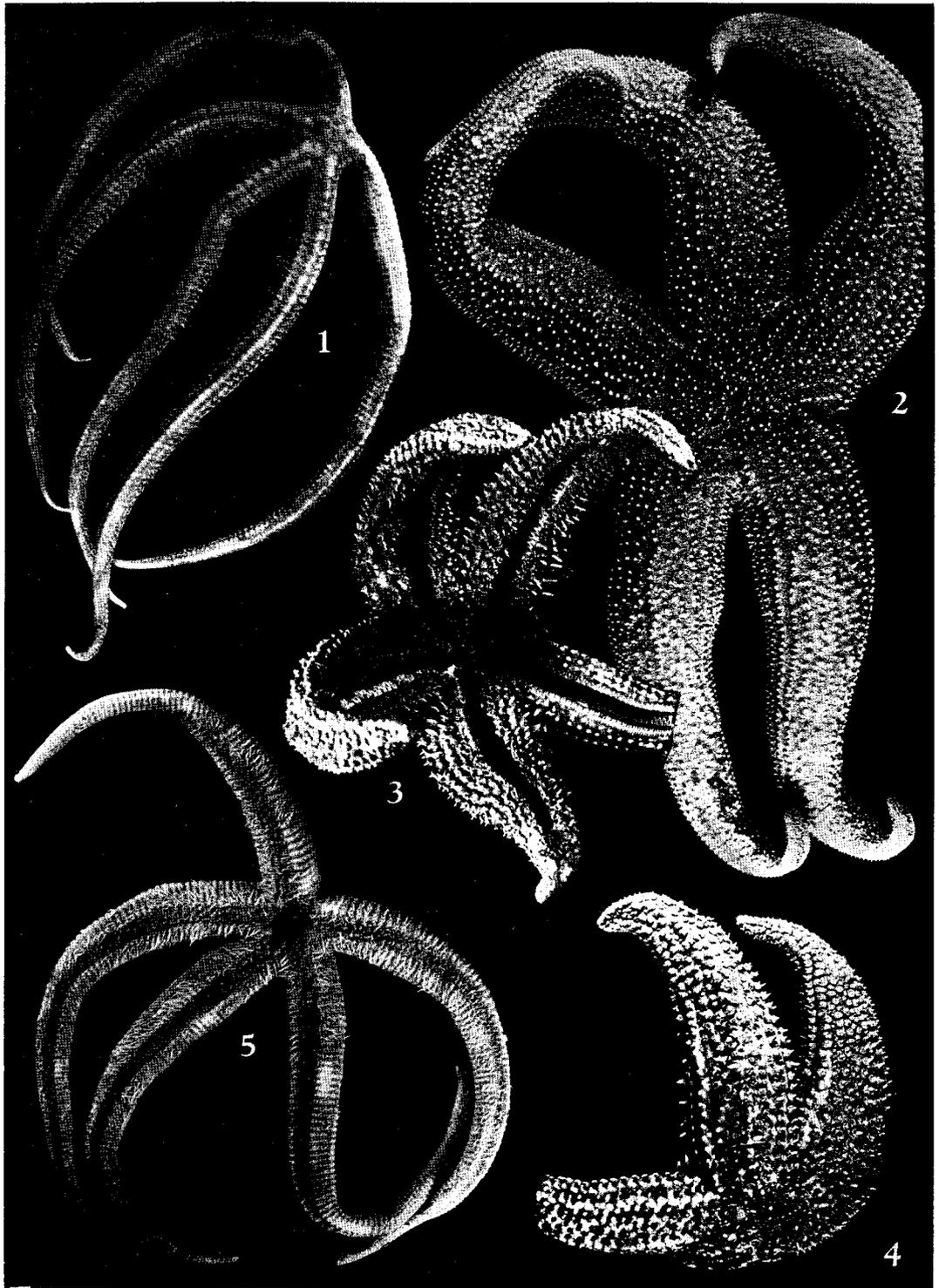
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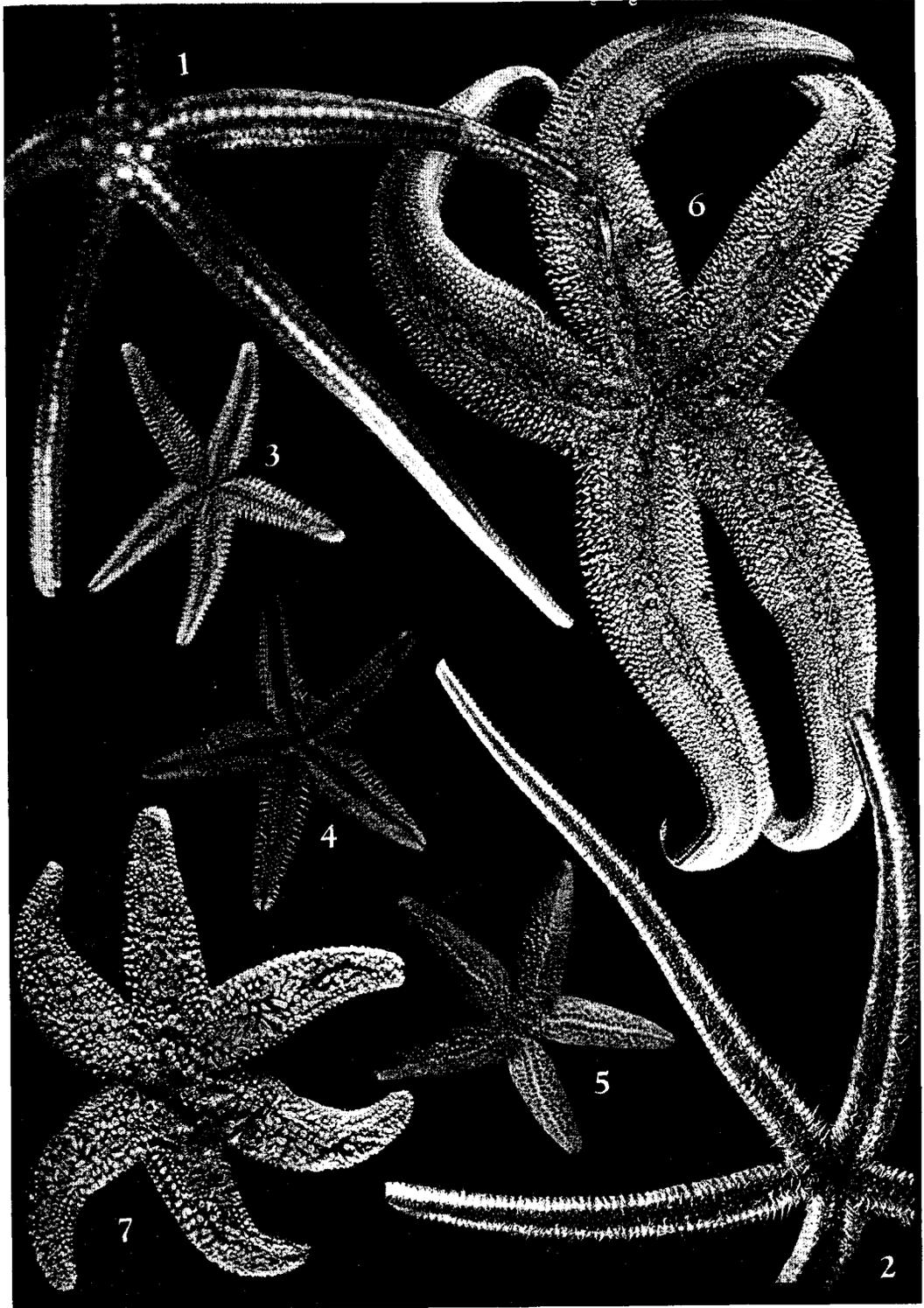
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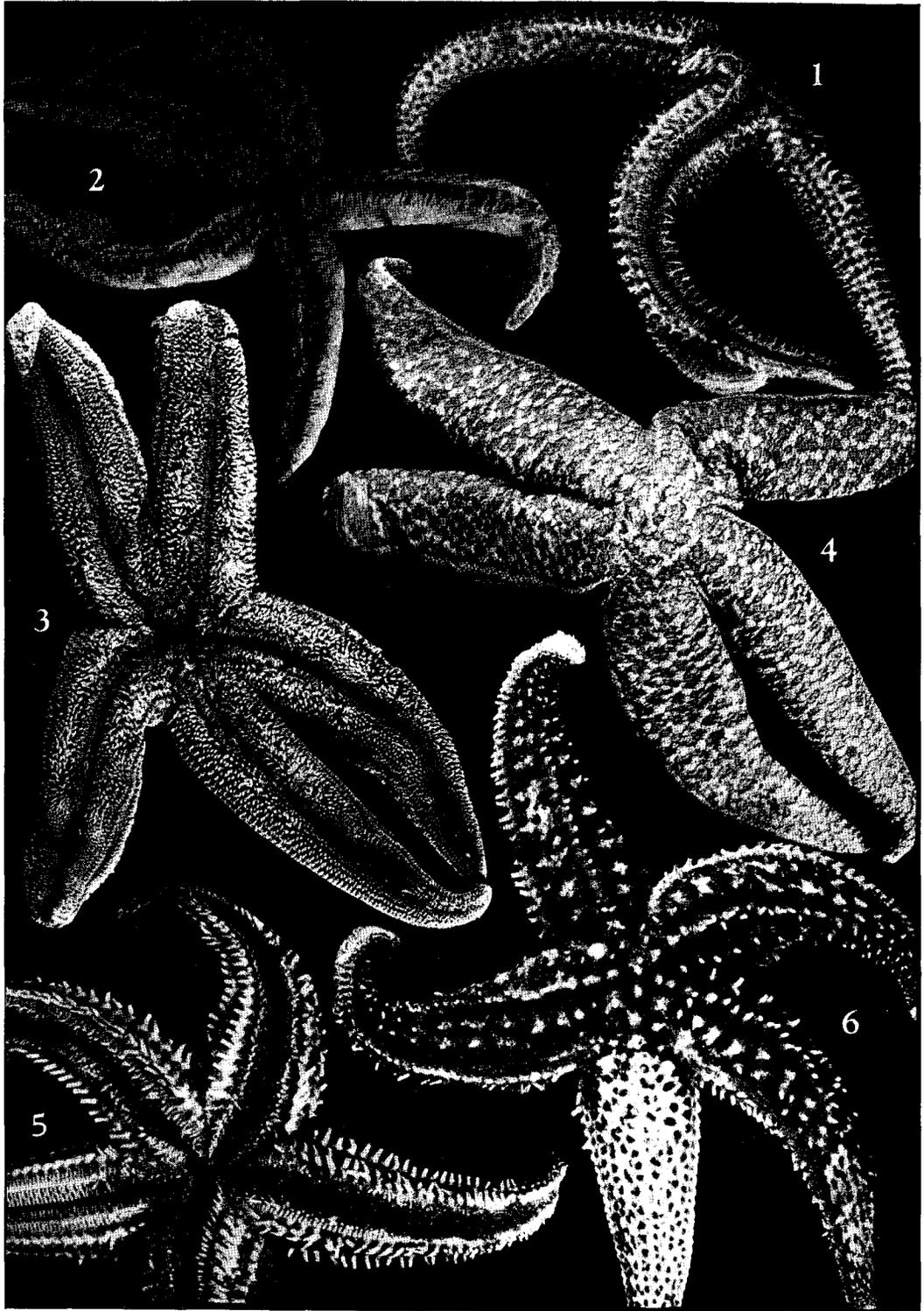
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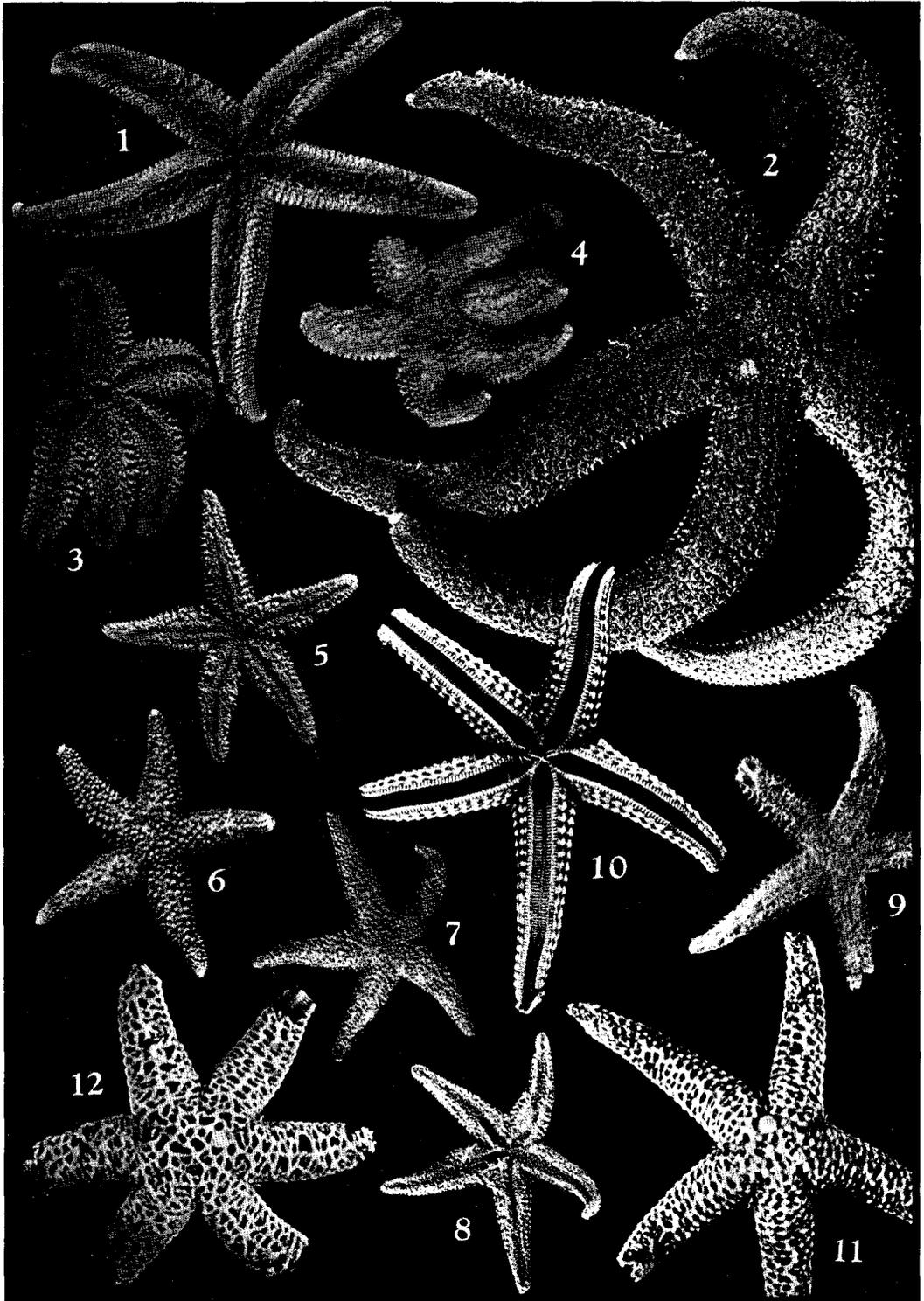
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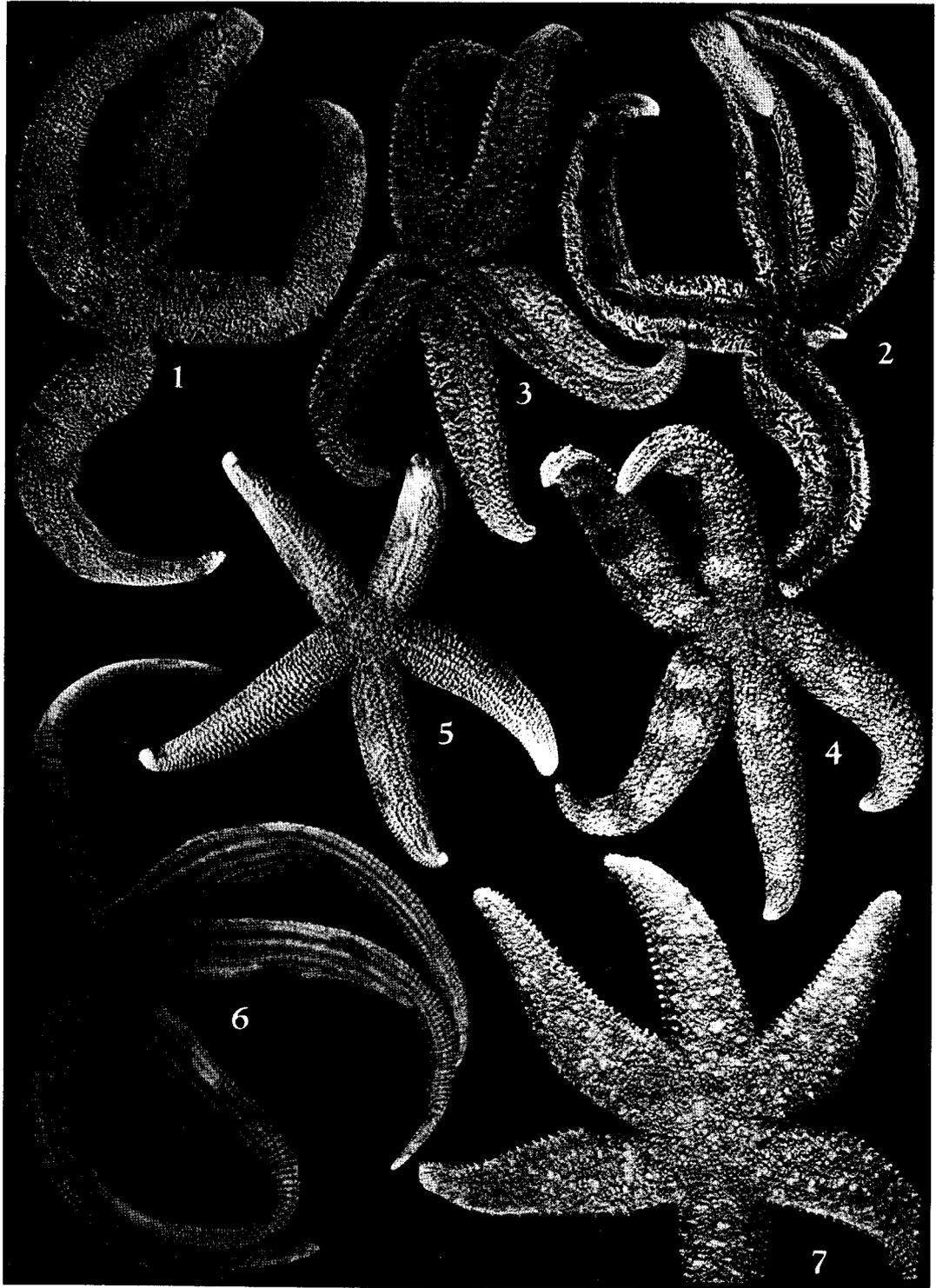
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