PALAEONTOLOGICAL SOCIETY OF JAPAN SPECIAL PAPERS NUMBER 13

THE ECHINOID FAUNA FROM JAPAN AND ADJACENT REGIONS

PART II

By

Syôzô NISIYAMA

PUBLISHED BY THE SOCIETY March 16, 1968

PALAEONTOLOGICAL SOCIETY OF JAPAN SPECIAL PAPERS

Editor : Tatsuro Matsumoto Associate Editor : Itaru Hayami

This paper is printed by the GRANT IN AID of the MINISTRY of EDUCATION

All Communications relating to this Journal should be addressed to THE PALAEONTOLOGICAL SOCIETY OF JAPAN c/o Geological Institute, Faculty of Science, University of Tokyo, Hongo, Tokyo.

> To be purchased through the University of Tokyo Press, c/o University of Tokyo, Hongo, Tokyo.

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Part II

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IV. SYSTEMATIC DESCRIPTION (CONTINUED)

(2-Cassiduloida, Clypeasteroida, Spatangoida)

Order CASSIDULOIDA CLAUS, 1880

Cassidulideae CLAUS, 1880, p. 364 (suborder).—Cassiduloida DUNCAN, 1889-a, p. 166.—LAMBERT, 1911-a, p. 28.—HAWKINS, 1920, p. 459 (with Nucleolitoida HAWKINS, 1920).—HAWKINS, 1920-a, p. 393 (with Nucleolitoida HAWKINS).—MORTENSEN, 1948-a, p. 94.—TERMIER and TERMIER, 1953, p. 915.—NISIYAMA, 1954, p. 328 (in Japanese).—DURHAM and MELVILLE, 1957, p. 260 (with Nucleolitoida HAWKINS, 1920).—KIER, 1962, pp. 1, 22.—PHILIP, 1963-c, p. 725.—PHILIP, 1965, p. 58.

Type-family.—Cassidulidae AGASSIZ, 1847.

- Procassiduloida LAMBERT, 1915-a, p. 18 (suborder).—LAMBERT, 1918-a, p. 35 (suborder).— LAMBERT and THIÉRY, 1921, p. 335.—SANCHEZ ROIG, 1926, p. 68.—SMISER, 1935, p. 45. Type-family.—Procassidulidae LAMBERT, 1915.
- Cassidulina HAWKINS: H.L. CLARK, 1925, p. 179 (with Nucleolitina HAWKINS, p. 178: non Cassidulina d'Orbigny, 1826, p. 282, nec GRAY, 1855-a, p. 34).—GRANT and HERTLEIN, 1938, p. 106.—H.L. CLARK, 1946, p. 355 (with Nucleolitina HAWKINS, p. 353).

Cassiduliformia BEURLEN, 1933, p. 30.

Type-family.—Cassidulidae Agassiz, 1847.

Forms of very varying shape, from regularly rounded to elongate ovoid; test generally low vaulted. Ambulacra usually petaloid adapically, exceptionally (the Neolampadids) quite rudimentary; petals usually all similar; phyllodes and bourrelets (the floscelle) usually well developed. Apical system of discrete plates or monobasal, central or slightly anterior; periproct varying in position, from slightly contiguous with apical system to peristome, very often in a distinct anal groove. Peristome central or slightly anterior; branchial slits absent or at most very indistinct in primitive forms. Posterior interambulacrum (5) not essentially different adorally from other interambulacra. Masticatory apparatus present only in the Conoclypeids, in the others at most present in young stage, totally resorbed in adults. Internal radiating walls present only in the Conoclypids, in the others absent; fascioles absent.

From the Lower Jurassic (Lias) to Recent.

The affinities and source of this order are not settled in the present state of our knowledge, and opinions concerning these problemns are diverse. It seems, however, evident that the Galeropygids represent primtive Cassiduloids, not Holectypoids, and they stand in the oldest relation to the Regular Echinoids, as in showing by the simple ambulacra with an incipient formation of phyllodes and the apical system with complemental plates, viz., the more primitive Diadematoids, or perhapsalso the Arbacioids.

MORTENSEN (1948-a, p. 99) opposes strongly against an opinion to distinguish the two orders (viz., Nucleolitoida and Cassiduloida) by the ambulacral structure, accepting only an order, the Cassiduloida; the Nucleolitoida is rejected and united into the Cassiduloida. Now it seems evident that the minor differences in the ambulacral and phyllodial structures cannot afford criteria for dividing them into orders or suborders.

S. NISIYAMA

MORTENSEN (1948-a) recognized two suborders of the Cassiduloida, viz., Cassidulina and Conoclypina; the latter much differ from the former in having the radiating internal supports (buttresses) and masticatory apparatus in the adult. DURHAM and MELVILLE (1957, p. 260) removed the Conoclypina to the Holectypoida, and divided the remaining Cassiduloids into two orders, as HAWKINS did so, viz., Cassiduloida and Nucleolitoida. KIER (1962, p. 23) rightly rejected this biordinal classification of the Cassiduloida, as MORTENSEN already did so. PHILIP (1963-c, pp. 724, 725) classified the Conoclypina into the Cassiduloida, on account of their characters indicating close similarity with advanced Cassiduloids; he erected a new suborder Neolampadina for the family of the Neolampadids. Although the detailed derivation of them is speculative, they appear to represent a separate branch from the Nucleolitids, being strikingly dissimilar from other Cassiduloids.

Thus the order Cassiduloida comprise three suborders, viz., the Cassiduloina, the Conoclypoina, and the Neolampadoina, and they are discriminated from one another by the following key.

Key to the suborders of the order Cassiduloida.

1.	No internal radiating supports (buttresses). Masticatory apparatus absent in the
	adult
	Internal radiating supports present. Masticatory apparatus present in the adult.
	Ambulacra adapically petaloid Conoclypoina
2.	Ambulacra adapically petaloid Cassiduloina
	Petals lacking, and adapical ambulacral plates with single pores
	Neolampadoina.
	There are fossil representatives of the suborder Cassiduloina in our collection.

Suborder CASSIDULOINA CLAUS, 1880

Cassidulina Delage and Hérouard, 1903, p. 263.—Cassidulina Hawkins: H.L. Clark, 1925, p. 179 (pro parte).—Cassidulina Delage and Hérouard: Mortensen, 1948-a, p. 101.— Cassidulina Claus: Philip, 1963-c, p. 725.—Philip, 1965, p. 59.

Ambulacra usually petaloid adapically; ambulacral plates simple or in part the plates are compound of three components; pores of petals dissimilar or similar and normally conjugate; no radiating internal supports (buttresses). Masticatory apparatus absent in the adults.

From the Lower Jurassic to Recent.

As for subdivision of this suborder, MORTENSEN (1948-a, p. 100) declared that the apical system is the only character that affords to divide them into families, whether "tetrabasal" or "monobasal" named by BERNARD (1895-a, p. 295). It is true that the genera having tetrabasal apical system are older and more primitive forms than those having monobasal system. But it is hardly decided whether the difference between the two types of apical system, viz., tetrabasal or monobasal, manifest the true genetic or phylogenetic relations or not, whether the similarity is a phenomenon of convergence or acutal genetic relation.

In his study of the Cassiduloids, KIER (1962) recognized striking examples of parallel evolution, particularly in the ambulacra, the apical system, and the phyllodes, in the various groups of them. KIER (1962) recognized 10 families in the suborder Cassiduloina, viz., the Galeropygidae LAMBERT, 1911, Clypeidae LAMBERT, 1898, Nucleolitidae AGASSIZ and DESOR, 1847, Echinolampadidae GRAY, 1851, Faujasidae LAMBERT, 1905, Archiacidae COTTEAU and TRIGER, 1869, Cassidulidae AGASSIZ, 1847, Clypeolampadidae KIER, 1962, Pliolampadidae KIER, 1962 and the Apatopygidae KIER, 1962. It is to be noticed, here, that some of these are poorly differentiated from one another and probably may be treated at most as subfamilies of others. The important families are discriminated from one another as shown by the following artificial key.

Key to the important families of the suborder Gassiduloina.

1.	No naked, granular zone in interambulacrum (5)
	Naked, granular zone in interambulacrum (5) 5
2.	No buccal pores. Apical system tetrabasal only 3
	Buccal pores present. Apical system monobasal only7
.3.	Periproct supramarginal, in contact with apical system. Ambulacra subpetaloid,
	flush with test. Bourrelets absent or slightly developed Galeropygidae
	Periproct separated from apical system, supramarginal to inframarginal. Am-
	bulacra petaloid adapically. Bourrelets developed
.4.	Petals usually broad, closed, of equal length; ambulacral plates double pored.
	Bourrelets well developed Clypeidae
	Petals moderately developed, usually open, narrow with narrow poriferous zones;
	ambulacral plates beyond petals generally double pored. Bourrelets moderately
	developed
5.	Periproct marginal to inframarginal, transverse or longitudinal; peristome trans-
	verse. Petals long, usually broad, open, usually with poriferous zones of
	unequal length in the same petal; single pores in ambulacral plates beyond
	petals. Bourrelets well developed; phyllodes widened. Apical system tetra-
	basal or monobasal Echinolampadidae
	Periproct supramarginal to inframarginal, often with anal groove. Petals broad,
	usually of equal length. Bourrelets strongly and well developed. Apical system
	tetrabasal or monobasal
×6 .	Petals generally closed, outer pores slit-like, pores strongly conjugate. Bourrelets
	strongly developed; phyllodes greatly widened Faujasidae
	Poriferous zones of unequal length in most Tertiary species. Bourrelets well
	developed; phyllodes widened, double or single pored. Buccal pores absent
	in pre-Senonian species Cassidulidae
7.	Periproct inframarginal. Petals narrow or broad, open, or closed; single pore in
	all ambulacral plates beyond petals. Bourrelets well developed
	Pliolampadidae.
	There are fossil representatives of the families, the Clypeidae, Echinolampadidae,
-Cas	ssidulidae, and the Pliolampadidae, in our collection.

S. NISIYAMA

Family CLYPEIDAE LAMBERT, 1898

Clypeinae LAMBERT, 1898, p. 168 (28) (tribus).—LAMBERT and THIÉRY, 1921, p. 342.—Clypeidae LAMBERT: KIER, 1962, pp. 15, 30. Type-genus.—Clypeus LESKE, 1778.

Forms usually large, low, broad, with flat adoral surface. Apical systemanterior, tetrabasal of discrete plates, always four genital pores. Periproct supramarginal to inframarginal, usually longitudinal, or rarely transverse; peristome anterior, pentagonal. Petals usually broad, closed, of equal length; outer pores slitlike, strongly conjugate; all ambulacral plates double pored. Bourrelets well developed; phyllodes in early species usually with three series of pore-pairs in each halfambulacrum, in later ones only one; no buccal pores. Adoral tubercles in later species larger than adapical; no naked, granular zone in interambulacrum (5) (mainly after KIER, 1962).

From the Jurassic (Bajocian) to Cretaceous (Cenomanian).

The Clypeidae seem to be, as KIER claimed (1962, p. 15), descended from the Galeropygidae or from a close ancestor of the latter. The Clypeidae are more advanced than the Galeropygidae as shown by their well-developed petals and usually more marginal or inframarginal periproct. KIER (1962, p. 30) referred the following genera to the family; i.e., *Clypeus* LESKE, 1778, *Bothryopneustes* FOURTAU, 1924, *Pygurus* AGASSIZ, 1839, *Astrolampas* POMEL, 1883, and *Pseudopygurus* LAMBERT, 1911. Within the family, the genera *Pygurus* (with subgenera), *Clypeus*, and *Pseudopygurus*, as stated by KIER (1962, pp. 15, 30), seem to be closely related to one another, and make a main stem of the family. They are common in having well developed petals, a low test, and in the primitive stage narrow phyllodes with crowded pores. The three genera are discriminated from one another as shown by the following key.

Key to the three genera of the family Clypeidae.

Genus Pygurus AGASSIZ, 1839

Pygurus Agassiz, 1839, pp. 68, 100.—Agassiz, 1840-a, pp. 5, 17.—Agassiz and Desor, 1847, p. 161.—D'Orbigny, 1853-55 (55), p. 299.—Desor, 1855-58 (57), p. 309.—Wright, 1856-67

'(60), p. 391.—COTTEAU, 1865-69 (67), p. 126.—DESOR and LORIOL, 1868-72 (72), p. 339.— LORIOL, 1873, p. 280.—QUENSTEDT, 1872-75 (75), p. 473.—ZITTEL, 1879, p. 531.—POMEL, 1883, p. 65.—DUNCAN, 1889-a, p. 188.—BEURLEN, 1933, p. 70.—MORTENSEN, 1948-a, p. 132, text-figs. 100a-b, 101a-c, 102a-c.—TERMIER and TERMIER, 1953, p. 915.—COOKE, 1955, p. 98.—KIER, 1962, pp. 41, 45, chart 3.

- Logotype.—Echinolampas montmollini AGASSIZ, 1835, p. 134, pl. 14, figs. 4-6.—Pygurus montmollini (AGASSIZ): D'ORBIGNY, 1853-55 (55), p. 305, pls. 916-917 (Neocomian of Switzerland and France).—KIER, 1962, p. 45, pl. 2, fig. 1. [SAVIN, 1903, p. 86.—SAVIN, 1905, p. 176].
- Echinopygus D'ORBIGNY, 1853-55 (55), p. 303.—POMEL, 1883, p. 65.—LAMBERT and THIÉRY, 1921, p. 354.—COOKE, 1955, p. 98 (subgenus ad Pygurus).
- Logotype.—Echinoaus lampas DE LA BECHE, 1833, p. 42, pl. 3, figs. 3-5.—Pygurus (Echinopygus) oviformis (LAMARCK) var. D'ORBIGNY, 1853-55 (55), p. 311, pl. 919 (Cenomanian of Sarthe).— Pygurus lampas (DE LA BECHE): KIER, 1962, p. 46, pl. 3, figs. 1-3 (Cenomanian of France and England). [LAMBERT and THIÉRY, 1921, p. 354].

Large forms of angular or undulating outline, with or without anterior depression; the posterior end usually somewhat rostrate; aboral side variable, often flattened; oral side somewhat pulvinate. Petals large and broad, equal, or frontal petal (III) shorter than others, open or with tendency to close; interporiferous zones wide, wide tapering poriferous zones with conjugate pores; pores unequal, the inner pore small, the outer pores long, slit-like; all ambulacral plates double pored. On oral side ambulacra form sunken lines. Apical system small, tetrabasal, posterior genital plates separated by genital (2), posterior oculars usually in contact; four genital pores. Peristome somewhat anterior, pentagonal, sunken, width greater or less than height; bourrelets well developed, phyllodes slightly widened, or very broad, double pored, with from one to three series of pore-pairs in each half-ambulacrum; no buccal pores. Periproct inframarginal, longitudinal or transverse, the test somewhat raised around it, so that there is a marked periproctal area, or none. Tubercles small, perforate, sometimes forming distinct horizontal lines (from MORTENSEN, 1848-a, and KIER, 1962).

This genus is characterized by its lampadiform test, usually somewhat rostrate behind, disparity of ambulacral pores and simplicity of ambulacral plating in petals, and ornamented floscelle, and inframarginal periproct. This genus is distinguished from related genus *Clypeus* in having an inframarginal periproct. The species which has a transverse periproct without marked periproctal area, and no anterior depression of the test, is selected as the type-species (*Ech. lampas*) of the genus (or subgenus) *Echinopygus*. COOKE (1955, p. 98) regarded that the differences of the periproct and anterior depression between the type-species of *Pygurus* and *Echinopygus* are may be of sufficient importance to justify the retention of *Echinopygus* as a subgenus under *Pygurus*, as it was originally proposed. KIER (1962, p. 47), however, pointed out that *Ech. lampas* is so similar in all its other characters, except the form of periproct, to the type-species (*Pyg. montmollini*) of *Pygurus*, and he believes that the former should be considered as congeneric with *Pygurus*.

As to the changing the name *Echinopygus* for *Pygurus*, as done by LAMBERT and THIERY (1921, p. 355)—because the name *Pygurus* was used already for an insect in 1833 by DEJEAN (but as a nomen nudum)—the writer agrees MORTENSEN'S treatment (1948-a, p. 133) that there is no reason at all for changing the name of this highly characteristic echinoid.

The genus Pygurus comprises, according to KIER (1962, pp. 45-51), three sub-

genera, viz., *Pygurus* sens. strict., *Mepygurus*, and *Pygropsis*. There are fossil representatives of the typical *Pygurus* in our collection.

Pygurus asiaticus TOKUNAGA, 1903

Pygurus asiaticus Токилада, 1903, p. 16, pl. 3, figs. 3-6. Echinopygus asiaticus (Токилада) Lambert and Thiéry, 1921, p. 355.

Although this species is recorded from Torinosu, near Sakawa-machi, Kôchr Prefecture and TOKUNAGA (1903, p. 17) presumed that it came from the Cretaceous, its exact horizon is still unknown. The horizon was misled to be the Cenomanian by LAMBERT and THIÉRY (1921, p. 355). There is no authentic specimen at the writer's disposal.

Since this species has an anterior depression of the test, high test (over 0.7 of test-length), and seems to have an oval periproct with periproctal area, it can be safely referred to the genus *Pygurus*. Although the nature of the apical system and the structure of the floscelle, particularly of the phyllodes, are not precisely detected, the original figure (TOKUNAGA, 1903, pl. 3, fig. 4) seems to show that they are similar to those of *Pyg. blumenbachi* (KIER, 1962, chart 3-d.)

A remark should be added here on the distinction of the species. This species resembles *Pyg. blumenbachi* (KOCH and DUNKER) (WRIGHT, 1857-78 (60), p. 400, pl. 37, figs. 1-2.—COTTEAU, 1867-74 (69), p. 157, pl. 38, fig. 3, pls. 39-40.—KIER, 1962, p. 42, pl. 3, fig. 4), from the Rauracian or Corallian of France and England, in the marginal outline of the test, and in the position and outline of the periproct, but differs from that species by having higher and conical test and longer petals. *Pyg. asiaticus* is also related to the type-species, *Pyg. montmollini* (AGGASSIZ, 1836) (loc. cit.), from the Neocomian of Switzerland and France, in the marginal outline of the test, position and outline of the periproct, and the form of petals, but is distinguished from that species in the heigher and conical test and in the broader poriferous zones in the petals.

Pygurus complanatus TANAKA, 1965

Pygurus (Pygurus) complanatus TANAKA, 1965, p. 128, pl. 15, figs. 1a-c, 2a-c.

Although this species is recorded from the presumed Ishido formation (presumed Cretaceous), at Lower course of the Onozawa, Saku-chô, Minami-Saku-gun, Nagano Prefecture, there is no authentic specimen at the writer's disposal.

This is a small-sized species for the genus, and is clearly distinguished from the Japanese known species, *Pyg. asiaticus* TOKUNAGA, 1903 (loc. cit.), in having a low test, no anterior depression, and a smaller posterior rostrum. This species also resembles to some extent *Pyg. impar* GAUTHIER in COTTEAU, PERON, and GAUTHIER, 1876 (1876-91 (76), 2, p. 74, pl. 5, figs. 10-11), from the Upper Neocomian of Algeria, but differs from the latter by having the shorter, narrower and more tapering petals. This species is also distinguished from the type-species, *Pyg. montmollini* (loc. cit.), in having the lower test, no distinct anterior depression, and a small posterior rostrum. The nature of the apical system and the structure of the floscelle are not precisely detected on the specimens owing to the ill-condition of preservation.

Family CASSIDULIDAE AGASSIZ, 1847

(Emended by KIER, 1962)

Cassidulides AGASSIZ in AGASSIZ and DESOR, 1847, p. 143 (pro parte).-DESOR, 1855-57 (57), p. 245.—Cassidulidae Agassiz: Cotteau, 1861-67 (67), p. 116.—A. Agassiz, 1872-74, pp. 332, 549.—ZITTEL, 1879, p. 524.—POMEL, 1883, p. 54.—DUNCAN, 1889-a, p. 180.—DELAGE and Hérouard, 1903, p. 263.—Meissner, 1904, p. 1386.—H. L. Clark, 1917, p. 103.—Hawkins, 1920, p. 459.—H.L. Clark, 1925, p. 179.—Beurlen, 1933, p. 68.—Smiser, 1935, p. 48.— GRANT and HERTLEIN, 1938, p. 106.-H.L. CLARK, 1946, p. 355.-MORTENSEN, 1948-a, p. 190.—TERMIER and TERMIER, 1953, p. 919.—KIER, 1962, p. 157. Type-genus.—Cassidulus LAMARCK, 1801.

Forms small to large, elongate, with flat adoral surface. Apical system anterior, tetrabasal or monobasal. Periproct supramarginal to marginal, longitudinal or transverse; peristome anterior, oval or pentagonal, transverse. Petals usually well developed, broad, usually of equal length, often inconspicuous; poriferous zones of unequl length in most Tertiary species; ambulacral plates beyond petals double pored in pre-Senonian species, single pored in Tertiary ones. Bourrelets well developed; phyllodes widened, double or single pored, one or more series of pores in each halfambulacrum; buccal pores absent in pre-Senonian species. Tubercles much larger adorally than adapically, naked granular zone in interambulacrum (5) (after KIER, 1962).

From the Lower Cretaceous (Albian) to Recent.

MORTENSEN (1948-a, pp. 140, 190) have limited the family Cassidulidae comprising the various forms, no less than twenty four genera, having the monobasal apical system and discriminated from the related family Nucleolitidae, which are characterized by having the tetrabasal apical system. KIER (1962, p. 159), however, distinguished the family Cassidulidae from the Nucleolitidae in having more developed bourrelets, wider phyllodes with fewer pores, and a naked, often pitted zone adorally in intermabulacrum (5). MORTENSEN (1948-a, p. 190) and KIER (1962, p. 18) claimed that the Cassidulidae represent a further development from the Nucleolitidae, i.e., the former evolved from the latter, and probably so that there is a line connecting the two families, e.g., Nucleopygus (a Cenomanian-Senonian Cassidulid) originating from Nucleolites (a Bajocian-Cenomanian Nucleolitid). KIER (1962, pp. 18, 157) classified only six genera into the family Cassidulidae, viz., Rhynchopygus, Nucleopygus, Hypsopygaster, Ochetes, Cassidulus, and Rhyncholamas. The important genera of the Cassidulidae are discriminated from one another as shown by the following key.

Key to the important genera of the family Cassidulidae.

1.	Apical system tetrabasal 2
	Apical system monobasal 3
2.	Bourrelets well developed; phyllodes widened, single pored, with slight crowding,
	only few pores occluded. Tubercles adorally much larger. Petals slightly or
	well developed, open or closing distally Rhynchopygus
	Bourrelets slightly or moderately developed, not pointed; phyllodes single pored,
	narrow or only slightly widened, very few or no occluded pores. Petals

2

Genus Cassidulus LAMARCK, 1801

Cassidulus LAMARCK, 1801, p. 348.—BLAINVILLE, 1834, p. 310.—GRAY, 1855-a, p. 34.—COOKE, 1942, p. 30.—MORTENSEN, 1948-a, p. 198, text-figs. 173a-d, 174, 175a-b, 176a-d (includes complete synonymy).—COOKE, 1959, p. 56.—KIER, 1962, p. 174.

Haplotype.—Cassidulus cariboearum LAMARCK, 1801, p. 349 (reference is made to Encycl. Méth., pl. 143, figs. 8-10.—The specific name was first spelled with the diphthong oe, not ae).—Rhynchopygus caribaearum (LAMARCK) A. AGASSIZ, 1872-74, p. 343, pl. 15, figs. 1-4.—Cassidulus caribaearum LAMARCK: MORTENSEN, 1948-a, p. 205, pl. 2, figs. 5, 14-18, pl. 11, figs. 5, 7-9, text-figs. 177, 178a-c, 179, 180-181, 183a-d, 184a-b.—KIER, 1962, p. 176, pl. 26, figs. 3-7, text-figs. 148-150 (Recent of West Indies).

Rhyncholampas A. Agassiz, 1869, p. 270.—H.L. Clark, 1925, p. 180.

Pseudotype.—Cassidulus cariboearum LAMARCK, 1801, p. 349.

Logotype.—Pygorhynchus pacificus A. AGASSIZ, 1863, p. 27.—Rhyncholampas pacificus (A. AGASSIZ): KIER, 1962, p. 180, pl. 27, figs. 5-8, pl. 28, figs. 1-3, text-figs. 154-159. [LAMBERT, 1918-a, p. 57 (41)].

Small to medium sized form of ovate outline. Test low, with acutely rounded margin, and somewhat concave along the midline orally. Petals slightly or well developed, straight, open or closing distally; poriferous zones of the same petal usually unequal; ambulacral plates beyond petals single pored. Apical system usually anterior, monobasal, with four genital pores. Periproct supramarginal, longitudinal, round, or transverse, with groove extending from opening to posterior margin. Peristome usually anterior, pentagonal, transverse. Bourrelets well developed, but rather low; phyllodes widened, single pored with slight crowding of pores, one or two or no occluded pores; buccal pores present. Naked median area in posterior interambula-crum (5) often covered by deep irregular pits; adoral tubercles much larger than aboral ones, their scrobicules often polygonal, with bosses eccentric anteriorly (from MORTENSEN, 1948-a, and KIER, 1962).

MORTENSEN (1948-a, p. 221) distinguished this genus from *Procassidulus* by only a character of the periproct, disregarding the difference of apical system. In the latter the periproct is round, or oval, not transverse, and the test does not form a pojection above it. Whereas KIER (1962, p. 160) claimed that the character of periproct in the Cassidulids (transverse or longitudinal) does not seem to be of generic

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singnificance.

H. L. CLARK (1925, p. 180), GRANT and HERTLEIN (1938, p. 107), and MORTENSEN (1948-a, p. 202) incorrectly stated that *Cassidulus cariboearum* is the type-species of the genus *Rhyncholampas*. KIER (1962, pp. 178, 179) pointed out that LAMBERT (1918-a, p. 57) clearly designated *R. pacificus* as the type-species of *Rhyncholampas*. KIER (1962, pp. 174, 179) distinguished *Cassidulus* from *Rhyncholampas* in having a smaller, more elongate test, narrower, non-lanceolate petals, a usually less posterior periproct, and phyllodes with fewer pores. *Cassidulus* has a more advanced apical system (monobasal) than *Rhynchopygus* (tetrabasal)—with which *Procassidulus* probably congeneric—, and there is little doubt that the former is descended from *Rhynchopygus*. This genus ranges from the Eocene to Recent, showing world-wide distribution.

'Cassidulus' yoshiwarai (LORIOL, 1902)

Ilarionia yoshiwarai LORIOL, 1902-a, p. 34, pl. 3, figs. 2-2d.—TOKUNAGA, 1903, p. 16.—LAMBERT and THIERY, 1921, p. 369.—MORISHITA, 1960, p. 68.—*Procassidulus yoshiwarai* (LORIOL) NISIYAMA, 1965, p. 78.

Locality and geological horizon.—Nishiura in Haha-jima (Hillsborough Island), Bonin Islands. Eocene (Eorupertia-zone, Ypresin). Topotype.—IGPS coll. cat. no. 7344.

There is a partly broken and ill-preserved specimen at the writer's disposal, and the exact generic position of the species is not certainly settled at present.

This species is originally assigned to the genus Ilarionia (DAMES, 1877, p. 34.-Haplotype.-Echinanthus beggiatoi LAUBE, 1868, p. 22, pl. 4, fig. 3.-Ilarionia beggiatoi (LAUBE): KIER, 1962, p. 206, figs. 4-10, text-fig. 170) by LORIOL, and followed by TOKUNAGA. This species has a floscelle of the cassidulid type, i.e., the bourrelets are well developed and inflated (cf. Cassidulus cariboearum-KIER, 1962, pl. 26, fig. 7), not forming a rim around peristome as in Il. beggiatoi (cf. KIER, 1962, pl. 39, fig. 7). Also the periproct of *Il. beggiatoi* lies on the truncate posterior end of test (KIER, 1962, pl. 39, fig. 9) and not in a distinct groove on supramarginal surface, as in the case of Rhynchopygus lapiscancri (KIER, 1962, pl. 24, fig. 5). But the periproct of this species is "Périproct ouver près du milieu de la hauter de la face postérieure, au sommet d'une area verticale peu profondément, mais distinctement excavée, il était ovale, petit et légèrement acuminé en arrière, une fracture ne me permet pas de la voir en entier, peut-être étaot-il surmonté par un léger rostre," fits with the feature of the periproct of Rh. lapiscancri. In its general features this species closely resembles Rh. lapiscancri (type-species of Procassidulus), but the former has a monobasal apical system, while the latter tetrabasal one.

It may perhaps be doubted whether this species really belongs to the genus *Ilarionia* or to other genus. In this place the writer preliminary refers it to the genus *Cassidulus*, although this does not settled with certainty, owing to the bad condition of the specimen.

Family Echinolampadidae Gray, 1851

Echinolampasidae GRAY, 1851-a, p. 37.—GRAY, 1855-a, p. 33.—Echinolampidae GRAY: WRIGHT,

1857-78 (57), p. 20.—Echinolampidées LORIOL, 1875, p. 42.—Echinolampinae ZITTEL, 1879, p. 527.—Echinolampadidés BERNARD, 1895-a, p. 295.—Echinolampidae GRAY: LAMBERT, 1905-a, p. 141.—LAMBERT, 1918-a, p. 37 (12).—Echinolampadidae GRAY: HAWKINS, 1920, p. 459.—Echinolampidae GRAY: LAMBERT and THIÉRY, 1921, p. 361.—Echinolampadidae GRAY: MORTENSEN, 1948-a, p. 263.—TERMIER and TERMIER, 1953, p. 291.—KIER, 1962, p. 99.

Type-genus.—Echinolampas GRAY, 1825.

Test medium to large, of rounded, usually oval outline, usually highly inflated; oral side somewhat pulvinate or quite flat, aboral side more or less highly vaulted. Apical system tetrabasal or monobasal. Petals long, usually broad, usually with poriferous zones of unequal length in the same petal; single pores in ambulacral plates beyond petals, only in the phyllodes pores may be some irregularities. Bourrelets well developed; phyllodes widened, single pored, with few or many pores; buccal pores present. Periproct generally inframarginal, rarely marginal, transverse or longitudinal. Peristome generally transverse. Adoral tubercles only slightly larger than aboral ones; narrow, naked, granular median zone in posterior interambulacrum (5) (from MORTENSEN, 1948-a, and KIER, 1962).

From the Cretaceous (Cenomanian) to Recent.

The family Echinolampadidae, in the limitation of MORTENSEN (1948-a), are characterized by having the monobasal apical system and the long and wide open petals. MORTENSEN (1948-a, pp. 268-269) distinguished his Echinolampadidae from his Cassidulidae only by the form of petals and put minor importance on the position of the periproct. KIER (1962, pp. 18-19), by using the evolutionary trends in the Cassiduloida as the criteria, seeked the origin of the Echinolampadidae for the Nucleolitidae, and suggested that the oldest genus Arnaudaster (a Cenomanian Echinolampadid—having the tetrabasal apical system) is probably derived from a genus like Pygorhynchus (an Albian Nucleolitid). KIER (1962) classified five genera, founding on the view point of phylogenetical relation, into the family Echinolampadidae. The view of MORTENSEN (1948-a, p. 268) and KIER (1962, p. 19) on the affinities and source of the Echinolampadidae, from the Nucleolitidae in broad sense, seem to be more radical and natural than the view of HAWKINS (1920, p. 459)-deriving directly from the Conulidae of the Holectypoida. The Echinolampadidae may represent one of the most highly specialized forms of the Galeropygidae-Nucleolitidae-Echinolampadidaestem of the Cassiduloida. The Echinolampadidae differ from the Pliolampadidae in having narrower poriferous zones of unequal length in the same petal, and in having a naked granular zone in the posterior interambulacrum (5).

The Echinolampadidae, as in KIER'S limitation, are a rather small family comprising about five genera, viz., *Arnaudaster*, *Parapygus*, *Plesiolampas*, *Echinolampas*, and *Conolampas*. They are discriminated from one another by the following key.

Key to the genera of the family Echinolampadidae.

1.	Apical system tetrabasal.	Periproct	marginal,	longitud	linal,	in a	slight	groov	·e
									2
	Apical system monobasal.	Periproct	inframar	ginal, tı	ansve	rse o	or longi	tudina	1,
	not in a groove		•••••						3

- Periproct longitudinal. Petals long, open, narrow poriferous zones, of unequal length in the same petal Plesiolampas
- Petals moderately developed, sometimes lanceolate, open, or closing distally; poriferous zones usually unequal, interporiferous zones wide..... Echinolampas Petals long, straight, with narrow poriferous zones Conolampas. There are fossil representatives of the genus Echinolampas in our collection.

Genus Echinolampas GRAY, 1825

- Echinolampas GRAY, 1825, p. 429.—BLAINVILLE, 1834, p. 209.—DESMOULINS, 1835-37 (35), p. 207.—AGASSIZ, 1836, p. 188 (20).—AGASSIZ, 1840, pp. 57, 99.—AGASSIZ, 1840-a, pp. 5, 17.—AGASSIZ and DESOR, 1846, p. 163.—ARADAS, 1850-54 (50), p. 239 (10).—D'ARCHIAC and HAIME, 1853-54 (53), p. 209.—GRAY, 1855-a, p. 34.—DESOR, 1855-57 (57), p. 300—V. MARTENS, 1866, p. 178.—A. AGASSIZ, 1872-74, pp. 335, 551.—LORIOL, 1875, p. 61.—ZITTEL, 1879, p. 530.—A. AGASSIZ, 1881-a, p. 122.—POMEL, 1883, p. 62.—DUNCAN and SLADEN, 1884, p. 152.—DUNCAN, 1889-a, p. 190.—COTTEAU, 1889-94 (89), p. 5.—DELAGE and HÉROUARD, 1903, p. 264.—A. AGASSIZ, 1904, p. 118.—MEISSNER, 1904, p. 1387.—FOURTAU, 1904-a, p. 427.—SAVIN, 1905, p. 167.—LAMBERT, 1906, p. 28.—DÖDERLEIN, 1906, p. 240.—HAWKINS, 1911-a, p. 258.—GREGORY, 1911, p. 668.—VADÀSZ, 1915, p. 121.—H. L. CLARK, 1917, p. 111.—LAMBERT, 1918-a, p. 38.—FOURTAU, 1920, p. 65.—LAMBERT and THIÉRY, 1921, p. 337.—JACKSON, 1922, p. 57.—H. L. CLARK, 1925, p. 182.—SANCHEZ ROIG, 1926, p. 74.—NISIYAMA, 1935, p. 145.—COOKE, 1942, p. 37.—H. L. CLARK, 1946, p. 358.—MORTENSEN, 1948-a, p. 270, text-figs. 254-255, 260-262, 264-265.—TERMIER and TERMIER, 1953, p. 921.—ROMAN, 1955, p. 689.—KIER, 1957, p. 848.—COOKE, 1959, p. 55.—KIER, 1962, p. 106.
 - Logotype.—Echinus oviformis GMELIN, 1786-92 (91), p. 3187.—Echinolampas oviformis (GMELIN): A. AGASSIZ, 1881-a, p. 123, pl. 37, figs. 10-11, pls. 39, 41, 43-44.—Echinolampas ovata ('LESKE') H. L. CLARK, 1917, p. 114, pl. 153, figs. 1-2.—MORTENSEN, 1948-a, p. 275, pl. 4, figs. 1-8, text-figs. 258, 266a, 267d, 270a.—Echinolampas ovifomis (GMELIN): KIER, 1962, p. 107, pl. 30, figs. 1-4, text-fig. 90. [POMEL, 1883, p. 62].

Medium-sized to large forms, of usually ovoid outline; aboral side gently convex, oral side pulvinate, sunken adorally; side tumid, not sharp. Apical system subcentral, or more or less eccentric to front, monobasal with four genital pores, madreporite large, oculars very small. Petals moderately developed, sometimes lanceolate, rather short, open, or closing distally; poriferous zones usually more or less unequal; interporiferous zones wide; single pores in ambulacral plates beyond petals. Bourrelets well developed; phyllodes single pored, usually moderately developed, with two to three series of pores in each half-ambulacrum; buccal pores present. Periproct transverse, inframarginal, with three large and few small periproctal plates. Peristome subcentral, transverse, or pentagonal; buccal membrane contains a number of small, isolated, thorny plates. A naked granular zone in posterior interambulacrum (5). Interambulacra large, with higher and fewer plates than ambulacra. Radioles simple, lightly thorny or smooth, miliary radioles scarcely widened distally. Pedicellariae of tridentate, ophicephalous, and triphyllous types. A masticatory apparatus. present in the young, at least in one species (*Ech. depressa*) (from MORTENSEN, 1948a, and KIER, 1962).

From the Eocene (Montian) to Recent, of world-wide distribution.

This genus dates back from the Eocene, but there are only several living representatives (no less than eight species); on the contrary, fossil species are very abundant in the Tertiary, according to ROMAN (1955, p. 689) there are more than 285 species enumerated hitherto under the genus. Because of this number of species several attempts have been made to divide the genus into subgenera or sections. LAMBERT and THIERY (1921-24, pp. 379-287) divided the genus *Echinolampas* into eight sections and one subgenus founding on the minor characters of the test. MORTENSEN (1948-a, pp. 270-293) expressed a view that *Macrolampas, Cylindrolampas*, and *Palaeolampas* may be treated as valid subgenera of the genus, and he has suppressed *Miolampas* and *Progonolampas* as synonyms of *Echinolampas*. KIER (1962, p. 107) claimed that all these sections and subgenera are based on characters too variable (KIER, 1957, p. 848) for the distinction of generic group, and made all these sections and subgenera as synonyms of *Echinolampas*. To this procedure the writer quite agrees.

These synonyms are alphabetically shown as follows, with their type-species indicated in parentheses after respective synonyms.

Craterolampas COTTEAU, 1891 (Echinolampas raulini COTTEAU), Cylindrolampas LAMBERT, 1918 (Echinolampas subcylindrica DESOR), Cypholampas (Clypeaster stelliferus LAMARCK), Euechinolampas POMEL, 1887 (Echinolampas florescens POMEL), Heterolampas COTTEAU, 1891 Galerites semiglobus LAMARCK), Hypsoclypus POMEL, 1869 (Conoclypus lucae DESOR in AGASSIZ and DESOR, 1847.=Conoclypus plagiostomus AGASSIZ, 1840 (nomen nudum)), Hypsoheteroclypeus Szörény, 1953 (Hypsoclypus doma Pomel), Isolampas Lambert, 1906 (Echinolampas goujoni POMEL), Libyolampas LAMBERT, 1914 (Echinolampas africana LORIOL), Macrolampas LAM-BERT, 1906 (Clypeaster hemisphericus LAMARCK), Macrolamas POMEL, 1883 (Echinolampas mattsensis QUENSTEDT), Miolampas POMEL, 1883 (Echinolampas depressa GRAY), Oeidolampas LAMBERT, 1918 (Echinolampas ataxensis COTTEAU), Palaeolampas BELL, 1880 (Palaeolampas crassa Bell), Planilampas MORTENSEN, 1948 (Echinolamas sternopetala A. AGASSIZ and H.L. CLARK), Politolampas LAMBERT, 1918 (Clypeaster politus LAMARCK), Progonolampas BITTNER, 1892 (Progonolampas novae-hollandiae BITTNER, 1892.=Echinolampas posterocrassus GREGORY, 1890), Psammelampas LAMBERT, 1913 (Echinolampas scutiformis DESMOULINS), Scutolampas LAMBERT, 1906 (Conoclypus plagiosomus AGASSIZ. = Echinolampas lucae (DESOR); KIER, 1962, pp. 111, 115), and Sphelatus POMEL, 1883 (Caratomus lehoni COTTEAU).

KIER, (1962, pp. 108, 226) has clearly pointed out that the specific name of the type-species should be written *oviformis*, as it was originally used, not *ovata* customarily used since 1917.

The genus Echinolampas differs from Plesiolampas (DUNCAN and SLADEN, 1882, p. 9.—Haplotype.—Plesiolampas elongata DUNCAN and SLADEN, 1882, p. 10, pl. 1, figs. 8-16 (Montian of India)) in having a transverse instead of longitudinal periproct, and from Conolampas (A. AGASSIZ, 1883-a, p. 48.—Haplotype.—Conolypus sigsbei A. AGASSIZ, 1879-a, p. 190, pls. 1-2 (Recent, West Indies)) only in having broader, curved poriferous zones in its petals.

The species of *Echinolampas* seem to form a very homogeneous group and consequently it is very hard to distinguish them from one another even in the Recent forms. The primary features by which the species may be distinguished from one another seem to be the following: (1) the relative length of the various poriferous zones (pore-series), but it must be used with caution, (2) the shape of the test is a similarly useful character, but of variable value, (3) the tuberculation of the test, considering the longitudinal series of the tubercles in the petals, (4) the distance separating the pore-pairs in area from each other, (5) the distance between the pores of a pair, and (6) the shape of peristome and the development of phyllodes may be factors to be considered.

At least three species of fossils of this genus are reported from Japan and the adjacent regions.

Echinolampas alexandri LORIOL, 1876

- Echinolampas alexandri LORIOL, 1876-a, p. 4, pl. 1, figs. 1-3.—MEIJERE, 1904, p. 145.—H. L. CLARK, 1917, p. 114, pl. 144, figs. 14-16, pl. 153, figs. 3-4.—KOEHLER, 1922, p. 144, pl. 4, fig. 10.—H. L. CLARK, 1925, p. 182.—MORTENSEN, 1948-a, p. 282, pl. 2, figs. 20-24, pl. 3, figs. 1-3, pl. 14, figs. 1, 4, 7, text-figs. 268c, 272a-c, 273a.—MORTENSEN, 1948-b, p. 95.
- Echinolampas depressus: Meijere, 1904, p. 144 (non Gray, 1851).—Echinolampas (Miolampas) depressus: Jeannet and Martin, 1937, p. 270, text-figs. 49a-d.—Науазака and Morishita, 1947-a, p. 105, pl. 9, fig. 1.

There are no authentic specimens referable to this species at the writer's disposal. The specimens reported from the Ryukyu Limestone (Pleistocene) of Tokunoshima under the name *Echinolampas* (*Miolampas*) depressus GRAY by HAYASAKA and MORISHITA may be this species or a close relative.

The figure 1a on plate IX of their work (HAYASAKA and MORISHITA, 1947-a) represents the aboral surface of their *depressus* and it fairly well agrees the figure 10 on plate IV of KOEHLER (1922, p. 144), the aboral surface of Ech. alexandri, in the form of petals and a slight impression above the ambitus in the posterior interambulacrum (5). Whereas trifle differences are observed between these two figures that in the Ech. depressus the petals are narrower than those of Ech. alexandri, the apical system of the former is more eccentric to front than that of the latter, and the test of former is narrower than the latter. The features of aboral surface of their Ech. depressus (i.e., Ech. alexandri) also more or less resembles those of the living Ech. koreana H. L. CLARK, 1925 (1925, p. 183, pl. 10, figs. 4-5.-MORTENSEN, 1948-a, p. 281, pl. 4, fig. 9, text-fig. 271), but is easily distinguished from the latter by the form of peristome and feature of floscelle. Although HAYASAKA and MORI-SHITA fail to describe the longitudinal series of tubercles in the petals, because of the nature of phyllodes (which is quite rudimentary as is observed from the figure 1b on plate IX of their work, and observed by the writer on the specimens (MCZ no. 4224), from Ceylon), and the shape of peristome (which is transversely oblong, measured 6 mm wide and 4 mm long, from the same figure), the specimens derived from the Ryukyu Limestone of Tokuno-shima may be most probably assigned to Echinolampas alexandri LORIOL, 1876.

The Recent *Echinolampas depressus* recorded by MEIJERE (1904, p. 144) from off Saleyer, and the fossil of same name recorded by JEANNET and MARTIN (1937, p. 270, text-figs. 49a-d) from the Pliocene of Java are not that West Indian species, but a close relative of or *Ech. alexandri*, and MORTENSEN (1948-a, p. 282) listed JEANNET and MARTIN's species as a synonym of *Ech. alexandri*. *Echinolampas subangulata* HERKLOTS, 1854 (1854, p. 10, pl. 3, fig. 4), from the Upper Miocene or Lower Pliocene of Java, seems to be also a close relative of or *Ech. alexandri*.

Echinolampas alexandri LORIOL, 1876, was orginally described from Mauritius but occurs also in the Malay and Philippines regions, and seems to be rather widely distributed further eastwards of those regions.

This species is characterized by the form of petals, the rather coarse tuberculation (median area of the antero-lateral petals (II and IV) with not more than 8, usually 4-8, longitudinal series of primary tubercles), the broad transverse peristome, and the quite rudimentary floscelle, but its specific validity is doubted by H. L. CLARK (1917, p. 114). It is however, readily distinguished from *Ech. oviformis* (loc. cit.) by the coarser tuberculation and the nature of phyllodes. This species, particularly in the young individuals, has also some resemblances to some species of *Echinolampas* (e. g., *Ech. depressa*, from West Indies, and *Ech. koreana*, from western Japan (Pl. 11, fig. 10)), in respect to petals as considered by MEIJERE and by JEANNET and MARTIN. However, in this species the inner poriferous zones of the posterolateral petals (I and V) are much longer than a half of the outer ones, whereas in *Ech. depressa* the inner poriferous zones of the postero-lateral petals are shorter than a half of the outer, and in *Ech. koreana* the inner poriferous zones of the postero-lateral petals shorter than those of *Ech. alexandri*, and decidedly differs in the form of peristome.

Echinolampas oviformis jacquemonti D'ARCHIAC and HAIME, 1853

Echinolampas jacquemonti D'Archiac and Haime, 1853-54 (53), p. 211, pl. 14, fig. 3.—Duncan and Sladen, 1885-a, p. 332, pl. 53, figs. 1-14.—Lambert and Thiéry, 1921, p. 378.— Echinolampas jackemonti D'Archiac and Haime: Hayasaka, 1948-a, p. 88.

The specimens of this species are not accessible to the writer. HAYASAKA reported the occurrence of this species from the Nakanô formation (Miocene) developed near Chilung City, Formosa, together with *Astriclypeus integer* YOSHIWARA, 1899 (not typical *integer*), *Breynia carinata* D'ARCHIAC and HAIME, 1853, and *Moira obesa* NISI-YAMA, 1935, of the typical Miocene species.

This 'species' judged from the description and figures of HAYASAKA (loc. cit.), resembles *Ech. oviformis*, a Recent species from the Indian Ocean (MCZ no. 2736 which the writer has examined), in the anteriorly eccentric apical system, rather high test, form of petals, and in rather fine tuberculation of test; but the longitudinal series of tubercles on the median area of the antero-laterol petals (II and IV) are fewer in this 'species' than those in *Ech. oviformis*, and the interporiferous zones are more or less broader than in that species, and other trifling differences are observable from *Ech. oviformis*. Here, the writer treats this is only a subspecies of *Echinolampas oviformis*.

The Indian fossil subspecies, *Ech. oviformis jacquemonti*, and the Malayan (Indonesian) fossil species, viz., *Ech. ovata* (=oviformis) (JEANNET and MARTIN, 1937, p. 269—Lower Miocene of Java), *Ech. elevata* BÖHM, 1882 (BÖHM, 1882, p. 364, pl. 1, figs. 3—Upper Miocene of Madoera.—*Ech. depressus* BÖHM, 1882, p. 363, pl. 1, fig. 2, non GRAY, 1851.—*Ech. madurensis* MARTIN, 1919, p. 54.—*Ech. madurensis elevata* BÖHM: GERTH, 1922, p. 505), and the Recent Indo-Malayan species, viz., *Ech. oviformis* and *Ech. alexandri*, seem to be closely related to one another, and further material may

show some names to be identical with one or the other and would become synonyms (or subspecies) of the one or the other species.

Echinolampas yoshiwarai LORIOL, 1902

(Pl. 10, fig. 7)

Echinolampas yoshiwarai LORIOL, 1902-a, p. 31, pl. 3, figs. 3-5.—TOKUNAGA, 1903, p. 17.— Echinolampas (Miolampas) yoshiwarai LORIOL: LAMBERT and THIÉRY, 1921, p. 383.— NISIYAMA, 1935, p. 151, p. 151, pl. 8, figs. 4-5.—NISIYAMA, 1936-a. p. 424 (in Japanese).— MORISHITA, 1950, p. 258 (in Japanse).—MORISHITA, 1960, p. 56.

Echinolampas concavus Науазака, 1948-а, p. 89 (Echinolampas sp., Науазака and Morishita, 1947-а, p. 103, pl. 9, fig. 2).

There are about thirty specimens referable to this species at hand, they are derived from the following localities and geological horizons.

Locality and geological horizon.—IGPS loc. no.—Ch-29.—Sea cliff a short distance south of shrine at Kanaya, Kanaya-mura, Kimitsu-gun, Chiba Prefecture. (tm, Nago, Lat. 35°09′20″N., Long. 139°49′30″E.), Nokogiriyama (Komayama) formation, Lower Pliocene (or Upper Miocene). Topotypes.—IGPS coll. cat. no. 5175.

Locality and geological horizon.—IGPS loc. no.—Ch-28.—In calcareous sandstone of sea cliff under the main road about 500 metres east of Myôgane-zaki, Motona, Hota-machi, Awa-gun, Chiba Prefecture. (tm Nago, Lat. 35°09'N., Long. 139°49'35"E.), Nokogiriyama (Komayama) formation, Lower Pliocene (or Upper Miocene). Hypotype.—IGPS coll. cat. no. 5175-A.

Locality and geological horizon.—IGPS loc. no.—Ch-30.—Creek side of the upper course of the River Motona, Motona, Hota-machi, Awa-gun, Chiba Prefecture. (tm Nago, Lat. 35°09′20″N., Long. 139°06′20″E.), Nokogiriyama (Komayama) formation, Lower Pliocene (or Upper Miocene). Hypotype.—IGPS coll. cat. no. 5175-B.

Locality and geological horizon.—IGPS loc. no.—Kn-13.—A point south of shrine at Wada, Hatsuse-mura, Miura-gun, Kanagawa Prefecture. (tm Yokosuka, Lat. 35°11′27″N., Long. 139°37′35″E.), Sajima formation, Lower Pliocene (or Upper Miocene). Hypotype.—IGPS coll. cat. 73792.

Locality and geological horizon.—IGPS loc. no.—So-8.—In calcareous sandstone at sea shore north of Shirahama shrine at Harada, Shirahama-mura, Kamo-gun, Shizuoka Prefecture. (tm Shimoda, Lat. 34°41′N., Long. 138°58′E.), Shirahama (Susaki, or Shimoshiraiwa) formation, Miocene. Hypotype.—IGPS coll. cat. no. 73793.

Locality and geological horizon.—IGPS loc. no.—Mi-53.—Cliff west of Kumanodô, Takadate-mura. Natori-gun, Miyagi Prefecture. (tm Sendai, Lat. 38°12'N., Long. 140°50'36"E.), Moniwa formation, Miocene. Hypotype.—!GPS ccil. cat. no. 73795.

Locality and geological horizon.—IGPS coll. cat. no.—Ni-11.—A point southeast of Kamagui, Tatekoshi-mura, Iwafune-gun, Niigata Prefecture. (tm Shiono-Machi, Lat. 38°13′24″N., Long. 139°34′42″E.), Tsugawa formation, Miocene. Hypotype.—IGPS coll. cat. no. 73794.

Locality and geological horizon.—IGPS loc. no.—Yt-10.—River cliff of the Sagae at Nakamura, Ôisawa-mura, Nishi-Murayama-gun, Yamagata Prefecture. (tm Ôtoriike, Lat. 38°23'13"N., Long. 140°00'03"E.), Ôisawa formation, Miocene. Hypotype.— IGPS coll. cat. no. 73795-A.

Locality and geological horizon.—IGPS loc. no.—Ao-13.—Tanosawa, near the railway station, Ôdose-mura, Nishi-Tsugaru-gun, Aomori Prefecture. (tm Ajigasawa, Lat. 40°45′07″N., Long. 140°02′03″E.), Tanosawa formation, Miocene. Hypotype.—Saito Ho-on Kai Mus., reg. no. 6163.

Locality and geological horizon.—IGPS loc. no.—Ak-8.—Sea side north of Hatake, Kitaura-machi, Minami-Akita-gun, Akita Prefecture. (tm Toga, Lat. 40°00′03″N., Long. 139°42′38″E.), Nishikurosawa formation, Miocene. Hypotype.—IGPS coll. cat. no. 73795-B.

Locality and geological horizon.—IGPS loc. no.—Sr-15.—The basin of the River Ôanzai, Kaminokuni-mura, Hiyama-gun, Shiribeshi, Hokkaido. (tm Kaminokuni, Lat. 41°44′29″N., Long. 140°06′28″E.), Kunnui formation, Miocene. Hypotype.—IGPS coll. cat. no. 73795-C.

The specimens enumerated in the following lines comprise some of examined ones by the writer and some reported of occurrence by other authors: they are—

Locality and geocogical horizon.—IGPS loc. no.—Fk-12.—Cliff at southern end of the park at Yanagawa, Yanagawa-machi, Date-gun, Fukushima Prefecture. (tm. Kôri, Lat. 37°51′05″N., Long. 140°36′05″E.), Yanagawa formation, Miocene.

Locality and geological horizon.—IGPS loc. no.—Yt-11.—Creek side a short distance east of Shunezaka, Kaneyama-machi, Mogami-gun, Yamagata Prefecture. (tm Uzen-Kaneyama, Lat. 38°57′N., Long. 140°21′10″E.), Nozoki formation, Miocene.

Locality and geolegical horizon.—IGPS loc. no.—Is-8.—A point of Higashi-Ichinose, Asakawa-mura, Kahoku-gun, Ishikawa Prefecture. (tm Kanazawa, Lat. 36°30′07″N., Long. 136°44′04″E.), Nozoki (Minazuki) formation, Miocene.

This species was originally described by LORIOL (1902-a, p. 31) from the basal part of the Nokogiriyoma (Komayama) formation at Kanaya, Chiba Prefecture, central Japan. Since the first report of this species from Chiba Prefecture, numerous other localities of it were noticed by many authors hitherto. In Ishikawa, Niigata, Yamagata, Akita and Aomori Prefectures, and in Hokkaido, this species occurs associated with Miogypsina kotoi HANZAWA, 1931 (HANZAWA, 1931, p. 154 (14), pl. 25, figs. 14-18.—HANZAWA, 1935, p. 23, pl. 3, figs. 1-40) and Operculina complanata japonica HANZAWA, 1935 (HANZAWA, 1935, p. 19, pl. 1, figs. 4-28), both are regarded as the characteristic higher foraminifers of the Helvetian stage in Japan; and further in Chiba, Shizuoka, Fukushima and Miyagi Prefectures, where the Miogypsina-Operculina zone is not exactly known, this species occupies a little higher zone than the zone of Lepidocyclina (Nephrolepidina) japonica HANZAWA, 1931 (HANZAWA, 1931, p. 151 (11), pl. 24, figs. 1-7, 11, pl. 25, figs. 1-5, pl. 26, figs. 1-3, 5). This species, in broadly speaking, together with an echinoid genus Astriclypeus (MORISHITA, 1952, pp. 107-113) occupies in geological horizon as nearly the same position as, or a little higher than, the Miogypsina-Operculina zone in Japan, particularly in central and northeastern Japan.

Comparing the numerous specimens from numerous localities with one another, they show considerable variation in size and tuberculation on the test. In the writer's earlier paper (NISIYAMA, 1935, p. 154), this species has six longitudinal series of primary tubercles in the median area of the paired petals. This may be the maximum case, as the number of longitudinal series of primary tubercles in the area varies from four to six, and the tubercles to 25 sq. mm on the aboral surface in the posterior interambulacrum (5) vary from fourty to sixty in number. The specimens from Yamagata Prefecture (from the Ôisawa and Nozoki formations) and from Hokkaido (from the Kunnui formation) are smaller than those from central Japan; but, in the form of petals and tuberculation on the test they seem to fall within the variation of *Ech. yoshiwarai*.

Comparing *Ech. yoshiwarai* with the Recent species, the writer finds its close affinity with *Ech. koreana* H. L. CLARK, 1925 (loc. cit.) in the relative length of the various poriferous zones, the shape of the test as well as in the tuberculation on the test, a great eccentricity of the apical system, and deeply sunken peristome. This species, however, is distinguished from that species by having the shorter and broader petals and larger peristome. This species may be regarded as an ancestral form of the living *Ech. koreana* in their close affinity. *Ech. yoshiwarai* is also closely related to the living *Ech. alexandri* (loc. cit.) in the relative length of the various poriferous zones, as well as in the tuberculation on the test, but this species has a great eccentricity of the apical system, a deeply sunken peristome, and more or less developed phyllodes, and it seems to be a distinct species from that species.

The species from the Miocene of Formosa, reported by HAYASAKA and MORI-SHITA (1947-a, p. 103, pl. 9, fig. 2) as *Echinolampas* sp., and named by HAYASAKA (1948-a, p. 89) as *Ech. concavus*, as an index fossil of the Miocene, particularly Lower Miocene of northern Formosa, seems to be a close relative of, or may be identical with, *Ech. yoshiwarai*, as once pointed out by MORISHITA (1950, p. 258, in citation).

From their descriptions and figures (HAYASAKA and MORISHITA, 1947-a), the writer found two points which coincide with those of *Ech. concavus* and LORIOL'S *Ech. yoshiwarai*. What is described as "being quite conspicuously concave actinally" in *Ech. concavus*, fairly well coincides with "Peristome très enfoncé" in *Ech. yoshiwarai*, and "apical system is excentric in front" in *Ech. concavus* also coincides with "Appareil apical concidant avex l'apex et très excentrigue en avant" in *Ech. yoshiwarai*. The figure 2a of the aboral surface of *Ech. concavus* on plate IX (HAYASAKA and MORISHITA, 1947-a) much resembles that of a specimen of *Ech. yoshiwarai* from the Miocene formation of Niigata Prefecture (pl. 10, fig. 7—IGPS coll. cat. no. 73794) in the relative length of the various poriferous zones of rather short petals.

To sum up, *Echinolampas yoshiwarai* LORIOL, 1902, or its relatives, flourished in warm seas with an echinoid, *Astriclypeus*, or with foraminifers, *Miogypsina* and *Operculina*, from western Japan (Miyazaki Prefecture as south) or south of Japan (as far south as northern Formosa) to Hokkaido (Shiribeshi as north), in a Miocene age and some seem to have been survived to the Lower Pliocene (or Upper Miocene) in central Japan (Chiba and Kanagawa Prefectures).

Echinolampas bombos NISIYAMA, n. sp. (Pl. 10, figs. 10-11, Pl. 11, figs. 1-6, 9)

Holotype.—IGPS coll. cat. no. 73726.

Locality and geological horizon.-Sea cliff near Akaiwa, at Nishi-ura, Haha-jima

(Hillsborough Island), Bonin Islands. Eocene (Lutetian) (Eorupertia-Alveolina zone).

There are seven specimens referred to this new species at hand. The holotype (pl. 11, figs. 1-3) measures 20.5 mm in longitudinal diameter, 19 mm in transverse one, and 17.5 mm in height.

Test small, very globular in form, broadly oval in marginal contour, almost circular in outline, well rounded in front, very faintly rostrated posteriorly with a slight tendency to elongation in longitudinal axis, and slightly protuberanted posteriorly, more or less faintly notched in posterior part of the lateral interambulacra (1 and 4), corresponding with the line of the greatest breadth. Longitudinal diameter more or less exceeds transverse one, with a proportion of 1.00: 0.92 in the holotype; height very large, about 0.85 of longitudinal diameter. Aboral surface very highly arched, to summit, the highest point situated at just anterior of the apical system, so the profile very inclined forwards, anterior slope much more rapidly inclined than the posterior one.

Aboral portion of ambulacra more or less petaloid, part of poriferous zones having distinctly indicated pairs of pores. Apical system eccentric to front, only 7 mm from the anterior margin, closely punctated with numerous madreporic pores, and with four large genital pores; it almost corresponds with the summit of test; anterior pair of genital pores (genitals 2 and 3) being closer together than the posterior pair (genitals 1 and 4).

Frontal petal (III) has 13 pore-pairs on the left-hand pore-series, 11 on the right, their length almost equal, 3 mm long and 1.5 mm wide, slightly curved inwards at the tip, the shortest of all petals. Antero-lateral petals (II and IV), about 2 mm wide at the broadest point, with posterior poriferous zones about 8 mm long with 26 or more pore-pairs; anterior poriferous zones about half as long as the posterior, about 4 mm long with 16 or more pore-pairs. Postero-lateral petals (I and V) about 2.5 mm wide, the longest of all petals; with outer poriferous zones about 9 mm long, with 29 or more pore-pairs; inner ones have almost the same number of, or less pore-pairs and a little shorter than the outer. Pores of each pair relatively apart while the successive pair rather close together, so that the vertical distance between two pores is smaller than the horizontal distance. Pores relatively large, oval or round in shape, faintly connected by a groove, whole effect a relatively broad poriferous zones.

Periproct somewhat sunken below the ambitus, ovaly round in outline, placed transversely, about 5 mm wide and 3 mm high, obliquely placed at the posterior end of test, but degree of obliquity shows more or less diversity: in holotype, angle formed by plane of periproct and that of oral surface of test about 145°, while in an other specimen it is about 150°

Peristone slightly eccentric to front, not so sunken, transversely pentagonal in outline, about 4.5 mm in transverse diameter and 2.5 mm in longitudinal one. Ambulacral areas become very constracted as they approach the peristome. Phyllodes very poorly developed and not widened, with two series of pores more or less regularly developed. Bourrelets are not prominent.

Tuberculation on test rather fine, about or over fifty primary tubercles to area 25 sq. mm on aboral surface in the posterior interambulacrum (5), and from 2 to 4 longitudinal series of primary tubercles (but very irregularly) in the median area of each petal.

The small size and very globular form of test, relative length of the various poriferous zones of petals, the remarkable form of the petals, and rather fine tuberculation on the test, form a notable combination of characters of this species.

Distinction.-This new species resembles Ech. posterocrassa GREGORY, 1890 (GRE-GORY, 1890, p. 483, pl. 13, figs. 4-6 (Lower Miocene of Victoria-CHAPMAN; Upper Eocene of South Australia-KIER)-KIER, 1962, p. 113, pl. 32, figs. 5-7=Progonolampas novae-hollandiae BITTNER, 1892, p. 357, pl. 3, fig. 1 (Oligocene of Australia)), in outline and the form of petals, but is distinguished from that species in its more globular form and more rounded outline. Ech. bombos is also related to Ech. sphaeroidalis D'ARCHIAC and HAIME, 1853 (D'ARCHIAC and HAIME, 1853-54 (53), p. 210.-DUNCAN and SLADEN, 1885-a, p. 338, pl. 53, figs. 15-19), a Oligocene or Miocene species of India, but differs from that species in the form of petals and in the globular form of test. This species also superficially resembles Pseudopygaulus antecursor (DUNCAN and SLADEN, 1882) (Eolampas antecursor DUNCAN and SLADEN, 1882-a, p. 61, pl. 17, figs. 11-15), from the Ranikot series (Eocene) of Western Sind, India, in the small ovoid form, quite simple phyllodes, shape of paired petals, more or less eccentric peristome, and in the position and form of periproct, but is easily distinguished from that species by having two series of ambulacral pores on each side of the frontal ambulacrum (III). That species has a higher test and the frontal ambulacral pores in a single series on each side-one of the characters of the family Archiaciidae COTTEAU and TRIGER, 1969.

Family PLIOLAMPADIDAE KIER, 1962

Pliolampadidae KIER, 1962, pp. 19, 192. Type-genus.—Pliolampas POMEL, 1888.

Forms large to medium in size, elongate, moderately inflated. Apical system monobasal, three or four genital pores. Periproct usually inframarginal, rarely marginal or supramarginal, usually longitudinal, rarely transverse. Peristome anterior, usually higher than wide, rarely transverse. Petals usually well developed, narrow or broad, open or closed distally; outer pores elongated transversely, strongly conjugate; poriferous zones of same petals of usually same length; single pores in all the ambulacral plates beyond petals. Bourrelets well developed, with few or many pores; buccal pores present. Adoral tubercles only slightly larger than the adapical; no naked granular zone in posterior interambulacrum (5) (from KIER, 1962).

From the Cretaceous (Senonian) to Recent.

In establishing the family Pliolampadidae, KIER (1962, pp. 19, 192) recognized that they are not homogeneous group and that they may not represent a natural or phylogenetic grouping. This author also stated (1962, p. 19) that the family can be divided into two morphological groups by the feature of petals and their poriferous zones, and the two may perhaps represent phylogenetic stocks. The heterogeneous Pliolampadidae should be divided into two subfamilies, as suggested by KIER, founding on the character of petals, or they may be united into the Cassidulidae or Nucleolitidae and the Pliolampadidae would be suppressed as a subfamily of them. But,

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for the present purposes, the writer adopts the Pliolampadidae originally recognized by KIER in his restricted usage. The Pliolampadidae seem to be orignated from the Nucleolitidae, and they are distinguished from the Echinolampadidae in having petals. with poriferous zones of equal length in the same petal and in usually lacking a naked granular zone in the posterior interambulacrum (5) adorally. KIER (1962) classified thirteen genera into the family; among them one group having open petals. with very broad poriferous zones, including such genera as *Pliolampas, Zuffardia, Termieria, Pseudopygaulus,* and *Studeria,* and the other having closed petals with narrow poriferous zones, including the genera *Gitolampas, Eurhodia, Ilarionia, Neocatopygus, Santeelampas, Daradaster,* and *Kephrenia.* The important genera of the family are discriminated from one another as shown by the following key.

Key to the important genera of the family Pliolampadidae.

1. Frontal ambulacrum (III) not petaloid, other ambulacra petaloid with broad petals. Periproct inframarginal, transverse or oval. Phyllodes single pored with slight crowding of pores; bourrelets present but not inflated... Pseudopygaulus Periproct inframarginal. Petals broad, open, equal, with broad poriferous zones. 2. Genital pores 3 or 4. Phyllodes broad, with large single pores.... Pliolampas Periproct supramarginal, transverse or longitudinal. Petals equal, broad, closing 3. distally. Peristome higher than wide. Phyllodes broad, single pored Eurhodia[.] 4. Genital pores 3, no pores in left anterior genital plate. Petals long, straight, open. Periproct marginal, longitudinal, slight groove extending adorally. Peristome slightly higher than wide. Bourrelets strongly developed, inflated; phyllodes slightly widened Studeria Petals broad, closing distally, with broad interporiferous zones. Peristome trans-5. verse, anterior, large, subpentagonal. Phyllodes single pored, with two or sometimes three series of pores in each half-ambulacrum. Periproct marginal, longitudinal, slightly visible from above or below Gitolampas Petals broad, closing distally, narrow poriferous zones. Peristome anterior, pentagonal, usually with rim around opening. Phyllodes single pored, narrow, few occluded pores. Periproct marginal, longitudinal Ilarionia. There are fossil representatives of the genera Gitolampas and Studeria in our collection. Ilarinoia yoshiwarai LORIOL, 1902, from the Bonin Islands, as described in the preceeding, has been removed from the family and referred to the Cassidulidae.

Genus Gitolampas GAUTHIER, 1889

Gitolampas GAUTHIER, 1889-a, p. 98.—LAMBERT and THIÉRY, 1921, p. 368—(subgenus ad *Echinanthus*).—LAMBERT and THIÉRY, 1924, p. 397.—MORTENSEN, 1948—a, p. 250, text-figs. 236a-c.—KIER, 1962, p. 207, text-figs. 171-175.

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- Haplotype.—Pliolampas tunetana GAUTHIER, 1880-a, p. 99, pl. 6, figs. 7-9 (Campanian of Tunisia).—Gitolampas tunetana (GAUTHIER): KIER, 1962, p. 210, text-figs. 175, pl. 42, figs. 1-6 (holotype and others-Eocene).
- Echinanthus [BREYNIUS] D'ORBIGNY, 1854, pp. 18, 21 (BREYNIUS, 1732, p. 59, pre-Linnean).—
 D'ORBIGNY, 1853-55 (54), p. 291.—DESOR, 1855-58 (57), p. 292.—LORIOL, 1875, p. 54.—
 ZITTEL, 1879, p. 530.—A. AGASSIZ, 1881-a, p. 122.—POMEL, 1883, p. 61.—COTTEAU, 1885-89 (88), p. 553.—DUNCAN, 1889-a, p. 183.—LAMBERT and DONCIEUX, 1905, p. 141.—LAMBERT, 1908-b, p. 364.— LAMBERT and THIÉRY, 1921, p. 366.—MORTENSEN, 1948-a, p. 240, text-figs. 226a-c (complete synonymy).—TERMIER and TERMIER, 1953, p. 919.
 - Logotype.—Cassidulus scutella LAMARCK, 1816, p. 35.—Echinanthus scutella (LAMARCK): COTTEAU, 1885-89 (88), p. 580, pl. 169, fig. 4, pls. 170-172 (Priabonian of Verona, Italy). [LAMBERT and THIÉRY, 1921, p. 366].
- Non Echinanthus Leske, 1778, p. 121.—KIER, 1962, p 226.
- Logotype.—Echinanthus ovatus LESKE, 1778, p. 127, pl. 20, figs. C, D. (The specimen now lost; the figure is so poor that it is not possible to know most of the generic characters of the species-KIER). [KIER, 1962, p. 226].
- Nec Echinanthus LESKE, 1778, pp. xix, 185 (including Clypeaster humils, Cl. altus, not in BREYNIUS).—GRAY, 1825, p. 427.—GRAY, 1855-a, p. 4.—A. AGASSIZ, 1872-74, pp. 106, 310.— Echinantus LESKE: POMEL, 1883, p. 61.
 - Logotype.—Echinus rosaceus, LINNAEUS, 1758, p. 665 (Ech. humilis LESKE, 1778, p. 185, p.p.) [GRAY, 1851, p. 56].
- Echanthus COOKE, 1942, p. 37.—COOKE, 1959, p. 62 (emended name for Echinanthus BREYNIUS). Orthotype.—Echinanthus georgiensis TWITCHELL in CLARK and TWITCHELL, 1915, p. 139, pl. 65, figs. 1a-d.—Echanthus georgiensis (TWITCHELL): COOKE, 1959, p. 62, pl. 26, figs. 13-16 (holotype).—Gitolampas georgiensis (TWITCHELL) KIER, 1962, p. 211, text-fig. 172, pl. 40, figs. 3-5 (holotype). (For other synonyms see KIER, 1962, pp. 207, 211, 211).

Forms of medium size, of oval, elongate or more rounded outline, often with pointed posterior extremity, rounded margin. Aboral side low-arched, oral side flattened. Apical system subcentral or anterior, monobasal, with four genital pores. Petals well developed, broad, usually closing distally, with broad interporiferous zones, poriferous zones of same petal of same length; pores conjugate, outer pores elongate but not slit-like; ambulacral plates beyond petals single pored. Periproct small, marginal or supramarginal, longitudinal, in a small but distinct groove. Peristome subcentral or anterior, transverse, subpentagonal. Bourrelets well developed, vertical walled; phyllodes broad, single pored, with two or sometimes three series of pores in each half-ambulacrum; buccal pores present. Tubercles perforate crenulate (from MORTENSEN, 1948-a, and KIER, 1962).

From the Upper Cretaceous (Senonian) to Miocene of Europe, Madagascar, North Africa, India, Japan, and the United States.

There has been considerable controversy, among paleontologists and neontologists, over the generic name *Echinanthus*. The paleontologists, following the old definition of *Echinanthus* by BREYNIUS (pre-Linnean) and later ones by D'ORBIGNY and DESOR, have associated the term with the Cassiduloid; the neontologists have either associated the term with all the *Clypeaster*, or have used it, following A. AGASSIZ (1872-74, pp. 106, 310), for the tumid *Clypeaster* particularly. MORTENSEN (1948-a, pp. 240-243) credited, standing on paleontologist's side, *Echinanthus* to BREYNIUS, and used it for a cassiduloid, with *Ech. scutella* as the type-species. KIER (1962, p. 226), however, claimed that this generic term must be credited to LESKE, the first post-Linnean author, and he designated LESKE's fourth species, *Ech. ovatus*, as the type-species. KIER also stated that, although *Ech. ovatus* is said to be identical with *Echinolampas* oviformis, LESKE's figure of it is so poor that it is not possible to known most of the generic characters of the species. Because of this procedure the generic term *Gitolampas* takes the place of *Echinanthus* used by many paleontologists, and the generic term *Echinanthus* must be referred to incertae sedis.

Gitolampas is very similar to *Ilarionia*, but differs in having more developed phyllodes and bourrelets. In *Gitolampas* the phyllodes are widened with a regular inner series of pores in each half-ambulacrum, whereas in *Ilarionia* they are narrow with very few occluded pores, and in the latter there is usually a rim surrounding the peristone.

This genus flourished in the Eocene of Europe, and the occurrence of a new species in northern Japan is noteworthy.

Gitolampas sendaica NISIYAMA, n. sp.

(Pl. 30, figs. 3, 5-7)

Holotype.—IGPS coll. cat. no. 35003.

Locality and geological horizon.—IGPS loc. no.—Mi-52.—A small valley, north of Moniwa electric power-house, Oide-mura, Natori-gun, Miyagi Prefecture. (tm Sendai, Lat. 38°13'N., Long. 140°47'26"E.), Moniwa formation, Miocene.

There are seven specimens referable to this new species at hand, ranging from 35 mm to 40 mm in longitudinal diameter, of which the best preserved one is selected as the holotype.

Test of medium size; marginal contour oval, well rounded in anterior margin, broadest posteriorly, subrostrate and truncate at the posterior extremity; margins rounded and tumid; longitudinal profile shows a gentle posterior slope and a more inclined and rounded anterior one; transverse profile overhangs periproctal region and an area below the periproct almost vertical; adoral surface slightly concave towards; the peristome.

Dimensions of the holotype; 39 mm in longitudinal diameter, 35 mm in transverse, and 25 mm in height.

Apical system eccentric to front, situated at 17 mm from the anterior margin, 3 mm long and 3 mm wide; monobasal, four genital pores large, ocular pores very small, madreporite large; highest point of test just posterior of the apical system.

Petaloid area rather small, about 0.7 of the aboral surface; petals rather short and rather broad. Frontal petal (III) 13 mm long and 4 mm wide, slightly longer and narrower than paired petals; poriferous zones rather narrow, about 1.5 mm wide at the broadest point, having about 35 pore-pairs on both sides; pores subequal, conjugate, the inner pores more or less round, groove being oblique and distinct; interporiferous zone very narrow, about 1 mm wide at the broadest point. Antero-lateral petals (II and IV), 12 mm long and 4.5 mm wide, angle between median line of the frontal petal (III) and those of the antero-lateral petals (II and IV) about 55°; poriferous zones somewhat unequal, outer poriferous zones more or less broader and longer than the inner, having about 28 pore-pairs in outer poriferous zone; poriferous zones slightly sunken; extremities open; pores somewhat unequal, the inner pores round and the outer elongate-oval, conjugated by a very distinct groove, ridge between two pore-pairs with a row of granules; interporiferous zone narrow, slightly raised, about 1 mm wide at the broadest point, and with 2 or 3 longitudinal series of granules. Postero-lateral petals (I and V) also 12 mm long and 4.5 mm wide, angle between median lines of the petals (II and IV) and those of the postero-lateral petals (I and V) about 90°, and angle between median line of the petal (I) and that of the petal (V) about 60°; poriferous zones more or less unequal, inner poriferous zones somewhat broader, longer and more curved than the outer; having about 30 pore-pairs in the inner poriferous zones; poriferous zones slightly sunken; extremities open; pores unequal, the inner pores round and the outer elongate-oval, conjugated by a distinct groove, ridge between two pore-pairs with a row of granules; interporiferous zones narrow, slightly raised, about 1 mm wide at the broadest point, and with 2 or 3 longitudinal series of small granules.



Fig. 26 [1]. a. Floscelle of Gitolampas sendaica NISI-YAMA, n. sp., ×1.8 (more or less diagramatically figured).
b. Phyllode of Gitolampas scutella (LAMARCK, 1816),
×3 (for comparison) (after HAWKINS, 1918).

Peristome very eccentric to front, situated at about 14 mm from the anterior margin, elongate transversely, pentagonal and rather small, 4 mm wide and 3 mm long, amount of angularity large; actual margin very deep, plunging upwards nearly vertically. Phyllodes more or less well developed contrary to general feature of the genus, widening and depressing largely and then contracting with a rather sharp curve as they approach margin of the peristome; plates rather short and broad, and pores consequently closely placed; pores rather large, sunken in little cavities, punctured between sutures of two neighbouring plates; 4 mm wide and about 6 mm long, frontal ambulacrum (III) a little smaller; a double series of supplementary pores, 6 to 9 in number, present within the phyllode. (Fig. 26 [1] a). Interradial peristomial plates form more or less well developed large bourrelets, which are more or less bombous, and with a slight crest rim, whole peristomial ring granulated with minute tuberculation.

Periproct moderately large, oval, elongate longitudinally, 4 m long and 3 mm wide, situated at the extreme top of posterior truncation, upper margin overhang and lateral margins slightly carinate, whilst lower margin has a small but distinct groove, which dies out as it passes over the margin onto the adoral surface. Median interradial portion of the posterior interambulacrum (5) subcarinate in neighbourhood of orifice.

Fractured specimens show a rather thick test, over 1.5 mm thick on the aboral side, but on the adoral side slightly thinner, and no arrangement of internal pillars or doubling of walls.

Distinction.—This new species resembles *Gitolampas wrighti* (COTTEAU, 1856) (*Rhynchopygus wrighti* COTTEAU in LEYMERIE and COTTEAU, 1856, p. 333.— Echinanthus wrighti (COTTEAU) COTTEAU, 1885-89 (89), p. 618, pl. 194, figs. 1-10), from the Eocene of France, but differs from that species by having narrower test, shorter petals, well developed floscelle, and by the truncation of the posterior end. *Git.* sendaica is also related to *Git. scutella* (LAMARCK, 1816) (loc. cit.), from the Priabonian of Italy and Germany, but differs, as the writer has found in comparing this species with *Git. scutella* from the Eocene of Germany side by side, in having the smaller and higher test, position of the periproct, and in the larger phyllodes. This new species also resembles *Git. intermedia* (DUNCAN and SLADEN, 1884) (Echinanthus intermedius DUNCAN and SLADEN, 1884, p. 144, pl. 32, figs. 4-8), from the Nummulitic strata (Eocene) of Western Sind, India, but differs from that species by having the higher test, broader poriferous zones in petals, well developed floscelle, and by the shorter periproct.

Genus Studeria DUNCAN, 1889

Studeria DUNCAN, 1889-a, p. 185.—LAMBERT and THIÉRY, 1921, p. 372.— H. L. CLARK, 1946, p. 357.—MORTENSEN, 1948-a, p. 233, text-figs. 217a-b, 218a-c (complete synonymy).— KIER, 1962, p. 216.

Haplotype.—Catopygus elegans LAUBE, 1869, p. 190, pl. 8, figs. 8-8c (Miocene of Australia). Tristomanthus BITTNER, 1892, p. 355.—KIER, 1962, pp. 216, 218 (as a synonym of Studeria).

- Logotype.—Nucleolites subcarinatus GOLDFUSS, 1826-33 (29), p. 142, pl. 143, fig. 10.—Studeria subcarinata (GOLDFUSS): KIER, 1962, p. 218, pl. 41, figs. 6-9, text-fig. 178 (Oligocene of Westphalia, Germany). [LAMBERT, 1906, p. 41].
- Phaleropygus Loriol, 1902, p. 15-LAMBERT and THIÉRY, 1921, p. 372 (as a synonym of Studeria).-MORTENSEN, 1948-a, p. 372.-KIER, 1962, p. 217.

Haplotype.—Phaleropygus oppenheimi LORIOL, 1902, p. 15.=Echinanthus meslei GAUTHIER: COTTEAU, 1882-83 (83), p. 88, pl. 10, figs. 19-20 (Miocene fossil).

- Hypselolampas H.L. CLARK, 1917, p. 104.—H.L. CLARK, 1925, p. 181.— KIER, 1962, p. 217 (as a synonym of Studeria).
 - Orthotype.—Catopygus recens A. AGASSIZ, 1879, p. 204.—A. AGASSIZ, 1881-a, p. 123, pl. 20, figs. 17-21 (Recent, off Kei Islands).

Forms of small to medium size, elongate, without depression in anterior margin, pointed or slightly truncated posteriorly. Aboral side moderately arched, oral side flattened and depressed around peristome adorally. Apical system anterior, monobasal, three genital pores, no pores in left anterior genital plate (3). Petals well developed, long, straight, extending almost or nearly to margin, open, adjacent porepairs usually widely open; ambulacral plates beyond petals single pored. Periproct marginal, longitudinal, with slight groove extending adorally. Peristome anterior, slightly higher than wide. Bourrelets very strongly developed, inflated; phyllodes slightly widened, single pored, with few pores; buccal pores present. Aboral tubercles slightly larger than adoral one; no naked granular zone in the posterior interambulacrum (5) (after KIER, 1962).

From the Oligocene to Recent, of Europe, Egypt and Australia, living in the Pacific Ocean.

As for the type-species of the genus, although MORTENSEN (1948-a, p. 234), along with earlier authors, cited *Catopygus recens* A. AGASSIZ, 1879, as the type, *Catopygus elegans* LAUBE, 1869, as in citation of LAMBERT and THIÉRY (1921, p. 372), must be made the type-species of *Studeria*, as clearly pointed out by H. L. CLARK (1946, p. 357) and KIER (1962, p. 216).

The generic statute of Studeria is uncertain. Studeria is similar to Pliolampas in having open petals, similar development of phyllodes, and a higher than wide peristome; in the number of genital pores, moreover, it is common with some species of *Pliolampas*, which has three or four genital pores. Studeria differs from *Plio*lampas in having a marginal periproct, instead of inframarginal periproct of Pliolampas, and more developed bourrelets. These differences, however, according to KIER (1962, p. 217), perhaps are not of sufficient importance to warrant maintence of .Studeria from Pliolampas. The genus Oligopodia (DUNCAN, 1889-a, p. 176.-Orthotype. -Nucleolites epigonus MARTENS, 1865, p. 143.-Oligopodia epigonus (MARTENS): MOR-TENSEN, 1848-a, p. 228, pl. 1, figs. 5-13, pl. 12, figs. 13-14, 17, 19, 24, text-figs. 211-214, 215a-b, 216) is one of closely related genera of Studeria. Oligopodia is characterized by having four genital pores, a supramarginal periproct in a furrow at posterior end of test, about equal-sized pores of petals, a well developed floscelle, and a higher than wide periproct. The difference from Studeria is found only in the number of genital pores and the position of periproct. The difference of position of periproct, however, is very small as is shown by the type-species of both genera, as in Olig. epigona the periproct is supramarginal and in longitudinal groove, while in Stud. elegans terminal, well on truncate and somewhat overhanging near the end of the test; moreover, in Stud. subcarinata (the type-species of Tristomanthus) it is posterior terminal in a groove. The number of the genital pores in Olig. epigona four, whereas in the species of Studeria, viz., elegans, subcarinata, and recens, three. In the species of Pliolampas, as clearly shown by KIER (1912, pp. 193-194), the number of the genital pores is three or four, and he claimed that the difference of number in the Pliolampas should not be used for a criterion of generic, or even of specific, distinction. If the difference of number of the genital pores between Oligopodia and Studeria is similar to the case of *Pliolampas*, the two genera should be united into one; but, if the difference between the living species of the two genera, viz., Olig. epigona and Stud. recens, would be constant and definite, it is necessary to reconsider the relation. By the writer's observation on the specimens of Olig. epigona (MCZ nos. 2697, 2757) and Stud. subcarinata (USNM 6338998) it is found that there is a difference of the tuberculation on the poriferous zones between them. In Olig. epigona a small secondary tubercle is placed near perradial suture and three or four miliaries are irregularly arranged on each plate, whereas in Stud. subcarinata three or four miliaries only make a row near the adapical suture and above the pore-pair. Perhaps this difference is not of importance to warrant distinction of the two genera. The writer prefers, as in the circumferences as mentioned above, that Studeria is a distinct genus which differs from *Pliolampas* in having a marginal periproct and more developed bourrelets, on the one hand, and from *Oligopodia* in having three genital pores.

Studeria okinawa (COOKE, 1954)

Oligopodia okinawa Сооке, 1954, p. 49, pl. 12, figs. 7-10.—Studeria okinawa (Сооке) Nisiyama, 1965, p. 78.

This species is described by COOKE (1954, p. 49) on the specimen derived from the Naha Limestone (Pliocene) of the Okinawa Island, and now deposited in the United States National Museum (USNM 561567).

Although COOKE assigned the species to *Oligopodia*, because of having the three genital pores (lacking in left anterior genital (3)) and a terminal periproct, at the posterior truncation in a groove, it may be referred to *Studeria*. The tuberculation on the poriferous zones, by the writer's observation on the holotype, consists of only miliary tubercles in a row and resembles that of *Stud. subcarinata*. The characteristic tubercles of this species described by COOKE as being apparently imperforate and not crenulate, may be owing to either the bad condition of preservation or to the senile stage that atrophy the normal condition.

This is a large-sized form for the genus and resembles *Stud. javana* (JEANNET, 1937) (*Pliolampas* (*Tristomanthus*) *javana* JEANNET in JEANNET and MARTIN, 1937, p. 267, text-figs. 46a-d), from the Pliocene of Java. This species, however, differs from that species in having a central peristome and straighter and narrower poriferous zones. This species also distinguished from *Stud. minuta* (HERKLOTS, 1854) (*Nucleolites minutus* HERKLOTS, 1854, p. 10, pl. 5, figs. 8-8b.—*Pliolampas* (*Tristomanthus*) *minutus* (HERKLOTS) JEANNET and MARTIN, 1937, p. 207), from the Upper Miocene of Java, by having a larger test, a central peristome and narrower poriferous zones.

Order CLYPEASTEROIDA A. AGASSIZ, 1873

Clypeasteroideae A. Agassiz, 1872-74(73), p. 309.—CLAUS, 1880, p. 358.—Clypeastroida DUNCAN,.
1889-a, pp. 25, 143.—MEISSNER, 1904, p. 1380.—HAWKINS, 1912-a, p. 492.—LAMBERT and THIÉRY, 1914, p. 287.—HAWKINS, 1920, p. 420.—MORTENSEN, 1948-c, p. 1.—TERMIER and TERMIER, 1953, p. 923.—NISIYAMA, 1954, p. 327 (in Japanese).—Clypeasteroida L. Agassiz : DURHAM, 1955, p. 113.—Clypeasteroida A. Agassiz : DURHAM and MELVILLE, 1957, p. 259.
—PHILIP, 1965, pp. 52, 58.

Clypeastrina JACKSON, 1912, p. 204 (suborder).—H.L. CLARK, 1914, p. 9.—H.L. CLARK, 1938, p. 148.—GRANT and HERTLEIN, 1938, p. 41.—H.L. CLARK, 1946, p. 334.

Type-family.—*Clypeasteridae* Agassiz, 1836.

Forms of very varying size, from very small (the Fibulariidae) to very large (the Astriclypeidae). Test usually flattened, or depressed, usually with well developed, often very stong internal skeletal supports, rarely obsolete. Ambulacra wider than the interambulacra on adoral surface, usually distinctly petaloid adapically; petals. usually without or with demi-plates; no phyllodes adorally. Small secondary tube-feet (pores), often in very great number, mainly along the limits between the ambulacral plates, or even extending over the interambulacral plates. Interambulacra continuous or discontinuous on adoral surface, terminated adapically by a single (or

a series of single plates) or a pair of plates. Apical system usually subcentral or sometimes distinctly posterior, rarely anterior, monobasal; genital pores four or five, exceptionally six. Periproct varying in position, from supramarginal to marginal, inframarginal or on oral surface, never contiguous with the apical sysiem. Peristome usually central, small, without gill-slits or external gills; but ambulacral gills only. Base of corona usually not resorbed. Masticatory apparatus well developed, but without compasses. Lantern procumbent, highly modified, teeth keeled, foramen magnum very shallow, small epiphyses and braces. Pyramids usually with ridges on lateral flanges. Perignathic girdle consisting of auricles only, separate on ambulacral, or fused on interambulacral plates. Radioles simple, small, usually very numerous, not arranged in vertical series, usually differentiated into primaries and miliaries. All four types of pedicellariae presented, but globiferous pedicellariae found only in the genus (or subgenus) Fibulariella. On the whole the pedicellariae are rather inconspicuous, in the more progressed forms (most the Scutellidae and Astriclypeidae) bivalved. Spheridia single, in the ambulacral midline, close to the peristome and usually wholly concealed in the calcareous skeleton. The living tissue turns green on being damaged or dying (mainly after MORTENSEN, 1948-c).

From the Upper Cretaceous (Senonian) to Recent.

It is formerly postulated that there is ground for the belief that the Clypeasteroida arose from the Holectypoida (particularly the Discoidiidae) of the primitive exocycloid group. This is assumed in the apical system, the structure of the ambulacra, the presence of internal radiating walls, the structure of lantern that lack of a compass, but the teeth are characteristic as they lack the lateral flanges present on all other keeled teeth, and in the perignathic girdle. The supposed evidence in support of this belief has been set forth briefly by JACKSON (1912, p. 217) and detailed by HAW-KINS (1920, pp. 461-466), and further by MORTENSEN (1948-c, pp. 164, 349, 356) have come to the same conclusion (but partly) through their researches on various forms. of the order. On the contrary, DURHAM (1955, pp. 114-177) opposed to the derivation of the Clypeasteroida as a whole from the Discoidiidae of the Holectypoida, as proposed by HAWKINS and others, and he also stated that a possible ancestral form of the Clypeasteroida has not been recognized. Whereas DURHAM and MELVILLE (1957, text-fig. 8 on page 265) postulated the derivation of the Clypeasteroida from the Holectypidae of the Holectypoida by showing a suggested phylogeny of their superorder Gnathostomata. Another attention of the origin of the Clypeasteroida should be directed to the crystallographic orientation of the calcite of echinoid test, as made by RAUP (1962, 1966). RAUP found that the c-axis is tangentially disposed in the Discoidiidae of the Holectypoida, and perpendicularly in all the Clypeasteroida. This crystallographic data do not support the direct derivation of the Clypeasteroida from the Discoidiidae, while in the other families of the Holectypoida some have perpendicular c-axis (i.e., the Holectypidae) and the others show P-T orientation (i.e., the Conulidae), so the crystallographic data by themselves do not absolutely preclude the derivation of the Clypeasteroida from the Holectypoida, as a whole.

The Clypeasteroida seem to be one of the most specialized sea-urchins, as exhibited by their complex structures of test, young geological occurrence, comprising numerous and various forms flourishing vigorously in the present days, particulary in the Pacific Ocean. They also seem to correspond with the Echinoida of the other specialized sea-urchins in the development of the Echinoidea as a whole.

MORTENSEN (1948-c) divided the order into two suborder, viz., Clypeasterina with separate radial suricles and demi-plates within the petals, and Laganina with fused interradial auricles and lacking demi-plates within the petals. DURHAM (1955-c, p. p. 117) and DURHAM and MELVILLE (1957, p. 259) divided the order into four, twice as numerous as the suborders of MORTENSEN, by considering of the characters of the head of the interambulacra, the auricles, the basicoronal plates, the madreporite, the miliary radioles, the spicules in the sucking disc of the tube-feet, the discontinuity of the interambulacra, and the arrangement of the plates within the petals, together with the known geologic record, viz., Clypeasterina, Laganina, Scutellina, and Rotulina. PHILIP (1965, pp. 52-53) adovated MORTENSEN's grouping of the Clypeasteroida. PHILIP stated that the two groupings of MORTENSEN still appear to provide the fundamental morphological and phylogenetic division of the order, although some representatives of the Laganina of MORTENSEN are now known to possess ambulacral demiplates, i.e., the Neolaganidae. The writer herein prefers DURHAM's groupings of the order, except the Rotulina that small group and almost unfamiliar to the writer, as in the case in the order Echinoida divided into two, the Temnopleuroina and Echinoina, and recognize the three, viz., the Clypeasteroina, Laganoina, and Scutelloina. The three suborders are discriminated from one another as shown by the following key.

Key to the suborders of the Clypeasteroida

1.	Auricles fused, interradial in position
	Auricles separate, radial in position. Petals with complex structure and reduced
	(or demi-) plates. Interambulacra discontinuous on adoral surface, terminated
	adapically by a pair of plates Clypeasteroina
2.	Petals with or without reduced (or demi-) plates. Interambulacra continuous on
	adoral surface, terminated adapically by a single or a series of single plates
	Laganoina
	No reduced (or demi-) plates within petals. Interambulacra continous or discon-
	tinuous on adoral surface, terminated adapically by a pair of plates. Oral
	ambulacral furrows usually present Scutelloina.
	There are fossil representatives of these suborders, the Clypeasteroina, Laganoina,
and	Scutelloina, in our collection.

Suborder CLYPEASTEROINA A. AGASSIZ, 1873

Clypeastrina GREGORY, 1900-b, p. 316 (pro parte).—MORTENSEN, 1948-c, pp. 3, 5.—TERMIER and TERMIER, 1953, p. 923.—Clypeasterina L. AGASSIZ: DURHAM, 1955, p. 117.—Clypeasterina A. AGASSIZ: DURHAM and MELVILLE, 1957, p. 259.—PHILIP, 1965, p. 58.

Test usually flattened or apically elevated, with usually complex internal supports. Plates of petals "compound" with alternating primary component and demiplate components, simple outside the petals. Interambulacra discontinuous on adoral surface, terminated adapically by a pair of plates. Apical system pentagonal or stellate, apices interambulacral; genital pores five or four; madreporite large, with numerous hydropores. Auricles separate, radial in position. Periproct inframarginal to supramarginal. Aboral miliary radioles simply serrate, not terminating in a crown or in a sac of glandular skin (mainly after DURHAM, 1955).

From the Eocene to Recent.

In this suborder, the auricles of each ambulacrum are not only distinct but also well separated from each other. In the other suborders, i.e., the Laganoina and the Scutelloina, the right hand auricle of one ambulacrum and the left hand auricle of the adjoining ambulacrum have become more or less completely transposed onto the separating interambulacral plate and are more or less completely fused into a single upright piece. This migration of the auricles is the most notable feature, as already pointed by HAWKINS (1918-a), of the Clypeasteroid morphology.

The modification of ambulacral structure within the petals found among the Clypeasteroida is capable of reference to roughly three types. The first type, which may be termed 'clypeasteroid', shows the plates of petals are of great height, and are arranged on the plane of alternating a primary and demi-plate components (text-figs. 27 [2] a-b). The second type, which may be termed 'Neolaganid' or 'triad', as



Fig. 27 [2]. Ambulacral structure of *Clypeaster japonicus* DÖDERLEIN, 1885.
a. A part of petal IIIa, plates 2nd to 5th from the

apical system, ×8.b. A part of petal IVa, plates 13th to 15th from the

apical system, $\times 4$.

clearly noticed by DURHAM (1955, pp. 117, 144, text-figs. 27a, c, on page 123), consists: of a primary and two demi-, or occluded, plate components, but on some places within

the petals 'clypeasteroid' type may occur. The third type, which may be termed 'scutellid' (or laganid), has petals composed of very great number of excessively slender primary plates (components) only (text-fig. 28 [3]). The primitive form of the third type, which may be termed 'fibulariid', shows short and not very marked petals containing large, similar pores set in distant series owing to the considerable height of the plates (or components). The 'fibu-



Fig. 28 [3]. Ambulacral structure of *Peronella japonica* MORTEN-SEN, 1948.

Distal part of the frontal ambulacrum. (III) on aboral side, $\times ca$ 2.

lariid' and 'scutellid' (or laganid) types are alike in the simplicity of their plating, and the latter is clearly the morphogenetic outcome of intensification of the tendencies present in the former, as is shown by the ontogenetical development of the latter type.

The arrangement of interambulacral plates in both the adapical and adoral ends is the another character of the order Clypeasteroida. In the Clypeasteroida, where the interambulacrum adapically adjoins the genital plates, there are usually two small plates to be seen side by side, terminating the two columns of interambulacral plates as usual. Whereas in the Laganidae and others, one of this pair greatly outstrips the other in growth and comes ultimately to occupy the entire adapical end of the interambulacrum, terminating a single plate or a single column of interambulacral plates unusual. Among the Clypeasteroida the adoral end of the interambulacrum may undergo a curious change during growth and time. In the primitive forms (e.g., Echinocyamus and Fibularia) the basicoronal plates, the oldest plates of the test outside the apical system, are relatively undifferentiated, that is the primordial interambulacral plate remains in the basicoronal row, being followed by a pair of large second (or first post-basicoronal) interambulacral plates of almost equal size, making what is called a "continuous interambulacrum" (NISIYAMA, 1940, p. 811). Whereas in the specialized and most of the Recent forms either the ambulacral (textfig. 29 [4]) or the interambulacral plates may become greatly enlarged at the expense



Fig. 29 [4]. Structure of oral surface of Clypeaster japonicus Döderlein, 1885, $\times 0.5$.

of the other, and to have the post-basicoronal interambulacral columns separated from the basicoronal row, making what is called a "discontinuous interambulacrum" (NISIYAMA, 1940, p. 811).

The difference in the termination of the aboral miliary radioles in the two types is another noticeable character of the Clypeasteroida. The difference is clearly shown by MORTENSEN (1948-c, p. 3). In the first type of the Clypeasteridae the aboral miliary radioles simply serrate and not terminate in a crown or in a sac glandular skin (MORTENSEN, 1948-c, text-fig. 2a on page 3), while in the second type of the Laganidae and the others the aboral miliary radioles terminate in a crown or in a glandular bag (MORTENSEN, 1948-c, text-figs. 2b-c on page 3). But unfortunately this cannot be readily applicable for fossil

forms. The ambulacral structure of petals, the structure of auricles, the character of adapical and adoral termination of interambulacral plates and others of the Clypeasteroida seem to have a triple (or more) morphogenetic origin.

The suborder Clypeasteroina make a well defined group and distinct from other suborders. They comprise two families, the Clypeasteridae AGASSIZ, 1836, and the Arachnoididae DUNCAN, 1889, are discriminated from each other as shown by the following key.

Key to the families of the suborder Clypeasteroina

 Genital pores 5. Oral ambulacral furrows simple, poorly defined; secondary tubefeet (ambulacral pores) spread irregularly in great number over the ambulacral plates; no "combed" areas. Tubercles uniform, not aranged in regular series, both on the oral and the aboral side. Buccal membrane naked Clypeasteridae
 Genital pores 4. Oral ambulacral furrows simple, well defined, continuing to the apical system; secondary tube-feet outside in dense oblique series (or "combed" areas), restricted to ambulacral areas. Tubercles partly arranged in regular oblique series. Buccal membrane plated Arachnoididae. The fossil representatives of the family Clypeasteridae in our collection.

Family CLYPEASTERIDAE AGASSIZ, 1836

Clypeastres AGASSIZ, 1836, pp. 170, 182, 185 (pro parte).—Clypeasteridae AGASSIZ: D'ORBIGNY, 1852, p. 121 (pro parte).—Clypeastridae AGASSIZ: DUNCAN, 1889-a, p. 148.—COTTEAU, 1889-94(91), p. 224.—GREGORY, 1900-b, p. 318.—H. L. CLARK, 1914, p. 19.—LAMBERT and THIÉRY, 1914, p. 297.—KOEHLER, 1922, p. 10.—H. L. CLARK, 1925, p. 148.—GRANT and HERTLEIN, 1938, p. 46.—H. L. CLARK, 1946, p. 335.—MORTENSEN, 1948-c, p. 6.—TERMIER and TERMIER, 1953, p. 923.—Clypeasteridae AGASSIZ: DURHAM, 1955, p. 118.
Euclypeastridae HAECKEL: A. AGASSIZ, 1872-74, pp. 375, 620 (pro parte).
Echinanthidae A. AGASSIZ, 1872-74, pp. 376, 620.—TENISON-WOODS, 1878, p. 168 (partim). Type-genus.—Clypeaster LAMARCK, 1801.

Test medium to very large, low or more or less high vaulted; edge usually tumid or more or less sharp; oral side flat or concave orally. Ambulacra adapically petaloid, on the oral side reduced to poorly defined simple furrows, but small secondary tube-feet (ambulacral pores) spread irregularly in great number over the ambulacral plates adjoining the furrows. No phyllodes. Interambulacra discontinuous on the adoral surface; the ambulacral plates adorally joining in the midline of the interambulacra, so as to separate the primordial interambulacral plate from the following post-basicoronal paired plates (text-fig. 29 [4]). Exceptionally the interambulacra may be swollen adorally so as to form bourrelets (infundibulum). Test with usually strongly developed inner supports, with needles, pillars, and other processes extending from floor to roof, especially near the edge of the test; sometimes these are fused to form concentric partitions, and the ambulacra may also be protected by an inner wall. Apical system central, 5 genital pores. Periproct usually inframarginal, or marginal. Peristome central, usually sunken, there being a more or less conspicuous oral infundibulum. Peristomial membrane naked, but containing small irregularly star-shaped spicules. Masticatory apparatus strongly developed; auricles double, on each ambulacrum. Tuberculation dense, uniform, the primary tubercles perforate, more or less distinctly crenulate. Primary radioles short, more or less setiform, sometimes widened and flattened distally; miliary radioles short, fine, not crown-shaped, usually serrate throughout. Pedicellariae of the tridentate, triphyllous, and ophicephalous types (mainly after MORTENSEN, 1948-c).

From the Middle Eocene to Recent.

As to the origin and the affinities of the Clypeasteridae, much discussions are made by previous authors, such as HAWKINS (1912, p. 492; 1920, p. 436), MORTENSEN (1948-c, pp. 18-19), and DURHAM (1955, pp. 114-116), but in the present state of our knowledge there is no positive evidence to tell with certainty the derivation of them.

Species of this family are very abundant particularly in the Tertiary. The fossil record is especially notable in the circum-Tethyan and Caribbean-Gulf of Mexico areas. According to MORTENSEN (1948-c, p. 19) there are more than 355 named fossil species and 30 living species that have been referred to the family. Because of this large number of species and the great morphologic diversity of them several attempts have been made to divide the family into genera, subgenera or sections, and more than 30 taxa of genus-groups or supraspecific ones have been proposed. LAMBERT and THIÉRY (1914, pp. 297-310) divided the family into four genera and fourteen sections under the genus Clypeaster. CHECCHIA-RISPOLI (1923-a, 1925-a), MORTENSEN (1948-c), ROMAN (1952), and a few others (e.g., SANCHEZ ROIG, 1952-a) tried to revise some supraspecific taxa among these names and to reduce them in number, e.g., MORTENSEN (1948-c) lumped up many of these sections into a single genus, but still recognized 10 sections under the genus. All these sections, subgenera, even genera, according to DURHAM (1955, p. 118), are based on characters too variable to be of supraspecific distinction, as the variations grade into one another without any observable breaks, as in the case of Echinolampas (KIER, 1962, p. 107). Accordingly, DURHAM (1955, p. 118) claimed that it seems best to recognized only a single genus, *Clypeaster*, and to reduce all the other supraspecific taxa to synonyms, and seems highly probable that the number of named fossil species should be greatly reduced, many being merely variants of morphologically highly variable species. To this procedure the writer quite agrees.

Genus Clypeaster LAMARCK, 1801

- Clypeaster LAMARCK, 1801, p. 349 (non DEJEAN, 1821).—LAMARCK, 1816, p. 12.—BLAINVILLE, 1834, p. 216.—DESMOULINS, 1835-37(35), p. 15.—AGASSIZ, 1836, p. 187(16).—AGASSIZ and DESOR, 1847, p. 129.—PHILIPPI, 1951, p. 321.—GRAY, 1855-a, p. 3.—DESOR, 1855-58(58), p. 329.—MICHELIN, 1861-a, pp. 101-145.—WRIGHT, 1864, p. 476.—A. AGASSIZ, 1872-74(72), p. 306.—POMEL, 1883, p. 68.—DUNCAN and SLADEN, 1883, p. 11.—DUNCAN, 1889-a, p. 151.—COTTEAU, 1889-94(91), p. 226.—H. L. CLARK, 1911, p. 604.—LAMBERT, 1912-b, p. 86.—H L. CLARK, 1914, p. 20.—LAMBERT, 1914-b, p. 275.—LAMBERT and THIÉRY, 1914, p. 298.—VADÀZ, 1915, p. 46.—JACKSON, 1922, p. 36.—CHECCHIA-RISPOLI, 1923-a, p. 61.—H. L. CLARK, 1925, p. 148.—CHECCHIA-RISPOLI, 1925-a, p. 65.—CHECCHIA-RISPOLI, 1929, p. 25.—GRANT and HERTLEIN, 1938, p. 42.—COOKE, 1942, p. 11.—H. L. CLARK, 1946, p. 336.—MORTENSEN, 1948-c, p. 37 (complete synonymy).—SANCHEZ ROIG, 1952-a, p. 119.—TERMIER and TERMIER, 1953, p. 923.—DURHAM, 1955, p. 118, text-figs. 1a-j, 15a-b, 25-26a, n, 28d.—COOKE, 1959, p. 33.
 - Logotype.—Echinus rosaceus LINNAEUS, 1758, p. 665 (partim: 'Habitat in O. Asiatico').— Clypeaster rosaceus (LINNAEUS): MICHELIN, 1861-a, p. 110, pl. 13, figs. a-r (Caribbean Sea).—MORTENSEN, 1948-c, p. 40, pl. 1, figs. 2-4, pl. 64, figs. 1-5, text-fig. 34 (Caribbean region). [DESMOULINS, 1835-37(35), p. 15.—H. L. CLARK, 1911, p. 604].
- Echinanthus LESKE, 1778, p. 185 (partim; non pp. xix, 121; non BREYNIUS, 1732—pre-Linnean).
 —GRAY, 1825, p. 427.—D'ARCHIAC and HAIME, 1853-54(53), p. 207.—D'ORBIGNY, 18, 21-24.
 —GRAY, 1855-a, p. 4.—A. AGASSIZ, 1872-74(72), pp. 106, 310.—TENISON-WOODS, 1878, p. 169.—POMEL, 1883, p. 61.—DUNCAN, 1889-a, p. 154 (partim).
Logotype.—Echinus rosaceus LINNAEUS, 1758, p. 665.—Echinanthus rosaceus (LINNAEUS): A. AGASSIZ, 1872-74, pp. 311, 514, pl. 11e, pl. 11d, figs. 1-2, pl. 11f, figs. 1-18, pl. 13, fig. 9 (Caribbean region). [GRAY, 1851-a, p. 35].

Scutum Schumacher, 1817, pp. 33, 85 (fide Durham, 1955, p. 119).

Haplotype.—Scutum rosaceum (LINNAEUS, 1758).

Nyctimene GISTL, 1848, p. 175 (non BORKHAUSEN, 1797, nec MORRIS, 1837 : fide DURHAM, 1955, p. 119).

Logotype.—Nyctimene rosacea (LINNAEUS, 1758). [DURHAM, 1955, p. 120].

Echinorodum VAN PHELSUM, 1774, p. 38 (non bin.).—LESKE, 1778, p. 8 (non. bin.).—POMEL, 1883, p. 68.—Echinorodorum POMEL: DURHAM, 1955, pp. 119. 120 (as a objective synonym of Clypeaster).

- Logotype.—Echinorodum rosaceum (LINNAEUS, 1758). [COOKE, 1942, p. 11.—DURHAM, 1955, p. 120].
- Diplothecanthus Duncan, 1889-a, p. 153.—MEISSNER, 1904, p. 1382.—GRABAU and SHIMER, 1909-10(10), p. 590.—CLARK and TWITCHELL, 1915, p. 218.—CHECCHIA-RISPOLI, 1923-a, p. 61.

Orthotype.—Diplothecanthus rosaceus (LINNAEUS, 1785).

Test of medium to large size, pentagonal or subcircular in tumid marginal outline, angles rounded, highly variable, flattened to highly elevated apically; oral surface flat to concave, usually with well developed oral infundibulum; margin of test rounded to flattened and inflattened. Apical system central, madreporite usually star-shaped; small ocular plates at re-entering angles, pores small; genital plates fused; genital pores in median sutures of interradia, more or less remote. Petals variable, closed and rounded to wide open and sublyrate; outer pore of petals elongate, inner rounded, often connected by a well defined furrow. Periproct usually inframarginal, rarely marginal, small, situated at junction between third and fourth or fourth and fifth post-basicoronal interambulacral plates. Buccal membrane naked, with imbedded irregular spicules. Internal skeletal supports variable in abundance, consisting of thin laminae and pillars, most strongly developed in flattened species; wall of test sometimes double. Basicoronal (primordial) interambulacral plates usually much smaller than ambulacral plates, separated from post-basicoronal plates by one to three pairs of ambulacral plates; six to ten ambulacral and four to six interambulacral post-basicoronal plates on oral surface (mainly after DURHAM, 1955).

From the Eocene (Auversian) to Recent.

As described above, more than thirty supraspecific taxa have been proposed for the genus, but it seems highly probable that all these taxa should fall in the synonyms of the genus *Clypeaster*. These synonyms are summarized as follows, with the type-species placed in parentheses after each synonym.

Alexandria PFEFFER, 1881 = Alexandraspis LAMBERT and THIÉRY, 1914 (Haplotype.—Alexandria magnifica PFEFFER, 1881), Anomalanthus BELL, 1884 (Haplotype.—Echinanthus tumidus TENISON-WOODS, 1878), Biarritzella BOUSSAC, 1911 (Orthotype.—Biarritzella marbellensis BOUS-SAC, 1911), Bunactis POMEL, 1887 (Logotype.—Clypeaster scillae DESMOULINS, 1835—LAMBERT, 1912), Coronanthus LAMBERT, 1913 (Haplotype.—Clypeaster microstoma LAMBERT, 1912), Dactylanthus LAMBERT, 1912 (Orthotype.—Clypeaster acclivis POMEL, 1887), Eurycoila LAMBERT, 1912 (Orthotype.—Clypeaster intermedius DESMOULINS, 1835), Eurypleura LAMBERT, 1912=Tholeopelta LAMBERT and THIÉRY, 1914 (Orthotype.—Clypeaster duchassaingi MICHELIN, 1861), Guebhardanthus LAMBERT, 1914 (Orthotype.—Clypeaster priscus OPPENHEIM, 1901), Herrerasia SANCHEZ ROIG, 1952 (Orthotype.—Clypeaster profundus SANCHEZ ROIG, 1949 (non AGASSIZ, 1840) = ?Cly. oxybaphon JACKSON, 1922), Laganidea POMEL, 1887 (Logotype.—Clypeaster atavus

S. NISIYAMA

POMEL, 1885-LAMBERT, 1912), Laubeanthus LAMBERT, 1914 (Orthotype.-Clypeaster breunigi LAUBE, 1872), Leptoclypus KOEHLER, 1922 (Orthotype.-Clypeaster annandalei KOEHLER, 1922), Miophyma POMEL, 1887 (Logotype.-Clypeaster altus LAMARCK, 1816-DURHAM, 1955), Oxypleura POMEL, 1887=Oxyclypeina LAMBERT and THIÉRY, 1913 (Logotype.-Clypeaster doma POMEL, 1887-LAMBERT, 1912), Orthanthus MORTENSEN, 1948 (Orthotype.-Clypeaster euclastus H.L. CLARK, 1914), Paleanthus LAMBERT, 1912 (Orthotype.-Clypeaster profundus (AGASSIZ) FABIANI, 1908), Paratina POMEL, 1887=Paratianthus LAMBERT and THIÉRY, 1913 (Logotype.-Clypeaster confusus POMEL, 1887-LAMBERT and THIÉRY, 1914), Pavaya POMEL, 1883 (Haplotype.-Clypeaster corvini PAUAY, 1874), Platypleura POMEL, 1887=Platyclypeina LAMBERT and THIÉRY, 1913 (Logotype.-Clypeaster marginatus LAMARCK, 1816), Plesiantus DUNCAN, 1889 (Orthotype.-Echinanthus testudinarius GRAY, 1851), Pliophyma POMEL, 1887 (Logotype.-Clypeaster altus POMEL, 1887—LAMBERT, 1912), Rojasaster SANCHEZ ROIG, 1952 (Orthotype.-Clypeaster hernandezi SANCHEZ ROIG, 1949), Rhaphidoclypus A. AGASSIZ, 1863 (Haplotype.-Clypeaster scutiformis LAMARCK, 1816), Stolonoclypus A. AGASSIZ, 1863 (Logotype.-Clypeaster prostratus RAVENEL, 1848=Echinanthus subdepressus GRAY, 1825-H.L. CLARK, 1911, p. 605), Zanolettia SANCHEZ ROIG, 1951 (Orthotype.-Zanolettia zanoletti SANCHEZ ROIG, 1951).

As for the classification of the species, the shape of test, the position of the periproct, the form and relative length of the petals, the tuberculation on test, and the character of the buccal membrane are all characters of more or less importance. In accordance with the flattening of the test, there has been a marked development of internal skeletal supports in the form of pillars, walls, needles and horizontal floors. In some cases, these undergo little change with age or show more or less definite manner in arrangement, and hence are of some systematic importance.

This genus may be regarded (MORTENSEN, 1948-c, p. 17) to be largely littoral sublittoral in habitat. Some species, however, have been recorded from a depth of about 500 metres.

There are more than four species of fossil representatives of this genus in our collection.

Clypeaster japonicus Döderlein, 1885

(Pl. 14, fig. 2)

Clypeaster japonicus Döderlein, 1885, p. 100 (28).—Yoshiwara, 1900, p. 388 (in Japanese).—
Yoshiwara (Tokunaga), 1907, pl. 14, figs. 5-8.—H. L. Clark, 1908, p. 304.—Lambert, 1914-a, p. 13.—H. L. Clark, 1914, p. 32, pl. 128, fig. 5, pl. 136, figs. 2-4, pl. 138, fig. 5.—
Lambert and Thiéry, 1914, p. 308.—H. L. Clark, 1925, p. 150.—Hayasaka and Morishita, 1947, p. 42, pl. 1, figs. 1a-b, pl. 2, figs. 1a-b.—Clypeaster (Stolonoclypus) japonicus Döderlein: Mortensen, 1948-c, p. 99 (complete synonymy), pl. 31, fig. 1, pl. 34, fig. 6, pl. 35, fig. 2, pl. 42, fig. 3, pl. 67, figs. 1-2, 9-10.—Clypeaster japonicus Döderlein: UTINOMI, 1954, p. 352.—Cooke, 1954, p. 47, pl. 10, figs. 7-8, pl. 11, figs. 3-4.

Clypeaster excelsior Döderlein, 1885, p. 101(29).—Yoshiwara, 1900, p. 389 (in Japanese).— LAMBERT and Thiéry, 1914, p. 308.

Clypeaster clypeus Döderlein, 1885, p. 100(28).—Yoshiwara, 1900, p. 388 (in Japanese).— Clypeaster (Stolonoclypus) japonicus var. clypeus Döderlein: Mortensen, 1948-c, p. 101, pl. 34, figs. 4, 7.

Clypeaster testudinarius: TOKUNAGA, 1903, p. 7 (non GRAY, 1851).

Clypeaster japonicus Döderlein, subsp. alta Hayasaka and Morishita, 1947, p. 44, pl. 2, figs. 2a-b (=excelsior Döderlein, 1885).

Clypeaster japonicus Döderlein, subsp. plana HAYASAKA and Morishita, 1947, p. 44, pl. 4, figs. 3a-b (=clypeus Döderlein, 1885).

Locality and geological horizon.—A point on Okinawa Island (exact locality unknown), Ryukyu Islands. Ryukyu Limestone, Pleistocene. Hypotype.—IGPS coll. cat. no. 8318.

There is a single specimen referred to this species at the writer's disposal. It measures 90 mm in longitudinal diameter, 78 mm in transverse one, and 41 mm in height.

Test thick and stout, distinctly longer than wide, ratio of length to width being 1,00:0.87, ambitus as seen from above is elongated pentagonal with margins slightly concave at distal ends of the interambulacra, and slightly convex at distal ends of the ambulacra, being widest along the line through the midline of margin in the antero-lateral ambulacra (II and IV); very high, ratio of longitudinal length to height being 1,00:0.45 (the value of height is exceeds the normal value of the living forms); aboral surface more or less gradually rises from the margin towards the summit, particularly on anterior part; margin obtuse and thick, about 15 mm, about one-sixth of longitudinal length of test. Adoral surface not so markedly concave, though the peristome distinctly sunken orally.

Petaloid area rather large, its total length about two-thirds of longitudinal diameter of test; all petals long and wide; frontal petal (III) 31 mm long and 18 mm wide at the widest point, the longest of all, and opens distally, with about 42 porepairs; antero-lateral petals (II and IV) 28 mm long and 17 mm wide at the widest point, make an angle about 70° between median line of the frontal petal (III) and that of antero-lateral petals (II and IV), with about 38 pore-pairs; postero-lateral petals (I and V) 30 mm long and 17 mm wide at the widest point, make an angle 75° between median line of antero-lateral petals (II and IV) and that of postero-laterals, with about 40 pore-pairs, more or less open distally.

Apical system central, madreporite pentagonal, 6 mm across, five genital pores rather distinct. Peristome central, rounded, 7 mm across, on the deeply sunken peristomial region. Periproct not preserved. Oral ambulacral furrows rather distinct and deep, but not reaching the edge of test as such.

Tuberculation on the test rather coarse, the ridge between pore-pairs of paired petals with only 4-5 primary tubercles, and primary interambulacral tubercles on adoral surface not very conspicuous.

This specimen may be referred to a higher form of this rather variable species, *Cly. japonicus* DÖDERLEIN, 1885, which was originally described under various names, i.e., *japonicus, clypeus*, and *excelsior* by DÖDERLEIN (1885, pp. 100-101), who took the specific ranges rather strictly. This specimen may be also assigned to *Clypeaster japoncus alta* HAYASAKA and MORISHITA, 1947, from the Pleistocene of Formosa. Their subspecies coincides fairly well with DÖDERLEIN's *excelsior* in the characters, as pointed out by MORTENSEN (1948-c, p. 101), and the *excelsior* now become a synonym of *Cly. japonicus* and hence subspecies *alta* must be dropped out as a junior subjective synonym of this species. COOKE's specimen of *Cly. japonicus* (USNM 561560) from the Pliocene of Okinawa (USGS 17557, west of Urasaki) seems to be assigned to DÖDERLEIN's *excelsior*.

H. L. CLARK (1914, p. 32) made *clypeus*, *excelsior*, and *Plesianthus ogasawarensis* YOSHIWARA, 1898 (1898, p. 60), as synonyms of *Cly. japonicus*. MORTENSEN (1948-c, p. 101) treated *clypeus* as a variety (or subspecies) of *japonicus* by the cclour of denuded test, e.g., in *clypeus* the test is uniformly white, while in *japonicus* the test is strikingly coloured aborally and the plates dark brownish and the edge white, the both are quite contrasting. *Clypeaster japonicus plana* HAYASAKA and MORI-SHITA, 1947, may be identical with DÖDERLEIN'S *clypeus* in the character of test.

It is now evident that the three forms of *Clypeaster japonicus*, the typical *japonicus*, *excelsior*- and *clypeus*-forms, occurred as fossils in the Pliocene and Pleistocene formations of Ryukyu Islands and Formosa.

On examinating the type-specimen of *Plesianthus ogasawarensis*, H. L. CLARK (1914, p. 32) made it as a synonym of *Cly. japonicus*, recognizing the difference of petals between this and *Cly. japonicus* as only a variation within the same and one species. The diverse opinions as to the systematic position and identification of *Plesianthus ogasawarensis* are established by MORTENSEN himself in the same work (1948-c). He regarded it as to be a distinct species from *japonicus* (p. 102), and also he expressed his opinion that (p. 103) it representing only a variety of *japonicus*. It cannot be drawn any certain conclusion as to the identification and true systematic position of *Pl. ogasawarensis* in the present state of our knowledge. But, there is no any doubt that *Pl. ogasawarensis* is closely related to *Cly. japonicus*. It is not quite certain whether it identical with *japonicus* or represent a variety of that species. The fossil representative of this form is not yet known at present.

Clypeaster virescens Döderlein, 1885

(Pl. 12, figs. 1, 4, Pl. 13, figs. 1-2, 7, Pl. 14, fig. 1)

- Clypeaster virescens Döderlein, 1885, p. 102(30).—Yoshiwara, 1900, p. 389 (in Japanese).—
 Yoshiwara (Tokunaga), 1907, pl. 14, figs. 9-10.—H. L. Clark, 1914, p. 39, pl. 122, fig. 15, pl. 123, figs. 28-31, pl. 128, fig. 8, pl. 138, fig. 4, pl. 140, figs. 1-2.—Lambert and Thiéry, 1914, p. 309.—H. L. Clark, 1925, p. 153.—Lambert and Thiéry, 1925, p. 580.—H. L. Clark, 1946, p. 338.—Clypeaster (Stolonoclypus) virescens Döderlein: Mortensen, 1948-b, p. 97.—Mortensen, 1948-c, p. 96 (complete synonymy), pl. 33, fig. 1, pl. 38, figs. 1-5, pl. 40, figs. 1, 10, pl. 67, figs. 5-7, 12-14, 20-21, 23, pl. 69, fig. 6, text-figs. 56, 57a-b.—Clypeaster virescens Döderlein: Mortensen in Morishita, 1950, p. 258.—Utinomi, 1954, p. 352.
- Clypeaster colloti: HAYASAKA and MORISHITA, 1947, p. 48, pl. 4, figs. 2a-b(?) (non LAMBERT, 1913).
- Clypeaster cf. virescens Döderlein: HAYASAKA and Morishita, 1947, p. 47, pl. 5, figs. 1a-b-(?).

Locality and geological horizon.—A point on Okinawa Island (exact locality unknown), Ryukyu Islands. Ryukyu Limestone, Pleistocene. Hypotype.—IGPS coll. cat. no. 8319.

Locality and geological horizon.—A point of Hakushaton, Byôritsu-gun, Shinchikushû (Paishan, Miaoli, Hsinchuhsien), Formosa. Byôritsu formation, Pliocene. Hypotype.—IGPS coll. cat. no. 35058-A.

Locality and geological horizon.—Shôgunsan, Byôritsu-gun, Shinchiku-shû (Chiangchünshan, Miaoli, Hsinchuhsien), Formosa. Byôritsu formation, Pliocene. Hypotype. —IGPS coll. cat. no. 35058.

In our collection of the fossil echinoids from Japan and the adjacent regions,.

there are four specimens of the related *Clypeaster*, which the writer considers to be referred to *Cly. virescens* DÖDERLEIN, 1885. They are not quite identical with one another, if they are compared in details differing more or less in size of test, as well as in the form and relative length of petals. However, as the number of specimens is too small for the comparison and hence to dwell upon a discussion on their systematic assignment, the writer brings all the specimens under one and same specific name *Cly. virescens*, of rather widely distributed and more or less variable species.

Test large, the largest of the specimens attains 102 mm in longitudinal diameter, rounded or roundedly pentagonal, being widest along the line through the middle part of both margins, longitudinal diameter a little exceeding the transverse one, the ratio being 1,00:0.94-0.96, rather flat and low, height about 0.2 of longitudinal diameter, not depressed at distal end of petals and gradually rising to the apex with a gentle but convex slope; oral surface almost flat, or slightly concave orally, only sunken near the peristome.

Petaloid area rather small, its total length about less than 0.7 of longitudinal diameter of test; all petals rather short and wide, more or less open distally, their width usually half their length; in well-preserved specimen, frontal petal (III) 25 mm long and 15 mm wide at the widest point and opens distally, with about 40 pore-pairs on each side; antero-lateral petals (II and IV) 24 mm long and 15 mm wide at the widest point, make an angle of about 75° between median line of the front petal and that of antero-lateral petals, with about 36 pore-pairs; postero-lateral petals (I and V), with about 41 pore-pairs, 27 mm long and 16 mm wide at the widest point, make an angle of about 75° between median line of antero-lateral petals and that of postero-lateral petals.

Apical system central, madreporite pentagonal, 5 mm across, five genital pores rather distinct; apical system and proximal part of petals more or less depressed. Peristome central, peristomial region only sunken orally. Periproct inframarginal, its posterior border being only 2-3 mm from the posterior margin of test. Oral ambulacral furrows simple, straight, and well defined, extending from the peristome to almost the margin.

Tuberculation on the test coarse; on each ridge between pore-pairs of petals, there are only 2-3 primary tubercles; primary tubercles scattered and rather large particularly on the interambulacral areas orally.

An ill-preserved specimen from the Pliocene of Formosa (IGPS coll. cat. no. 35058) is conferable with this species, in its relative length and form of petals and the number of primary tubercles on each ridge between pore-pairs of petals, as well as flatness of the test and the depressed apical system.

This species resembles *Cly. humilis* (LESKE, 1778) (see below), a living species of the Indian Ocean, but is distinguished from that species in the longer and opened petals and coarser tuberculation of the test. The species are now living together in the Philippines Seas and the adjacent regions.

Clypeaster colloti LAMBERT was reported by HAYASAKA and MORISHITA (1947, p. 48, pl. 4, figs. 2a-b) from the Byôritsu formation of Formosa. It may not be that species, but possibly be referred to this species. Cly. colloti, Cly. martini DESMOULINS, and five related forms of Cly. colloti (i.e., C. scutellatus SERRES, C. folium AGASSIZ,

C. subfolium POMEL, C. marginatus LORIOL, and C. tessellatus POMEL) as mentioned. by LAMBERT (1913-c, p. 113), are all classified by LAMBERT and THIÉRY (1914, p. 304). in the Section Platyclypeina, to which Cly. virescens from Japan is undoubtedly assigned, because the close relation of Cly. virescens to them is very evident. HAYASAKA and MORISHITA's description and figures of the specimen under the name colloti well agree with the features of Cly. virescens, in the relative length of petals, small petaloid area (its total length about 0.6 of longitudinal diameter), coarse tuberculation on the interambulacral areas orally, flattened oral side, feature of the oral ambulacral furrows, and in the position of periproct, as well as in the depressed apical system and in the height of test. The two authors failed to describe the number of primary tubercles on each ridge between pore-pairs of petals, but judged from its narrow poriferous zones and observation on figure given by the two authors,. the number of them may be less than four as usual in this species. The proportion of longitudinal diameter to the transverse of this specimens, as measured by the twoauthors, being 1,00:0.83, is less than that of Cly. virescens, which is 1,00:0.9 or more. The smallness of breadth of test in this specimen may be due to either the irregular growth of test, as stated by two authors (1947, p. 49), or the deformation of the test by lateral compression, as shown in the figures 2a-b on plate 4 given by the two authors. Restored outline of the test may increase the width and the greatest width may be lying on the transverse line of middle of the test. The specimen from the Byôritsu formation (Pliocene) may be referred to the living Cly. virescens, rather than to the European Miocene species Cl. colloti (LAMBERT, 1913-c, p. 112, pl. 9, figs. 1-5-Langhian), under the circumference as described above.

Another Formosan species, which is described by HAYASAKA and MORISHITA. (1947, p. 47, pl. 4, figs. 1a-b) under the name Clypeaster cf. virescens, from the Miocene formation, may not be referred to this living species. Although the specimen seems to be closely allied to the living species, it differs from the living species in some details, and the true specific position of the specimen is not settled with certainty at present. This specimen is more or less related to the living Cly. virescens,. but differs from that species, as pointed out by the two authors, in the form of petals, the greater petaloid area (its total length being about 0.7 of longitudinal diameter), the finer tuberculation on the test, and in the position of periproct. The number of primary tubercles on each ridge between pore-pairs of petals in this specimen, as counted from the figure (1a on plate 5 given by the two authors), is more than seven, and it is greater than that of Cly. virescens. These features prevent the identification of this specimen to Cly. virescens with certainty. This specimen also resembles the Indian Cly. humilis, but is distinguished from that species by the form of petals, greater petaloid area, and by the coarser tuberculation on the test. This species is also more or less related to the Indian Miocene species, Cly. complanatus DUNCAN and SLADEN, 1885 (1885-a, p. 325, pl. 4, figs. 10-11), and Cly. sladeni LAMBERT and THIÉRY, 1914 (LAMBERT and THIÉRY, 1914, p. 304.—Cly. profundus DUNCAN and SLADEN, 1885-a, p. 319, pl. 4, figs. 1-4-non AGASSIZ: FABIANI, 1908, p. 80, pl. 1, fig. 20), but differs from these species in the form of petals and the tuberculation on the test, although the true relationship of those species with the living Cly. virescens needs further elucidation. For the exact determination of this form new material isdesired in order to settle whether it is certainly Cly. virescens or quite another species.

Clypeaster virescens DÖDERLEIN, 1885, is a rather variable species, and is known from central and southern Japan, the Philippines, Indo-China, as south as New Zealand, in depth of about from 100 to 300 meters.

Clypeaster humilis (LESKE, 1778)

(Pl. 12, figs. 2-3, 5)

- Echinanthus humilis LESKE, 1778, p. 185, pl. 17, fig. A, pl. 18, fig. B, pl. 19.—Clypeaster humilis (LESKE): A. AGASSIZ, 1872-74, pp. 100, 510, pl. 11a, figs. 1-8.—MARTIN, 1880-a, p. 79.— DUNCAN, 1885, p. 205, pl. 31, figs. 56-58.—BROWN, 1910, p. 41.—H. L. CLARK, 1914, p. 36, pl. 123, fig. 23, pl. 137, pl. 138, fig. 4.—LAMBERT and THIÉRY, 1914, p. 301.—FOURTAU, 1914-a, p. 102, pl. 11.—KOEHLER, 1922, p. 51, pl. 3, figs. 1-5, 12, pl. 14, fig. 51.—H. L. CLARK, 1925, p. 149.—BRIGHTON, 1931, p. 325.—Clypeaster (Stolonoclypus) humilis (LESKE): JEANNET and MARTIN, 1937, p. 242, text-fig. 26.—Clypeaster humilis (LESKE): H. L. CLARK, 1946, p. 377.—Clypeaster (Stolonoclypus) humilis (LESKE): P. 102.
 MORTENSEN, 1948-c, p. 88 (complete synonymy), pl. 17, fig. 1, pl. 28, figs. 1-4, pl. 29, figs. 1-3, 5-8, pl. 30, fig. 1, pl. 40, figs. 2-3, pl. 67, figs. 3, 8, 11, 15-18, text-figs. 53a-b.—DURHAM, 1955, p. 121, text-fig. 260 (reproduced from MORTENSEN, 1948-c).
- Scutella placunaria LAMARCK, 1816, p. 12.—Echinanthus placunarius (LAMARCK) GRAY, 1855-a, p. 7.—MICHELIN, 1861-a, p. 135, pl. 35, fig. 2.—Stolonoclypus placunarius (LAMARCK) A. AGASSIZ, 1863, p. 25.
- Scutella ambigena LAMARCK, 1816, p. 12.—Clypeaster ambigenus (LAMARCK): BLAINVILLE, 1834, p. 299.
- Clypeaster latus HERKLOTS, 1954, p. 6, pl. 2, fig. 1.
- Clypeaster tumescens HERKLOTS, 1854, p. 7, pl. 2, fig. 2.
- Clypeaster testudinarius: MARTIN, 1880, p. 4 (non GRAY, 1851).
- Clypeaster rosaceus: Lovén, 1887, p. 172, pl. 6, fig. 2 (non Linnaeus, 1758).—Meijere, 1904, p. 133, pl. 18, figs. 352-353.—Fourtau, 1904, p. 444.
- Clypeaster cf. deserti: HAYASAKA and MORISHITA, 1947, p. 45, pl. 3, figs. la-b (non KEW, 1915).

Clypeaster aff. humilis (LESKE): HAYASAKA, 1947, p. 112, pj. 12, fig. 1(?).

Clypeaster okinawa COOKE, 1954, p. 47, pl. 11, figs. 1-2.

Locality and geological horizon.—Hakushaton, Byôritsu-genu, Shinchiku-shû (Paishan, Miaoli, Hsinchuhsien), Formosa. Byôritsu formation, Pliocene. Hypotype.— IGPS coll. cat. no. 35059.

There are two specimens referable to this species at hand, they are not well preserved, and the test is partly broken off, but the remaining part shows characteristics of this species.

Outline of the test assumes nearly oval, with margins slightly concave at median part of the interambulacra. Test low, less than 15 mm high; margin thin, about 2 mm thick; aboral surface more or less flat distal to the petaloid area, where it rises more steeply; perradial (ambulacral median) sutures distinct throughout the aboral surface; adoral surface slightly and gradually concave orally.

Petaloid area small, its total length seems to be nearly half the longitudinal diameter; petals short, but rather wide, their width more than half their length, narrow proximally and broadest distally, interporiferous zones elevated, poriferous zones converging rather abruptly and tending to close the petals; measurement of the petals being, 25 mm long and 14 mm wide, the frontal petal (III) longest of all;

each petal having about 40 pore-pairs on each side; number of primary tubercles on each ridge between pore-pairs of petals is seven in the broadest poriferous zone; distance between distal end of antero-lateral petal (II) and the margin is about 28 mm, and that between distal end of postero-lateral petal (probably I) being 26 mm.

Apical system probably central, but destroyed, and the details of it is not observed. Peristome and periproct not preserved in the specimens at hand. Oral ambulacral furrows not well preserved, but may be extending from the peristome to the margin.

These specimens can be referable with this most variable and perplexing species, *Cly. humilis*, in having the low test, thin margin, flattened area outside the petaloid area, distinct perradial sutures, and in the form of petals, relative length of each pletal, as well as in the number of primary tubercles on each ridge between porepairs of petals. This highly variable species was described by many authors under various names from the Indo-West Pacific Oceans. It is generally agreed that they can be regarded mostly as synonyms of this species.

The specimen described by HAYASAKA and MORISHITA (1947, p. 45) under the name Cly. cf. deserti KEW from the Byôritsu formation (Pliocene) of Formosa, may not be the named species, but can be referred to this species. It is very large, although Cly. humilis rarely attains 150 mm or more in the longitudinal diameter. The size of the specimen, however, cannot be taken for distinguishing it from this species. If the outline of test in their specimen is restored to elongate pentagonal, as stated by the two authors, it well agrees with Cly. humilis in general features. In the low test, less than one-fifth of the longitudinal diameter, thin margin, flattened part outside the petaloid area, rather distinct perradial sutures, form of the petals, and in the relative length of each petal, considering its deformation by compression, the characters of their specimen point to the living Cly. humilis.

Another specimen, described by HAYASAKA (1947, p. 112, pl. 12, fig. 1) under the name Cly. aff. humilis, from the Pitoushan group (Pliocene) of Formosa, may be assigned to this species in its general features. The low test, thin margin, feature of flattened or slightly concave part outside the petaloid area, small petaloid area (its total length nearly half the longitudinal diameter measured from the figure given by that author), the form of petals, relative length of each petal, and rather broad poriferous zones of this specimen, as by accounting its deformation of the test and the petals by compression, offer general resemblances to the living Cly. humilis (LESKE, 1778). This may be the same case in Cly. okinawa of COOKE (1954, p. 47, pl. 11, figs. 1-2). The affinities and distinctions among his Formosan specimen and the related Cly. malumbangensis ISRAELSKY, 1933 (1933, p. 301, pl. 1, fig. 1.—JEANNET and MARTIN, 1937, p. 247, text-fig. 30) and Cly. brevipetalus MARTIN in JEANNET and MARTIN, 1937 (1937, p. 246, text-fig. 29) are discussed by HAYASAKA (1947, pp. 113-114). It may be stated as pointed out by HAYASAKA, that the Formosan specimen is more similar to Cly. humilis than to Cly. malumbangensis, although the roundedly pentagonal outline of the test is not recognized in the former. Cly. brevipetalus, however, is distinguished from the Formosan species by having the shorter petals, flatter and thinner test, as well as dissimilar shape of petals. At any rate, the specimens derived from the Pitoushan group (Pliocene) of Formosa and from the Naha Limestone (Upper Pliocene) of Okinawa may be called *Clypeaster humilis*, if the specific range is taken rather widely as usually done in this kind of highly variable species.

Clypeaster humilis (LESKE, 1778) is distributed in the Indo-West Pacific Oceans, ranging from the Red Sea to the Philippines Seas, where it occurs together with *Cly. virescens*, in depth of littoral to about 40 meters. The occurrence of this species as fossils together with *Cly. virescens* from the Pliocene formation of Formosa and Ryukyu Islands seems to be very probable.

Clypeaster reticulatus (LINNAEUS, 1758)

- Echinus reticulatus LINNAEUS, 1758, p. 666 (pro parte).—Echinodiscus reticulatus (LINNAEUS) LESKE, 1778, p. 207, pl. 45, figs. 8-9.—Clypeaster reticulatus (LINNAEUS) DESMOULINS, 1835-37(37), p. 214.—LORIOL, 1883, p. 37.—LOVÉN, 1887, p. 168.—H. L. CLARK, 1914, p. 34, pl. 124, figs. 3-6.—LAMBERT, 1914-a, pp. 12, 13.—Clypeaster (Rhaphidoclypus) reticulatus (LINNAEUS) : LAMBERT and THIÉRY, 1914, p. 301.—Rhaphidoclypus reticulatus (LINNAEUS) KOEHLER, 1922, p. 68, pl. 6, figs. 3-4, pl. 15, fig. 10.—Clypeaster reticulatus (LINNAEUS) : H. L. CLARK, 1925, p. 151.—STOCKLEY, 1927, p. 114, pl. 21, fig. 7.—ROXAS, 1928, p. 262, pl. 6, figs. 27-28.—CURRIE, 1930, p. 175, pl. 16, fig. 5.—Clypeaster (Rhaphidoclypus) reticulatus (LINNAEUS) : BRIGHTON, 1931, p. 325.—JEANNET and MARTIN, 1937, p. 244, text-fig. 27.— Clypeaster reticulatus (LINNAEUS) : NISIYAMA, 1942, p. 21 (in Japanese).—Clypeaster cf. resiculatus (LINNAEUS) : HAYASAKA and MORISHITA, 1947, p. 50, pl. 4, figs. 1a-b.—Clypeaster (Rhaphidoclypus) reticulatus (LINNAEUS) : MORTENSEN, 1948-c, p. 71 (complete synonymy), pl. 18, figs. 1-21, pl. 26, fig. 3, pl. 65, figs. 2, 13, 16, text-figs. 8, 47.—Clypeaster reticulatus (LINNAEUS) : UTINOMI, 1954, p. 352.—DURHAM, 1955, pp. 95, 112, 120, 121, textfigs. 15b, 25e, 26a.
- Clypeaster scutiformis LAMARCK, 1816, p. 12.—BLAINVILLE, 1934, p. 216.—AGASSIZ, 1836, p. 187(20).—AGASSIZ and DESOR, 1847, p. 130.—Echinanthus scutiformis (LAMARCK) GRAY, 1855-a, p. 5.—Rhaphidoclypus scutiformis (LAMARCK) A. AGASSIZ, 1863, p. 25.—Clypeaster scutiformis LAMARCK: A. AGASSIZ, 1872-74, pp. 101, 512, pl. 13, figs. 1-4.—MEIJERE, 1904, p. 131, pl. 18, figs. 344-351.—BROWN, 1910, p. 41.—FOURTAU, 1904-a, p. 422.—FOURTAU, 1914-a, p. 88.

Clypeaster rosaceus var. crassilimbata STAFF and RECK, 1911, p. 44.

Laganum multiforme var tayabum PRATT and SMITH, 1913, p. 325, pl. 2, fig. 3.

There is no authentic fossil specimen referable to this species at the writer's disposal, although HAYASAKA and MORISHITA (1947, p. 50, pl. 4, figs. 1a-b) reported the occurrence of this species from the Ryukyu Limestone (Pleistocene) of Tokunoshima, Ryukyu Islands.

Of the specimen, test small, under 50 mm in longitudinal diameter and width four-fifths (0.83) of length, adoral surface strongly concave around the peristome which is deeply sunken, frontal petal (III) nearly closed, with rather few pore-pairs, about 30 on each side, antero-lateral petals (II and IV) short, about 0.87 of the frontal, petaloid area rather large (its total length 0.62 of the longitudinal diameter) and somewhat depressed, at least distal portion lying lower than the thickened test-margin though the apical system much thicker. These are the characteristic features that enable us to identify it with the living *Cly. reticulatus*. This specimen seems to be of a relatively flat type, with the edge moderately thick, as in the specimens from the Philippines described by MORTENSEN (1948-b, p. 98). The narrower poriferous zones of the petals in this specimen may be due to the inner mould in its preservation,

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as stated by the two authors (1947, p. 51), which is usually more or less different from the external feature of the test. The characteristic suture lines, particularly on the aboral surface, and the tuberculation on the test are not preserved in this specimen.

This species widely distributed over the Indo-Pacific Oceans, from Red Sea and East African coast to Hawaii, Formosa and to southern Japan, as far north as Kii Peninsula (UTINOMI, 1954, p. 352), in depth of from littoral zones to about 120 metres.

Clypeaster saipanicus COOKE, 1957

Clypeaster saipanicus COOKE, 1957, p. 362, pl. 119, figs. 14-17.

Locality and geological horizon.—A point near Mt. Laulau, at Laulau, Saipan Island, Micronesia, South Sea Islands. Laulau (Tagpochau) formation, Lower Miocene (Eulepidina-Spiroclypeus—horizon). Hypotype.—IGPS coll. cat. no. 78230.

There is only a single specimen referred to this species at hand. It is rather well preserved, but partly fractured and some details of the aboral surface are more or less faded. The holotype is small (42.5 mm in longitudinal diameter) and the genitals have no pores, while the specimen at the writer's disposal is large (79 mm) and five genital pores are distinct, and other differences are observable between them. But, the differences may be due to the growth change of two individuals, and the two specimens are regarded to be conspecific with each other. The following is a supplementary description of the species based on the adult individual. Dimensions of the specimen.—79 mm in the longitudinal diameter, 58 mm in the transverse, and 22 mm in height.

Test of medium-size, thick, and depressed. Outline suboval, being widest along the line through the distal points of postero-lateral petals (I and V), somewhat concave on postero-lateral interambulacral margin (1 and 4), slightly concave on the middle part of posterior interambulacral margin (5), anterior part elongate and posterior part more rounded, width 0.73 of test-length, being less than the usual type of Cly. reticulatus. In longitudinal profile, anterior part evenly arched with rounded and thick margin, which measures 19 mm at the thickest point, to the highest point, with the margin slightly decreasing the thickness, and whence the test gradually and gently declines to the posterior end, margin thinnest at about the middle part, where it measures 16.5 mm; margin of lower surface runs almost in parallel with that of upper surface. Aboral surface depressed under the thick margin, particularly the middle portion of petaloid area conspicuously lower than the thickened margin, except for the frontal petal (III), which lies on a rather flattened area of the frontal margin; adoral surface gradually concave orally and peristomial region deeply and suddenly sunk, thus leaving small interior space for a flattened masticatory apparatus between the apical region of upper side and the peristomial region of lower side; apical region more or less raised, but decidedly lower than the thickened margin. In transverse profile, upper and lower surfaces of both sides are raised from the lower middle part, nearly in parallel with each other.

Petaloid area rather large, whose total length measures 52 mm, 0.66 of longitudinal diameter; petals rather long and narrow, their width being more or less half

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their length, and tending to close at their distal end except for the frontal petal (III), which is more or less open distally; interportierous zones rather narrow, about half the width, and more or less elevated; large primary tubercles alternately placed on second or third primary plate (component) in the interportiferous zones; portferous zones rather broad and more or less depressed, with less than forty pore-pairs on each side, there are no less than six primary (but small) tubercles on each ridge between pore-pairs at the broadest zone. Frontal petal (III) 26 mm long and 12 mm wide, the longest of all; interporiferous zone narrow, about 5 mm wide at middle of the petal, and slightly divergent distally, with about forty pore-pairs on each side; antero-lateral petals (II and IV) 20 mm long and 12 mm wide, interportiferous zones 5 mm wide at middle of the petals and convergent distally, poriferous zones 4 mm wide at the widest point, with about forty-four pore-pairs on each side; angle between median line of frontal petal and that of antero-laterals being about 75°; postero-lateral petals (I and V) 22 mm long and 12 mm wide, interportferous zones 5.5 mm wide at the middle of the petals and convergent distally, poriferous zones 4.5 mm wide at the widest point, with about thirty-six pore-pairs on each side, angle between median line of posterolateral petals and that of antero-laterals being about 77°.

Apical system central and slightly raised, rather small, 4 mm long and 3.5 mm wide, genital pores rather large, ocular pores very small but visible by naked eye. Peristome central, small, region around it strongly concave and quite deep. Periproct small, circular, about 3 mm across, inframarginal, outer margin being 4 mm from the posterior margin of test. Oral ambulacral furrows rather narrow and deep, but not reaching the margin as such. Tuberculation on the test rather fine, primary tubercles on adoral surface closer and more or less smaller than those of *Cly. reticulatus*, primary tubercles on adoral surface not well preserved, but they are more or less smaller than those on adoral surface.

This species very closely resembles *Cly. reticulatus* (the preceding species) in many features of test, but is easily distinguishable from that species by having large primary tubercles on the interporiferous zones of petals, decidedly sunken peristomial region, and much thickened margin. *Cly. sapainicus* also closely relates to *Cly. pulvinatus* DUNCAN and SLADEN, 1885 (1885-a, p. 322, pl. 50, figs. 5-6), from the Gaj Series (Miocene) of India, in the general features of test, but differs from that species in the form of petals and presence of large primary tubercles on the interporiferous zones of the petals, more inflated margin and in the much deeply sunken peristomial region. It is very interesting that this characteristic Miocene species, which is very similar to the living *Cly. reticulatus*, has already flourished during the Miocene Epoch in the Central Pacific, and that its relationships with the Indian Miocene and the Indo-Pacific Pliocene species seem to be very close.

Suborder LAGANOINA MORTENSEN, 1948

Laganina DESOR: MORTENSEN, 1948-c, pp. 3, 156 (pro parte).—DURHAM, 1955, p. 131.—Laganina MORTENSEN: DURHAM and MELVILLE, 1957, p. 259. Type-family.—Laganidae DESOR, 1858.

Auricles fused into a single piece situated on interambulacrum. Ambulacral

structure within the petals simple or compound of the "neolaganid" type or "clypeasteroid" on some places. Test flattened or inflattened, with internal skeletal supports when flattened. Interambulacra narrow, continuous on adoral surface, terminated adapically with usually a single plate or rarely a series of single plates. Apices of apical system opposite interambulacra. Aboral miliary radioles terminating in a crown. Usually no spicules in tube-feet.

From the Upper Cretaceous (Senonian) to Recent.

In the feature of auricles the Laganoina are common with the Scutelloina, but differ from the latter in having the aboral miliary radioles with terminal crown, whereas in the Scutelloina they terminate usually in glandular bag. That the narrow interambulacra terminate adapically with a single plate is a striking feature of this suborder, which differs from, in having this character, the Clypeasteroina and Scutel loina that have the interambulacra terminating adapically with a pair of plates. This simple plate at the adapical end of interambulacral column seems to be, as described by DURHAM (1955, p. 131) and above, a more specialized feature than a pair of plates at the adapical end of the Clypeasteroina and Scutelloina, and this feature has occurred even in the primitive member of the Laganoina. On the contrary, in the Laganoina the interambulacra on the oral surface are narrow and arranged in continuous condition; particularly in the primitive forms they retain an undifferentiated condition. Thus, the Laganoina are distinguished from, in having this continuous arrangement of the oral interambulacral plates, the Clypeasteroina and the specialized forms of the Scutelloina that show the discontinuous arrangement of the plates. The absence of the internal skeletal supports (internal radiating partition walls) in some forms (e.g., Fibularia) of this suborder is regarded by H.L. CLARK (1914, p. 56) and DURHAM (1955, p. 132) as a more primitive character than the presence of them. Whereas MORTENSEN (1948-c, p. 164) maintained that this absence of internal supports must be regarded as a specialized stage owing to disappearance of the structures by degeneration, not a starting point or initial stage of development of them.

The evidence of direct derivation of the younger Clypeasteroina and the Scutelloina from the primitive forms, the older geological occurrence, of the Laganoina is not sound in the present state of our knowledge.

The Laganoina comprise the following three families, viz., the Fibulariidae GRAY, 1885, Laganidae DESOR, 1858, and Neolaganidae DURHAM, 1954. The last family was established by DURHAM (1954, p. 680) on New World fossil forms, as contrasting with the Laganidae which comprise Old World fossil and Indo-Pacific Recent forms. Three families are discriminated from one another as shown by the following key.

Key to the families of the Laganoina.

- - Test of generally small forms, inflattened or flattened, shape variable. Petals variable, often indistinct, open. Simple internal supports of radial partitions or absent. Oral ambulacral furrows usually absent, indistinct when present.

There are fossil representatives of the family Fibulariidae and Laganidae in our collection.

Family FIBULARIIDAE GRAY, 1855

Fistularina GRAY, 1885-a, p. 27 (Fibularina in systematic index, p. 65).—Fibularina GRAY: A. AGASSIZ, 1872-74, p. 505.—Fibulariidae GRAY: DUNCAN, 1889-a, p. 144.—Fibularidées COTTEAU, 1889-94(92), p. 385.—Fibulariidae DUNCAN: GREGORY, 1900-b, p. 317.—MEISSNER, 1904, p. 1380.—H. L. CLARK, 1911, p. 604.—H. L. CLARK, 1914, p. 55.—KOEHLER, 1922, p. 131.—LAMBERT and THIÉRY, 1914, p. 289 (pro parte).—H. L. CLARK, 1925, p. 162.—GRANT and HERTLEIN, 1938, p. 47.—H. L. CLARK, 1946, p. 347.—MORTENSEN, 1948-c, p. 156 (complete synonymy).—TERMIER and TERMIER, 1953, p. 924.—DURHAM, 1955, p. 132. Type-genus.—Fibularia LAMARCK, 1816.

Scutellinidées Cotteau, 1889-94(91), p. 303.

Type-genus.—Scutellina AGASSIZ, 1841.

Eoscutidae LAMBERT, 1900, p. 49.-LAMBERT and THIÉRY, 1914, p. 287.

Type-genus.—Eoscutum LAMBERT in LAMBERT and THIÉRY, 1914.

Echinocyamidae LAMBERT, 1900, p. 49.—LAMBERT and THIÉRY, 1914, p. 287.—COOKE, 1942, p. 27 (pro parte).

Type-genus.—Echinocyamus (VAN PHELSUM) LESKE, 1778.

Lenitinae LAMBERT in LAMBERT and THIERY, 1914, p. 289.-LAMBERT, 1915, p. 27.

Type-genus.-Lenita DESOR in AGASSIZ and DESOR, 1845.

Usually small forms of very varying shape, inflattened or flattened. Petals variable, often indistinct, open, usually few-pored; pores in petals rounded, outer pore not elongate, not conjugate. Simple internal skeletal supports of radial partitions (they are radially arranged, either ten or fifteen in number) or absent. Apical system and peristome usually central; periproct either on aboral side or, more usually, on oral side. Auricles broad and low. Primordial basicoronal plates not specialized. Oral ambulacral furrows usually absent, indistinct when present. Primary radioles short, simple, with a regular axial canal; miliary radioles with a terminal crown. Pedicellariae of the ophicephalous, tridentate, and triphyllous types; globiferous pedicellariae are quite exceptionally found (mainly after MORTENSEN, 1848-c, and DURHAM, 1955).

From the Upper Cretaceous (Senonian) to Recent.

The Fibulariidae differ from the Laganidae in having the not well-defined petals. with rounded pores, non-specialized primordial basicoronal plates, and the simple internal radiating partitions that contrast to the complex structure of that family, and in lacking the distinct oral ambulacral furrows. The internal supports of the family, when present, are all radially arranged partitions, and may be either ten (but only a pair in a case) or fifteen in number. They protrude from the inner margin of test and extend inward for a variable distance. When there are only ten supports (e.g., *Echinocyamus* and *Eoscutum*), they occur at the margin of the interambulacra, when there are fifteen (e.g., *Porpitella* and *Lenita*), the additional partition wall occurs midway between the other two

The lack of oral ambulacral furrows in most species and the relatively undifferentiated basicoronal plates seem to be primitive characters.

MORTENSEN (1948-c) put under the family Fibulariidae the genera Runa, Echinocyamus (with subgenus Mortonia), Fibularia (with subgenera Fibulariella and Thagastea), Fibulina (with subgenus Cyamidia), Togocyamus, Scutellina, Eoscutum, Porpitella, Lenita, and Sismondia, adding incertae sedis genera, Orchoporus and Tarphpygus. DURHAM (1955) referred to the family the genera Fibularia, Fibulariella, Echinocyamus, Mortonia, Thagastea, Togocyamus, Cyamidia, Scutellina, Porpitella, Eoscutum, Lenita, Tarphypygus, and Fibulaster. DURHAM (1955, pp. 139, 141) referred the genus Sismondia to the Laganidae rather than to the Fibulariidae, on account of its rather specialized basicoronal plates, the conjugate pore-pairs in the petals, and the incipient concentric internal supports—small side-branches on partition walls. The writer regards, herein, the genus Sismondia as a highly specialized form of the Fibulariidae. The important genera and subgenera of the family are discriminated from one another as shown by the following key.

Key to the important genera and subgenera of the family Fibulariidae.

1.	Periproct supramarginal 2
	Periproct marginal or distinctly on oral side 5
2.	A broad bare longitudinal median area on oral side, flanked by large tubercles
	with sunken areoles. 10 well developed internal radiating partitions, with 5
	additional partition walls
	No broad hare longitudinal median area on oral side
:3	Test very low flattened 4
	Test high not flattened Portferous zones of petals more or less straight No
	Poristomial (appl) ambulantal furrous 10 internal radiating partitions
4	O d'in the second
•4.	Outline of test elongated; oral side concave orally. Petals well formed; poriferous
	zones of petals more or less incurved distally. 15 internal radiating partitions
	Porpitella
	Outline of test round; oral side flat. Petals well developed, very small, nearly
	closed. 10 internal radiating partitions Eoscutum
5.	Periproct marginal or submarginal. Outline of test round, test flattened. Petals
	well defined, tending to close distally. No oral ambulacral furrows
	Scutellina
	Periproct distinctly on oral side
<i>'</i> 6.	Petals well formed, long; pore-pairs of petals distinctly conjugate, outer pore
	moderately elongate. Test flattened. 10 internal radiating partitions with
	small side branches
	Pore-pairs of petals not distinctly conjugate. Internal radiating partitions without
	side branches, when present
7.	Test low, more or less flattened, radiating partition walls present, more or less

	completely developed
	Test high, globular or fusiform; no internal radiating partitions
8.	Hydropores few in number, not in a groove. Buccal membrane naked. Periproct
	naked, usually covered with several large naked plates and at times some
	additional small plates. 5 pairs of internal radiating partitions
	Echinocyamus
	Madreporite with a single hydropore. Periproct covered with small irregular plates
	carrying radioles. A single posterior pair of partitions only in the type-
	species Mortonia
9.	Test subconical. Interambulacra terminated adapically with a single series of 3 or
	4 plates rather than paired plates. Madreporite with several hydropores. A
	faint anterior ambulacral furrow (usually ?) present
	Test not subconical. Interambulacra terminated adapically with a single plate. No
•	faint anterior ambulacral furrow 10
10.	Buccal membrane entirely naked. Periproct covered with five large plates. Hydro-
	pores in a groove. No globiferous pedicellariae Fibularia
	Buccal membrane covered by numerous small plates. Periproct covered with many
	small plates. Hydropores not in groove. Globiferous pedicellariae present
	There are fossil representatives of the genera Fibularia (with subgenus Fibu-
	lariiella), Echinocyamus, and Sismondia in our collection.

Genus Echinocyamus VAN PHELSUM, 1774

- Echinocyamus van Phelsum, 1774, p. 131, pl. 1, figs. 1-35, pl. 2, figs. 1-35 (Explicatio Tabulae).
 —Leske, 1778, pp. 149, 213.—Gray, 1825, p. 428 (pro parte).—Blainville, 1830, p. 195.— Agassiz, 1841-b, p. 125.—Agassiz and Desor, 1847, p. 140.—Gray, 1855-a, p. 27.—Desor, 1855-58(57), p. 217.—A. Agassiz, 1872-74(73), pp. 304, 505.—Pomel, 1883, p. 73.—Duncan, 1889-a, p. 144.—Cotteau, 1889-94(92), p. 348.—Bell, 1892, p. 348.—Mortensen, 1907, p. 38.—H. L. Clark, 1911, pp. 596, 598, 605.—H. L. Clark, 1914, p. 59.—Koehler, 1922, p. 132.—H. L. Clark, 1925, p. 164.—Mortensen, 1927-b, p. 132.—Mortensen, 1932-e, pp. 351-355.—Grant and Hertlein, 1938, p. 47.—H. L. Clark, 1946, p. 349.—Mortensen, 1948-c, p. 170 (complete synonymy).—Termier and Termier, 1953, p. 924.—Durham, 1955, p. 133, text-figs. 8k, 9b, 9i, 14a, 30f.—Kier, 1957, p. 859.—Cooke, 1959, p. 31.
 - Logotype.—Spatangus pusillus MÜLLER, 1776, p. 18.=Echinocyamus angulosus LESKE, 1778, p. 215.=Echinocyamus pusillus (O.F. MÜLLER): MORTENSEN, 1907, p. 39, pl. 12, figs. 27-29, 31 (Denmark, and North Sea). [BLAINVILLE, 1830, p. 194.—AGASSIZ and DESOR, 1847, p. 140.—Bull. Zool. Nomencl., vol. 4, 1950, p. 519].
- Fibularia LAMARCK: LAMBERT, 1891, p. 751.—LAMBERT, 1907-b, p. 36.—LAMBERT and THIÉRY, 1914, p. 289.

Logotype.—Fibularia angulosa (LESKE) LAMARCK, 1816, p. 17. [LAMBERT, 1907-b, p. 36]. Anaster SISMONDA, 1842, p. 45.

Haplotype.—Anaster studeri SISMONDA, 1842, p. 46, pl. 2, figs. 8-9 (Miocene of Italy).

Echinocentrotus CHECCHIA-RISPOLI, 1907, expl. pl. 17(2), figs. 40-44.

Haplotype.—Echinocentrotus pusillus (O.F. MÜLLER) CHECCHIA-RISPOLI, 1907, expl. pl. 17, figs. 40-44.

Small, elongate to rounded, moderately flattened to somewhat inflattened; oral surface flat to concave around peristome; edge usually tumid, more rarely almost sharp. Petals (or subpetals) of approximately equal length, usually widely open,

sometimes poorly defined; pores of each pair usually stand very obliquely, pore-pairs not conjugate; interporiferous zone with a varying number of tubercles usually irregularly arranged; accessory pores in most species very indistinct; adorally there are two larger pores in each ambulacrum, from which the buccal tentacles issue. Apical system central or subcentral, not distinctly limited, genital and ocular plates fused; hydropores few in number, often only one, not in a groove. Peristome central, round or elongate pentagonal, often conspicuously sunken. Buccal membrane entirely naked. Peristome close to peristome, situated at junction between first and second pair of post-basicornal plates, usually covered with five or six large, naked, radiating plates and at times some additional small plates. Primary tubercles in general spread without any distinct order, more or less distinctly scrobiculate; glassy tubercles scattered irregularly among the primaries; miliary tubercles spread in considerable number irregularly between the primaries. Primary radioles simple, finely thorny or smooth; miliary radioles smooth, widened distally into a small crown. Pedicellariae of the ophicephalous, tridentate, and tridhyllous types, the two latter very scarce and difficult to find; no globiferous pedicellariae. No spicules in tube-feet. Five pairs of internal radiating partition walls, which may continue to auricles or be much shorter (mainly after MORTENSEN, 1948-c, and DURHAM, 1955).

From the Upper Cretaceous (Senonian) to Recent, world-wide as fossils, living in European Seas and Indo-Pacific Oceans.

The interchange of the two names *Echinocyamus* and *Fibularia* introduced by LAMBERT (1891, pp. 749-752) was met with protest by COTTEAU (1889-94 (92), p. 349), LORIOL (1897-a, p. 8), MORTENSEN (1907, pp. 38-39.—1910-a, p. 120.—1932-e, pp. 351-353.—1948-c, pp. 170-175), and DURHAM (1955, p. 133). Their arguments seem to the writer to be sufficient to dispose of LAMBERT's unwelcome attempt to upset the hitherto usage of the two names, and there is no need of repetition here. But that interpretation of LAMBERT, as stated by DURHAM (1955, p. 134), has produced an unfortunate situation in the literature, and most species, particularly of fossil forms, referred to the genera *Fibularia* and *Echinocyamus* between 1891 and 1948 have to be reexamined for correct generic allocation.

The species of this genus are world-wide in their geographical distribution, although they are not yet known from the East Coast of the Japanese Islands. There are nearly eighty species hitherto described under this genus, of which about sixteen are living species including a fair number in the Pacific Ocean.

There are two fossil representatives of the genus *Echinocyamus* in our collection.

Echinocyamus crispus MAZZETTI, 1893

(Text-figs. 30 [5]a-d)

Echinocyamus crispus MAZZETTI, 1893, p. 239, pl. 13, figs. a-d.—MAZZETTI, 1894, p. 215.—
 MEIJERE, 1904, p. 105, pl. 6, figs. 48-50, pl. 18, figs. 300.—H. L. CLARK, 1914, p. 62.—
 Fibularia crispa (MAZZETTI) LAMBERT and THIÉAY, 1914, p. 292.—Echinocyamus crispus MAZZETTI: KOEHLER, 1922, p. 137, pl. 12, figs. 16-17, 21.—Fibularia crispa (MAZZETTI):
 JEANNET and MARTIN, 1937, p. 239.—Echinocyamus crispus MAZZETTI: MORTENSEN, 1948-b, p. 107.—MORTENSEN, 1948-c, p. 185 (complete synonymy), pl. 46, figs. 46-47, 55, text-figs. 112a.—MORISHITA, 1953-a, p. 61, pl. 6, fig. 1.—MORISHITA, 1954-a, p. 225.—

Morishita, 1960, p. 56.—Nisiyama, 1965, pp. 78, 85.

Echinocyamus elongatus H. L. CLARK, 1914, p. 61, pl. 126, figs. 9-11.—H. L. CLARK, 1925, p. 165.
 —Fibularia elongata (CLARK) LAMBERT and THIÉRY, 1925, p. 577.—Echinocyamus elongatus
 H. L. CLARK: DURHAM, 1955, p. 83, text-fig. 8k (reproduced from H. L. CLARK, 1914).

Locality and geological horizon.—Plateau above Kami-Katetsu, Kikai-jima Ôshimagun, Kagoshima Prefecture (Ryukyu Islands). Ryukyu Limestone, Pleistocene. Hypotype.—IGPS coll. cat. no. 73756.

There are eighteen specimens referable to this species at the writer's disposal, ranging from 3 mm to 7.5 mm in longitudinal diameter. A well preserved specimen is 6 mm in logitudinal diameter, 4.8 mm in transverse one, and 2 mm height.

Test rather high, oval in marginal outline, more constricted in the anterior than the posterior part, which is well rounded. Transverse diameter being 0.8 of the longitudinal, widest point situated at about the line through the distal ends of posterolateral ambulacra (I and V). Aboral surface markedly arched to the summit, highest point situated at the posterior part of the apical system; in longitudinal profile, the anterior slope almost equal to the posterior, or slightly more arched anteriorly; in transverse profile, arched in regular form from the thick margin. Oral surface markedly concave orally, particularly the peristome deeply sunken, and the test posterior to the peristome decidedly concave.

Apical system situated at about 3 mm from the anterior margin or slightly eccentric anteriorly, with four genital pores markedly larger than the ambulacral pores. Anterior pair of genital pores (2 and 3) placed closer together than the posterior genitals (1 and 4); a madreporic pore situated at a little posteriorly between anterior pair of genital pores (2 and 3), and smaller than a genital pore. Ocular pores visible, though very minute, that of the frontal ocular (III) placed more outward than that between the anterior pair of genital pores (2 and 3), those of antero-lateral oculars (II and IV) stand midway between genitals of 1 and 2 and that of 3 and 4, respectively; but far apart from the center and consequently wider apart than the anterior of genital pores. Postero-lateral ocular pores (I and V) placed posteriorly than the posterior pair of genital pores (1 and 4), and far away from the center.

Frontal petal (III) about 1.5 mm in length and about 0.5 mm in breadth, with 7 or 8 pore-pairs on each side, slightly curved inwards near the distal end. Pairs of pores slightly oblique, and the obliquity increases toward the distal end of poriferous zone. Antero-lateral petals (II and IV) slightly over 1.0 mm in breadth, have about 7 pore-pairs on each side, slightly curved inward as in the frontal petal. Postero-lateral petals (I and V) slightly over 1.0 mm in breadth, about 7 pore-pairs on each side; pores as in the frontal petal.

There are many evident keel-like ridges with accessory pores proximally on the ambulacra on aboral surface, those on the postero-lateral ambulacra (I and V) most prominent, alternating with each other, and numbering about four or more ridges on each side. Ridges on the antero-lateral ambulacra (II and IV) moderately developed, and those on the frontal ambulacrum (III) not so prominent and rather faint.

Peristome situated at the center, 3 mm from the anterior margin; pentagonal in outline, measures over one mm in longitudinal diameter and also in transverse one, very markedly concave orally.



Periproct small, round or slightly elongate transversely, placed at about midway between posterior margin and the peristome, less than half as large as peristome.

Tuberculation of test rather coarse and large, larger than the genital pores. Glassy tubercles insignificant.

Radiating partition walls within the the test well developed, all of which exactly reach the peristomial region, and well define the interambulacra. Auricles rather broad, high and situated at each interambulacrum, where they are united with radiating partition walls. Ambulacra more than twice as wide as the interambulacra at the ambital region.

Although this species was originally described from the Red Sea, it seems to be common in the East Indies, where the "Siboga" and "Investigator" took this species at many stations. It probably spreads more eastwards down to Quam and Hawaii Islands under the name *elongatus* H. L. CLARK, 1914. The "Albatross" took the species at many stations in the Philippines, furthermore MORTENSEN (1948-c, p. 48) and UTINOMI (1954, p. 353) reported the occurrence of this species as far north as southern Japan, about North 33° latitude.

Fossils of this species were reported from the Pleistocene of Ceram by JEANNET and MARTIN (1937, p. 239), and this is the first record of fossil from the Ryukyu Islands.

Echinocyamus prostratus NISIYAMA, n. sp. (Text-fis. 31 [6]a-d)

Holotype.—IGPS coll. cat. no. 73757. Locality and geological horizon.—Plateau

above Kami-Katetsu, Kikai-jima, Ôshima-gun, Kagoshima Prefecture (Ryukyu Islands). Ryukyu Limestone (Pleistocene).

There are six specimens referred to this new species at the writer's disposal, ranging from 4.5 mm to 8 mm in longitudinal diameter.

Test low, flat, oblong, rather narrow, elongated oval in marginal outline, slightly

more contracted in anterior part than the posterior; posterior interambulacrum (5) slightly protuberance posteriorly, so there are slight but distinct notches on the margins corresponding to the postero-lateral ambulacra (I and V). Widest of transverse diameter situated at margin about one-third from the posterior end. Aboral surface slightly arched to the apex from margin of test, highest point situated at just posterior of the apical system; in longitudinal profile, anterior slope somewhat straighter or less arched than the posterior slope, posterior part arched more rapidly from margin, thicker and tumider than the anterior; in transverse profile, test slightly arched in regular form from the relatively thick margin, and its outline approaches crescent above the marginal contour of test. Oral surface flattened somewhat along the longitudinal median area, and slightly concave orally at least from periproct to peristome. Margins of adoral surface rounding onto side, which are more or less round.

Dimensions of holotype.—8 mm in longitudinal diameter, 5 mm in transverse one, and about 2 mm in height.

Apical system rather small, markedly arched above, four genital pores decidedly larger than the ambulacral pores, situated at over 4 mm from the anterior extremity and slightly eccentric to posterior. Anterior pair of genital pores (2 and 3) placed closer together, 0.4 mm across, than the posterior pair (1 and 4), which 0.8 mm across. There is a small pore posterior to between the anterior pair of genital pores, it is probably a madreporic pore. Ocular pores exceedingly minute, only visible under high magnification and by careful examination.

Petals rather broad, short, subequal, and rudimentary. Poriferous zones almost



Fig. 31 [6]. Echinocyamus prostratus NISIYAMA, n. sp., ×7.3. a. Aboral view; b. Oral view; c. Internal view; d. Side view.

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straight, broad in their course, and outline slightly petaloid. Frontal petal (III), 2 mm long and 0.6 mm wide, slightly incurved at the tip; pores round, subequal, or with. outer pore of a zone slightly larger, pores of a pair being wide apart, with no trace of conjugation. Pairs of pores slightly oblique, amount of obliquity increases towards. distal end of the poriferous zone. Inner pores of companion zone form vertical series. parallel with one another, interporiferous zone consequently of relatively uniform width, which slightly raised than the poriferous zones. Antero-lateral petals (II and IV) having seven or eight pore-pairs in each side, about 1.6 mm long by 0.6 mm wide, slightly incurved at distal end as in the frontal, but relatively narrower than that. Postero-lateral petals (I and V), 2 mm long and 0.6 mm wide, having eight or nine pore-pairs on each side; pores as in the frontal petal.

Peristome situated at centre, 4 mm from the anterior margin, elongated pentagonal in outline, elongated longitudinally, one mm in longitudinal diameter and 0.7 mm in transverse one, and slightly concave orally.

Periproct very large, elongated oval in outline, placed longitudinally, situated at about midway between posterior margin and peristome, one mm in longitudinal diameter, and 0.5 mm in transverse one. Length twice the breath, and the length about as same as diameter of inner margin of the peristome.

Tuberculation on the test rather large, consists of small primary tubercles sunken in deep scrobicules irregularly distributed over each surface. Primary tubercles more or less larger than genital pores, and glassy tubercles insignificant.

Radiating partition walls within the test fairly well developed, a pair of the posterior interambulacrum (5) well rounded the periproct, but those of other interambulacra scarcely reached the peristomial region. Auricles rather narrow, decidedly narrower than those of *Ech. crispus* (loc. cit.), but relatively high. Ambulacra more than twice as wide as interambulacra at the ambital region.

Distinction.—This new species occurs meet with *Ech. crispus*, but is easily distinguished from the latter species, even in *elongatus*-type, by the elongated periproct, the flatness of the aboral surface and flattened oral surface, which of the latter evenly concave orally.

This is the most distinct and easily recognized species among the genus *Echino-cyamus*, and the large and much elongated oval periproct placed longitudinally, the produced posterior interambulacrum (5) and notches of the postero-lateral ambulacra. (I and V) form a notable combination of characters of this species.

This species has a peculiar form of the periproct as that of *Cyamidia nummulitica* (DUNCAN and SLADEN, 1884) (*Echinocyamus nummuliticus* DUNCAN and SLADEN, 1884, p. 132, pl. 25, figs. 14-20), from the Nummulitic Series (Eocene) of India, but it is regrettable that DUNCAN and SLADEN sliped to describe the internal structure of that species. This species is also distinguished from that species by having a narrower and more flattened test. This species also superficially resembles *Fibularia* (*Fibulariella*) *acuta* YOSHIWARA, 1898 (YOSHIWARA, 1898, p. 57.—TOKUNAGA, 1903, p. 7, pl. 2, figs. 5-6), from the Japanese Seas, but is easily distinguished from that species by having the radiating partition walls within the test when the interior of test is clearned.

Genus Fibularia LAMARCK, 1816

Fibularia LAMARCK, 1816, p. 16.—BLAINVILLE, 1830, p. 192.—DESMOULINS, 1835-37 (35), p. 186.—AGASSIZ, 1836, p. 186 (19).—AGASSIZ and DESOR, 1846, p. 142.—GRAY, 1855-a, p. 28.—DESOR, 1855-58 (57), p. 220.—A. AGASSIZ, 1872-74 (73), p. 506.—POMEL, 1883, p. 73.—Duncan, 1889-a, p. 146.—COTTEAU, 1889-94 (92), p. 390.—MORTENSEN, 1907, p. 38.—H. L. CLARK, 1911, pp. 598, 605.—H. L. CLARK, 1914, p. 56.— KOEHLER, 1922, p. 132.—H. L. CLARK, 1925, p. 162.—MORTENSEN, 1932-e, pp. 351-355.—H. L. CLARK, 1946, p. 347.—MORTENSEN, 1948-c, p. 203 (complete synonymy).—TERMIER and TERMIER, 1953, p. 924.—DURHAM, 1955, p. 132, text-figs. 5d, 6g.—KIER, 1957, p. 870.—COOKE, 1959, p. 30.

Logotype.—Fibularia ovulum LAMARCK, 1816, p. 17.—A. AGASSIZ, 1872-74, p. 507, pl. 13e, figs. 1-3 (Indian Ocean). [AGASSIZ and DESOR, 1847, p. 140.—Bull. Zool. Nomencl., 1950, vol. 4, p. 519].

Echinocyamus van Phelsum: Lambert, 1891, p. 749.—Lambert and Thiéry, 1914, p. 287. Logotype.—Echinocyamus craniolaris Leske, 1778, p. 214. [Lambert and Thiéry, 1914, p. 287].

Test small, inflated, elongate ovate to sub-circular. Apical system small, central, with large madreporite. Petals often very slightly developed, open, with few porepairs. Pores non-conjugate, usually oblique. Peristome usually rounded, often sunken; periproct small, usually rounded, on oral surface close to peristome. No internal radiating partitions or walls. Hydropores only one or two, placed in a small, sunken groove. Buccal membrane naked. Five large periproctal plates. Usually lacking accessory and buccal pores. Tube-feet without calcareous disc. Radioles as in *Echinocyamus* (mainly after KIER, 1957, and DURHAM, 1955).

From the Upper Cretaceous (Senonian) to Recent.

Fibularia is very similar to Echinocyamus. The main difference between this genus and Echinocyamus is the total absence of internal radiating partition walls. In general the shape is higher, more globular, or it is elongate, more or less pointed in both ends; but the shape does not give a reliable distinction between the two genera. In Fibularia there are usually no accessory pores, except only one case—Fib. nigeriae HAWKINS, 1912 (HAWKINS, 1912-c, pp. 297-301)—it has accessory pores. The presence of both accessory pores and radiating partition walls, as described by KIER (1957, p. 859), seems to be related to one another.

As to the name of the type-species, H. L. CLARK (1914, p. 57) took regrettable step of changing the hitherto unanimously used the name *ovulum* LAMARCK to name *craniolaris* LESKE, and latter writers have adopted the name *craniolaris* without going critically into the matter (as it was to the writer as one of authors). In studying this nomenclatorial question on carefully, MORTENSEN (1948-c, p. 108) found that LESKE's fourteen names based on the figures of VAN PHELSUM, including *craniolaris*, are reality only one and the same species, and all the other thirteen nominal species are synonyms of *Echinocyamus pusillus* (O. F. MULLER, 1776), from the Adriatic Sea and the type-species of the genus *Echinoyamus*. The LAMARCK's second species, *Fib. ovulum* (p. 17), is characterized as being of the high type, which is in all later echinelogical literatures (up to LAMBERT) designated as *Fibularia*.

This genus dates from the Upper Senonian, one of the oldest occurrence among the order, and ranges to the Recent seas, and is confined chiefly to the East Indian regions and the Pacific in the Recent distribution, ranging from Japan to Australia, but a few are also known from the Red Sea.

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Fibularia cribellum MEIJERE, 1904

Fibularia cribellum MEIJERE, 1904, p. 112, pl. 6, figs. 53-54, pl. 18, figs. 313-314.—H. L. CLARK,.
1914, p. 58.—Echinocyamus cribellum (MEIJERE) LAMBERT and THIERY, 1914, p. 288.—
Fibularia cribellum MEIJERE: KOEHLER, 1922, p. 139, pl. 22, fig. 20.—Echinocyamus cf.
cribellum (MEIJERE): JEANNET and MARTIN, 1937, p. 238.—Fibularia cribellum MEIJERE:
MORTENSEN, 1948-b. p. 109.—MORTENSEN, 1948-c, p. 212, pl. 46, figs. 19-20, text-fig. 95.

Locality and geological horizon.—Plateau above Kami-Katetsu, Kikai-jima, Ôshimagun, Kagoshima Prefecture (Ryukyu Islands). Ryukyu Limestone, Pleistocene. Hypotype.—IGPS coll. cat. no. 73755.

There are five specimens referable to this species at the writer's disposal, ranging from 3.5 mm to 5 mm in longitudinal diameter.

Large specimen measures 5 mm in longitudinal diameter, 4 mm in transverse one, and 2 mm in height. Test high, height about two-fifths of longitudinal length, oval in marginal outline, contracted in anteriorly than posteriorly, which is well rounded. Transverse diameter being about 0.8 of the longitudinal, widest point situated at about one-fourth from the posterior extremity. Aboral surface arched to the summit, highest point situated just posterior to the apical system; in longitudinal profile, posterior slope more arched than the anterior; in transverse profile, both slopesarched in regular form from inflated margin. Oral surface somewhat concave to the peristome and anterior part more or less rounded.

Apical system large, situated at about 2.5 mm from the anterior margin, with. four genital pores, which much smaller than the ambulacral pores; madreporite with only one hydropore placed at a little posteriorly between anterior pair of the genital pores (2 and 3); ocular pores not observable.

Ambulacral pores large, round in shape, decidedly larger than the genital pores, flush on aboral surface and petals not well defined; ambulacral pores very few in number, total number being 30 in all subpetals together; there are no rows of accessory pores.

Peristome situated at centre, 2.5 mm from the anterior margin, rounded decagonal in outline, slightly elongated longitudinally, about 0.8 mm in longitudinal diameter.

Periproct small, rounded-oval in outline, slightly elongated transversely, 0.5 mm in transverse diameter, placed at about midway between posterior margin and the peristome.

Tuberculation on the test rather coarse and large, primary tubercles as large as or slightly larger than the genital pores. Glassy tubercles insignificant.

No radiating partition walls within the test; auricles broad and high. Ambulacra nearly twice as wide as the interambulacra at the ambital region; interambulacral plates near the ambital region high, hexagonal in form; ambulacral plates somewhat lower and decidedly broader than the interambulacral plates.

This small species is well characterized by its few but large rounded pores of the subpetals and does not appear to grow longer than seven mm in longitudinal diameter. *Fib. cribellum* resembles *Fib. volva* AGASSIZ, 1846 (AGASSIZ and DESOR, 1846, p. 142.—H.L. CLARK, 1921, p. 151, pl. 35, fig. 6.—MORTENSEN, 1948-c, p. 213, pl.

46, fig. 5, text-fig. 117b (the type)), a Recent species of East Indies, but the typelocality uncertain—probably the Red Sea; but is distinguished from that species by having the fewer and larger ambulacral pores, and by the more oval form of test. This species also much resembles *Fib.* (*Fibulariella*) angulipora MORTENSEN, 1948 (MORTENSEN, 1948, p. 72.—MORTENSEN, 1948-c, p. 22, pl. 46, figs. 21-25, pl. 56, figs. 5-6, text-fig. 95), from the Gulf of Siam, in the form of test and in the feature of petals, but differs from that species in having the rounded ambulacral pores, in that species ambulacral pores marked!y triangular, and the only one madreporic pore (hydropore), in that species several madreporic pores.

This species seems to be common in the Malay region, from Sulu Sea to Timor Sea, and Kei Islands, where the "Siboga" and "Investigator" took the specimens at many stations, and it spreads more northwards to the Philippines, where the "Albatross" collected the species at stations. Bathymetrical range of this species is recorded from 15 to 400 metres, very rarely down to 522 metres in depth.

The fossils referred to this species were reported from Pleistocene of Ceram by JEANNET and MARTIN (1937, p. 238), and this is the first record of fossil in northern hemisphere.

Subgenus Fibulariella MORTENSEN, 1948

Fibulariella Mortensen, 1948, p. 72.—Mortensen, 1948-c, p. 219.—Durham, 1955, p. 133 (genus).

Orthotype.—Fibularia acuta Yoshiwara, 1898, p. 57.—Yoshiwara (Токимада), 1907, pl. 14, figs. 3-4 (Japan, Recent).

Similar to *Fibularia*, in general characters of test, but differs from it in having the periproct usually elongate, and periproct being covered with small irregular plates. Hydropores may be several isolated pores, ca. 8-10, scattered irregularly over anterior part of apical system, not in a groove. Buccal membrane contain (or covered with) numerous small plates. Tube-feet contain a small, but well developed calcareous disc. Globiferous pedicellariae of peculiar type present, but ophicephalous pedicellariae (apparently) lacking (mainly after MORTENSEN, 1948-c, and DURHAM, 1955).

The type-species, *Fib. acuta* YOSHIWARA, 1898, together with *Fib. marioi* COTTEAU, 1895 (COTTEAU, 1895, p. 19, pl. 3, figs. 11-14) are referred to *Thagastea* POMEL, 1888 (p. 100), by LAMBERT and THIÉRY (1914, p. 288), but the two species have no distinct groove in the frontal ambulacrum (III) on oral surface, the presence of it is said to be the character of *Thagastea*.

The characters of this subgenus can be safely apply to the living specimens which have still buccal membrane, tube-feet, and pedicellariae, but in fossil state it would be difficult to differentiate from *Fibularia*. However, if well-preserved denuded test or fossil specimens are available, the features of hydropores and periproct should be recognizable.

Fibularia (Fibulariella) acuta YOSHIWARA, 1898

(Pl. 13, figs. 3-4, 11, text-figs. 32 [7]a-b)

Fibularia acuta Yoshiwara, 1898, p. 57.—Yoshiwara, 1899, p. 4.—Yoshiwara, 1900, p. 387 (in Japanese).—Echinocyamus acutus (Yoshiwara) Lambert, 1899, p. 121.—Fibularia

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acuta YOSHIWARA: TOKUNAGA, 1903, p. 7, pl. 2, figs. 5-6.—Echinocyamus acutus (YOSHIWARA): LAMBERT, 1904-a, p. 148.—Fibularia acuta YOSHIWARA: YOSHIWARA (TOKUNAGA), 1907, pl. 14, figs. 3-4.—Echinocyamus (Thagastea) acutus (YOSHIWARA): LAMBERT and THIÉRY, 1914, p. 288.—Fibularia acuta YOSHIWARA: H. L. CLARK, 1914, p. 58, pl. 126, figs. 1-4 (type).—Thagastea acuta(YOSHIWARA) COLLIGNON and COTTREAU, 1927, p. 144 (12).—Fibularia acuta YOSHIWARA: NISIYAMA, 1937, p. 55.—Fibularia (Fibulariella) acuta YOSHIWARA: MORTENSEN, 1948, p. 72.—Fibularia acuta YOSHIWARA: MORTENSEN, 1948-b, p. 109.—Fibularia (Fibulariella) acuta YOSHIWARA: MORTENSEN, 1948-c, p. 219 (complete synonymy), pl. 46, figs. 27-28, pl. 69, figs. 3-4, 9, 11, 14, text-figs. 104d, 125.—TOKIOKA, 1953, p. 146 (24), text-figs. 1-2.—UTINOMI, 1954, p. 353.

Locality and geological horizon.—IGPS loc. no. Ch-32.—Road-side cutting at Kawaguchi, Narita-machi, Inba-gun, Chiba Prefecture (tm Narita, Lat. 35°47'N., Long. 140°20'E.). Narita formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 15178.

Locality and geological horizon.—IGPS loc. no. Ty-13.—Takinokawa, Kita Ward, Tokyo Prefecture (tm Tokyo Tôhoku-bu (Tokyo Northeast), Lat. 35°44′26″N., Long. 139°45′34″E.). Tokyo formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 7135.

Locality and geological horizon.—IGPS loc. no. Ch-31.—Road-side cutting at Hossaku, Kioroshi-machi, Inba-gun, Chiba Prefecture (tm Sakura, Lat. 35°49′42″N., Long. 140°07′34″E.). Narita formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 27454.

There are more than thirty specimens referable to this species at the writer's disposal, ranging from 3.5 mm to 8 mm in longitudinal diameter.

Large specimen measures 7.5 mm in longitudinal diameter, slightly less than 5 mm in transverse one, and about 2.5 mm in height. Test low, height about one-third of longitudinal diameter, oval in marginal outline, constricted in anterior part than the posterior, which varies pointed to well rounded. Transverse diameter being 0.65 of the longitudinal, widest length situated at about one-third from the posterior extremity. Aboral surface not arched, more or less flat, highest point situated just anterior to the apical system; in longitudinal profile, posterior slope somewhat lower and shorter than the anterior slope; in transverse profile, both slopes gradually raised to the summit from rather thick margins. Oral surface more or less concave to the peristome, apart from the periproct to posterior margin somewhat rounded.

Apical system situated about 3 mm from the anterior margin, somewhat eccentric in front, with four genital pores, which as large as or more or less larger than the



Fig. 32 [7]. Test structure of *Fibularia (Fibulariella) acuta* Yoshi-WARA, 1898.

a. Structure of aboral surface, ×2.8.b. Structure of oral surface, ×2.8.

ambulacral pores; madreporic pores (hydropores) numerous, about 10 in number; ocular pores as usual.

Frontal petal (III) rather well defined; pores of the petal small, usually smaller than genital pores; the longest of all petals, over half the test-radius, diverging greatly and much open distally, with about 6 pore-pairs in each poriferous zone; pore-pairs very oblique (Text-fig. 32 [7]a). Antero-lateral petals (II and IV) short, with about 5 pore-pairs in each poriferous zone, the pore-pairs oblique as in the frontal. Postero-lateral petals (I and V) with about 6 pore-pairs in poriferous zone, and extending about half the test-radius.

Peristome situated at near centre, 3.5 mm from the posterior margin, rounded decagonal in outline, slightly elongated longitudinally, about 1.2 mm in logitudinal diameter.

Periproct small, scarcely half the peristome or less, more or less elongated longitudinally, 0.6 mm in longitudinal diameter, close to peristome, situated at junction between basicoronal and first pair of post-basicoronal plates, about one-fourth of testradius from the peristome (Text-fig. 32 [7]b).

Tuberculation rather coarse, primary tubercles much larger than the genital pores; no prominent tubercles near the peristomial region.

This species now living northern (e.g., Miyako Bay in Sanriku Coast), central (Sagami Bay) and western Japan (Kyushu), and southwards as south as Bonin Islands and Formosan Channel or to the Philippines, in down to 75 metres depth. The original figures of YOSHIWARA (TOKUNAGA) (TOKUNAGA, 1903, pl. 2, figs. 5-6) represent more or less pointed both ends of test, but another figures of H. L. CLARK (1914, pl. 126, figs. 1-4, from Kyushu, one of the syntypes) and figures of TOKIOKA (1953, text-figs. 1-2) show test having the rounded posterior end. The forms from western Japan slightly differ from those from central Japan in the marginal outline of test. The forms from northeastern and northern Japan (e.g., Miyako Bay, Sendai Bay, and near Kyuroku-shima in the Japan Sea) can be discriminative as a local subspecies (or variety) in having the clearly pointed posterior end and more regular arrangement of primary tubercles on the test, particularly on the petaloid area, and here names the form as *Fibularia (Fibulariella) acuta septemtrionalis* (Pl. 13, figs. 5, 12).

Genus Sismondia DESOR, 1857

Sismondia DESOR, 1855-58 (57), p. 225.—DUJARDIN and HUPÉ, 1862, p. 556.—POMEL, 1883, p. 72.—DUNCAN and SLADEN, 1884, p. 137.—COTTEAU, 1889-94 (91), p. 261.—DUNCAN, 1889-a, p. 145.—OPPENHEIM, 1901, p. 90.—LAMBERT and THIÉRY, 1914, p. 296.—NISIYAMA, 1937-a, p. 41 (foot-note).—H. L. CLARK, 1946, p. 350.—MORTENSEN, 1948-c, p. 234 (complete synonmy), text-figs. 145a-d, 146, 147a-b, 148, 149a-c, 150.—TERMIER and TERMIER, 1953, p. 925.—DURHAM, 1955, p. 141, text-fig. 31b.

Logotype.—Scutella occitana DEFRANCE, 1827, p. 231 (Eocene of Manche).—Sismondia occitana (DEFRANCE): COTTEAU, 1889-94 (91), p. 272, pls. 271-272, pl. 273, figs. 1-6 [POMEL, 1883, p. 72.—LAMBERT and THIÉRY, 1914, p. 296].

Sismondaea MAYER-EYMAR, 1897, p. 2.

Logotype.—Sismondaea macrophylla MAYER-EYMAR, 1897, p. 2, pl. 3, fig. 1 (Eocene of Egypt). (Here definitely designate).

Small to medium size, ovoid or subpentagonal, moderately flattened, but usually with margins thickened; oral surface slightly concave, apical system rarely raised. Petals distinct and long, moderately open, somewhat lyrate, length about three-fourths or more the corresponding radius; pore-pairs usually conjugate, outer pore moderately elongate. Apical system central, with four genital pores, hydropores in a groove (in type-species), or one. Peristome central, somewhat pentagonal, in a slight depression; oral ambulacral furrows more or less distinct or indistinct. Periproct on oral surface, close to peristome, a single pair of plates between periproct and basicoronal row (in type-species). Ambulacra about three times as wide as interambulacra at ambitus. Basicoronal plates of moderate size, forming a well-defined star, interambulacral plates larger than ambulacral plates. About eight post-basicoronal ambulacral plates to a column on oral surface (in type-species). Strong more or less branching, internal radiating partition walls (from DURHAM, 1955, and MORTENSEN, 1948-c).

From the Eocene to Miocene.

In his study of the Clypeasteroid genera, DURHAM (1955, pp. 139, 141) referred this genus to the family Laganidae rather than to the Fibulariidae as formerly referred to. He regarded that the features characterized by the type-species, *Sis. occitana*,—the specialized basicoronal plates in a star, the conjugate pore-pairs in the petals, the hydropores in a groove, and the incipient concentric internal supports all indicate that it is a primitive member of the Laganidae. It is a fact that *Sismondia* shows an incipient complication of the internal skeletal supports a closer relation between it and the Laganidae, but it can hardly be the direct ancestor of the Laganidae on the evidence of geological occurrence of them.

This is an extinct genus dates from the Eocene and diminishes in the Lower Miocene, in Europe, Africa, India, Asia, Indo-Pacific, and Australia, with comprising about twenty species. This genus differs from Echinocyamus in having the more definite plating of the apical system, the longer and more definite petals, and in the pore-pairs connected by a groove. Furthermore, the test of Sismondia is flatter and more pentagonal, although in some of Echinocyamus the shape of the test may approach that typical of that genus. But, the distinction of this genus from Echinocyamus is somewhat dubious in certain point. In his study of the Tertiary Echinoidea, KIER (1957, pp. 859-870), after the examination of numerous specimens, claimed that the Eocene-Oligocene species, Sis. polymorpha DUNCAN and SLADEN, 1884 (1884, p. 137, pl. 25, figs. 1-13) could not be classified into this genus, but should be into Echinocyamus. He stated (1957, p. 862) that the supposed conjugate pore-pair in the Indian original specimens may have mistaken the horizontal sutures between the ambulacral plates, which pass through the pores, for conjugation furrows. The specimens from the Miocene formation in our collection seem to be having the similar furrows in the poriferous zones. However, they are provisionally classified into the genus Sismondia.

Sismondia convexa NISIYAMA, 1937

Sismondia convexa NISIYAMA, 1937-a, p. 41, text-figs. 1-13 on page 44.

Locality and geological horizon.—Minami-zaki, Chichi-jima (Peel Island), Bonin Islands. Eulepidina-Limestone. Lower Miocene (Aquitanian). Holotype.—IGPS coll. cat. no. 7100a. Paratypes.—IGPS coll. cat. no. 7100b. Hypotype.—IGPS coll. cat. no. 60325.

This is, beyond doubt, one of the best defined species in the genus *Sismondia*, and is characterized by much convex form and the ambital margin of test, form of the petaloid area, mode of occurrence of the accessory pores along the adapical sutures of the ambulacral plates, all which form a notable combination of characters. The convexity of this species does not seem to have been effected by either outer physiological or by pathological deconstruction phenomena, as being the arrangement.

of the coronal plates or the petaloid area very regularly placed and there are no traces of fracture on the tests. In regarding the convexity of test only, this species simulates *Porpitella supera* (AGASSIZ, 1841) (*Scutellina supera* AGASSIZ, 1841-b, p. 103, pl. 21, figs. 15-19.—*Porpitella supera* (AGASSIZ) POMEL, 1883, p. 72.—Eocene of Grignon), thus suggesting "parallelism" in development subject to environmental influences and not an indication of genetic connection. *Sismondia convexa* seems to be the nearly final representative of the genus.

Considerable variation occurs in the specimens at the writer's disposal in the shape of the marginal outline of the test. The change seems to be apparently related to both size and developmental stage. The ambital outline may assume almost any form from rounded-ovoid as in the small existing *Echinocyamus platytatus* H. L. CLARK, 1914 (1914, p. 27, pl. 123, figs. 13-16, pl. 127, figs. 1-6) (in small specimens), to decagonal-ovoid, characteristic of the living sea-urchin *Clypeaster japonicus* DÖDER-LEIN, 1885 (loc. cit.) and *Cly. europacificus* H. L. CLARK, 1914 (1914, p. 27, pl. 123, figs. 13-16, pls. 129-131, 136, fig. 1), but much smaller (in large specimens). Since all coronal plates have undergone considerable changes in size, and often in shape, during the growth of the test.

Sismondia javana ladronensis NISIYAMA, n. subsp.

(Pl. 13, figs. 6, 8-10, 13-16, pl. 14, figs. 3-8)

Sismondia polymorpha DUNCAN and SLADEN?: COOKE, 1957, p. 362, pl. 119, figs. 9-13.

Holotype.—IGPS coll. cat. no. 73737.

Locality and geological horizon.—In a doliné at Denshin-yama, Saipan Island, Micronesia, South Sea Islands. Tagpochau formation, Miocene (*Eulepidina-Spiroclypeus* horizon; *Sismondia* zone). Holotype and paratypes.

Locality and geological horizon.—Tanapako, western slope of Denshin-yama, Saipan Island, Micronesia, South Sea Island. Donney (Tagpochau) formation, Miocene (*Eulepidina*-horizon). Hypotype.—IGPS coll. cat. no. 73738.

There are thirty-three specimens referred to this new subspecies at the writer's disposal, ranging from 3.5 mm to 12 mm in longitudinal diameter.

Holotype measures 15.5 mm in longitudinal diameter, 10 mm in transverse one, and 2.5 mm in height. Test stout, depressed, subovoid in marginal outline, with a tendency towards pentagonal, slightly contracted anteriorly and feebly truncated posteriorly. Aboral surface more or less nearly plane, excepting for slightly raised petals, and sloping slightly from the highest point to thick and well rounded margin. Oral surface more or less concave and regularly depressed around the peristome.

Petaloid area rather large, its total length about 8 mm long; petals subequal, about 3 mm long and 1.8 mm wide, open by a millimeter at their distal ends, poriferous zones (15-16 pore-pairs on each side) rather broad, broadest near middle of petals, outer poriferous zones a little convergent near their bases and then somewhat divergent distally, inner zones of poriferous zones usually slightly divergent throughout; pores round or ovoid in shape, pairs slightly oblique and connected by a shallow groove (horizontal suture between the ambulacral plates); interporiferous zones broad,

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over about twice that of the poriferous zones at the widest part; interporiferous zones raised, particularly in the postero-lateral petals (I and V), and there are about four longitudinal series of primary tubercles on median area of the interporiferous zones; minute (accessory) pores in petals scarcely observable, few in number, 3 or 4, and arranged in a row near adapical sutures of the plates.

Apical system eccentric in front, about 4.5 mm from the anterior margin of test; somewhat raised and small, tuberculated, with four genital pores close to interradial angles of the madreporite; ocular plates small and somewhat escutcheon-shaped with apex directed away from the center and occupy a place at junction of two neighbouring genital plates, so that the ocular pores placed further outer side than genital pores; large hydropore seems to be one, placed nearly a center of the system.

Peristome nearly central on oral surface, small and subdecagonal in outline, about 1 mm in diameter. Periproct round, about 0.7 mm in diameter, situated just midway between peristome to the posterior margin, probably a single pair of plates between periproct and basicoronal row, as usual. Tuberculation rather sparse, appearing imperforate, sunken in deep scrobicules, and primary tubercles larger than the ambulacral pores. Radiating partition walls within the test (in paratypes) well developed, stout and rather broad as in *Sis. javana*.

Distinction.—This new subspecies closely resembles Sis. javana GERTH, 1922 (GERTH, 1922, p. 502, pl. 62, figs. 4-4a.—JEANNET and MARTIN, 1937, p. 241, text-figs. 24-25), from the Lower Miocene formation of West Progo Mountains in Java, and probably conspecific with that species, but it differs from the typical species in having the borader and lower test, and by the raised and broader petals. This species also seems to be related to Sis. polymorpha DUNCAN and SLADEN, 1884 (DUNCAN and SLADEN, 1884, p. 137, pl. 25, figs. 1-13), from the Khirtar Series of western Sind in India. After an examination of numerous specimens from the Eocene formation of British Somaliland, KIER (1957, p. 859) referred that species to Echinocyamus, and recognized the developmental trend of that species-that towards a more elongate shape and a movement of the periproct towards the peristome. COOKE (1957, p. 363) also took Sis. polymorpha as a very variable and long ranged species-including Sis. murravica TATE, 1893 (TATE, 1893, p. 193, pl. 13, fig. 5.—DURHAM, 1955, p. 141, textfig. 27e), from the Miocene of Australia, Sis. javana (loc. cit.), and Sis. convexa NISI-YAMA, 1937 (loc. cit.), all probably become junior synonyms of that species-identified his specimens from the Miocene formation of Saipan Island with that species with a some suspension. But this subspecies is distinguished from that species by the position of the periproct—in that species the periproct is situated at junction between the second and third post-basicoronal interambulacral plates, whereas in this subspecies at junction between the first and second post-basicoronal interambulacralsit cannot be considered conspecific each other-notwithstanding the developmental trend of that species-, and the broader and lower test-contrasting the general trend of that species. This subspecies is also related to the young specimens of Sis. convexa, from the Miocene of Chichi-jima in Bonin Islands, but differs from that species in having the ovoidal form of test, the broader petals and more curved poriferous zones, and the raised interporiferous zones of petals. The three forms from the Lower Miocene, viz., Sis. javana, Sis. javana ladronenis, and Sis. convexa, in the West

Pacific region seem to be closely related and can be considered even conspecific one another, and they may flourished in the warm sea before their extinction.

Family LAGANIDAE DESOR, 1857

Laganes DESOR, 1855-58 (57), p. 216 (Tribe; pro parte).—Laganiens DUJARDIN and HUPÉ, 1862, p. 556 (partim).—Laganidae DESOR: A. AGASSIZ, 1872-74 (73), p. 516.—BELL, 1883, p. 130.—Laganiens POMEL, 1883, p. 69.—Laganidae A. AGASSIZ: DUNCAN, 1889-a, p. 156.—Laganidées Cotteau, 1889-94 (91), p. 248.—Laganidae A. AGASSIZ: GREGORY, 1900-b, p. 317.—MEISSNER, 1904, p. 1380.—H. L. CLARK, 1911, p. 604.—H. L. CLARK, 1914, p. 43.—Laganidae DUNCAN: LAMBERT and THIÉRY, 1914, p. 310.—Laganidae A. AGASSIZ: KOEHLER, 1922, p. 78.—H. L. CLARK, 1925, p. 155.—H. L. CLARK, 1946, p. 342.—MORTENSEN, 1948-c, p. 238 (complete synonymy).—TERMIER and TERMIER, 1953, p. 925.—Laganidae DESOR: DURHAM, 1954, p. 677.—DURHAM, 1955, p. 138.

Type-genus.— Laganum LINK, 1807.

Small to large forms; test flattened, seldom discoidal, outline varying from angulated to rounded, with a complicate structure of internal supports. Petals well developed, open, outer member of pore-pair slightly elongated, pores usually conjugate. Apical system central; genital pores four or five, exceptionally six; hydropores numerous. Peristome central; periproct on oral side between peristome and posterior edge of test. Oral ambulacral furrows simple, distinct, not reaching margin. Interambulacra continuous on oral surface, very narrow; adapical terminal interambulacral plate single, rhomboidal in outline. Basicoronal plates forming well-defined pentameral star with ambulacral plates at apices of rays; no abrupt change in size of oral post-basicoronal ambulacral plates. Ambulacral structure within the petals simple, "laganid" type. Primary radioles simple, short, with a regular axial canal; miliary radioles smooth, with a terminal crown. Pedicellariae of tridentate, triphyllous, and ophicephalous types. A single sphaeridium in each ambulacrum, wholly covered over. No spicules in tube-feet or internal organs. Larva with skeleton basket structure (mainly after MORTENSEN, 1948-c, and DURHAM, 1955).

From the Eocene to Recent.

The family Laganidae differ from the Neolaganidae, to which all the New World species referred (DURHAM, 1954), in having the simple plates in the petals and the basicoronal plates in a well-defined pentameral star, as well as the shape of the adapical terminal interambulacral plate. The main distinction between the Laganidae and the Fibulariidae is in the internal skeletal supports, that is simple radiating partition walls, or no internal skeleton at all in the Fibulariidae, and a more complicate skeletal supports in the Laganidae. It seems probable that the Laganidae, Eolaganidae, and the Fibulariidae may have evolved as three parallel stems from the common ancesters; otherwise the Laganidae and the Neolaganidae must have a different immediate ancestor from the Fibulariidae.

A historical sketch of the modern classification of the family Laganidae is as follows. H. L. CLARK (1911, p. 604.—1914, p. 43.—1925, pp. 155-162.—1946, p. 342) had under the family only two genera, viz., *Laganum* and *Peronella*. LAMBERT and THIÉRY (1914, pp. 310-314) had under their "subfamily" Laganidae a tribus Echinodiscinae including *Echinodiscus* and *Peronella*, and another tribus Rumphinae includ-

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ing the genera Merriamaster, Rumphia, Jacksonaster, and Laganum. The fossil Merriamaster is a only genus that additioned to the family by the two authors. Their division of Peronella into three genera, Echinodiscus, Peronella and Rumphia, and of Laganum into Jacksonaster and Laganum, seems to be based on a slight difference of the features. MORTENSEN (1948-c) had under the family the genera Laganum and Peronella, as already did so by H. L. CLARK. Finally DURHAM (1955, pp. 139-144) had under the family Laganidae the genera, Laganum, Peronella, Sismondia, Hupea, Peronellites, Rumphia, Jacksonaster, and Fibulina. The genus Peronellites is a fossil form, and the genera Sismondia and Fibulina are removed from the Fibulariidae and referred to the Laganidae. The distinctions of the genera, as the usage of DURHAM, excepting Sismondia, Peronellites, and Fibulina, of the family are best seen in the following table.

	Genital pores	Hydropores		Periproct	
Laganum (L. laganum)	5, within madreporite	in a groove		radially elongate	
Jacksonaster (J. depressus)	5 or 6, variably situated	in a groove		transversely elongate	
Hupea (H. decagonalis)	ea H. decagonalis) 5, within madreporite not in a groove		a groove	round	
Peronella (P. peronii)	nella . peronii) 4, variably situated not in a groove		n a groove	round	
Rumphia (R. japonica)	4, within madreporite	not in a groove		transversely elongate	
······································	Oral ambulacral furro	ws Bas		sicoronal plates	
Laganum (L. laganum)	more or less indistinc	ct mc		oderately large	
Jacksonaster (J. depressus)	more or less indistinct		mo	moderately large	
Hupea (H. decagonalis)	indistinct		moderate size		
Peronella (P. peronii)	indistinct		moderately large		
Rumphia (R. japonica)	more or less distinct		lar	large	
	Pair(s) of plates between periproct and basicoronal row		Post-basicoronal A-,IA-plates to a column on oral surface		
Laganum (L. laganum)	a single pair		A-plates 8 IA-plates 6		
Jacksonaster (J. depressus)	a single pair, large		A-plates 5 IA-plates 3 or 4		
Hupea (H. decagonalis)	three or four pairs		A-plates 6 or 7 IA-plates 4 or 5		
Peronella (P. peronii)	a single pair		A-plates 5 or 6 IA-plates 4 or 5		
Rumphia (R. japonica)	two pairs		A-plates 5 or 6 IA-plates 3 or 4		

This table, mainly built from DURHAM's diagnoses (1955), emphasizes the some trifling nature of these genera. The features of the genital pores, whether five (exceptionally six) in all the interambulacra, or for lacking in the posterior interambulacrum (5), the hydropores, whether they are in a groove, or not in a groove, and the position of periproct, whether it situated at junction between first and second or second and third, or between third and fourth post-basicoronal interambulacral plates, may be considered that they can be used as criteria for generic distinction rather than specific level. The genital pores of Peronella peronii, the type-species of Peronella, far out from the apical system should be once considered a generic character; however, same feature occurs in a species of other genus, e.g., Laganum (or Jacksonaster) putnami (MCZ 2251, of the syntypes). The difference of position of periproct between two species that having the other characters are to be considered as congeneric, as in the case of *Clypeaster*—the periproct situated at junction between third and fourth or fourth and fifth post-basicoronal interambulacral plates, may be regarded as a distiction of specific level. Thus the difference of position of periproct between *Peronella* and *Rumphia* does not supply an evidence of separating the two.

The above discussed genera can be grouped in three main groupings, and they are discriminated from one another as shown by the following key.

Key to the genera of the family Laganidae.

- Hydropores not in a groove, individually visible. Periproct situated at junction between third and fourth post-basicoronal interambulacral plates Hupea Hydropores in a groove. Periproct situated at junction between first and second

post-basicoronal interambulacral plates Laganum. There are fossil representatives of the genera *Peronella* and *Laganum* in our collection.

Genus Peronella GRAY, 1855

- Peronella GRAY, 1855-a, p. 13.—A. AGASSIZ, 1872-74, pp. 148, 520.—BELL, 1883, p. 134.—POMEL, 1883, p. 69.—H. L. CLARK, 1911, pp. 599, 605.—H. L. CLARK, 1914, p. 50.—LAMBERT and THIÉRY, 1914, p. 312.—H. L. CLARK, 1925, p. 159.—JEANNET and MARTIN, 1937, p. 249.—COOKE, 1942, p. 24.—H. L. CLARK, 1946, p. 344.—MORTENSEN, 1948-c, p. 251 (complete synonymy), text-figs. 171a-b, 172-174.—TERMIER and TERMIER, 1953, p. 925.—DURHAM, 1955, p. 139, text-figs. 8j, 31e.
 - Haplotype.—Laganum peronii AGASSIZ, 1841-b, p. 123, pl. 22, figs. 21-24 (South Sea).— MORTENSEN, 1948-c, p. 259, pl. 51, figs. 32, 38-43, 45, 47, pl. 72, fig. 15, text-figs. 175-176, 178a (Eastern and southern Australia).
- Rumphia Desor, 1855–58 (57), р. 229.—Ромеl, 1883, р. 69.—Lambert and Thiéry, 1914, р. 312 (partim).—Сооке, 1942, р. 26.—Durham, 1955, р. 142.

Orthotype.—Laganum rostratum AGASSIZ, 1841-b, p. 118, pl. 25.

Polyaster MICHELIN, 1859-a, p. 397 (4) (non Polyaster GRAY, 1840).-Michelinia DUJARDIN

and Hupé, 1862, p. 560 (pro Polyaster Michelin, 1859: non Michelinia Koninck, 1842).

Haplotype.—Polyaster elegans MICHELIN, 1859-a, p. 397 (4), pl. 14, fig. 1.—Peronella lesueuri elegans (MICHELIN) H. L. CLARK, 1925, p. 160, pl. 8, figs. 1-2 (Australia; Recent).

Echinodiscus BREYNIUS: LAMBERT, 1907-C, p. 124 (BREYNIUS, 1732, p. 68-pre-LINNEAN).— LAMBERT and THIÉRY, 1914, p. 311.—JEANNET and MARTIN, 1937, p. 250. (Non Echinodiscus LESKE, 1778, p. 195.—See Bull. Zool. Nomencl., vol. 4, 1950, p. 535).

Logotype.—Echinodiscus orbicularis LESKE, 1778, p. 144, pl. 45, figs. 6-7.—Laganum orbiculare (LESKE): AGASSIZ, 1841-b, p. 120, pl. 22, figs. 16-20. [LAMBERT, 1907-c, p. 124].

Medium sized to large, flattened, outline more or less rounded, elongated, or polygonal; oral surface flat to somewhat concave; apical area more or less raised. Petals well formed, usually open, elongate; pore-pairs conjugate, outer pore slightly elongated. Apical system usually central, with four genital pores, lacking in posterior interambulacrum (5), variably situated, hydropores in isolated pores scattered irregularly over the madreporite and individually visible, not in a groove. Peristome central, with simple oral ambulacral furrows radiating from it, reaching to about midways towards margin. Periproct small, varies in position, situated at junction between first and second or second and third post-basicoronal interambulacral plates. Basicoronal plates moderately large, forming a pentameral star. About five or six ambulacral and four to five interambulacral post-basicoronal plates on oral surface; interambulacra much narrower than ambulacra at ambitus. Primary radioles of edge of test form a distinct marginal fringe; miliary radioles smooth, widening into a terminal crown. Primary tubercles perforate, crenulate, with areole more or less conspicuously sunken; glassy tubercles quite numerous between primaries, especially on aboral side. Pedicellariae of tridentate, ophicephalous, and triphyllous types (mainly after MORTENSEN, 1948-c, and DURHAM, 1955).

There have been much disputed and discussion as to apply of this generic name, and it ascribed to the Indo-Pacific species which have four genital pores and scattered hydropres. *Rumphia* is separated from *Peronella* by former authors on the difference of position of the periproct; as, in the former it close to the margin, while in the latter at about midway between the peristome and the margin. This difference, in reality, is due whether to the difference of number of pairs of plates between basicoronal row and periproct, or of length of first post-basicoronal interambulacral plates. But, the number of genital pores, as described above, and the feature of hydropores should not be discriminated from each other as a generic level. *Hupea*, the much discussed generic name, should be defined, according to DURHAM (1955, pp. 141-142) to having *Scutella decagonalis* LESSON: BLAINVILLE, 1827 (=*Hupea decagonalis* POMEL, 1883) as the type-species, and differs from *Laganum* in having the scattered hydropores and three pairs of plates between basicoronal row and periproct.

Aside from the position of the genital pores (in the type-species, they are far removed from the apical system), the position of the periproct and the size and form of the petals seem to be the important specific characters, and the form of the test and the thickenss of its margins are also of value. This genus dates from the Eocene of Europe and widely distributed in the Indo-Pacific regions in usually small depths.

Peronella pellucida Döderlein, 1885

(Pl. 14, figs. 11-12, Pl. 15, figs. 4, 6-8)

Peronella (Laganum) pellucida Döderlein, 1885, p. 104 (32).—Laganum pellucidum (Döderlein) Yoshiwara, 1900, p. 391 (in Japanese).—Peronella pellucida Döderlein: Meijere, 1904, p. 130 (nominal).—Laganum pellucidum (Döderlein): Yoshiwara (Tokunaga), 1907, pl. 16, figs. 5-6(?).—A. Agassiz and H. L. Clark, 1907-b, p. 123.—H. L. Clark, 1908, p. 306.—Peronella pellucida Döderlein: H. L. Clark, 1914, p. 53, pl. 142, figs. 1, 8-10.— Rumphia pellucida (Döderlein) LAMBERT and Thiéry, 1914, p. 313.—Peronella pellucida Döderlein): LAMBERT and Thiéry, 1925, p. 581.—Rumphia pellucida (Döderlein): LAMBERT and Thiéry, 1925, p. 582.—Echinodiscus pellucidus (Döderlein): Jeannet and Martin, 1937, p. 250 (nominal).—Peronella pellucida Döderlein : Mortensen, 1948-b, p. 101.—Mortensen, 1948-c, p. 281 (complete synonymy), pl. 47, fig. 5, pl. 48, figs. 3-4, pl. 72, figs. 1, 11, text-figs. 160c, 166, 170a, 185a, 187c.—UTINOMI, 1954, p. 253.—Cooke, 1954, p. 47, pl. 10, figs. 3-4.—Nisiyama, 1965, pp. 79, 85.

Locality and geological horizon.—Plateau above Kami-Katetsu, Kikai-jima, Ôshimagun, Kagoshima Prefecture (Ryukyu Islands). Ryukyu Limestone, Pleistocene. Hypotype.—IGPS coll. cat. no. 73765.

There are two specimens referred to this species at the writer's hand, they are small in size, less than 30 mm in longitudinal diameter, and partly broken off.

Larger specimen measures 29 mm in longitudinal diameter, 27 mm in transverse one, and about 5 mm in height. Test thin, rounded-oval in marginal outline not as in rough pentagonal of large specimens, greatest breadth lies middle of the test, highest point just posterior to the apical system, height less than one-fifth of longitudinal diameter; margins more or less thin, about 0.07 of longitudinal diameter, its ratio slightly greater than that of the adult individuals but less than that of *Per*. *rubra* DÖDERLEIN, 1885, and it is usually found in the young specimens the margins relatively thicker than compared to those of adult individuals. Oral surface slightly concave to the peristome.

Petaloid area small, its total length about 13 mm in length, less than half of longitudinal diameter; petals subequal, widest at about the middle, narrowing gradually distally, and more or less open at their tips. Apical system central, comparatively large; genital pores placed within the apical system. Peristome more or less eccentric in anterior as usual in the young individuals, about 14 mm from the anterior margin, 2 mm across. Periproct large, oval in outline, transversely elongated, situated a little nearer the posterior margin than to peristome, about 6 mm from the posterior margin, about 0.4 of test-radius; its ratio slightly less than that found in the adult individuals, in adult individuals the ratio of test-radius to the length from the posterior margin to periproct usually being 1:0.5, but it is usually found that in the young individuals the ratio of test-radius. Oral ambulacral furrows short, about 6 mm in length, but rather distinct.

This species closely allied to *Per. rubra* DÖDERLEIN, 1885 (DÖDERLEIN, 1885, p. 106.—H. L. CLARK, 1914, p. 54, pl. 142, figs. 5-7.—MORTENSEN, 1948-c, p. 274, pl. 51, figs. 23, 29, text-figs. 170b, 183c, 188b) (Pl. 15, figs. 1-3, 5), a Recent species from Japan to Java Sea, in 5-60 metres depth, but differs from that species in having the thinner

margin of test, the smaller petaloid area, in the form of petals, and having the bared periproct, in that species the periproct covered with radioles. *Per. pellucida* also closely resembles *Per. hinemoae* MORTENSEN, 1921 (1921, p. 177, pl. 6, figs. 22-23), a Recent species from New Zealand, but differs from the New Zealandian species in having the larger petaloid area. COOKE (1954, p. 47) reported an occurrence of this species from the Naha Limestone (Pliocene) of Okinawa Island. The specimen (USNM 561561) seems to be safely identified with this species.

This species is reported from central (Sagami Bay) and southwestern Japan (Nagasaki and Kagoshima Gulf) as far south as Kei Islands, in 15-550 metres depth, MORTENSEN (1948-b, p. 101) reported a doublful specimen from the Philippine Islands in 33 metres depth.

Peronella japonica MORTENSEN, 1948

(Pl. 14, figs. 9-10)

Peronella decagonalis (LESSON): A. AGASSIZ, 1872-74, pp. 148, 520 (pro parte).—Döderlein, 1885, p. 105 (53) (non Blainville, 1827, nec Lesson, 1841).—Ives, 1891, p. 214.—Laganum decagonalis Lesson: Yoshiwara, 1900, p. 390 (in Japanese).—Tokunaga, 1903, p. 8.—Yoshiwara (Tokunaga), 1907, pl. 15, figs. 9-13, pl. 16, figs. 7-8.

Peronella lesueuri (AGASSIZ): H.L. CLARK, 1914, p. 53 (pro parte).—H.L. CLARK, 1925, p. 159 (pro parte).

Peronella japonica MORTENSEN, 1948, p. 71.—MORTENSEN, 1948-c, p. 277, pl. 49, figs. 1, 6-12, text-figs. 168-169, 177c, 178c, 180b, 184a, 187a.—UTINOMI, 1954, p. 353.—DURHAM, 1955, p. 83, text-fig. 8j, p. 121, text-fig. 26p.—NISIYAMA, 1965, pp. 79, 85.

Locality and geological horizon.—IGPS loc. no.—Ty-12.—Shinagawa in Tokyo. (tm Tokyo Seinanbu (Tokyo Southwest), Lat. 35°37′34″N., Long. 139°44′30″E.). Tokyo formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 7907.

Locality and geological horizon.—IGPS loc. no.—Ch-27.—Small cliff of the River Heguri at Kuwabara, Hôjo-machi, Tateyama City, Chiba Prefecture (tm Nago, Lat. 35°0′23″N., Long. 139°53′08″E.). Raised Beach deposits, early Holocene. Hypotype.— IGPS coll. cat. no. 15156.

Fossils of this species are reported from the Tokyo formation (TOKUNAGA, 1903, p. 10—as *Laganum decagonalis*), and a conferable specimen from the Byoritsu formation (1947-a, p. 99—as *Peronella* cf. *decagonalis* A. AGASSIZ).

The largest of the specimens at the writer's disposal measures 69 mm in longitudinal diameter, 65 mm in transverse one, and 8 mm in height. Test flat, low, roughly and irregularly decagonal in marginal outline; slightly elongate. Margins very thin, about 4 mm at the thickest point, and being 0.06 of longitudinal diameter of test; posterior end of test more or less restricted. Petaloid area rather large, its total length about 40 mm in length and being 0.66 of longitudinal diameter; petals rather narrow, and rather long, breadth about one-third of their length, more or less nearly closed at their tips. Frontal petal (III) the longest of all, about 22 mm in length. Tubercles on ridges in the poriferous zones usually miliaries but a few primary tubercles sporadically interrupted in the zones. Apical system central, four genital pores distinct and placed within the apical system. Oral surface nearly flat or very slightly concave orally; peristome central, rather small, 3.5 mm in diameter. Periproct oval, more or less transversely elongated, situated at about 6 mm from the posterior margin, and being 0.17 of longitudinal radius of test, or placed about twice its length (about 3 mm across) from the posterior margin; two pairs of plates between basicoronal row and periproct; naked in the living specimens. Ratio of longitudinal diameter to transverse one being 1:0.8 and not reverse as in the case of *Per. lesueuri elegans* (MICHELIN, 1859) (H. L. CLARK, 1925, p. 160, pl. 8, figs. 1-2).



Fig. 33 [8]. Test structure of *Peronella japonica* MORTENSEN, 1948.
a. Structure of oral surface, ×0.6.
b. Structure of aboral surface, ×0.6.

The genital pores present before the individual attains less than 35 mm in longitudinal diameter. In the young individual, 34 mm in longitudinal diameter, ambulacral plates, particularly on oral surface, are perforated by numerous minute (accessory) pores in irregular rows parallel to adapical sutures, and in irregular series parallel to adradial sutures.

By comparing the living specimens from Tateyama Bay, Chiba Prefecture, with those from Tanabe Bay, Wakayama Prefecture, the writer finds that the former have usually delicate test and thinner margin than the latter. The fossil specimens from the Tokyo formation much resemble the specimens from Tateyama Bay in the delicate test and thin margin.

This species recently separated from its ally, *Per. lesueuri* (VALENCIENNES, 1841), by MORTENSEN, (1948, p. 71), since the two species usually confounded with each other. The living specimens from Tateyama Bay, Tanabe Bay, Inland Sea, and Sea of Japan are readily assigned to this species. But the living specimen from North Formosa reported by HAYASAKA (1948, p. 24, pl. 6, fig. 1) cannot be assigned whether it belongs to *japonica* or *lesueuri*. *Per. lesueuri* is distributed in the living from Indo-China—Malay to Australian Seas, and as north as Hongkong, in littoral zones to 70 metres depth (MORTENSEN, 1948-c, p. 275). As judged from its general distribution, and from HAYASAKA's figure (figure 1 on Plate 6) and description (1948, p. 24) the living specimen from Formosa probably be assigned to *Per. lesueuri*. To settle this problem, it is necessary numerous specimens of undoubtedly assign to *Per. lesueuri* from Malay region, and more material in the question from Formosa and Ryukyu Islands, and further good specimens of safely assign to *Per. japonica* from central Japan, to compare these specimens side by side with one another and to make detail observation.

The same case is to be regarded for the specimen reported under the name Pero-

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nella cf. decagonalis A. AGASSIZ by HAYASAKA and MORISHITA (1947-a, p. 99, pl. 8, fig. 4) from the Byoritsu formation of Formosa. From their description and the figure of the specimen, it cannot be decided whether it belongs to *lesueuri* or *japonica*; the periproct seems to be more or less wider apart from the posterior margin than in *japonica*, but it is not a conclusively specific character. But this fossil specimen from the Byoritsu formation (Pliocene) of Formosa differs from *Hupea* cf. decagonalis (BLAINVILLE, 1827) from the Neogene formation of Java (Pl. 16, figs. 1-3, 6 under the name *Laganum* cf. decagonale in explanation text—IGPS coll. cat. no. 37624) in having the longer and broader petals and thicker margin of test. *Peronella decagonalis* A. AGASSIZ (1872-74, pp. 148, 520), the name is conferred to the specimen by the two authors, is a composite species, being as comprise the Japanese *Per. japonica* and the Malay-Australian *Per. lesueuri*, and moreover the specific name decagonalis is pre-occupied by BLAINVILLE, 1827.

Peronella japonica MORTENSEN, 1948, is distributed from central Japan (Tokyo-Bay) to southwestern Japan (Kagoshima Gulf) in the littoral zones to 50 metres depth, and dates back at least to the Pleistocene of central Japan.

In his study on the Pliocene Echinoids from Okinawa, COOKE (1954, pp. 47-48) described four species under the genus *Peronella*, but, unfortunately, the writer did not made an observation on these specimens stored in the United States National Museum when he visited there. The first species, *Per. pellucida*, as stated above, is now living in the Japanese Seas. The fourth, *Per. merrilli* ISRAELSKY (COOKE, 1954, p. 48, pl. 10, figs. 5-6), as judged from his figures, seems to be removed from *Peronella*. The specimen has no genital pores, broad petals, poriferous zones tending to close distally, long and rather distinct oral ambulacral furrows, and more or less sunken peristome. Although its compound ambulacral structure within the petals is not recognized, it seems highly probable that it represents a species of young *Clypeaster*. *Per. merrilli* (ISRAELSKY, 1933, p. 304, pl. 2, figs. 17-19.—Pliocene of the Philippines) itself is usually regarded as a junior synonym of *Per. lesueuri*. The second and third species are his new species, viz., *Per. kamimura* and *Per. motobu*. They are separated from each other by triflc differences and seem to represent one and same species.

Peronella kamimura COOKE, 1954

Peronella kamimura Сооке, 1954, р. 47, pl. 11, figs. 5-6. Peronella motobu Сооке, 1954, р. 48, pl. 10, figs. 1-2.

No specimens of this species have been available for study. This species is characterized by having a large petaloid area, its total length being about 0.6 or more of longitudinal diameter of test, and large, nearly as large as the peristome, transversely elongated periproct, situated at 0.4 to 0.3 of test-radius from the posterior margin. In the form and position of the periproct, this species resembles *Per. macro-proctes* KOEHLER, 1922 (KOEHLER, 1922, p. 113, pl. 9, figs. 5, 11, 14, pl. 10, figs. 10-12, pl. 13, fig. 4.—MORTENSEN, 1948-c, p. 297, pl. 5, figs. 30, 36), a Recent species of Indian Ocean, but differs from that species in having the longer and narrow petals and their extremity opens distally. The difference between *Per. kamimura* and *Per.*.
motobu, e. i., the form of petals and the position of periproct, seems to be not of the specific level, but of the developmental stages of the two. It seems highly probably that *Per. motobu* represents the young individuals of *Per. kamimura*. The interrelationships of this species to the other Indo-West Pacific species of *Peronella*, both Recent and fossil, viz., *Per. oribicularis, Per. peronii*, and *Per. angulosa* (HERKLOTS, 1854) (*Laganum angulosum* HERKLOTS, 1854, p. 8, pl. 2, fig. 4.—*Echinodiscus angulosus* (HERKLOTS): JEANNET and MARTIN, 1937, p. 259.—Upper Miocene of Java), need further elucidation.

This species is reported from the Naha Limestone (Pliocene) of Okinawa Island, Ryukyu Islands.

Subgenus Peronellites HAYASAKA and MORISHITA, 1947

Peronellites HAYASAKA and MORISHITA, 1947-a, p. 101.—DURHAM, 1955, p. 142.

Orthotype.—Peronella (Peronellites) ovalis HAYASAKA and MORISHITA, 1947-a, p. 101, pl. 8. figs. 3, 5 (Miocene of Formosa).

This subgenus is characterized, according to the two authors, by its markedly vaulted proximal ends of petals as well as the apical system.

The vaulted character of the apical system as well as the proximal end of petals is found among the genus *Laganum*, particularly in *Lag. fudsiyama* DÖDERLEIN, 1885 (DÖDERLEIN, 1885, p. 104.—H. L. CLARK, 1914, p. 46, pl. 124, figs. 13-16, pl. 127, figs. 7, 8, pl. 140, figs. 3-4, pl. 141, figs. 4-9), as the name implies, and it is interesting to find that the same character occurs in the fossil species of the genus *Peronella*. If this character proves to be constant, the specific character should be stand as in the case of *Laganum*, but it is not regarded as a character of subgeneric level.

Peronella (Peronellites) ovalis HAYASAKA and MORISHITA, 1947

Peronella (Peronellites) ovalis HAYASAKA and MORISHITA, 1947-a, p. 101, pl. 8, figs. 3, 5.

No specimens of this species are available, and the figures and original description are somewhat inadequate for comparison. However, the distinctive characters of this species based on the description and figures will be summarized as follows.

Genital pores at proximal ends of interambulacra more or less close to madreporite; petaloid area small, its total length about half of longitudinal diameter of test, or less; petals narrow and slightly open at distal ends; height of test less 0.15 of longitudinal diameter; test about four-fifths as wide as long, or less; margin of test thin, less than 0.1 of longitudinal diameter; apical system slightly eccentric in front; proximal ends of petals and apical system markedly vaulted.

The figure from side view is not given in the original literature and the vaulted character of the apical system is not indicated. MORTENSEN (1948-c, p. 258) doubted its subgeneric (or generic) validity, but DURHAM (1955, p. 142) recognized it as a distinctive genus. In its general features, except for the number of genital pores, this species superficially resembles *Hupea decagonalis* (BLAINVILLE, 1827). The species is reported from the Kanshirei formation (Miocene) of Fenchihu and Changchihkeng, T inanhsien, Formosa.

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Genus Laganum LINK, 1807

- Laganum LINK, 1806-08 (07), p. 161 (Laganum KLEIN, 1734, p. 25-pre-Linnean).—AGASSIZ, 1841-b, p. 105.—AGASSIZ and DESOR, 1846, p. 131.—GRAY, 1855-a, p. 8.— Desor, 1855-58 (57), p. 227.—DUJARDIN and HUPÉ, 1862, p. 559.—A. AGASSIZ, 1872-74 (73), pp. 137, 511.— BELL, 1883, p. 130.—POMEL, 1883, p. 69.—DUNCAN, 1889-a, p. 156.—COTTEAU, 1889-94 (91), p. 251.—MEISSNER, 1904, p. 1381.—H. L.CLARK, 1911, p. 605.—H. L. CLARK, 1914, p. 44.— LAMBERT and THIÉRY, 1914, p. 313.—KOEHLER, 1922, p. 82.—H. L. CLARK, 1925, p. 155.— JEANNET and MARTIN, 1937, p. 249.—COOKE, 1942, p. 23.—H. L. CLARK, 1946, p. 342.— MORTENSEN, 1948-c, p. 301 (complete synonymy), text-figs. 191b, 192a-b.—TERMIER and TERMIER, 1953, p. 925.—DURHAM, 1955, p. 139, text-figs. 1c, 2c, 7b-c, 12b, 15e, 31f.—COOKE, 1959, p. 50.
 - Tautotype.—Laganum petalodes LINK, 1806-08 (07), p. 161.—Echinodiscus laganum LESKE, 1778, p. 140, pl. 22, fig. C (Indian Ocean).— Laganum bonani KLEIN: AGASSIZ, 1841-b, p. 108, pl. 22, figs. 25-29, pl. 23, figs. 8-12 (Vanikoro).
- Lagana Gray, 1825, p. 427 (5) (by error).—Blainville, 1830, p. 196.—Blainville, 1834, p. 214.

Tautotype.—Lagana minor GRAY, 1825, p. 428 (6).—Echinodiscus laganum LESKE, 1778, p. 140.

- Jacksonaster LAMBERT and THIÉRY, 1914, p. 313.—LAMBERT, 1915, p. 94, note.—JEANNET and MARTIN, 1937, p. 250.—DURHAM, 1955, p. 143, text-figs. 1h, 5f, 7a, 26h, 31c.
 - Orthotype.—Jacksonaster conchatus (M'CLELLAND) LAMBERT and THIÉRY, 1914, p. 313.— Echinarachnius conchatus M'CLELLAND, 1841, p. 181, pl. 4, figs. 8-9.—Laganum depressum. LESSON in AGASSIZ, 1841-b, p. 110, pl. 23, figs. 1-7.

Test of usually moderate size or large, polygonal, round, or elliptical outline, more or less flattened, but rising to a varying degree towards apical system; edge of test in some species more or less conspicuously thickened and then with a corresponding depression between edge and elevated central part, but in other species very flat and very thin; oral surface usually flat. Petals well formed, moderately open, elongate; pore-pairs conjugate, outer member of poriferous zones only slightly Apical system usually central, with 5 or 6 genital pores in all interelongated. ambulacra or double in posterior interambulacrum (5); hydropores in a groove, not individually visible. Peristome usually central, with more or less distinct oral ambulacral furrows radiating out from it, sometimes extending slightly more than half distance to margin. Periproct on oral surface, varies in position, but situated at junction between first and second pairs of post-basicoronal interambulacral plates; often transversely elongate, and covered with radioles or naked. Basicoronal plates moderately large, in a well-defined star; 5 to 8 ambulacral and 3 to 6 interambulacral post-basicoronal plates in a column on oral surface. Miliary radioles smooth, widening into a terminal crown. Primary tubercles perforate, crenulate, with areole more or less conspicuously sunken; glassy tubercles numerous. Pedicellariae of tridentate, ophicephalous, and triphyllous types; valves of tridentate pedicellariae often expanded upper blade and crenulated (mainly after MORTENSEN, 1948-c, and DURHAM, 1955).

From the Eocene to Recent.

Jacksonaster is differentiated from Laganum, by former authors, by the more nearly marginal periproct, the fewer plates on the oral surface, the greatly elongated first pair of post-basicoronal plates in the posterior interambulacrum (5), as well as by the differences in shape of the periproct and in feature of the miliary radioles. The difference of position of periproct between *Lag. laganum* and *Jack. depressus* is due to the difference of length of first pair of post-basicoronal plates in the posterior interambulacrum (5), and it seems to be considered that the difference is not a distinction of generic level. The features of radioles are said to vary profundly even in the same individual, e.g., the obliqueness and the amount of serration on the rod-tips of radioles are subject to great variation due to the position of the radioles on the test. The generic separation of the two groups after these variable characters seems to be notworthy.

This genus dates from the Eocene and is distributed widely in the Indo-West Pacific Oceans in usually small depth, of mainly warm or tropical region.

Laganum fudsiyama Döderlein, 1885

- Laganum fudsiyama Döderlein,1885, p. 104 (32).—YOSHIWARA, 1900, p. 391 (in Japanese).— TOKUNAGA, 1903, p. 11.—YOSHIWARA (TOKUNAGA), 1907, pl. 16, figs. 1-4.—A. AGASSIZ and H. L. CLARK, 1907-b, p. 128.—H. L. CLARK, 1914, p. 46, pl. 124, figs. 13-16, pl. 127, figs. 7-8, pl. 140, figs. 3-4, pl. 141, figs. 4-9.—Jacksonaster fudsiyama (Döderlein) LAM-BERT and THIÉRY, 1914, p. 313.—Laganum fudsiyama Döderlein: H.L. CLARK, 1925, p. 158.—Jacksonaster fudsiyama (Döderlein): LAMBERT and THIÉRY, 1925, p. 582.—Laganum fudsiyama Döderlein: NISIYAMA, 1937, p. 55.—Jacksonaster fudsiyama (Döderlein): JEANNET and MARTIN, 1937, p. 250 (nominal).—Laganum fudsiyama Döderlein: MOR-TENSEN, 1948-b, p. 106.—MORTENSEN, 1948-c, p. 338 (complete synonymy), pl. 54, figs. 5-6, 10-13, pl. 70, figs. 8-9, 14-15, text-figs. 194b, 199b, 200a-c, 201.—UTINOMI, 1954, p. 354.— Jacksonaster fudsiyama (Döderlein): DURHAM, 1955, p. 82, text-fig. 7b.—MORISHITA, 1960, p. 57.—NISIYAMA, 1965, pp. 79, 85.
- Laganum conicum MEIJERE, 1904, p. 120, pl. 6, fig. 68, pl. 18, figs. 325-238.—Jacksonaster conicus (MEIJERE) LAMBERT and THIÉRY, 1914, p. 313.—JEANNET and MARTIN, 1937, p. 250 (nominal).
- Laganum solidum Meijere, 1904, p. 121, pl. 6, figs. 64, 66.—Jacksonaster solidus (Meijere) LAMBERT and Thiéry, 1914, p. 313.—JEANNET and MARTIN, 1937, p. 250 (nominal).
- Laganum diploporum A. AGASSIZ and H. L. CLARK, 1907-b, p. 129.—H. L. CLARK, 1914, p. 48, pl. 127, figs. 9-12, pl. 142, figs. 2-4.—Jacksonaster diploporus (A. AGASSIZ and H. L. CLARK) LAMBERT and THIÉRY, 1914, p. 313.—Laganum diploporum A. AGASSIZ and H. L. CLARK: NISIYAMA, 1937, p. 56.

No fossil specimens of this species are available to the writer, although TOKUNAGA (1903, p. 11) reported an occurrence of this species from the Koshiba formation of Kanagawa Prefecture, central Japan.

The distinctive characters of this species is summarized as follows.

Test large, attains over 70 mm in longitudinal diameter, with decagonal or rounded ambitus, its length little, or not at all, exceeding the breadth; periproct distinctly nearer to margin than to peristome, or distance of periproct from the posterior edge of test about 30 per cent of the distance from peristome to posterior edge of test, usually transversely elongated; petaloid area more or less markedly elevated and margins not swollen, area relatively small, its total length 0.5 of longitudinal diameter of test or less; petals narrow, not lyriform; poriferous zones little curved and more or less widely open at their tips; height of test varies, but usually high, height ranging from 0.2 to 0.4 of longitudinal diameter of test; posterior interambulacrum (5) with one or rarely two genital pores; tuberculation of test varies coarser or finer, within a petal 10 mm long, there are 20-50 primary tubercles, and in one 15 mm long, there are about 40-90 primaries.

In Lag. diploporum the striking character is the presence of double genital pores in the posterior interambulacrum (5). The writer (NISIYAMA, 1937, p. 56) once regarded that, after A. AGASSIZ and H. L. CLARK, the presence of six genital pores as a distinctive specific character, and reported an occurrence of this species from east coast of Boso Peninsula, central Japan. As to this species, MORTENSEN (1948-b, p. 106) stated that "Moreover, I must likewise regard *L. diploporum* A. Agassiz and H. L. CLARK as identical with *L. fudsiyama*, the only essential character distinguishing it from the latter species, the doubling of the posterior genital pore, being not at all constant (as already realized by CLARK), and there are no other reliable characters by which to distinguish them." It seems highly probable that his statement seems to fit with the nature of the species fairly well, by comparing the specimens of *Lag. fudsiyama* and *Lag. diploporum* from the east coast of Boso Peninsula side by side.

This species ranges from central Japan (Tokyo Bay) as south as northeastern Borneo through western Japan (Kagoshima Gulf), and the bathymetrical range reported from 50 to 645 metres.

Laganum fudsiyama tokunagai Otuka, 1938

Laganum fudsiyama tokunagai Otuka, 1938, p. 18, pl. 2, figs. 22-23 (Miocene of Kanbara town, Shizuoka Prefecture).

No specimens, other than the holotype, of this subspecies have been available for study.

Holotype.—Reg. no. 4006, in the Geological Institute, the University of Tokyo, Japan.

Locality and geological horizon.—IGPS loc. no.—So-15.—Near a house on the top of Shiroyama hill, northern part of Kanbara-machi, Ihara-gun, Shizuoka Prefecture (tm YOSHIHARA, Lat. 35°07'N., Long. 138°36'E.). Shiroyama formation, Miocene.

This subspecies is distinguished from the typical species in its outline of periproct, of which the former is more rounded and is situated nearer to the posterior margin, i.e., one-fourth of the test-radius from the posterior margin, than that of the typical species, i.e., ca. one-third of the test-radius, and in the form of petals.

Although in this subspecies the feature of hydropores is not recognized, the subspecies in its general features superficially resembles *Hupea decagonalis* (BLAIN-VILLE, 1827) (*Scutella decagonalis* BLAINVILLE, 1827, p. 229.—*Laganum decagonum* LESSON: AGASSIZ, 1841-b, p. 112, pl. 23, figs. 16-20.—*Laganum decagonale* (BLAINVILLE): MORTENSEN, 1948-c, 331, pl. 55, figs. 14-19, pl. 70, figs. 10, 16-17, 19, 21-22, text-figs. 161a, 162a, 163c, 193b, 196b, 199b), a Recent species as well as fossil of the Malay region, but differs from that species in having the larger and more well-defined petaloid area and the larger periproct. This subspecies may be raised as a specific rank.

Laganum fudsiyama untenensis COOKE, 1957

Laganum fudsiyama untenensis COOKE, 1957, p. 48, pl. 9, figs. 7-11.

No specimen of this subspecies has been available for study. In the discussion of this subspecies, COOKE (1954, p. 48) stated that the typical species varies conspicuously in the degree of elevation of the apical system, and in the subspecies the upper range of height lies near the lower limit of variation of the typical species. This subspecies seems to have a thicker margin, ca. 0.01 of test-length, than the typical species, and the petaloid area is more or less larger. The periproct is situated at about 30 per cent or more of the distance from the posterior margin of test, as usual of the typical species. It is not certain whether this subspecies is identical with the specimens from the Koshiba formation (Pliocene) of central Japan, or not.

This subspecies is reported from the Naha Limestone (Pliocene) of Okinawa Island, Ryukyu Islands.

Laganum pachycraspedum NISIYAMA, n. sp.

(Pl. 15, figs. 9-10, 17)

Holotype.--IGPS coll. cat. no. 73759.

Locality and geological horizon.—IGPS loc. no.—So-8.—In the calcareous sandstone at sea shore north of Shirahama shrine at Harada, Shirahama-mura, Kamo-gun, Shizuoka Prefecture (tm Shimoda, Lat. 34°41′25″N., Long. 138°58′E.). Shirahama (Susaki) formation, Miocene.

There are several specimens referred to this new species at the writer's disposal, some are fragmentary and others are attached to a hard sandstone matrix on both aborally and adorally.

Test rather large, attains 48 mm in longitudinal diameter, stout and thick, pentagonal oval in marginal outline, longitudinal diameter exceeds the transverse one, greatest breadth lies on just behind the apical system; apical area somewhat raised, aboral surface depressed, especially on area around the petaloid area; margins very thick, about over 0.18 of longitudinal diameter of test, thicker anteriorly than posteriorly; oral surface more or less concave to the peristome.

Dimensions of holotype.—38 mm in longitudinal diameter, 33 mm in transverse one, and 7 mm in height.

Petaloid area rather large, its total length over 0.6 of longitudinal diameter of test; petals slightly raised, narrow and widely open at their tips; frontal petal (III) 11 mm long and 3 mm wide at the middle of petal, poriferous zones about one mm wide at the widest point and with about forty pore-pairs, pores of rounded oval in shape, outer member slightly elongate; antero-lateral petals (II and IV) 11 mm long and 3.5 mm wide near the middle of petals, make an angle about 70° between median line of frontal petal (III) and that of antero-laterals (II and IV), outer poriferous zone broader than the inner poriferous, and more incurved than the latter, and with about thirty pore-pairs, pores of rounded oval in shape, outer member slightly elongate; make an angle of about 75° between median line of antero-laterals (II and IV) and

that of postero-laterals (I and V); poriferous zones about one mm wide at the widest point, with about forty pore-pairs, pores of rounded oval in shape; on interporiferous zones of petals there are two or three series of small tubercles, and each poriferous zone carries at least one series of small tubercles.

Apical system central, madreporite pentagonal, 2.5 mm across, five genital pores fairly distinct and placed within the apical system; ocular pores more or less distinct, close to the madreporite; hydropores in a narrow groove (in paratype). Peristome central, more or less sunken, rounded pentagonal in outline; periproct situated at about midway between peristome and the posterior margin of test, slightly nearer to the posterior margin than to peristome, elliptical in shape and transversely elongated; a single pair of plates between periproct and basicoronal row. Oral ambulacral furrows rather distinct but short, the length of frontal ambulacrum (III) about 7 mm, those of antero-laterals (II and IV) about 7 mm, and of postero-laterals (I and V) 9 mm long, reaching to about midway or less towards the margin of test.

Distinction.—This new species closely resembles *Lag. depressum* LESSON, 1841 (in AGASSIZ, 1841-b, p. 110, pl. 23, figs. 1-7), a common living, as well as fossil, of Indo-West Pacific regions, in the outline of test and in the petaloid area, but is distinguished from that species by the much thicker margin and by the position of periproct, which much nearer to the peristome than that of latter species. *Lag. pachycraspedum* is also related to *Lag. laganum* (LESKE, 1778) (*Echinodiscus laganum* LESKE, 1778, p. 140, pl. 22, fig. C.—*Laganum bonani* KLEIN: AGASSIZ, 1841-b, p. 108, pl. 22, figs. 25-29, pl. 23, figs. 8-12), an another common living species of the Indo-West Pacific Oceans, in the swollen margin and in the depressed area around the petaloid area, but differs from that species in having the transversely elongated periproct, which in that species decidedly longitudinally elongated, and in the marginal outline of test.

Laganum pachycraspedum resembles, in its general features, the species now inhabiting in the tropical and subtropical waters, and it will be naturally supposed that the climate at that time of this species decidedly warmer than present day in this district.

Laganum depressum LESSON, 1841

(Pl. 15, figs. 11-16)

Laganum depressum Lesson in Agassiz, 1841-b, p. 110, pl. 23, figs. 1-7.—Agassiz and Desor, 1846, p. 132.—Gray, 1855-a, p. 10.—A. Agassiz, 1863, p. 26.—A. Agassiz, 1872-74, pp. 138, 518, pl. 13f, figs. 5-8.—A. Agassiz, 1881-a, p. 120.—Yoshiwara, 1900, p. 390 (in Japanese).—Meijere, 1904, p. 114, pl. 6, fig. 57, pl. 18, figs. 317-318.—Gregory, 1906, p. 235.— Yoshiwara (Tokunaga), 1907, pl. 15, figs. 5-6.—Brown, 1910, p. 45.—H. L. Clark, 1914, p. 45, pl. 124, figs. 7-12.—Koehler, 1922, p. 88, pl. 9, figs. 1-2, 7-8, pl. 13, fig. 3, pl. 14, fig. 2.—H. L. Clark, 1925, p. 157.—Stockley, 1927, p. 115, pl. 21, figs. 5a-b.—Roxas, 1928, p. 264, pl. 6, figs. 31-32.—Currie, 1930, p. 175.—Brighton, 1931, p. 325.—H. L. Clark, 1932, p. 216.—H. L. Clark, 1938-a, p. 417.—H. L. Clark, 1945, p. 325, pl. 42, fig. C.— Mortensen, 1948-b, p. 105.—Mortensen, 1948-c, p. 313 (complete synonymy), pl. 52, figs. 12, 14, pl. 53, figs. 3-4, 6-32, pl. 70, fig. 20, text-figs. 153b, 157, 161b, 162c, 163c, 165, 167, 196a, 197.— Jacksonaster depressus (Lesson): Durham, 1955, p. 140(?), text-figs. 1h, 5j, 7a, 26h, 31c.—Laganum depressum Lesson: NISIYAMA, 1965, pp. 79, 85.

Echinarachnius conchatus M'CLELLAND, 1841, p. 181, pl. 4, figs. 8-9.—Jacksonaster conchatus:

(M'CLELLAND) LAMBERT and THIÉRY, 1914, p. 313.—LAMBERT and JEANNET, 1928, p. 5.—Laganum conchatum (M'CLELLAND) JEANNET and MARTIN, 1937, p. 251, text-figs. 33-34.

- Laganum fragile MAZZETTI, 1894, p. 217 (non Laganum fragile DAMES, 1877).—Laganum mazetti THIÉRY, 1909-a, p. 137 (pro Lag. fragile MAZZETTI, 1894).—LAMBERT and THIÉRY, 1925, p. 582.
- Laganum delicatum MAZZETTI, 1894, p. 248, text-figs. a-d (pro Lag. fragile MAZZETTI, 1894, non DAMES, 1877).

Laganum dyscritum H.L. CLARK, 1932, p. 216, pl. 1, figs. 5-9.

Laganum aff. boschi R. MARTIN: HAYASAKA and MORISHITA, 1947-a, p. 97, pl. 9, figs. 3a-b.

Locality and geological horizon.—About 100 metres east of Hakushaton, Byôritsugun, Shinchiku-shû (Paishatun, Miaoli, Hsinchuhsien), Formosa. Byôritsu formation, Pliocene. Hypotype.—IGPS coll. cat. no. 73771.

Locality and geological horizon.—Plateau above Kami-Katetsu, Kikai-jima, Ôshimagun, Kagoshima Prefecture (Ryukyu Islands). Ryukyu Limestone, Pleistocene. Hypotype.—IGPS coll. cat. no. 73772.

There are several specimens from the Byôritsu formation of Formosa and the Ryukyu Limestone of Ryukyu Islands referred to this species have been available for study. The fossil specimens from the Byôritsu formation are characterized by the smaller form than the living individuals from the neighbouring seas.

Test moderate, attains 40 mm in longitudinal diameter, stout and thick, elongate pentagonal in marginal outline, posterior margin more or less distinctly re-enteringly curved, longitudinal diameter exceeds transverse one, greatest breadth lies on anterior to the apical system; aboral surface more or less raised, margin more or less thickened; oral surface more or less concave to the peristome.

Dimensions of the largest specimen.—40 mm in longitudinal diameter, 38 mm in transverse one, and 8 mm in height.

Petaloid area rather large, its total length 25 mm long and over 0.6 of longitudinal diameter of test; petals slightly raised and more or less open at their distal tips; frontal petal (III) 13 mm long and 3.5 mm wide at the middle of petal; antero-lateral petals (II and IV) 12 mm long and 4 mm wide at the middle of petals; postero-lateral petals (I and V) 14 mm long and 4 mm wide at the middle of petals; distance from extremity of the frontal petal (III) to the ambital margin about 5 mm, distance from extremity of the antero-lateral petals (I and IV) to the ambital margin 5 mm, and distance from extremity of the postero-laterals (I and V) to the ambital margin 6 mm long in each.

Apical system central, rather small, 2 mm across, madeporite pentagonal, genital pores placed within the apical system; hydropores in a groove. Peristome central, more or less sunken, rounded pentagonal in outline, 2.5 mm across. Periproct transversely elongated and situated about 5 mm from the posterior margin of test, or about 25 per cent or more of distance from the posterior margin of test to peristome. Oral ambulacral furrows distinct, more or less sunken and rather long, length of frontal ambulacrum (III) about 13 mm, those of the antero-laterals (II and IV) about 12 mm, and those of the postero-laterals (I and V) about 15 mm long, reaching over midway towards the margin of test.

The dimensions of specimens described above would be fall into the limit of

variation of this very variform and widely distributed species, *Laganum depressum*. The fossil specimens from the Byôritsu formation (Pliocene) of Formosa closely resemble *Laganum multiforme* MARTIN, 1880 (MARTIN, 1880, p. 3, text-fig. 2.—MARTIN, 1880-a, p. 76.—JEANNET and MARTIN, 1937, p. 250, text-figs. 31-32), from the Miocene of Java, in the size and outline of test, but differs from that species in having the narrower petals.

The specimens from the Ryukyu Limestone (Pleistocene) of Kikai-jima are generally larger than those from the Byôritsu formation of Formosa. Although all of them are bad state of preservation, the preserved part shows that they have characteristic features that are probably referred them to this species. *Laganum* aff. *boschi* R. MARTIN, reported by HAYASAKA and MORISHITA (1947-a, p. 97, pl. 9, figs. 3a-b) from the Ryukyu Limestone of Tokuno-shima in Ryukyu Islands, may be identical with this species or its variety. The general features and dimensions of the specimen described by the two authors agree with those of *Lag. depressum*. According to MORTENSEN (1948-c, p. 317), *Lag. boschi* MARTIN, 1937 (in JEANNET and MARTIN, 1937, p. 253, text-figs. 35-36b), from the Pliocene and Upper Miocene of Java, would be identical with *Lag. depressum* or its variety; to this treatment the writer agrees.

This species is closely related to *Lag. boninense* MORTENSEN, 1948 (MORTENSEN, 1948, p. 70.—MORTENSEN, 1948-c, p. 328, pl. 55, figs. 1-3, pl. 70, fig. 12, text-fig. 162b), a Recent species from the Bonin Islands, but differs from that species in having the thicker margin, the lower central part of test, larger petaloid area, and in the periproct placed nearer to the posterior margin than in that species.

Laganum ellipticum AGASSIZ, 1841 (AGASSIZ, 1841-b, p. 111, pl. 23, figs. 13-15) and Lag. conchatum (M'CLELLAND, 1841) (Echinarachnius conchatus M'CLELLAND, 1841, p. 181, pl. 4, figs. 8-9.—Lag. conchatum (M'CLELLAND) JEANNET and MARTIN, 1937, p. 251, text-figs. 33-34), which have doubtful priority, are usually regarded as synonyms of this species.

This species is widely distributed in the Indo-West Pacific Oceans and ranges from Macao, China (occurrence of Ryukyu Islands is uncertain) to as far south as Queensland, from the ebb-zone down to 85 metres in depth, and dates back to the Pliocene epoch. The Miocene form from Malay and Indonesia called under this name would be separate as a distinct species (as *Lag. multiforme* MARTIN, 1880) or a subspecies of *Lag. depressum* LESSON, 1841.

Suborder SCUTELLOINA HAECKEL, 1896

Scutellaria HAECKEL, 1896, p. 231.—Scutellina GRAY: DURHAM, 1955, p. 149 (non Scutellina AGASSIZ, 1841).—Scutellina HAECKEL: DURHAM and MELVILLE, 1957, p. 259.—PHILIP, 1965, p. 58 (pro parte). Type-family.—Scutellidae GRAY, 1825.

Test of moderate size to large forms, very flat, rarely discoidal, with or without lunules or marginal slits; oral side usually very flat; internal supports usually well developed of complicate structure, both concentric and radial. Ambulacra usually petaloid adapically, ambulacral structure within the petals simple "scutellid" type; plates of petals usually much smaller than oral ambulacral plates; pore-pairs usually conjugate; ambulacra as wide as or wider than interambulacra at ambitus. Interambulacra terminating adapically in a pair of small plates, continuous or discontinuous on oral surface. Apical system central, or more or less eccentric to anterior or posterior, with 4 or 5 genital pores; pentagonal or stellate, apices corresponding to interambulacra. Peristome central, small, mostly with edge rather abruptly sunken; buccal membrane naked. Periproct small, varies in position. Basicoronal interambulacral plates as large as or larger than ambulacral plates, often greatly developed. Auricles fused into a single piece situated on interambulacrum. Oral ambulacral furrows distinct, often highly complicated rarely simple, with small terminal projection extending over buccal tube-feet pores. Primary radioles of oral side simple, of aboral side clubshaped; miliary radioles mostly simple, terminating in a glandular bag. Pedicellariae (in living species) bivalved or trivalved, ophicephalous type may occur. Tube-feet with a pair of spicules in sucking disc. Larva with a skeleton of basket type, usually complicate (from DURHAM, 1955).

From the Eocene to Recent.

In the feature of auricles that fused into a single piece and placed on interradial, the Scutelloina are in common with the Laganoina, but they differ from the Laganoina in having the interambulacra terminating adapically by a pair of plates, contrasting to single plate of the latter, the miliary radioles with terminal glandular bag, and usually well developed oral ambulacral furrows. PHILIP (1965, pp. 53, 56), however, did not recognized this suborder in the restricted usage of DURHAM (1955), but united it into the Laganoina in the usage of MORTENSEN (1948-c) and preferred the name Scutellina for his suborder.

As for the ancestry of the Scutelloina, MORTENSEN (1948-c, p. 356) and others have come to conclusion that the scutelloid echinoids are near relatives of the Laganoina, and that their origin is probably very near member of the Laganoina, if not identical with it. The oldest known scutelloid echinoid is the genus *Eoscutella* GRANT and HERTLEIN, 1938 (GRANT and HERTLEIN, 1938, p. 386.—DURHAM, 1955, p. 156.— Orthotype.—*Scutella coosensis* KEW, 1920, p. 65, pl. 8, figs. 1a-b), from the Middle Eocene of Oregon and California. This genus seems to be a highly specialized form in many respects, as shown by the bifurcating ambulacral furrows, very large basicoronal interambulacral plates, and developed internal supports. It seems highly improbable that this genus is the ancestor of the later members of the Scutelloina, as well as the direct descendant of the Eocene form of the Laganoina from the morphological gaps and the geological appearance of the two. After all, it must be admitted that there is little proof to tell with certainty about the ancestry of the Scutelloina.

A historical sketch of the modern subdivisions of the Scutelloina is as follows. LAMBERT and THIÉRY (1914-21, pp. 316-326) had a single family, the Dendrasteridae, under the Scutelloina. They had a tribus Phelsumasteridae, which take the place of the Scutulinae LAMBERT (1907-c, p. 124), under the Dendrasteridae, comprising the genera, *Phelsumaster* (viz. *Echinarachius*), *Mortonella* (with subgenus *Periarchus*), *Scutulum*, *Scutella*, *Iheringiana*, *Anorthoscutum*, and *Dendraster*; and a tribus Rotulinae, with the disc perforated by lunules or indented, comprising *Rotuloidea*, *Heliophora*, *Rotula*, *Amphiope* (with subgenus *Tetrodiscus*), *Scutaster*, and *Astriclypus*; and another tribus Monophorinae (Monophorasterinae, emend.), comprising Monophoraster, Mellita, Leodia, and Encope (with subgenus Mellitella). H. L. CLARK (1925, pp. 167– 176) also had a single family, the Scutellidae GRAY, under the suborder Scutelloina. He did not recognized the subfamilies and placed various genera, viz., Echinarachnius, Dendraster, Echinodiscus, Astriclypeus, Encope, Mellita, and Rotula, into a single family Scutellidae. MORTENSEN (1948-c) also had a single family, the Scutellidae, under the Scutelloina, and divided the family into four subfamilies, viz., Scutellinae, Astriclypeinae, Monophorinae, and Rotulinae. He had the subfamily Scutellinae, comprising the Recent genera Echinarachnius, Scaphechinus, and Dendraster, and the fossil genera Scutella, Periarchus, Protoscutella, Eoscutella, Iheringiana, Scutulum, Mortonella, Anorthoscutum, Samlandaster, Astrodapsis, Merriamaster, and Praescutella; to the subfamily Astriclypeinae belong the genera Echinodiscus, Amphiope, Scutaster, and Astriclypeus: to the Monophorinae the genera Monophoraster, Mellita, and Encope (with the subgenus Mellitella); and to the Rotulinae the genera Rotuloidea and Rotula.

In his study on the clypeasteroid echinoids, DURHAM (1955, pp. 116-117, 149-183) recognized, by considering their geographic and geologic distribution together with a careful analysis of their relationships, nearly ten times as many families (except the Rotulidae) and one and a half as many genera in the Scutelloina as MORTENSEN did (1948-b). The families are those recognized by DURHAM in his strict usage are as follows :—Scutellidae GRAY, 1825, Protoscutellidae DURHAM, 1955, Eoscutellidae DURHAM, 1955, Dendrasteridae LAMBERT, 1900, Echinarachniidae LAMBERT, 1914 (emend. by DURHAM, 1955), Monophorasteridae LAHILLE, 1895, Mellitidae STEFANINI, 1912, Astriclypeidae STEFANINI, 1912, Abertellidae DURHAM, 1955, and Scutasteridae DURHAM, 1955. PHILIP (1965, p. 58) in his preliminary family subdivisions of the Scutelloina, in the strict usage of DURHAM (1955), had only two families (except for the Rotulidae), the Astriclypeidae STEFANINI, 1912, and Scutellidae GRAY, 1825.

In DURHAM'S strict usage of the suborder Scutelloina, two groups are recognized by their major structural features. The first group is characterized by having flat tests without lunules or marginal slits; it approximately corresponds with MORTEN-SEN'S strict usage of the Scutellinae and with PHILIP'S Scutellidae. The second group is characterized by having large tests with lunules or marginal slits in the ambulacra or in the posterior interambulacrum (5); it corresponds with PHILIP's usage of the Astriclypeidae and with MORTENSEN'S Astriclypeinae plus Monophorinae.

The writer (NISIYAMA, 1935, pp. 135-138; 1940, pp. 808-819) and DURHAM (1955, pp. 116, 149) once pointed out that the first group (MORTENSEN'S usage of the Scutellinae) should not be a monophyletic origin, but may be diphyletic or polyphyletic origin, and the northern Pacific genera (e.g., California and Japanese ones, such as *Echinarachnius, Astrodapsis*, and *Dendraster*) should be phylogenetically different from the Atlantic genera (e.g., East Coast of North and Central American ones, such as *Mortonella, Periarchus*, and *Protoscutella*), which are obviously older in geological occurrence than the former. The European genera of mainly Miocene epoch (e.g., *Scutella* and *Parascutella*) retain some primitive characters but have specialized in the oral ambulacral furrows, and seem to be, as stated by DURHAM (1955, p. 116), the North Pacific lineage (e.g., *Echinarachnius*) is derived from their ancestry. They should be classified into a single family. The separation of the North Pacific genera (e.g., *Echinarachnius, Scaphechinus, Dendraster*, and *Astrodapsis*) into two families, the Dendrasteridae and the Echinarachniidae, as proposed by DURHAM (1955, pp. 157–169), seems to be arduous and troublesome in discrimination of the two. DURHAM's distinctions of the two families are best seen in the following table.

1	Dendrasteridae	Echinarachniidae	
Internal supports	well-developed	well-developed	
Petals	well-formed; a few isolated pores outside petals; anterior petal widely open; outer member elongate	well-formed; a few isolated pores outside petals; usually open; outer member elongate	
Interambulacrum (5) discontinuous on oral surf		usually discontinuous in advanced species	
Interambulacra	nearly as wide as ambulacra at ambitus	usually two-thirds (or less) width of ambulacra	
Basicoronal interambulacral plates	larger than ambulacral plates	larger than ambulacral plates	
Genital pores	four	four	
Periproct	inframarginal to supramarginal	marginal to inframarginal	
Oral ambulacral furrows	bifurcating or trifurcating just outside basicoronal plates	with central trunk, some- times with lateral branches near ambitus	

This table, built from DURHAM'S diagnoses, emphasizes the trifling nature of these "families." DURHAM (1955, p. 162) classified the Japanese genus *Scaphechinus* together with the Californian *Dendraster* into his Dendrasteridae; but, *Scaphechinus*, in its general features, geographical distribution, and in phylogenetical point, has close relation to the primitive genus *Echinarachnius* of DURHAM's usage of the Echinarachniidae than to the genus *Dendraster*. The two families should be united into a single family or subfamily.

The occurrence of lunules or marginal slits in the test is one of the most characteristics of the second group. The lunules (or marginal slits) combined with subarenaceous life of the animal, permitting through the water and sand-grains on both adoral and aboral sides, enables the animal easily slip under the substratum of sandgrains under the sea water. The occurrence of ambulacral lunules in *Echinodiscus* (or *Amphiope*) is very characteristic in the echinoid morphology. The origin of *Echinodiscus* (or *Amphiope*) is not clear, but if a *Scutella*-like form with test of large, discoid, and with branching oral ambulacral furrows, has got the development of two postero-lateral ambulacral lunules, approaches the form in outline of *Echinodiscus*. This assumption has not contradiction in the geological and geographical distribution and in the features of the both genera. Unfortunately, the genus *Scutella* has no living representative, and the pedicellariae are not known; hence, it cannot be ascertained whether it has same type of pedicellariae (e. g., ophicephalous type—an unique character of adult *Echinodiscus*) as in *Echinodiscus* or has not.

The occurrence of a posterior interambulacral lunule in Mellita and Encope is

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more or less different course from the postero-lateral ambulacral lunules of *Echino*discus (or Amphiope) in the mode and in the geographical distribution. DURHAM (1955, p. 116) suggested that they may have been derived from the protoscutellid (or scutellid) ancestry. In the South American genus *Monophoraster* of the Miocene epoch, there occurs only a posterior interambulacral lunule of small-size as in *Mellita*, and because of this presence of a lunule it has been placed with *Mellita* and *Encope* in a subfamily or family. DURHAM (1955, p. 117) claimed that the specialized interambulacra of *Monophoraster* preclude any association with *Mellita* or *Encope*.

In any case, the morphological differences between *Echinarachnius* and *Echino*discus and between *Dendraster* and *Mellita* are greater or at least no lesser than the differences between *Laganum* and *Scutella*, or they much greater than the differences between *Echinarachnius* and *Astrodapsis*, or between *Laganunm* and *Peronella*. It seems highly probable that the genera *Echinodiscus* and *Astriclypeus*, and *Mellita* and *Encope*, having ambulacral lunules or marginal slits or a posterior interambulacral lunule make a separate family from the Scutellidae (or Dendrasterinae in the strict usage), which without these lunules or marginal slits.

The writer recognizes, herein, as far as the Indo-West Pacific forms are concerned 4 families and 6 subfamilies in the suborder Scutelloina, viz., the Protoscutellidae DURHAM, 1955 (with the subfamilies, Protoscutellinae DURHAM, 1955, and the Eoscutellinae DURHAM, 1955), the Scutellidae GRAY, 1825 (with the subfamilies, Scutellinae GRAY, 1825, and the Dendrasterinae LAMBERT, 1900), the Astriclypeidae STEFANINI, 1912 (with the subfamilies, Astriclypeinae STEFANINI, 1912, and the Mellitinae STEFA-NINI, 1912), and the Monophorasteridae LAHILLE, 1896. It is to be noticed that there are striking examples of parallel evolution within the suborder, in the oral ambulacral furrows, the arrangement of coronal plates on the oral surface, and in the basicoronal row, and some of these families (or subfamilies) are poorly differentiated from one another. The families and subfamilies are discriminated from one another as shown by the following key.

Key to the families and subfamilies of the Scutelloina.

1.	Test of usually moderate size, without lunules or marginal slits 2
	Test of usually large forms, with lunules or marginal slits 5-
2.	Genital pores 5 or 4. Petals well-developed, moderately closed. Interambulacra
	usually continuous on oral surface. Periproct marginal or on oral surface.
	Oral ambulacral furrows simple to bifurcating Protoscutellidae
	Genital pores 4. Petals well-formed, open distally or moderately closed. Inter-
	ambulacra discontinuous or continuous on oral surface. Periproct supramar-
	ginal to inframarginal, or on oral surface. Oral ambulacral furrows variable,
	simple to bifurcating or trifurcating4
3.	Genital 5. Periproct on oral surface. Oral ambulacral furrows simple to bifur-
	cating Protoscutellinae
	Genital pores 4. Periproct marginal. Oral ambulacral furrows bifurcating just
	outside basicoronal platesEoscutellinae

4. Petals moderately closed, no primary pore-pairs outside petals. Interambulacra continuous on oral surface. Periproct on oral surface. Oral ambulacral furrows bifurcating just outside basicoronal platesScutellinae Frontal petal usually open distally, paired petals open or more or less closed, a few isolated pores outside petals. Interambulacra, particularly the posterior (5), discontinuous on oral surface. Periproct supramarginal to inframarginal. Oral ambulacral furrows simple to bifurcating or trifurcatingDendrasterinae 5. Genital pores 5 or 4. Ambulacral lunules or marginal slits or a posterior interambulacral lunule present. Interambulacra usually discontinuous, rarely the posterior (5) continuous, on oral surface; on oral surface widening toward ambitus, about as wide as ambulacra at ambitus Astriclypeidae 6 Genital pores 4. Only a posterior interambulacral lunule present or none. Interambulacra continuous on oral surface, much narrower than ambulcra, narrower at ambitus than midway on oral surface Monophorasteridae 6. Genital pores 4. Ambulacral lunules or marginal slits present, but no posterior interambulacral lunule. Interambulacra discontinuous on oral surface Astriclypeinae Genital pores 5 or 4. A posterior interambulacral lunule and ambulacral lunules or marginal slits present. Paired interambulacra discontinuous, but rarely There are fossil representatives of the families, the Scutellidae (the subfamily Dendrasterinae) and the Astriclypeidae (the subfamily Astriclypeinae) in our collection.

Family Scutellidae Gray, 1825

Scutellidae GRAY, 1825, p. 427 (pro parte).—Scutellidae AGASSIZ: A. AGASSIZ, 1872-74, pp. 106, 524 (pro parte).—Scutellinae LAHILLE, 1895, pp. 33-34.—MORTENSEN, 1948-c, pp. 359, 360.— DURHAM, 1955, p. 150 (partim).
Type-genus.—Scutella LAMARCK, 1816.

Test usually of moderate size, very flat, without lunules or marginal slits. Internal skeletal supports within test more or less complicate structure or rather simple. Ambulacra usually distinctly petaloid adapically, on oral surface forming distinct, usually branching, or rarely simple, furrows, which usually terminating adorally in a small projection over peristome; petals well-formed, a few isolated pores outside petals or none, open distally or moderately closed; outer member of pore-pair elongated. Interambulacra discontinuous, particularly the posterior (5), or continuous on oral surface, nearly as wide as ambulacra or two-thirds ambulacra at ambitus. Apical system central, or more or less eccentric to anterior or posterior, with 4 genital pores. Peristome central, small, rounded, mostly with edge abruptly sunken. Periproct supramarginal to inframarginal, or on oral surface. Basicoronal interambulacral plates as large as or larger than ambulacral plates. Oral ambulacral furrows variable, simple to bifurcating or trifurcating, or with central trunk, sometimes with lateral branches near ambitus. Primary radioles of oral side simple, those on aboral side more or less conspicuously club-shaped; miliary radioles mostly simple, terminating in a glandular bag. Pedicellariae bivalved in living species. Tube-feet with only a pair of spicules in sucking disc. Larva with a skeleton of basket type, usually rather complicate (after MORTENSEN, 1948-c, and DURHAM, 1955).

From the Oligocene to Recent.

This family comprises, as described above, the European fossil forms and North Pacific Recent and fossil forms. The North Pacific forms themselves constitute a subfamily separate from the European forms.

Subfamily DENDRASTERINAE LAMBERT, 1900

Dendrasteridae LAMBERT, 1900, table opp. p. 50 (pro parte).—LAMBERT and THIÉRY, 1914, p. 316 (pro parte).—DURHAM, 1955, p. 157 (partim).

Type-genus.—Dendraster AGASSIZ, 1847.

Phelsumasteridae LAMBERT and THIÉRY, 1914, p. 316 (partim).—Echinarachniidae LAMBERT: DURHAM, 1955, p. 163 (emended for Phelsumasteridae LAMBERT and THIÉRY, 1914). Type-genus.—Echinarachnius GRAY, 1825=Phelsumaster LAMBERT and THIÉRY, 1914.

Petals well-formed, a few isolated pores outside petals, outer member of pore-pair elongated; petals open distally or paired ones moderately closed. Posterior interambulacrum (5) usually discontinuous on oral surface; interambulacra nearly as wide as or two-thirds ambulacra at ambitus. Basicoronal interambulacral plates larger than ambulacral plates. Oral ambulacral furrows variable, simple to bifurcating or trifurcating just outside basicoronal plates, or with central trunk, sometimes with lateral branches near ambitus. Radioles, pedicellariae, and tube-feet as in the diagnosis of the family (from DURHAM, 1955).

From the Upper Oligocene to Recent, Pacific Coast of North America to Japan.

This subfamily comprises North Pacific Recent genera Dendraster, Echinarachnius, and Scaphechinus, and fossil genera Astrodapsis, Kewia, and others. Since the relationships of the North Pacific forms, viz., Echinarachnius parma (LAMARCK, 1816), Scaphechinus mirabilis A. AGASSIZ, 1863, Astrodapsis antiselli CONRAD, 1856, and Dendraster excentricus (ESCHSCHOLTZ, 1831), to one another are very close, it is necessary either to unite all the species in a single group, or otherwise to separate them by drawing

arbitrary lines; and the external features useful for a natural classification of this group are once discussed by the writer (NISIYAMA, 1940, pp. 809-812) and DURHAM (1949; 1952; 1955). The writer, herein, discusses the oral ambulacral furrows and the arrangement of plates on the oral surface, which are hitherto rather little paid attention.

The oral ambulacral furrows of *Ech. parma* (textfig. 34 [9]) do not branch until over halfway to the margin, with a pair of simple side branches distally, issuing at angle of about 45° at the height of the 3rd ambulacral plates (or the distal end of first postbasicoronal plates); the main furrow continues beyond



Fig. 34 [9]. Oral ambulacral furrows of *Echinarachnius parma* (LAMARCK, 1816), $\times 0.6$.

the branching to the edge of the test, may even pass a little onto the aboral side. The oral ambulacral furrows of *Ast. antiselli* resembles those of *Ech. parma* in the



Fig. 35 [10]. Oral ambulacral furrows of Scutellaster oregonensis major (KEW, 1920), $\times 0.6$ (from DURHAM, 1949).



Fig. 36 [11]. Oral ambulacral furrows of *Scaphechinus mirabilis* A., AGASSIZ, 1863, ×0.7.

manner of branching, but they are broad and the side branches are few in number. The oral ambulacral furrows of *Scaph. mirabilis* (text-fig. 36 [11]), are characterized by the furrows bifurcating at the second (or just outside the basicoronal plates) ambulacral plates into two diverging main branches, which have a varying number of small side-branches distally, mainly on the outer side; the main stem of the furrows does not continue beyond the bifurcating point. The oral ambulacral furrows of Scutellaster as typified by those of Scut. oregonensis major (KEW, 1920) (text-fig. 35 [10]) are somewhat similar to those of *Dendraster* in that the system of the two postero-lateral ambulacra (I and V) is the most complex, while that of the frontal ambulacrum (III) is the most reduced; the branching is usually a modified trifurcation instead of a bifurcation. In Dend. excentricus the furrows bifurcating just outside the basicoronal plates, which are decidedly smaller than those of Scaph. mirabilis, and a second time, somewhat unequally, about a half or two-thirds the distance to the margin, and subsequently several short minor branches are given off (text-fig. 37 [12]); and as in Scutellaster the system of the frontal ambulacrum (III) is the simplest, while those of the postero-lateral ambulacra extend over the margin onto the aboral surface.

In the ambulacral and interambulacral plates system (the arrangement of the plates) on the oral surface, the marked differences are apparent between some of these species and close similarities between others. The arrangement in *Merriamaster*, *Dendraster*, *Scaphechinus*, and *Ast. antiselli*, is much similar, whereas in *Echinarachnius* and *Scutellaster* is markedly different from each other and from the other four. The plates of the basicoronal row surrounding the peristome in each case consists of ten ambulacral and five interambulacral plates, thus conforming to the typical scutellid pattern of the family. In the comparative meaning, the plates of the basicoronal row are the smallest in *Dendraster*, and successively larger in *Merriamaster*, *Ast. antiselli*, *Scutellaster*, *Echinarachnius*, and *Scaphechinus*.

On the basis of the arrangement of the plates, *Scutellaster* appears to be the most primitive in that the basicoronal interambulacral plates are contact with post-basicoronal plates in areas 1, 2, 3 and 4, and only in the posterior area (5) the interambulacral plate has been pushed dorsally so that the first post-basicoronal ambulacral plates of the postero-lateral areas (I and V) are in contact. In the postero-lateral



Fig. 37 [12]. Oral ambulacral furrows of *Dendraster excentricus* (ESCHSCHOLTZ, 1831), $\times 0.55$.



Fig. 38 [13]. Structure of oral surface of *Echinarachnius* parma (LAMARCK, 1816), ×0.8.

interambulacral areas (1 and 4), only one column of plates is in contact with the basicoronal plate, with the plate making this contact being very high and rather narrow. In the antero-lateral interambulacral areas (2 and 3), both columns make contact with the basicoronal plate. The plates of the basicoronal row are moderately large and the interambulacral plates in the antero-lateral areas (2 and 3) are larger than the other three. On the oral surface, there are from three to six post-basicoronal ambulacral plates to a column, and two to three post-basicoronal interambulacral plates to a column. The interambulacral plates of the basicoronal row are from one to three times as large as the adjacent ambulacral plates.

In *Echinarachnius*, some are just as in *Scutellaster*, but the others in contrast to that genus, the basicoronal interambulacral plates are just barely in contact in the antero-lateral areas (2 and 3) with the post-basicoronal plates and are completely separated from them in areas 1, 4 and 5. The basicoronal interambulacral plates have become greatly enlarged in contrast to the adjacent ambulacral plates and have a total area six to eight times as great as the ambulacrals (text-fig. 38 [13]). There are usually five post-basicoronal ambulacral plates to a column on the oral surface, and three post-basicoronal interambulacral plates in *Ech. parma* is pointed out by DUR-HAM (1949, p. 58; 1955, pp. 109, 111). The shape of the basicoronal interambulacral.



Fig. 39 [14]. Structure of oral surface of *Scutellaster* oregonensis quaylei GRANT and HERTLEIN, 1938, $\times 1.4$ (from DURHAM, 1949).



Fig. 40 [15]. Structure of oral surface of *Echinarachnius laganolithinus* NISIYAMA, 1940,. ×0. 6.

plates is shown formerly by the writer (NISIYAMA, 1940, text-fig. 1 on p. 808) for a specimen from Maine, much differ from the shape in the figure given by DURHAM (1949, text-fig. 28 on p. 54) for a specimen from Alaska, but resembles that given by JACKSON (1912, text-fig. 52 on p. 52) for a specimen from Maine.

Dend. excentricus, Merriamaster perrini, and Ast. antiselli are characterized by the plates of the basicoronal row being quite small in comparison to the next row of plates, and by all the interambulacral areas being approximately equally separated from the basicoronal interambulacral plates, so that the first row of post-basicoronal ambulacral plates of each ambulacrum is in lateral contact with the plates of the adjacent ambulacrum. In addition, in contrast to the condition prevailing in *Echinarachnius* but similar to that in *Scutellaster*, the first post-basicoronal ambulacral plates are considerably larger than subsequent plates of the same column. In *Dend. excentricus* (text-fig. 41 [16]), there are three to four (except the posterior interambulacral area (5) which has two or rarely three) post-basicoronal plates in each interambulacral column, and one large and three to five smaller plates in each ambulacral column on the oral surface.



Fig. 41 [16]. Structure of oral surface of *Dendraster excentricus* (ESCHSCHOLTZ, 1831), $\times 0.6$ (from GRANT and HERTLEIN, 1938).



Fig. 42 [17]. Structure of oral surface of Scaphechinus mirabilis A. AGASSIZ, 1863, $\times 0.7$.

Scaphechinus (text-fig. 42 [17]) is characterized by all the interambulacral areas being separated from the basicoronal interambulacral plates, so that the first row of post-basicoronal ambulacral plates of each ambulacrum is in lateral contact with the plates of the adjacent ambulacrum as in *Dendraster*. But the basicoronal interambulacral plates have become greatly enlarged in contrast to the adjacent basicoronal ambulacral plates and have a total area four to five times as great as in *Echinarachnius*. There are two to three (except the posterior interambulacral area (5) which has two) post-basicoronal plates to a column as in *Echinarachnius*, and one large and three to four smaller plates in each ambulacral column on the oral surface as in *Dendraster*.

In *Merriamaster* (text-fig. 43 [18]), the arrangement of the plates is quite similar to *Dendraster* except that the basicoronal plates are proportionately a little larger, and that there are more plates in the columns on the oral side and the individual plates near the ambitus have a very low altitude in proportion to their length, a character in which they are allied to *Astrodapsis*. In the ambulacral areas, there is one large



Fig. 43 [18]. Structure of oral surface of *Merriamaster perrini* (WEAVER, 1908), $\times 1.2$ (from DURHAM, 1949).

post-basicoronal plate followed by four to six plates in a column, with the most plates in the anterior areas, while there are three to five post-basicoronal plates in the column of the interambulacral areas, again with the most plates in the anterior areas.

The internal partition walls and buttresses of the genera *Dendraster*, *Echinarachnius*, *Merriamaster*, and *Scutellaster* are shown by DURHAM (1949, pls. 1-2), of the genus *Scaphechinus* by the writer (NISI-YAMA, 1940, text-figs. 35-38 on p. 834, pl. 43, fig. 4), of the genus *Pseudoastrodapsis* by the writer (NISI-YAMA, 1948, figs. 11-12), and of the genus *Kewia* by NAGAO (1928, pl. 1, fig. 6). All the genera are typified

by two fairly closely spaced radial partition walls extending from the periphery inwards some distance in each interambulacrum, together with a variable development, or almost lacking, of supplementary concentric buttresses. Those of *Kewia* and *Pseudoastrodapsis* (at least in the type-species) are the simplest, extending in only half of the distance from the periphery and having no supplementary buttresses. Those of *Merriamaster* are the simple, extending in only about one-third of the distance from the periphery and having only a slight development of supplementary buttresses, this latter feature separates it from *Astrodapsis*, which in the primitive species examined has no supplementary buttresses, in this fact *Astrodapsis* coincides with *Pseudoastrodapsis*. *Scutellaster* has the radial partition walls and buttresses about equivalent to *Merriamaster* but much heavier. *Echinarachnius* has the same radial partition walls, and finer but more abundant buttresses covering a greater area of the floor, but not as many as in *Dendraster*. *Scaphechinus* has the quite same radial partition walls as in *Echinarachnius*, and almost same or more or less abundant supplementary buttresses as in *Echinarachnius*.

The extinct genus *Astrodapsis* is highly diverse in the major morphology (textfig. 44 [19]), but is readily separable from the genera discussed above by the numerous low plates of the ambulacral columns outside of the petals extending over the ambitus onto the oral surface before they begin to increase in size, in addition to having



Fig. 44 [19]. Structure of oral surface of Astrodapsis (from DURHAM, 1955).
a. A. brewerianus (REMOND, 1863), ×1.5.
b. A. antiselli CONRAD, 1856, ×0.7.

raised petals, and oral ambulacral furrows of the general type of Echinarachnius.

In *Kewia*, the basic pattern of the arrangement of plates on the oral surface seems to be the most primitive as in that of *Scutellaster*, the basicoronal plates are large, and the tip of the large basicoronal interambulacral plates just touching the base of subsequent plates in each area except the posterior interambulacrum (5). There are three post-basicoronal plates in each ambulacral column, and only two post-basicoronal interambulacral plates to a column. The oral ambulacral furrows usually indistinct and seem to be simple, not divided or rarely divided distally near the margin of the

test. The internal partition walls extending in about one-third to a half of the distance from the periphery and without or with a few supplementary buttresses.

In *Pseudoastrodapsis* (text-fig. 45 [20]); the basicoronal plates are moderately large and the interambulacral plates are much smaller than the ambulacral plates; interambulacral areas on the oral surface very narrow, about one-fourth the width of the ambulacral areas at the ambitus; the post-basicoronal interambulacral plates in contact with the basicoronal plates in the areas 1, 2, 3 and 4, but moderately separated in the posterior area (5). There are four to five post-basicoronal interambulacral plates in the areas 1, 2, 3 and 4, and three plates in the posterior area (5), and about six to seven post-



Fig. 45 [20]. Structure of oral surface of *Pseudoastro*dapsis nipponicus (NISIYAMA, 1948), $\times 1.8$ (from DURHAM, 1952).

basicoronal ambulacral plates to a column on the oral surface. The oral ambulacral furrows, at least in the type-species, are simple and unbranched. *Pseudoastrodapsis*, at least in the type-species, has five pairs of internal radiating partition walls but no supplementary buttresses as in most species of *Astrodapsis*.

Allaster has similar arrangement of ambulacral and interambulacral plates on the oral surface as in *Kewia* and *Scutellaster*, and the oral ambulacral furrows are simple and unbranched as in *Kewia* or *Pseudoastrodapsis* (in the type-species). Also it has five pairs of strong internal radiating partition walls extending in about one-fourth the distance from the periphery.

In summary of the above discussion, with regarding the eccentricity of the apical system, the position of periproct, the form and details of ambulacral plates, and the amount of elevation of petaloid area and depression in interambulacra, the North Pacific genera of the family are discriminated from one another as shown by the following key.

Key to the genera of the subfamily Dendrasterinae.

1.	Oral ambulacral furrows simple or branching only distallly, the main stem gener-
	ally continuing to the edge of test 2
	Oral ambulacral furrows bifurcating near the peristome, the main stem not con-
	tinuing beyond the point of bifurcation 10
2.	Oral ambulacral furrows simple, not branching

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	Oral ambulacral furrows branching distally 7
3.	Periproct supramarginal. Edge of test thin and sharp 4
	Periproct marginal. Edge of test thin, or swollen 5
4.	Interambulacra continuous, except posterior area (5), on oral surface. Aboral
	surface low arched. Fossil Kewia
	Interambulacra apparently all discontinuous on oral surface. Test flattened.
	Fossil Tenuirachnius
5.	Edge of test thin and sharp 6
	Edge of test swollen. Aboral surface depressed. Petals open distally. Fossil
	Allaster
6.	Test usually longer than broad. Paired interambulacra continuous on oral sur-
	face. Peripheral ambulacral plates low altitude. Fossil Remondella
	Test broader than long. Interambulacra usually discontinuous on oral surface.
	Margin of test more or less strongly indented at posterior ambulacra (I and
	V). Fossil Vaquerosella
7.	Petals more or less conspicuously raised, with intervening interambulacral de-
	pressions. Periproct inframarginal
	Petals not raised. Periproct marginal, or rarely supramarginalEchinarachnius
8.	Apical system central. All petals subequal
	Apical system posterior. Petals unequal, postero-lateral petals (I and V) shorter
	than the others. Fossil Merriamaster
9.	Interambulacral areas on oral side very narrow, about one-fourth of ambulacral
	areas. Fossil Pseudoastrodapsis
	Interambulacral areas on oral side rather broad, more than half ambulacral areas.
10	Fossil Astrodapsis
10.	Apical system subcentral. All petals subequal. Periproct supramarginal or
	marginal II
	Apical system posterior. Petals unequal, postero-lateral petals (I and V) much
11	snorter than the others. Periproct on oral surface Dendraster
11.	reciproci supramarginal. Paired interambulacra usually continuous on oral
	surface. Petals large and more or less subequal, postero-lateral petals more
	Perioroct marginal or rarely supramarginal Interambularra usually diagon
	tinuous on oral surface. Petals subsqual more or less open distally
	cindous on oral surface. Tetals subequal, more of less open distanty
	Among these North Pacific general it seems evident that Soutellaster is not closely
rela	ated to Echingrachnius as was suggested by STEWART (in WOODDING STEWART
and	RICHARDS 1940 p 83) and the both genera are distinct from <i>Dondrastor</i> although

related to *Echinarachnius* as was suggested by STEWART (in WOODRING, STEWART, and RICHARDS, 1940, p. 83), and the both genera are distinct from *Dendraster*, although an upper Miocene species of *Tenuirachnius*, which could have given rise to *Dendraster*. *Merriamaster* is probably not as closely related to *Echinarachnius*, as it is to *Dendraster* or to *Astrodapsis*. *Scaphechinus* is closely related to *Echinarachnius*, but it differs from that genus in mode of bifurcation of the oral ambulacral furrows and in the arrangement of plates on the oral surface. *Pseudoastrodapsis* resembles superficially the Californian genus *Astrodapsis*, but is distinguished from that genus by the arrangement of plates on the oral surface. *Kewia* is evidently related to the

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primitive forms of *Echinarachnius*, and MORTENSEN (1948-c, p. 365) doubted its generic or subgeneric validity and regarded it as a synonym of that genus. *Allaster* probably most related to *Pseudoastrodapsis* than to any other genera in the form of petals and general features of the test on one hand, and also resembles *Kewia* in the arrangement of plates on the oral surface, the oral ambulacral furrows, and simple internal supports, on the other hand.

The genus Dendraster may be regarded as characterized by an eccentric apical system, small plates in the basicoronal row, post-basicoronal interambulacral plates not in contact with basicoronal plates, periproct usually on oral surface, and unequal bifurcating ambulacral furrows extending onto aboral surface in the posterior areas. Echinarachnius is characterized by a normally central apical system, very large plates in the basicoronal row; in advanced species with interambulacral plates in the anterolateral areas (2 and 3) just barely in contact with basicoronal plates, oral ambulacral furrows equally trifurcaitng distally near the margin, and periproct usually marginal; but, in primitive species, post-basicoronal interambulacral plates may be continuous in the areas from 1 to 4, except the posterior (5), and periproct more or less supramarginal. In Scutellaster, as far as known, the periproct is always supramarginal, the apical system is usually somewhat eccentric, the ambulacral furrows approach those of *Dendraster* in complexity, but the major branching is a modified trifurcation instead of bifurcation. Merriamaster is intermediate between Dendraster and Astrodapsis, having small plates in the basicoronal row, the post-basicoronal interambulacral plates separated from the basicoronal plates, a rounded margin, supramarginal periproct, a few concentric internal buttresses, and simple branching ambulacral furrows which may extend onto the aboral surface. Kewia is characterized by the simple, unbranched, or indistinct oral ambulacral furrows, the basicoronal interambulacral plates usually in contact with the subsequent plates except the posterior area (5), petals composed of relatively small number of plates, the eccentric in front position of the apical system, the supramarginal position of periproct, and by the strong internal partition walls without or with a few supplementary buttresses. As for Vaquerosella, particularly Vag. merriami (ANDERSON, 1905)-from the Temblor (Miocene) formation of California, DURHAM (1949, p. 60) stated that it appears possible that it could be ancestral to all later scutellids (dendrasterids) of California region. The Californian fossil genus Remondella, as stated by DURHAM (1949, p. 60), may be near the ancestral stock of Scutellaster or also be a side-branch of the stock that produced Astrodapsis.

The above discussion on the related genera of the North Pacific dendrasterid echinoids is summarized as follows. The least specialized genus is the *Kewia*, which is regarded to be nearly as the ancestral radicle of the North Pacific echinarachnid echinoids, particularly of the *Echinarachnius* of Japanese and Californian species, and the morphological relation of *Kewia* to *Echinarachnius* seems to be direct and continuous. The *Kewia*, or the primitive *Echinarachnius*, on the Japanese side probably near to ancestral radicle of the more specialized *Echinarachnius* and *Scaphechinus*, and that on the Californian side together with *Vaquerosella* and *Tenuirachnius* may be near to ancestral radicle of the more specialized *Echinarachnius*, *Astrodapsis*, *Scutellaster*, *Merriamaster*, and *Dendraster*, as stated by DURHAM (1949, pp. 60-62). The northwestern Pacific peculiar echinoid, *Allaster*, may be a side-branch of the stock

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that probably produced *Pseudoastrodapsis*. Astrodapsis brewerianus (RÉMOND, 1963), from the Briones formation (Miocene) of California, is regarded the most primitive species currently referred to Astrodapsis in its general features, and may be descendant of a primitive *Tenuirachnius*, as described by DURHAM (1949, p, 60). The writer regards the North Pacific forms of the dendrasterids, e.g., *Kewia*, *Echinarachnius*, *Allaster*, *Astrodapsis*, *Pseudoastrodapsis*, *Vaquerosella*, *Remondella*, *Scutellaster*, *Merriamaster*, and *Dendraster*, as each separate and valid genus.

The fossil representatives of the genera, Kewia, Echinarachnius, Scaphechinus, Allaster, and Pseudoastrodapsis in our collection.

Genus Kewia NISIYAMA, 1935

- Kewia NISIYAMA, 1935, p. 131, foot-note (subgenus ad *Echinarachnius*).—NISIYAMA, 1940, pp. 817, 819, 853 (subgenus).—MORTENSEN, 1948-c, pp. 363, 365(?).—DURHAM, 1955, p. 164, text-figs. 3a, 34d, 36f (genus).
- Orthotype.—Scutella blancoensis KEW, 1920, p. 64, pl. 11, figs. 1a-c (San Lorenzo Series, Oregon).—Echinarachnius blancoensis (KEW) GRANT and HERTLEIN, 1938, p. 57, pl. 26, figs. 5-7 (Empire formation, Oregon).

Test usually of small size, oval or round outline, at times slightly elongated posteriorly, aboral side low arched, oral side flat or more or less concave orally, highest point usually slightly anterior to apical system. Petals composed of comparatively small number of plates, frontal petal broadly open distally, paired petals open or moderately closed; petals about two-thirds length of radius; pore-pairs more or less conjugate. Ambulacra more or less wider than interambulacra at ambitus. Oral ambulacral furrows usually simple, unbranched, and not reaching to edge. Peristome eccentric in front or central, moderately large, more or less sunken. Apical system usually eccentric in front, with four genital pores. Periproroct usually supramarginal, close to margin. Basicoronal plates of moderate size, somewhat irregular in typespecies, interambulacral plates considerably larger than ambulacral plates; post-basicoronal interambulacral plates in areas 1, 2, 3, and 4 in contact with basicoronal plates or approximately so; posterior area (5) widely separated from basicoronal row; on oral surface interambulacral areas 1a, 2a, 2b, 3a, 3b, and 4b with three post-basicoronal plates, areas 1b, 4a, 5a, and 5b with two or three post-basicoronal plates to a column; post-basicoronal ambulacral plates on oral surface three to five to a column. Interambulacra one-third to one-half as wide as ambulacra at ambitus, with posterior area (5) narrowest. Five pairs of strong partition walls within test, without or with and the second second a few supplementary buttresses.

From the Oligocene to Miocene of Oregon, California and Japan, as well as Sakhalin.

As for the geological horizon of the type-species, K. blancoensis, DURHAM kindly wrote to the writer (March 6, 1953), as—"Your genus Kewia (type Scutella blancoensis KEW) has had me worried for some time because later literature than that you cited claimed that Scutella blancoensis was from beds of Pliocene age, yet it is a primitive species in its structure. However last Fall I (Dr. DURHAM) visited the type locality and found that it is from another formation which is of lower Miocene age. Now it fits into the evolutionary sequence much better."

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MORTENSEN (1948-c, p. 365) doubted the Kewia as a valid genus or subgenus of Echinarachnius, as the almost all species referred to this genus (or subgenus) have characters considerably resembling those of neanic (or some nepionic) stage of species referred to the genus *Echinarachnius*, and there is a doubt on maturity of described and figured specimens of the species of Kewia. The writer, however, after examined many specimens referable to Kewia, found that the specimens have well-marked genital pores as in adult specimens of *Echinarachnius*; while in the young specimens of almost equal size of longitudinal diameter of Scaphechinus brevis (NISIYAMA, 1940, text-figs. 38-60, 64) the genital pores have not yet appeared outside. In the examined specimens of *Kewia* in our collection, there is no specimens over 50 mm in longitudinal diameter of test, and the specimens may be regarded as nearly as adult forms. On the contrary, in the fossil specimens of Echinarachnius examined, the writer found that small specimens (less than 30 mm in longitudinal diameter) are comparatively few in number and without outside development of genital pores, whereas adult specimens (over 60 mm in longitudinal diameter) are common and with well developed genital pores. Hence, the writer regarded the specimens with well marked genital pores as nearly as the adult forms referred to the genus Kewia, notwithstanding small size of their test and the primitive characters in their general features. The primitive characters in general features ascertained in the species of *Kewia* and their older geological age fit into the evolutionary sequence fair well.

Kewia may be differentiated from *Echinarachnius* by its supramarginal periproct, more elongate first pair of post-basicoronal interambulacral plates, simpler internal skeletal supports, and by the usually greater closure of the paired petals.

There are apparently more than four species of the genus in Japan and the adjacent regions.

Kewia parva (NISIYAMA, 1940)

Echinarachnius (Kewia) parvus Nisiyama, 1940, p. 822, pl. 44, figs. 7-12.—Kewia parva (Nisiyama) Durham, 1955, p. 166.—Nisiyama, 1965, p. 79.

Holotype.—IGPS coll. cat. no. 60328.

Locality and geological horizon.—Near Kawakami Hot spring, Toyokita-mura, Sakaehama-gun, South Sakhalin. Shirahimeyama formation, Oligocene.

There are about one hundred and fifty specimens referable to this species in the collection, ranging from 10 to 28 mm in longitudinal diameter; the holotype (22 mm in longitudinal diameter) has well-marked outside genital pores; periproct round, supramarginal at about 1.5 mm from the posterior edge of test, and placed in a very shallow groove.

This species closely resembles *K. blancoensis* (KEW, 1920) (loc. cit.), from the Empire formation (Lower Miocene or Oligocene) of Cape Blanco, Oregon, but is distinguished from that species by the periproct lying in a very shallow groove and situated further apart from the posterior edge of the test, the petals are wider open and more flaring, narrower and shorter, do not extend to so near the margin, and the poriferous zones are more or less narrower, and further the test is less elevated with the posterior end more pointed. This species may be regarded as a primitive

member of the genus, and in its morphological features it is less developed than the American species, as is indicated by the form of test, the primitive characters of the petals as well as in the feature of the oral ambulacral furrows. It appears possible that it represents the near ancestral stock from which the Japanese echinarachniids are probably derived.

Kewia nipponica (NAGAO, 1928)

Scutella nipponica NAGAO, 1928, p. 16, pl. 1, figs. 5-6.—Echinarachnius (Kewia) nipponicus (NAGAO) NISIYAMA, 1940, p. 821.—Echinarachnius nipponicus (NAGAO) : MORISHITA, 1955, p. 228, pl. 11, figs. 3-4 (reproduced from NAGAO, 1928).—Kewia nipponica (NAGAO) DURHAM, 1955, p. 166.—Echinarachnius nipponicus (NAGAO) : MORISHITA, 1960, p. 58.—Kewia nipponica (NAGAO) : NISIYAMA, 1965, p. 79.

Holotype.—IGPS coll. cat. no. 35956.

Locality and geological horizon.—IGPS loc. no.—Fo-31.--A point of Takasu, Shimagomachi, Wakamatsu City, Fukuoka Prefecture (tm Orio, Lat. 33°52′56″N., Long. 130° 41′40″E.). Yamaga formation, Oligocene. Holotype.

Locality and geological horizon.—IGPS loc. no.—Fo.-32.—A point of Asakawa, Shimago-machi, Wakamatsu City, Fukuoka Prefecture (tm Orio, Lat. 33°52′44″N., Long. 130°42′16″E.). Yamaga formation, Oligocene. Paratypes.

The holotype measures 48 mm in longitudinal diameter of the test. The test is greatly depressed, and the outside genital pores have appeared; the ambulacra are more than twice as broad as the interambulacra at the ambitus. It may be added, here, that, there are five pairs of internal radiating partition walls within the test and no supplementary buttresses, the oral ambulacral furrows are simple and not divided, and the position of the periproct is probably supramarginal. This species is apparently distinct from known members of this genus and its relationships to the other species remain uncertain at present. NAGAO (1928, p. 16) stated that this species resembles some Lower Miocene fossils from the western coast of North America, such as Scutella tejonensis KEW, S. andersoni TWITCHELL, and S. merriami (ANDERSON), and it is most closely related to the first of those American forms, but is smaller and has a more depressed test and shorter petals. Of those Californian species, S. tejonensis Kew, 1920 (Kew, 1920, p. 76, pl. 12, figs. 2a-2b) and S. merriami (ANDERSON, 1905) (Astrodapsis merriami ANDERSON, 1905, p. 193, pl. 14, figs. 33-34.-Scutella merriami (ANDERSON) KEW, 1920, p. 72, pl. 12, figs. 3a-f) are referred to the genus Vaquerosella by DURHAM (1955, p. 167). The genus Vaquerosella (DURHAM, 1955, p. 166.—Orthotype.—Scutella andersoni TWITCHELL in CLARK and TWITCHELL, 1915, p. 183, pl. 85, figs. 3a-3d) is in common with the genus *Kewia* in the simple oral ambulacral furrows and in the feature of petals, but differs from the latter in having the marginal periproct and the discontinuous interambulacral plates on the oral surface, as well as having the broader than long test. NAGAO'S species may be referred to the genus . Kewia, on account of its general features.

Kewia elongata (NISIYAMA, 1940).

Echinarachnius (Kewia) elongatus NISIYAMA, 1940, p. 824, pl. 44, figs. 13-16, text-fig. 9.—Kewia elongata (NISIYAMA) DURHAM, 1955, p. 166.—NISIYAMA, 1965, p. 79.

Holotype.—IGPS coll. cat. no. 60329.

Locality and geological horizon.—A point of Chagama-zawa, Shiritoru-machi, Motodomari-gun, South Sakhalin. Kawabata (Sandstone) formation?, Miocene.

There are more than six specimens referable to this species at the writer's disposal, ranging from 23 mm to 35 mm in longitudinal diameter. The holotype measures 28 mm in longitudinal diameter of the test. The marginal outline of test subelliptical; the outside genital pores have appeared; the interambulacra are about half of the ambulacra at the ambitus; periproct rounded, 1 mm in diameter, supramarginal in position and situated at 0.5 mm from the posterior edge of test.

This species superficially resembles Vaquerosella andersoni (TWITCHELL, 1915), from the Vaqueros and Temblor formations (Miocene) of California, but may be distinguished from that species by its less strongly notched margin in the postero-lateral ambulacral areas (I and V), and small petaloid area, by which it is especially characterized. The longitudinally elongated outline of test, more or less defined petals, and distinct oral ambulacral furrows of this species are obviously more specialized than the ovate and transversely elongated test, with somewhat flaring petals, and simple, indistinct oral ambulacral furrows of K. parva. Comparing this species with K. nipponica, a peculiar form of Kyushu, the longitudinally elongated outline of test, the simple but rather distinct oral ambulacral furrows of the latter may be regarded as almost equally specialized as those of the former. But, in the greater eccentricity of the apical system of K. nipponica and the somewhat flaring form of petals, K. nipponica is less specialized than K. elongata. Although the true generic position of the present species is more or less uncertain, it agrees with Kewia in the form of petals and the arrangement of plates on the oral surface, the simple oral ambulacral furrows, and in the position of periproct.

The large first post-basicoronal ambulacral plates and the comparatively wide poriferous zones of this species suggest that the probable derivation of *Scaphechinus* from it or its allies.

Kewia minoensis (MORISHITA, 1955)

Sismondia naganoensis MORISHITA, 1953-a, p. 218, pl. 1, figs. 1-2, text-fig. 2.

Echinarachnius brevis: MORISHITA, 1954-a, p. 225, pl. 7, figs. 1-3, text-fig. 2 (non Echinarachnius brevis IKEDA, 1936).

Echinarachnius minoensis Morishita, 1955, p. 229, pl. 11, figs. 5-7 (pro Echinarachnius naganoensis (Morishita, 1953), non Morishita, 1953).—Morishita, 1960, p. 57.—Kewia minoensis (Morishita) Nisiyama, 1965, p. 79.

There is no authentic specimen of this species at the writer's disposal, although MORISHITA reported the occurrence of this species from the Miocene formations of many localities.

Localities and geological horizons of this species (after MORISHITA) are as follows.—

1. Shimizusawa, Aida-mura, Higashichikuma-gun, Nagano Prefecture (Lat. 36°20' N., Long. 138°E., near Matsumoto City). Aoki formation, Middle Miocene.

2. East of Haginoshima and Inkyoyama, Kamado-mura, Toki-gun, Gifu Prefecture (Lat. 35°25'N., Long. 137°20'E., near Tajimi City). Togari Tuffaceous Sandstone, Middle Miocene.

3. Yoshimura, Nagashino-mura, Minami-Shidara-gun, Aichi Prefecture (Lat. 34° 50'N., Long. 137°35'E., near Toyohashi City). Nagashino formation, Middle Miocene.

4. Okuyamada, Ujidawara-mura, Tsuzuki-gun, Kyoto Prefecture (Lat. 34°50'N., Long. 135°50'E., near Uji City). Tsuzuki formation, Middle Miocene.

5. Koyama, Susa-machi, Abu-gun, Yamaguchi Prefecture (Lat. 34°35'N., Long. 131°35'E.). Susa formation, Middle Miocene.

6. Furuichi-machi, Nara City (Lat. 34°40'N., Long. 135°50'E.). Fujiwara formation, Middle Miocene.

The test is small and measures less than 20 mm in longitudinal diameter. The outline of test is subpentagonal and pointed behind; the outside genital pores have already appeared; periproct is round in outline and supramarginal being at about 0.5 mm from the posterior periphery.

The genital pores of this species seem to have fairly appeared outside in specimens under 10 mm in longitudinal diameter of test, and the specimens described by MORISHITA, as stated by MORISHITA (1955, p. 230), may represent adult stage, if not were full grown, in spite of their small size. Although MORISHITA failed to describe the arrangement of ambulacral and interambulacral plates on the oral surface and details of the oral ambulacral furrows of this species, it may be safely referable to the genus *Kewia* in its general features. The internal radiating partition walls (1953-a, text-fig. 2 on p. 218, fig. 2 on pl. 1; 1955, fig. 6 on pl. 11) are strong and extending in about two-thirds of the distance from the periphery inward, but without any concentric buttresses as in those of K. nipponica (NAGAO, 1928, fig. 6 on pl. 1). The internal structure of this species remarkably contrasts to that of Scaphechinus mirabilis (NISIYAMA, 1940, text-fig. 36 on p. 834) and Scaph. brevis (NISIYAMA, 1940, textfig. 38 on p. 834) of almost same size. In the two species of Scaphechinus the internal radiating partition walls are short, extending in only about a half of the distance from the periphery and having a few but rather distinct supplementary buttresses. This feature of internal partition walls of this species also be regarded as one of the characters of *Kewia*, that separates it from *Echinarachnius* (or *Scaphechinus*).

The relationships of this species to other species of the genus *Kewia* are not certain. But the great resemblance of the aboral features of this species with young of *Scaphechinus brevis*, as MORISHITA (1954-a, p. 225) has referred it to young of that species, may offer more bearing of its relationships to the living species of *Echinara-chnius* (or *Sacaphechinus*) from Japan than to other species of *Kewia*.

In summary of the above described species, we have no means to know which species is the nearest ancestral form of the Japanese *Kewia*, but it seems highly probable that the species with the inconspicuous petals, the anteriorly eccentric position of the apical system, the supramarginal periproct, the indistinct and simple oral ambulacral furrows, the continuous arrangement of post-basicoronal interambulacral plates with the basicoronal row on the oral surface, and the small form of the test are the most primitive. We are equally ignorant as to the place of origin of the Japanese *Kewia*, but there can hardly be any question that it was somewhere along the northern Japanese region. If these two points were accepted, *Kewia parva*, the oldest species of the genus in Japan and the adjacent regions, would be the nearest to the original one of the Japanese Kewia or of the echinarachniid echinoids. The phylogenetic position of K. nipponica is doubtful, as stated in the preceding page, but may be more specialized than K. parva. The relation of K. nipponica to the three Japanese Kewia, e.g., K. parva, K. elongata, and K. minoensis may be correlated with that of Vaquerosella tejonensis to the three Californian species, Vaq. andersoni, Vaq.

Genus Echinarachnius GRAY, 1825

- Echinarachnius GRAY, 1825, p. 428 (pro parte).—Agassiz, 1841-b, p. 88.—GRAY, 1855-a, p. 14.— DESOR, 1855-58 (57), p. 230 (pro parte).—A. Agassiz, 1872-74, pp. 107, 524 (pro parte).— Echinarachnius LESKE: DUNCAN, 1889-a, p. 158 (pro parte).—MEISSNER, 1904, p. 1383.— H. L. CLARK, 1911, pp. 598, 605.—H. L. CLARK, 1914, p. 66.—H. L. CLARK, 1925, p. 168.— NISIYAMA, 1935, p. 136, foot-note.—GRANT and HERTLEIN, 1938, p. 56.—NISIYAMA, 1940, pp. 804, 826.—MORTENSEN, 1948-c, p. 363 (complete synonymy), text-figs. 215-216.—DUR-HAM, 1949, p. 52.—TERMIER and TERMIER, 1953, p. 925.—DURHAM, 1955, p. 163, text-figs. 1i, 3b, 6e, 8a, 9a, 10a, 23-24, 26l, 34a-c, pl. 2, fig. 4.—MORISHITA, 1955, p. 223.—COOKE, 1959, p. 44.
 - Logotype.—Scutella parma LAMARCK, 1816, p. 11.—Echinarachnius parma (LAMARCK): A. AGASSIZ, 1872-74, p. 316, pl. 11d, figs. 4-5, pl. 11e, figs. 4-5, pl. 12, figs. 1-3 (East Coast of United States). [AGASSIZ, 1841-b, p. 88]. [Non Echinarachnius LESKE, 1778, nec LAMBERT and THIÉRY, 1914].
- Phelsumia POMEL, 1883, p. 70 (pro Echinarachnius GRAY, 1825, non LESKE, 1778; non Phelsuma GRAY, 1840).—Phelsumaster LAMBERT and THIÉRY, 1914, p. 316 (pro Phelsumia POMEL, 1883, non Phelsuma GRAY, 1840).
 - Orthotype.—Phelsumaster parma (LAMARCK) LAMBERT and TRIÉRY, 1914, p. 316.=Scutella parma LAMARCK, 1816, p. 11.
- Non Echinarachnius LESKE: LAMBERT and THIÉRY, 1914, p. 315.

merriami, or to K. blancoensis.

Type-species.—Echinarachnius placenta (LINNAEUS): LAMBERT and THIÉRY, 1914, p. 315.= Echinus placenta LINNAEUS, 1758, p. 666.

Test of medium or large size, usually of round outline, more or less indented at sutures, aboral side gently arched, oral side perfectly or nearly flat. Petals well developed, about three-fourths length of radius, usually broadly open distally, flaring at end; poriferous zones relatively narrow, a few small isolated pore-pairs (supernumerary pedicels) continuing pore-series of petals; outside petals ambulacra usually widen conspicuously, interambulacra being correspondingly restricted, about two-thirds as wide as or less ambulacra at ambitus. Peristome of moderate size, central, abruptly sunken; periproct small, marginal or rarely supramarginal, situated usually between third pair of post-basicoronal plates. Apical system usually central, with four genital pores. Oral ambulacral furrows with a pair of simple side branches distally, issuing at angle of about 45° at height 3rd (or distal end of 2nd) post-basicoronal ambulacral plates (trifurcating about one-third distance from margin); main furrow continues beyond branching point to edge of test, may even passes a little onto aboral side; in some species there are 2-3 side branches, which may even again have 1 or 2 side branches; furrows terminating adorally in a small, but fairly conspicuous, projection over peristome. Basicoronal plates rather large, interambulacral plates about twice as high as ambulacral plates; basicoronal interambulacral plates somewhat variable in relation to post-basicoronal plates, i.e., just barely in contact in contact in all areas in some specimens, in others in contact only in areas 2 and 3; usually 3 post-basicoronal plates in each interambulacral column on oral surface except in 2b and 3a, which have 4 plates; usually 5 post-basicoronal ambulacral plates in each column on oral surface except in IIb and IIIa, which may have 6. Pedicellariae of any kinds have two valves, in the living species, bidentate pedicellariae absence of any apophyses, biphyllous type very small and of rather odd shape. Radioles on aboral side widened terminal part. Pedicels without calcareous disc or ring, but each suck is strengthened by a pair of calcareous rods (spicules) (after MORTENSEN, 1948-c, and DURHAM, 1955).

From the Miocene to Recent, northwestern Pacific region; Pliocene to Recent, northeastern Pacific; and Recent, northwestern Atlantic.

This genus is characterized by the mode of trifurcating of the oral ambulacral furrows, the central position of the apical system, the usually marginal position of the periproct, and the well-formed petals, and by the arrangement of plates on the oral surface. The arrangement of plates on the oral surface of test, as discussed in detail by DURHAM (1955), shows variation in structure of morphological importance. The distinct oral ambulacral furrows which trifurcate on the height of the 3rd (or the distal end of second) post-basicoronal ambulacral plates in the median line, the discontinuous arrangement of the interambulacral plates in some areas on the oral surface, the central position of the apical system, the rather thick margin with the marginal periproct, and the well-formed petals which composed of rather large number of plates of this genus are evidently more specialized than the indistinct and simple oral ambulacral furrows, the continuous arrangement of the interambulacral plates except the posterior area (5) on the oral surface, the anteriorly eccentric position of the apical system, the thin margin with the supramarginal periproct, and the flaring and rather ill-defined petals of Kewia. The morphological relation of the primitive Kewia, the older geological age, to the specialized Echinarachnius, the younger geological age, seems to be direct and continuous.

As for the specialization of the oral ambulacral furrows of the genus Echinarachnius, MORISHITA (1955, pp. 227-228) (he does not separate the genus into three genera (or subgenera), viz., Kewia, Echinarachnius, and Scaphechinus, but included the various forms into a single genus Echinarachnius), in discussing the morphological changes of the genus in Japan through the epochs between the Oligocene and the Recent, described as follows—"3) Simple actinal ambulacral furrows of the early types changed to the later complex ones. The furrows are undifferentiated of bifurcated only near at the margin in the Oligocene and the Miocene species, while the bifurcation take place near around the peristome and even rebifurcation in common in the later forms. after the Pliocene", with showing the changes of ambulacral furrows by diagrammatic figures (MORISHITA, 1955, text-figs. 2a-2d on p. 227). His statement on this point, as far as the morphological changes of the oral ambulacral furrows concerned with his ' Echinarachnius', may agree, as a whole with the writer's view on the features and development of the furrows within the genera Kewia, Echinarachnius, and Scaphechinus, with their geological occurrence. But, in regarding the development of the oral ambulacral furrows only, the *Echinarachnius*-type of trifurcation has occurred contemporaneously (the Miocene epoch) in the genera Echinarachnius and Astrodapsis, as described in the preceding page, and in Echinarachnius it persists to the Recent with

slight modification. The Scaphechinus-type of bifurcation, which branching at the height of distal part of the basicoronal ambulacral plates, also has occurred in the genera Scaphechinus and Dendraster during the Pliocene (or upper Miocene) epoch, and in the both genera it persists to the Recent. These genera are discriminated from each other by the features of the oral ambulacral furrows together with other several distinctive characters. The *Scaphechinus*-type of bifurcation of the furrows was still existed in the older epoch than this group, e.g., the genus Scutella LAMARCK, 1816; the genus seems to have no genetic connexion with Echinarachnius (or Scaphechinus). The feature of the furrows of Scutella, from the Upper Oligocene to Miocene of Europe, so simulates that of Scaphechinus, the North Pacific form, particularly to Scaph. mirabilis, that this species is regarded as a surviving species of the extinct genus Scutella by STEFANINI (1912, p. 702) and LAMBERT and THIÉRY (1914, p. 319), expressing as Scutella mirabilis (A. AGASSIZ). In the form of petals, the marginal periproct, and the arrangement of plates on the oral surface, Scaph. mirabilis may be regarded as to represent a descendant of primitive Echinarachnius, not of Scutella. Thus, the branching type of oral ambulacral furrows of this group, in simply regarding it only itself, cannot be taken for a guide of the geological age. The morphological changes of oral ambulacral furrows of the genus Echinarachnius in Japan given by MORISHITA (loc. cit.) must be assuming that the various forms included in this genus were developed along many lines from a source (or a stem), and they are closely related one another.

The genus *Echinarachnius* appears to have been greatly flourished in northwestern Pacific region during the Tertiary, and there are at least seven fossil representatives in Japan.

Echinarachnius microthyroides NISIYAMA, 1940

Echinarachnius (Echinarachnius) microthyroides NISIYAMA, 1940, p. 828, pl. 44, figs. 17-20, text-fig. 11.—MORISHITA, 1950, p. 256.—MORISHITA, 1953-a, p. 219, pl. 1, fig. 3(?).—MORISHITA, 1955, p. 228, pl. 9, fig. 5.—DURHAM, 1955, p. 164.—MORISHITA, 1960, p. 57.—HASHIMOTO and UJIIÉ, 1965, p. 87, pls. 1-3.—NISIYAMA, 1965, p. 79.

Holotype.—IGPS.coll. cat. no. 7900.

Type-locality and geological horizon.—IGPS loc. no.—It-21.—A point of Nagamine, Fukuoka-machi, Ninohe-gun, Iwate Prefecture (tm Ichinohe, Lat. 40°15'N., Long. 140° 18'E.). Suenomatsuyama (Nagamine) formation, Upper Miocene or Lower Pliocene.

Since the writer (NISIYAMA, 1940, p. 828) first decribed this species from the Suenomatsuyama formation of Iwate Prefecture, it has been reported from the following localities and geological horizons.

1. Mugurahara, Sendanno-mura, Higashi-Tonami-gun, Toyama Prefecture. Yokawa group (Tsubono siltstone), Miocene (MORISHITA, 1950, p. 256).

2. Kawashita, Togakushi-mura, Kami-Minochi-gun, Nagano Prefecture. Shigarami formation, Middle or Upper Miocene (MORISHITA, 1953-a, pp. 291-220, pl. 1, fig. 3).

3. Kamitsugu-mura, Kita-Shidara-gun, Aichi Prefecture. Formation unknown (MORISHITA, 1955, p. 229).

4. Left side cliff of the Uryûgawa, east of Soeushinai, Horokanai-machi, Uryû

County, Hokkaido. Wakkanai formation, Miocene (HASHIMOTO and UJIIÉ, 1965, pp. 87-92).

MORISHITA (1960, p. 57) regarded the geological range of this species to be restricted to the Upper Miocene, although he considered the Shigarami formation to be Pliocene; MORISHITA'S specimens from Shigarami formation are exceptional individuals with larger and thinner test than that of the typical species.

The holotype measures 41 mm in longitudinal diameter of test; the marginal outline of test longitudinally subovate; edge of test very thin; petaloid area rather small, about 0.60 or less of longitudinal diameter; periproct small, rather elliptical than circular, placed in a small notch at margin; oral ambulacral furrows rather distinct, trifurcate at two-thirds of test-radius from the peristome on median area at the height of the third (or distal end of second post-basicoronal) ambulacral plates; five or six post-basicoronal ambulacral plates and three post-basicoronal interambulacral plates to a column; basicoronal interambulacral plates large, about twice as high as ambulacral plates.

This species superficially resembles *Kewia fairbanksi* (ARNOLD, 1907) (*Scutella fairbanksi* ARNOLD, 1907, p. 562, pl. 42, fig. 3, pl. 43, fig. 3.—CLARK and TWITCHELL, 1915, p. 184, pl. 85, figs. 4-6.—KEW, 1920, p. 66, pl. 11, figs. 2a-2c.—*Echinarachnius fairbanksi* (ARNOLD) GRANT and HERTLEIN, 1938, p. 58, pl. 14, fig. 5), from the Temblor formation (Miocene) of California, but is distinguished from that species by the longitudinally elongated test, with the marginal periproct, and smaller petaloid area, and by the mode of the oral ambulacral furrows. Also this species is separated from *Kewia elongata* (NISIYAMA, 1940) (loc. cit.) by the larger test with the marginal periproct, coronal plates of a large number, and trifurcating oral ambulacral furrows.

HASHIMOTO and UJIIÉ (1965, pp. 87-92) studied the statistical characters of this species based upon seventy-eight individuals from the Wakkanai formation of Hokkaido. Their results obtained from that study are summarized as follows. This species grew through its life without any significant modification of the general outline of test, and also the constant relative growth of the petaloid area throughout its life. In the arrangement of coronal plates on the oral surface, the discontinuous condition of basicoronal interambulacral plate and first post-basicoronal interambulacral plates in the posterior interambulacrum (5) is typical but with many different cases present in other interambulacral areas. The scarcity of trifurcation of the oral ambulacral furrows in the specimens from Soeushinai suggests that they might be the oldest representatives of this species. A specimen reported from the Shigarami formation in Nagano Prefecture (MORISHITA, 1953-a, p. 219) has larger test and a much thinner than the typical ones, and would be assigned to other species than to this species.

Echinarachnius microthyroides seems to be a well-defined and rather invariable species of the Japanese Miocene formations.

Echinarachnius subtumidus NISIYAMA and HASHIMOTO, 1950

Echinarachnius subtumidus NISIYAMA and HASHIMOTO, 1950, p. 39, text-figs. 1-3 (on p. 40).— Durham, 1955, p. 164.—Morishita, 1955, p. 229.—Morishita, 1960, p. 59.—Nisiyama, 1965, p. 79. Holotype.--IGPS coll. cat. no. 73696.

Locality and geological horizon.—IGPS loc. no.—Te-10.—Road-side cutting along the River Ponrurumoppe behind the Tôgeshita primary school about 1 kilometre west of Tôgeshita railroad station, Rumoe City, Teshio, Hokkaido (tm Ebishima, Lat. 43°51/N., Long. 141°47′52″E.). Tôgeshita formation, Miocene. HASHIMOTO, 1950, pp. 12, 15.

Test rather small, about 33 mm in longitudinal diameter, thick and stout, subcircular in outline; periproct rather large, elliptical in outline, rather supramarginal in position; oral ambulacral furrows distinct, trifurcate on median area of the distal end of second post-basicoronal ambulacral plates; there are five to six post-basicoronal ambulacral plates and three interambulacral plates to a column.

This species is related to *Ech. microthyroides* (loc. cit.), but differs from that species in having the much thicker test, larger petaloid area, and the different arrangement of coronal plates on the oral surface. *Ech. subtumidus* also resembles *Ech. laganolithinus* NISIYAMA, 1940, from the Shibikawa formation of. Akita Prefecture, but is distinguished from that species by the much thicker margin of the test, mode of trifurcation of the oral ambulacral furrows, and by the arrangement of coronal plates on the oral surface.

The features of aboral surface of the test and the arrangement of coronal plates on the oral surface of this species suggest that it may be a form intermediate between *Ech. microthyroides* and *Ech. lagnolithinus* in the Japanese echinarachniids. It is interesting fact that the stout and thick margin of the test is found in *Scaphechinus raritalis* (NISIYAMA, 1951), from the granule conglomerate facies of the Taya formation of Akita Prefecture, and this species calls *Ech. subtumidus* in the outline and stoutness of test, although the two species evidently differ in systematic position. This species occurs associated with molluscs, viz., *Callista hokkaidoensis* (NOMURA), *Mya cuneiformis* (BÖHM), *Cryptomya busoensis* YOKOYAMA?, and *Olivella koishii* NOMURA (NOMURA, 1935, pp. 32-39.—HASHIMOTO, 1950, p. 15).

Echinarachnius naganoensis MORISHITA, 1953

Echinarachnius naganoensis MORISHITA, 1953-a, p. 220, pl. 4, fig. 4, text-fig. 3a.—MORISHITA, 1955, p. 233, pl. 10, figs. 3-4.—MORISHITA, 1960, p. 58.—NISIYAMA, 1965, p. 79.

There is no authentic specimen of this species at the writer's disposal.

MORISHITA (1953-a, p. 222; 1955, p. 234) reported this species from following localities and geological horizons.—

1. Eastern valley of Ichiba (Doro-sawa); southern valley of Ronji (the confluence of Higashi-sawa and Tsubone-sawa); western valley of the Huruma shrine (Shimizutani); Naniai-mura, Kami-Minochi-gun, Nagano Prefecture (Lat. 36°40'N., Long. 138° 10'E., near Nagano City). Ogawa formation, Pliocene (or upper Miocene).

2. Southern valley of Sendo (Obayashi-no-sawa); left bank of the Dojiri River, southwards of Tagoshi; right bank of the Dojiri River, southwards of Ichinose; left bank of the Dojiri River, south of Ikari; Sakai-mura, Kami-Minochi-gun, Nagano Prefecture (Lat. 36°40'N., Long. 138°10'E., near Nagano City). Ogawa formation, Pliocene (or upper Miocene).

3. Northeastern part of Shin-machi (east of Chibarada), Minochi-mura, Kami-

Minochi-gun, Nagano Prefecture (Lat. 36°40'N., Long. 138°10'E., near Nagano City).

4. Mizuhara-mura, Naka-Kubiki-gun, Niigata Prefecture (Lat. 36°40'N., Long. 138°05'E., near Takada City). Shiiya formation, Pliocene (or upper Miocene).

In this species the features of the oral ambulacral furrows and the arrangement of coronal plates on the oral surface are not known, but the periproct seems to be supramarginal. The large petaloid area, about 0.8 of test-diameter, and the form of petals seem to be very similar to those of *Ech. parma obesus* H. L. CLARK, 1914, as in comparison the figure of this species (MORISHITA, 1955, fig. 3 on pl. 10) with the figure of that species (MORISHITA, 1955, fig. 2 on pl. 11) it is easily recognizable, although the petaloid area of this species is more or less larger than that of latter species (or subspecies). The internal radiating partition walls, which is not mentioned by MORISHITA, of this species, as observed from the figure given by MORISHITA (1953-a, fig. 3 on pl. 1), are stouter and heavier and having smaller development of supplementary buttresses than those of *Ech. parma* (DURHAM, 1949, fig. 8 on pl. 1). This internal feature of this species makes a distinct separation of it from *Ech. parma* or *Ech. parma obesus*.

Echinarachnius humilis NISIYAMA, n. sp.

(Pl. 16, fig. 8)

Holotype.--IGPS coll. cat. no. 73775.

Locality and geological horizon.—IGPS loc. no.—AK-52.—A small cliff of creek about 500 metres north of bridge at Inari, Taihei-mura, Minami-Akita-gun, Akita Prefecture (tm Akita, Lat. 39°44'N., Long. 140°13'30"E.). Chôkai formation, Pliocene. Collected by the writer, 1942.

There are one well preserved and several fragmentary specimens of this new species at the writer's disposal.

Test large, 74 mm in longitudinal diameter, 81 mm in transverse one, and 5 mm in height; marginal outline of test not regularly rounded, undulating, broadly notched in ambulacra; transverse diameter decidedly larger than the longitudinal, the greatest breadth lies posterior to centre of test. Aboral surface depressed and rising gently from very thin and nearly flat submarginal area to the apex, which is eccentric in front lying in the frontal ambulacrum (III) and just anterior to the apical system. Apical system rather small, 4 mm wide and 3 mm long, situated at 35 mm from the anterior margin, eccentric in front, with small genital pores.

Petaloid area small, about 0.5 of test-length; petals narrow, slightly elevated and subequal. Frontal petal (III), 20 mm long and 8 mm wide, slightly wider than the others, broadly open at its extremity; poriferous zones (having about 60 pore-pairs) 1 mm in width; interporiferous zone 6 mm in width; inner series of pores at first diverge, then slightly converge and diverge again; outer series more divergent from beginning of the petal, converge to some degree at half way to length of petal and since continue almost to the inner series. Antero-lateral petals (II and IV) 19 mm long and 7 mm wide; poriferous and interporiferous zones similar to those of the frontal. Postero-lateral petals (I and V) 18 mm long and 7 mm wide; similar to the antero-lateral petals in form.

Oral surface evidently concave orally, and greatly sunken at region of the peristome. Peristome central, nearly circular in outline, 3 mm in diameter. Periproct oval in outline, small in size, and situated in a notch at the posterior margin. Arrangement of coronal plates on the oral surface likes that of *Ech. laganolithinus* (NISIYAMA, 1940, text-fig. 12 on p. 831). Oral ambulacral furrows rather broad and distinct, main branches given off at distal end of first post-basicoronal ambulacral plates in medial area. Tuberculation very fine; glassy knobs occurring between tubercles on oral surface usually small.

This new species superficially resembles *Kewia fairbanksi* (ARNOLD, 1907) (loc. cit.), from the Temblor formation (Miocene) of southern California in outline of test and form of petals, but is easily distinguished from that species by the larger and thinner test, mode of trifurcation of the oral ambulacral furrows, and the orally concaved oral surface. *Ech. humilis* also related to *Ech. laganolithinus*, from the Shibikawa formation of Oga Peninsula, Akita Prefecture, but is distinguished from that species by the broader and thinner test, mode of trifurcation of the apical system, and by the narrower and shorter petals. This species differs from *Ech. naganoensis* in having the broader and thinner test and the smaller petaloid area.

Echinarachnius ishioi MORISHITA, 1950

Echinarachnius ishioi Morishita, 1950, p. 257, text-figs. 2a-b (in Japanese).---Morishita, 1955, p. 233, pl. 10, fig. 6.--Morishita, 1960, p. 57.--Nisiyama, 1965, p. 89.

There is no authentic specimen of this species at the writer's disposal.

Locality and geological horizon (after MORISHITA).—Tagawa, Konade-mura, Nishi-Tonami-gun, Toyama Prefecture (Lat. 36°40'N., Long. 136°50'E., near Takaoka City). Tagawa formation, Pliocene.

This species is characterized, according to MORISHITA (1955, p. 233), by having the elevated test, widely opened petals and inframarginal periproct; it has coarse tuberculation on the aboral surface.

Although the mode of the oral ambulacral furrows and the arrangement of coronal plates on the oral surface of this species are not accessible to the writer, this species seems to be related *Ech. parma obesus*, in the general features. But, it may be separated from that species (or subspecies) in the more or less raised interportiferous zones, the broader portiferous zones of the petals, and in the larger and coarser tuber-culation on the aboral surface (MORISHITA, 1955, fig. 6 on pl. 10).

Echinarachnius rumoensis HAYASAKA and SHIBATA, 1952

Echinachnius rumoensis HAYASAKA and SHIBATA, 1952, p. 82, text-figs. 1a-c.—Morishita, 1955, p. 229.—Morishita, 1960, p. 58.—Nisiyama, 1965, p. 79.

Locality and geological horizon.—IGPS loc. no.—Te-10.—Road-side cutting along the River Ponrurumoppe behind the Tôgeshita primary school about 1 kilometre west of Tôgeshita railroad station, Rumoe City, Teshio, Hokkaido (tm Ebishima, Lat. 43°51'N., Long. 141°37′52″E.). Tôgeshita formation, Miocene.

S. NISIYAMA

No specimens of this species have been available for study. The original description of this species given by two authors (HAYASAKA and SHIBATA, 1952, p. 82) is excellent and precise and the remarks on the species seem to be very adequate in consideration of its affinities and distinction. *Ech. rumoensis* seems to be a quite distinct species from *Ech. subtumidus*, and the occurrence of different species of the same genus together with in same locality is not rather rare case in the echinoid assemblage, the writer met with the similar case in fossils as well as in the living species.

The oral ambulacral furrows of Ech. rumcensis trifurcate, the main stem and simple two side branches, at the proximal part of the second (the first post-basicoronal) ambulacral plates, according to the figure given by the two authors (text-fig. 1b on p. 83), notwithstanding of their description that they trifurcate at the distal end of the basicoronal ambulacral plates. In the postero-lateral ambulacra (I and V), and in the other ambulacral areas (II, III and IV) they trifurcate at the height of the middle part of the second (or the first post-basicoronal) ambulacral plates. This mode of trifurcation of the furrows is similar in the main to the *Echinarachnius*-type of trifurcation, and the main stem continues to near the edge beyond the trifurcating point; the trifurcating point, however, in the typical Echinarachnius being at the height of the 3rd (or second post-basicoronal) ambulacral plates, while in this species it is much nearer to the peristome, at least at the middle part of the second ambulacral plates. This trifurcating type of this species differs from the bifurcating type of *Scaphechinus*; in the latter type the oral ambulacral furrows bifurcate at the exactly distal end of basicoronal ambulacral plates, and the side branches run as more or less curved grooves not rather straight as in the *Echinarachnius*-type. The mode of trifurcation of the furrows of this species is also similar to that of Scutellaster (text-fig. 35 [10]) in the trifurcating point lies on the height of the first post-basicoronal ambulacral plates, but differs in no having any of smaller side-branches distally.

If the *Echinarachnius*-type of trifurcation of the oral ambulacral furrows were less specialized stage than the *Scaphechinus*-type of bifurcation in the development of the furrows among the North Pacific echinarachniid echinoids, as described in the preceding pages, the mode of trifurcation in *Ech. rumoensis* would be stand an intermediate stage between the *Echinarachnius*-type of trifurcation and the *Scaphechinus*type of bifurcation, but it still holds the trifurcation of the *Echinarachnius*-type.

It is very interesting to find that the trifurcating point of the furrows in *Ech. rumoensis* more or less differs on the first post-basicoronal ambulacral plates in the different areas of the same individual. In the postero-lateral areas (I and V) it on the proximal part, and in the frontal area (III) rather on the distal part; that is to say, the trifurcation of the furrows in the postero-lateral areas is the most progressed, that in the antero-lateral areas is an intermediate, being on the middle part of the plates, and that in the frontal area is the least progressed stage, as in the case of that of *Scutellaster* (DURHAM, 1949, p. 55). This different degrees of development of the furrows in one individual seem to coincide with those of the arrangement of coronal plates on the oral surface in this species; that is to say, the basicoronal interambulacral plate is broadly separated from the first post-basicoronal interambulacral plates by the enlarged adjacent plates (I2a and V2b) in the posterior area (5), the most advanced, in the areas (1 and 4) the basicoronal interambulacral plates shortly discontinuous or almost touched with the first post-basicoronal interambulacral plates, the intermediate advanced, and in the areas (2 and 3) the basicoronal interambulacral plates usually broadly touched with the first post-basicoronal interambulacral plates, the least advanced degree. These different degrees of developmental structures in this species agree with the writer's view, as a whole, in that the North Pacific echinarachniid echinoids have developed firstly from the posterior part and then to the anterior part in the evolutionaray trends, and the development towards the anterior part is progressed further until the *Dendraster* reaches in its extremity.

The arrangement of coronal plates on the oral surface of this species, according to the two authors, seems to be inconstant and rather variable. In the antero-lateral interambulacral areas (2 and 3) the basicoronal interambulacral plates usually broadly contact with the first post-basicoronal interambulacral plates, in the posterior area (5) the basicoronal interambulacral plate usually discontinuous with the first post-basicoronal plates, and in the postero-lateral areas (1 and 4) they are more or less variable in slightly discontinuous or quite continuous with the first post-basicoronal plates. This variation of the arrangement of coronal plates, particularly in the postero-lateral interambulacral areas (1 and 4), in this species should be regarded as one of the characters of *Echinarachnius*, and the form of the first post-basicoronal row of this species differs from that of the Scaphechinus and close similar to that of the Echinarachnius. Though Ech. rumoensis approaches to the genus Scaphechinus in some features, e.g., the mode of oral ambulacral furrows and the arrangement of coronal plates on the oral surface, it still retains the *Echinarachnius*-type of structures, and can be assigned to the genus *Echinarachnius* as a particular species. It cannot be settled at present whether this species has arose the genus Scaphechinus or has developed as a side-branch of Echinarachnius towards Scaphechinus.

Echinarachnius laganolithinus NISIYAMA, 1940

Echinarachnius (Echinarachnius) laganolithinus NISIYAMA, 1940, p. 830, pl. 44, fig. 21, pl. 45, figs. 1-9, text-fig. 12.—Echinarachnius laganolithinus NISIYAMA: MORTENSEN, 1948-c, p. 364, text-fig. 216 (reproduced from NISIYAMA, 1940).—MORISHITA, 1955, p. 232, pl. 10, figs. 1-2.—DURHAM, 1955, p. 164.—MORISHITA, 1960, p. 57.—NISIYAMA, 1965, p. 79.

Holotype.—IGPS coll. cat. no. 60330.

Locality and geological horizon.—IGPS loc. no.—Ak-38.—Road cliff south of Iwakura and north of Tayazawa, Wakimoto-mura, Minami-Akita-gun, Akita Prefecture (tm Funakawa, Lat. 39°55'N., Long. 139°53′54″E.). Shibikawa formation, Pliocene. Holotype and paratypes.

Locality and geological horizon.—IGPS loc. no.—Ak-39.—Small cliff east of shrine at Ôkura, Wakimoto-mura, Minami-Akita-gun, Akita Prefecture (tm Funakawa, Lat. 39°54′56″N., Long. 139°54′34″E.). Shibikawa formation, Pliocene. Hypotypes.—IGPS coll. cat. no. 7902.

Locality and geological horizon.—IGPS loc. no.—Ak-1.—Sea cliff near Anden, Iriaimura, Minami-Akita-gun, Akita Prefecture (tm Funakawa, Lat. 39°58′05″N., Long. 139°51′05″E.). Shibikawa formation, Pliocene. Hypotypes.—IGPS coll. cat. no. 9229. There are about sixty specimens of this species at the writer's disposal, ranging from 20 mm to 77 mm in longitudinal diameter of the test.

Test large, attains nearly 80 mm in transverse diameter, marginal outline of test subcircular, and rather low; petaloid area rather small, its total length being 0.63 of longitudinal diameter of test; petals narrow, slightly elevated and nearly equal in length and breadth; poriferous zones narrow, about one-fourth of interporiferous



Fig. 46 [21]. Oral ambulacral furrows of *Echinarachnius laganolithinus* N1S1-YAMA, 1940, $\times 0.57$.

zones; oral surface evidently concave orally and greatly sunken at region of peristome; periproct small, oval in outline, and situatnd in a small notch at posterior margin; oral ambulacral furrows broad and distinct (text-fig. 46 [21]), with two main sidebranches give off at half of test-radius (at distal end of first or proximal part of second post-basicoronal ambulacral plates in median area) and further on two or three smaller side-branches, which may even again have one or two small side-branches distally; the main stem, however, continues beyond the trifurcating point towards the edge of test; coronal plates on oral surface like those of *Ech. parma*, but somewhat less in number.

This species is closely related to *Ech. parma*, but is distinguished from that species by the characteristic mode of trifurcation of the oral ambulacral furrows, the orally concaved oral surface, the sunken peristome, the narrower and shorter form of the petals, and by the arrangement of coronal plates on the oral surface. Some young individuals of this species resemble *Ech. microthyroides*, but differs in the form of petals, the larger petaloid area, and in the mode of trifurcation of the oral ambulacral furrows. It also resembles *Ech. parma sakhalinensis* ARGAMAKOVA, 1934, p. 25, pl. 1, fig. 3), from the Pliocene of North Sakhalin, but differs in having its margin more conspicuously notched in the postero-lateral ambulacra (I and V), the smaller petaloid area, and the peculiar mode of trifurcation of the oral ambulacra furrows.

In young individuals, the apical system is slightly eccentric, a little nearer to the anterior margin, the highest point is anterior to the apical system, the periproct is distinctly supramarginal, the greatest breadth is in the postero-lateral interambulacra (1 and 4), more protruded behind, and the post-basicoronal interambulacral plates are usually continuous with the basicoronal interambulacral plates in each interambulacrum, except the posterior area (5). This species may represent a side-branch of *Echinarachnius parma*-series.

Echinarachnius cf. parma (LAMARCK, 1816)

(Pl. 16, fig. 7)

Compared with:

Scutella parma LAMARCK, 1816, p. 11.—Echinarachnius parma (LAMARCK) GRAY, 1825, p. 428.— AGASSIZ, 1841-b, p. 89, pl. 20, figs. 7-18.—AGASSIZ and DESOR, 1846, p. 133 (pro parte).—
GRAY, 1855-a, p. 15.—A. AGASSIZ, 1863-a, p. 352.—A. AGASSIZ, 1872-74, p. 316, pl. 11d, figs. 4-5, pl. 11e, figs. 4-5.—*Phelsumia parma* (LAMARCK) POMEL, 1883, p. 70.—*Echinarachnius parma* (LAMARCK) : RATHUBUN, 1886, p. 288.—YOSHIWARA, 1900, p. 393 (in Japanese).— TOKUNAGA, 1903, p. 12, pl. 3, fig. 2.—YOSHIWARA (TOKUNAGA), 1907, pl. 15, figs. 14-15.— MORTENSEN, 1907, p. 179.—H. L. CLARK, 1911, p. 605.—H. L. CLARK, 1914, p. 67, pl. 125, figs. 7-8.—*Phelsumaster parma* (LAMARCK) LAMBERT and THIÉRY, 1914, p. 316.—*Echinarachnius parma* (LAMARCK) : H. L. CLARK, 1925, p. 168.—ARGAMAKOVA, 1934, pp. 22, 39, pl. 1, figs. 1-1a, pl. 2, figs. 1a, 2-3, 3a.—GRANT and HERTELIN, 1938, p. 62, pl. 9, figs. 1-2, pl. 19, fig. 2, pl. 30, fig. 8.—IKEDA, 1939, pl. 4, fig. 9, pl. 6, figs. 4-5.—IKEDA, 1940, p. 3, pl. 2, fig. 4.—NISIYAMA, 1940, p. 808, text-fig. 1.—COOKE, 1942, p. 16.—MORTENSEN, 1948-c, p. 367 (complete synonymy), pl 71, figs. 16, 23-26, text-figs. 202a, 204a, 205a, 208a, 210a, 212a, 217.—DURHAM, 1949, pp. 53, 54, 56, 61, pl. 1, fig. 8, text-fig. 1.—DURHAM, 1955, p. 164, textfigs. 1i, 3b, 6e, 8a, 9a, 10a, 23-24, 261, 34a-b, pl. 4, fig. 4.—MORISHITA, 1955, p. 231, pl. 9, fig. 6, pl. fig. 1 (reproduced from IKEDA, 1940).—DURHAM, 1957, p. 629, pl. 72, fig. 5.— COOKE, 1959, p. 41, pl. 13, figs. 5-6.—MORISHITA, 1960, p. 58.—NISIYAMA, 1965, p. 79.

Locality and geological horizon.—IGPS loc. no. Ni-25.—Sea cliff facing the Mano Bay, about 250 metres southeast of the contact point of the two main roads near the primary school, Sawane-machi, Sado-gun (Sado Islands), Niigata Prefecture (tm Kawarada, Lat. 37°59′47″N., Long. 138°16′38″E.). Sawane formation, Pliocene. Hypotypes.— IGPS coll. cat. no. 78213.

Locality and geological horizon.—IGPS loc. no. Ni-26.—Road-side cutting at Funabashi, Nishikoshi-mura, Mishima-gun, Niigata Prefecture (tm Izumozaki, Lat. 37°30′48″N., Long. 138°42′22″E.). Funabashi Sandstone, Pliocene. Hypotypes.—Tokyo Science Museum, fossil coll. cat. no. 373.

Locality and geological horizon (after MORISHITA, 1955, p. 231).—Maitani, Akamaru-mura, Nishi-Tonami-gun, Toyama Prefecture (Lat. 36°41'N., Long. 136°50'E., near Takaoka City). Omma Sandstone, Pliocene.

There are about twelve specimens conferred with this species at the writer's disposal, ranging from 60 mm to 72 mm in longitudinal diameter of the test.

The large specimen measures 72 mm in longitudinal diameter, 71 mm in transverse one, and about 10 mm in height. Marginal outline of test subcircular, not regularly rounded, more or less undulating, rather truncated posteriorly and rounded anteriorly, more or less notched in ambulacral midlines, notches being greater in postero-lateral ambulacra (I and V) than in anterior ones (II, III and IV); longitudinal diameter slightly larger or as nearly as the transverse, the greatest breadth lying on middle line of test. Aboral surface rather depressed and rising gently from thin and nearly flat submarginal area to the highest point, which is eccentric posteriorly and lying in the posterior interambulacral area (5) behind the apical system. Margin of test thin, thinner posteriorly than anteriorly, about 2.5 mm at the thickest part. Apical system rather small, 4.5 mm wide and 5 mm long, situated at 35 mm from the anterior margin, nearly central, or slightly eccentric anteriorly, with four small genital pores.

Ambulacra much wider than interambulacra at ambitus, width of frontal ambulacrum (III) being nearly twice the adjoining antero-lateral interambulacra (2 and 3) respectively. Petaloid area rather small, its total length about 0.6 of longitudinal diameter. Petals rather broad, their breadth more than half of their length, slightly elevated proximally and nearly equal in length and width. Frontal petal (III), 21.5 mm long by 11 mm wide, broadly open at its extremity; poriferous zones (having about 58 pore-pairs on each side) 2 mm wide at the broadest part; half interporiferous zone 3.5 mm in width, being less than twice as wide as the poriferous zone; inner series of pores at first diverge and then slightly converge in some length and then diverge again distally; outer series of pores more divergent from beginning of the petal, slightly converge at half way to length of petal and since continue almost parallel to the inner series. Antero-lateral petals (II and IV), 21 mm long and 11 mm wide, open at their extremities; poriferous zones (having about 58 pore-pairs on each side) 2 mm wide at the broadest part; half interporiferous zone 3.5 mm in width; inner series of pores at first diverge and more or less converge from middle to distal part of petals and again diverge near distal ends; outer series of pores more divergent from beginning of petals, converge to some degree at halfway to length of petals and since continue almost parallel to the inner series. Postero-lateral petals (I and V) also 21 mm long and 11 mm wide; poriferous zones (having also about 58 pore-pairs on each side) 2 mm in width; half interporiferous zone also 3.5 mm in width; similar to antero-lateral petals in form. Interambulacral plates on aboral surface rather large, 10 or 11 plates in each column from the ambitus to the apical system.

Oral surface more or less concave orally, not flattened, peristomial region not deeply sunken. Peristome central, large, nearly circular in outline, 4 mm in diameter; median keel of ambulacral furrows in each area rather conspicuous and scarcely bends downwards. Periproct round, comparatively large, 1.5 mm in diameter, situated in a small notch at posterior edge, almost inframarginal. Coronal plates on oral surface rather numerous; in a specimen of 60 mm in longitudinal diameter, in each ambulacral column there are four to six post-basicoronal plates; in interambulacral area, there are two post-basicoronal plates to a column in posterior area (5), two in anterior and three in posterior columns in postero-lateral areas (1 and 4), and three postbasicoronal plates to a column in antero-lateral areas (2 and 3). Basicoronal row comparatively large; basicoronal interambulacral plates have become greatly enlarged, particularly the antero-lateral ones (2 and 3), in contrast to adjacent basicoronal ambulacrals. Basicoronal interambulacral plates just barely in contact with (continuous) first post-basicoronal (second) interambulacral plates in areas (1, 2, 3 and 4),. and only in posterior area (5) the interambulacral plates separated from first postbasicoronal interambulacral plates by enlarged adjoining ambulacral plates (discontinuous). Oral ambulacral furrows broad, 1.6 mm wide at the proximal part, and distinct; in a specimen of 64 mm in longitudinal diameter, in frontal ambulacrum (III) the furrow trifurcates at distal end of second post-basicoronal ambulacral plates in median area, issuing two side-branches distally at about 30° angles to each side of the main furrow, in the antero-lateral ambulacral areas (II and IV) the furrows trifurcate at middle part of second post-basicoronal ambulacral plates in median area, issuing two side-branches distally at nearly 40° angles to each side of the main furrow, and in the postero-lateral ambulacral areas (I and V) the furrows trifurcate also at middle part of second post-basicoronal ambulacral plates in median area, issuing twoside-branches distally at nearly 40° angles to each side of the main furrow. Tuberculation rather fine, primary tubercles on oral surface larger and coarser than those: on aboral surface.

This species has a close relation to *Ech. laganolithinus* (loc. cit.) in particularly the features on the aboral surface, the depressed upper surface and in the thin margin, but is distinguished from that species by the mode of trifurcation of the oral ambulacral furrows, the larger basicoronal row, the larger peristome, and more or less broader petals. The differences of trifurcation-type in the oral ambulacral furrows seem to be far from the variation within same species. This form also resembles Ech. naganoensis (loc. cit.), but differs from that species in having the thinner test (0.14 of longitudinal diameter), shorter and narrower petals, and in the position of the apical system. This form is evidently and most closely related to Ech. parma (LA-MARCK, 1816), from the east coast of United States of America and Canada as well as west coast of Alaska and Canada, in general features. But the mode of the oral ambulacral furrows and the form and size of the basicoronal row of this form are more or less differing from the typical parma (in the emended sense of AGASSIZ, 1841-b, p. 89). DURHAM (1949, p. 58; 1955, p. 164, text-figs. 23 and 24) stated that Ech. parma, especially specimens from the northeastern shores of the United States, is very variable. The writer has found these slight differences in comparing these fossil specimens with a small number of specimens of Ech. parma from Maine, U.S.A., in the collection of the Saito Ho-on Kai Museum, Sendai, Japan. In considering the variational range of this variable species, Ech. parma, as rather very wide, the fossil specimens as described above should be assigned to this species with some uncertainties, and the writer hesitates to propose a new subspecific name for the fossil specimens separating from the typical parma.

It is very interesting fact that *Ech. parma* or its closely allied species has already represented in the Pliocene formation of Japan, and this species has the discontinuous distribution, i.e., occurring on the Pacific Coast from Puget Sound to the Aleutian Islands and on the Atlantic Coast from Labrador to Maryland, without any intervening records in the Arctic region. MORTENSEN (1927-a, pp. 199-200; 1948-c, p. 373) once suggested an interesting explanation as to the origin of North Atlantic *Ech. parma*, an unique representative of the North Atlantic *Echinarachnius*. He has concluded that the species migrated through the Arctic region in some epoch warmer than (the post-glacial period) the present one. If the wandering of this species from the North Pacific home to the North Atlantic were accepted, as MORTENSEN stated, it would be probably early as, the writer supposes, during as the interglacial age of the Pleistocene epoch or earlier.

The writer's former speculation (NISIYAMA, 1940, p. 851) as to the origin of *Ech.* parma obesus must be abandoned for new material at the writer's disposal. *Ech.* parma obesus may be a direct descendant of this fossil form and *Ech.* laganolithinus may be regarded as a side-branch of the *Ech.* parma-series. *Ech.* asiaticus MICHELIN, 1859 (MICHELIN, 1859-a, p. 3.—H. L. CLARK, 1914, p. 68, pl. 143, figs. 1-4 (MCZ 4215— off Cape Nalachef)) would be descended together with *Ech.* parma obesus from the same stock (the *Ech.* parma-series); the differences in the colour of test and in the specialization of the aboral radioles of the two forms suggest that they may have developed under somewhat different conditions. More available material for study of these species may confirm in future the speculation suggested herein.

S. NISIYAMA

Echinarachnius cf. parma obesus H.L. CLARK, 1914

(Pl. 16, figs. 4-5, Pl. 18, fig. 8)

Compared with:

Echinarachnius parma var. obesa H.L. CLARK, 1914, p. 67, pl. 143, figs. 5-8.—Echinarachnius parma obesus H.L. CLARK: IKEDA, 1935-a, p. 205, pl. 4, fig. 9.—Echinarachnius parma obesa H.L. CLARK: GRANT and HERTLEIN, 1938, p. 63.—Echinarachnius parma obesus H.L. CLARK: IKEDA, 1940, p. 4.—NISIYAMA, 1940, p. 827, pl. 43, fig. 10, text-fig. 10.— MORTENSEN, 1948-c, p. 372.—MORISHITA, 1955, p. 235, pl. 11, fig. 2 (reproduced from IKEDA, 1935).—NISIYAMA, 1965, pp. 79, 85.

Locality and geological horizon.—A point neighbourhood of the River Paromai, North Sakhalin (ca. Lat. 53°N., Long. 143°E.). Paromai formation (*Echinarachnius*zone), Pliocene. Hypotypes.—IGPS coll. cat. no. 30663.

There are several specimens conferable with this subspecies at the writer's disposal. A rather well preserved specimen measures 47 mm in longitudinal diameter, 49 mm in transverse one, and about 12 mm in height. Marginal outline of test subcircular, slightly undulating, only slightly notched in the postero-lateral ambulacra (I and V), transverse diameter slightly larger than the longitudinal, the greatest diameter being immediately posterior to the centre of test. Aboral surface moderately raised, and rising from rather thick marginal area (about 2 mm in thickness) to the apex, which is situated on the centre of test. Apical system rather large, 4 mm wide and 5 mm long, situated at 24 mm from the anterior margin, with small four genital pores.

Petaloid area rather large, 34 mm in length, its total length about 0.7 of longitudinal diameter of test. Petals long and wide, their breadth being more than half their length, subequal in length and width; all petals about 17 mm long and 10 mm wide, generally open at their extremities; poriferous zones rather broad, about 2 mm wide at the widest part and having about 42 pore-pairs on each side; a ridge between two pore-pairs with seven or eight tubercles in a row; a half interporiferous zone rather narrow, about 3 mm wide.

Oral surface quite flat, not concave orally as in fossil species. Peristome central. Periproct small, marginal in position. Oral ambulacral furrows rather distinct in the preserved part, the frontal ambulacral furrows seems to trifurcate at distal end of second post-basicoronal ambulacral plates in median area, details of other furrows are not observable. Arrangement of coronal plates on oral surface inaccessible to the writer owing to bad condition of the specimens.

The specimens at the writer's disposal, in the stout and high test, nearly one fourth (0.23) of the longitudinal diameter, the long and widely opened petals, the central position of the apical system, the flat oral surface, and in the mode of trifurcation of the oral ambulacral furrows, seem to be most closely related to *Ech. parma obesus*. However, the form of test, details of the petals, and the uncertainty of the arrangement of coronal plates on the oral surface of this prevent to identify it with *Ech. parma obesus* with certainty. In the form as well as the stoutness and thickness of test, form of petals, and the mode of trifurcation of this form closely resemble those of *Ech. subtumidus* (loc. cit.), but is easily distinguished from that species by the marginal position of the periproct, while in that

species it is evidently supramarginal.

It is a very interesting fact that this thick form of *Echinarachnius parma*-series. has already represented as early during as the Pliocene of North Asiatic coast. It may represent a descendant of the Pliocene *Echinarachnius parma*—series, not a direct descendant of the Miocene *Ech. tumidus*.

This subspecies distributed in the living from Kamtchatka to east coast of northern Japan (about Latitude 41° North) through east coast of Sakhalin and Hokkaido, from the littoral zones down to about 60 metres in depth.

Genus Scaphechinus A. AGASSIZ, 1863

Scaphechinus A. Agassiz, 1863-a, p. 359.—NISIYAMA, 1935, p. 136, foot-note (subgenus).— NISIYAMA, 1937, p. 57 (subgenus).—GRANT and HERTLEIN, 1938, p. 56, foot-note.—NISI-YAMA, 1940, p. 832 (subgenus).—MORTENSEN, 1948-c, p. 374.—NISIYAMA, 1951, p. 3 (subgenus).—TERMIER and TERMIER, 1953, p. 926.—DURHAM, 1955, p. 162, text-figs. 4e, 5a, 6d, 26k, 34e.

Haplotype.—Scaphechinus mirabilis A. AGASSIZ, 1863-a, p. 359 (Hakodate Bay, Hokkaido).— Echinarachnius mirabilis (A. AGASSIZ) A. AGASSIZ, 1872-74, pp. 107, 526, pl. 13a, figs. 5-6 (Japan).

Chaetodiscus LÜTKEN, 1864, p. 172.

Haplotype.—Chaetodiscus scutella LÜTKEN, 1864, p. 172 (Japan and China).=Scaph. mirabilis A. AGASSIZ, 1863-a, p. 359.

Scutella MARTENS, 1865, p. 140 (non Scutella LAMARCK, 1816).—LAMBERT and THIÉRY, 1914, p. 317 (pro parte).

Haplotype.—Scutella japonica MARTENS, 1865, p. 140 (Tokyo, Bay, Japan).=Scaph. mirabilis: A. AGASSIZ, 1863-a, p. 359.

Test of medium-size to large, usually of subrounded to subpentagonal outline, oral side usually perfectly flat, margin often indented at sutures, aboral side low arched. Petals well-formed, usually open distally, a few small isolated pore-pairs continuing the pore-series of petals; outside petals ambulacra widen conspicuously, interambulacra being correspondingly restricted, at edge of test only about half width of ambulacra. Apical system usually central, or slightly eccentric in front, with four genital pores. Periproct marginal or rarely supramarginal. Oral ambulacral furrows bifurcating at distal end of basicoronal ambulacral plates into two diverging main branches, which have a varying number of small side-branches distally, mainly on outer side; main stem of the furrows does not continue beyond the bifurcating point. Basicoronal plates large, interambulacral plates much larger than ambulacrals; interambulacral areas usually well separated from basicoronal row (discontinuous) by a pair of ambulacral plates, or rarely in contact with it in some areas. Usually there are 3 or 4 post-basicoronal interambulacral plates to a column on oral surface; 4 or 5 post-basicoronal ambulacral plates to a column on oral surface. Internal concentric and radial supports well developed (NISIYAMA, 1940, fig. 4 on pl. 43). Radioles of aboral side more or less solid, with widened terminal part. Pedicellariae of bidentate and biphyllous types present (from MORTENSEN, 1948-c, and DURHAM, 1955).

From the late Miocene to Recent, Japan and Formosa.

The type-species, *Scaph. mirabilis* A. AGASSIZ, 1863, was included into *Echinara-chnius* by A. AGASSIZ (loc. cit.) and later authors, but some, such as STEFANINI (1912, p.

803) and LAMBERT and THIÉRY (1914, p. 319), regarded it to be a surviving member of the European Scutella. In the mode of the oral ambulacral furrows and the undulated marginal outline it much resembles Scutella; but, in the discontinuous arrangement of the interambulacral plates on the oral surface, the mode and shape of the petals, and the position of periproct the two are quite different. However, question still remains as to the origin of the mode of bifurcation of the oral ambulacral furrows and to that of the discontinuous arrangement of the interambulacral plates on the oral surface (or in other words, the basicoronal row is circled by a ring of ten large first post-basicoronal (second) ambulacral plates). This peculiar arrangement seems to have suddenly developed since at least as the late Miocene without any intermediate form between it and its forerunners. The pedicellariae and radioles are very similar to those of *Ech. parma*, the type-species of the genus *Echinarachnius*, and so far as radioles and pedicellariae are concerned, Scaph. mirabilis cannot be separable from Ech. parma. Also there is a question as to whether this species is a final representative of the European Scutella or a descendant of the North Pacific sand-dollars, the echinarachniids. By the fact that the similar discontinuous arrangement of the interambulacral plates on the oral surface occurs in the West American sand-dollars, such as Dendraster excentricus, since the Pliocene, this feature may be a parallelism independent in occurrence on both sides of the North Pacific Ocean. It seems probable that this feature probably related to a widening of the ambulacral areas in response to the warm water of more southern seas than their forerunners. These features of the oral ambulacral furrows, as well as discontinuous arrangement of the interambulacral plates on the oral surface, and elevation of petals and depression in the interambulacra, should be regarded as the ultimate stage in morphological development of the North Pacific Echinarachnius-series, but not as the descendant of the European Scutella. Furthermore, the geological and geographical distribution of the series supports the above assumption. MORTENSEN (1948-c, p. 374) and DURHAM (1955, p. 162) separated Scaph. mirabilis from Ech. parma as a distinct genus, to which the writer quite agrees.

This genus is a typical Japanese echinarachniids and its geographical distribution is confined to the Japanese Islands and west, from Hokkaido at the north and ranging as far as south to southern Kyushu, in the present day. This genus comprises at least three Recent species, and the two species of them occurred as fossil from the Pliocene and Pleistocene of Japan and Formosa, and one or more fossil species from the Mio-Pliocene or Pliocene of North Japan.

Scaphechinus raritalis (NISIYAMA, 1951)

Echinarachnius (Scaphechinus) raritalis Nisiyama, 1951, p. 3, text-figs. 1-3.—Echinarachnius raritalis Nisiyama: Morishita, 1960, p. 59.—Scaphechinus raritalis (Nisiyama) Nisiyama, 1965, p. 79.

Holotype.—IGPS coll. cat. no. 72978.

Locality and geological horizon.—IGPS loc. no.—Ak-51.—Cliff along the River Sannai, opposite Taya, Iwami-Sannai-mura, Kawabe-gun, Akita Prefecture (tm Taiheizan, Lat. 39°42'N., Long. 140°17'E.). Taya formation, Mio-Pliocene or late Miocene (HATAI and NAKAMURA, 1940, p. 22.—HATAI and NISIYAMA, 1952, p. 344).

There are six specimens of this species at the writer's disposal, ranging from 14 mm to 38 mm in longitudinal diameter. The holotype measures 38 mm in longitudinal diameter, 39 mm in transverse one, and 6.5 mm in height. Periproct rather large, elliptical in outline, supramarginal in position; basicoronal row encircled by first post-basicoronal row of ten large second ambulacral plates (discontinuous arrangement of the interambulacral plates); oral ambulacral furrows rather narrow and distinct, bifurcate on median area of the distal end of basicoronal ambulacral plates.

This species is related to *Scaph. griseus* (MORTENSEN, 1927), a Recent one from Sakhalin and the northern Japan Sea and as fossil from the Pliocene and Pleistocene of Japan, in the supramarginal position of the periproct and in lacking the depression of the interambulacral spaces on the aboral surface and a slight depression around the petaloid area; but is disinguished from that species in the much thicker marginal area, the eccentric position of the highest point which is a little nearer to the posterior margin, and in the larger basicoronal ambulacral and interambulacral plates and smaller first post-basicoronal ambulacral plates.

This species is the oldest representative of the known *Scaphechinus* in Japan. The large basicoronal row and small first post-basicoronal ambulacral plates of this species being in contrast to the small basicoronal row and large first post-basicoronal ambulacral plates of the *Scaph. mirabilis-griseus-brevis* group are very interesting; because these features may be regarded as primitive characters and are observable in the young specimens of the Recent species of the genus.

Scaphechinus tsudai (MORISHITA, 1950)

Echinarachnius tsudai Morishita, 1950, p. 257, text-fig. 1 (in Japanese).—Morishita, 1955, p. 233, pl. 10, fig. 5.—Morishita, 1960, p. 59.—Scaphechinus tsudai (Morishita) Nisiyama, 1965, p. 79.

No specimens of this species have been available for study.

Locality and geological horizon (after MORISHITA).—Futamata, Asakawa-mura, Kahoku-gun, Ishikawa Prefecture (Lat. 36°35'N., Long. 136°50'E., near Kanazawa City).

This species is characterized by having the thin and flat test, the long, straight and widely opened petals, the more or less depressed interambulacral areas at margin of test, the marginal periproct, and the oral ambulacral furrows bifurcated at just outside of basicoronal plates.

This species closely resembles *Scaph. mirabilis* A. AGASSIZ, 1863, in the mode of bifurcation of the oral ambulacral furrows and depression in the interambulacral spaces on the aboral surface, but is easily distinguished from that species by the form of petals and the lower test (0.07 of the longitudinal diameter). This species may represent a side-branch of *Scaph. mirabilis*-series in Japan. This species occurs associated with molluscs (MORISHITA, 1950, p. 257), viz., *Turritella saishuensis*, YOKO-YAMA, *Anadara amicula* (YOKOYAMA), *Glycymeris yessoensis* (SOWERBY), and *Patino-pecten yessoensis yokoyamae* MASUDA.

Scaphechinus mirabilis A. AGASSIZ, 1863

(Text-figs. 36 [11], 42 [17], 47 [22], 48 [23], 49 [24] and 50 [25])

Scaphechinus mirabilis 'BARN.' A. AGASSIZ, 1863-a, p. 359.-VERRILL, 1869, p. 384.-Echinarachnius mirabilis (A. AGASSIZ) A. AGASSIZ, 1872-74, pp. 107, 526, pl. 13a, figs. 5-6.-Döder-LEIN, 1885, p. 73.—IVES, 1891, p. 215.—YOSHIWARA, 1900, p. 392 (in Japanese).—Tokunaga, 1903, p. 11.—Tokunaga, 1906, p. 71.—Yoshiwara (Tokunaga), 1907, pl. 17, figs. 9-10.— Scutella mirabilis (A. AGASSIZ) STEFANINI, 1912, p. 703.-Echinarachnius mirabilis (A. AGASSIZ) : H.L. CLARK, 1914, p. 69, pl. 129, fig. 6.—Scutella mirabilis (A. AGASSIZ) : LAM-BERT and THIÉRY, 1914, p. 319.-Echinarachnius mirabilis (A. AGASSIZ): H.L. CLARK, 1925, p. 168.-Mortensen, 1929, p. 477.-Tortonese, 1933, p. 149, pl. 7, fig. 35.-Ikeda, 1935-a, p. 202, pl. 6, figs. 6-8.—IKEDA, 1935-b, p. 1765, text-fig. 5, p. 1766, text-fig. 6.— Echinarachnius (Scaphechinus) mirabilis (A. AGASSIZ): NISIYAMA, 1937, p. 57.-Echinarachnius mirabilis (A. AGASSIZ): IKEDA, 1939, pl. 2, figs. 1-2, pl. 4, fig. 7, pl. 8, fig. 4, pl. 12, fig. 10, pl. 13, figs. 1-3.-IKEDA, 1940, p. 4.-Echinarachnius (Scaphechinus) mirabilis (A. AGASSIZ): NISIYAMA, 1940, p. 835, pl. 43, figs. 1-4, pl. 44, figs. 1-6, text-figs. 13-35, 61-62.—HAYASAKA, 1947, p. 94, pl. 8, figs. 1-2.—Scaphechinus mirabilis A. AGASSIZ: MORTENSEN, 1948-c, p. 375 (complete synonymy), pl. 61, fig. 9, pl. 63, fig. 4, pl. 71, figs. 19-21, text-figs. 208d, 218a, 210-220.-Echinarachnius mirabilis (A. AGASSIZ): MORISHITA, 1950, p. 256.—Scaphechinus mirabilis A. AGASSIZ: UTINOMI, 1954, p. 354.—Echinarachnius mirabilis (A. AGASSIZ): MORISHITA, 1955, p. 231, pl. 8, figs. 5-6.—Scaphechinus mirabilis A. AGASSIZ: DURHAM, 1955, p. 162, text-figs. 4e, 5a, 6d, 26k, 34e.-Echinarachnius mirabilis (A. AGASSIZ): MORISHITA, 1960, p. 58.—Scaphechinus mirabilis A. AGASSIZ: NISIYAMA, 1965, pp. 79, 85.

Chaetodiscus scutella LÜTKEN, 1864, p. 172.

Scutella japonica MARTENS, 1865, p. 140.

Echinarachnius pacificus PFEFFER, 1881, p. 65.

Locality and geological horizon.—Wanga, Byôritsu-gun, Shinchiku-shû (Wanga, Miaoli, Hsinchuhsien), Formosa. Byôritsu formation, Pliocene. Hypotype.—IGPS coll. cat. no. 61258.

Locality and geological horizon.—Hakushaton, Byôritsu-gun, Shinchiku-shû (Paishatun, Miaoli, Hsinchuhsien), Formosa. Byôritsu formation, Pliocene. Hypotype.—IGPS coll. cat. no. 61258-A.

Locality and geological horizon (after MORISHITA, 1955, p. 232).—Takemata, Mitanimura, Kahoku-gun, Ishikawa Prefecture (Lat. 36°35'N., Long. 136°45'E., near Kanazawa City). Omma formation, Pliocene.

Locality and geological horizon (after MORISHITA, 1955, p. 232).—Kuramadera, Akamaru-mura, Nishi-Tonami-gun, Toyama Prefecture (Lat. 36°45'N., Long. 137°E., near Takaoka City). Omma formation, Pliocene.

Locality and geological horizon (after MORISHITA, 1955, p. 232).—Hotta, Kamishiromura, Himi-gun, Toyama Prefecture (Lat. 36°50'N., Long. 137°E., near Himi City). Omma Sandstone, Pliocene.

Locality and geological horizon.—IGPS loc. no. Ak-1.—Sea cliff near Anden, Iriaimura, Minami-Akita-gun, Akita Prefecture (tm Funakawa, Lat. 39°58′05″N., Long. 139°51′05″E.). Shibikawa formation, Pliocene. Hypotype.—IGPS coll. cat. no. 60330-A.

Locality and geological horizon.—IGPS loc. no. Kn-14.—Roadside cutting at Wada, Hatsuse-mura, Miura-gun, Kanagawa Prefecture (tm Yokosuka, Lat. 35°11′42″N., Long. 139°38′04″E.). Miyata formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 58340-A.

Locality and geological horizon.--IGPS loc. no. Kn-15.--Small cliff at Ôkine, Hatsu-

se-mura, Miura-gun, Kanagawa Prefecture (tm Yokosuka, Lat. 35°12′N., Long. 139° 38′E.). Miyata formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 58340-B.

Locality and geological horizon.—IGPS loc. no. Ty-12.—Shinagawa in Tokyo (tm Tokyo Seinanbu (Tokyo Southwest), Lat. 35°37′34″N., Long. 139°44′30″E.). Tokyo formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 22251-A.

Locality and geological horizon.—IGPS loc. no. Ty-14.—Oji (precise locality unknown), Kita Ward, Tokyo Prefecture (tm Tokyo Tohoku-bu (Tokyo Northeast), ca. Lat. 35°45′N., Long. 139°43′E.). Tokyo formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 22251-B.

Locality and geological horizon.—IGPS loc. no. Ty-15.—Kameido (precise locality unknown), Kôtô Ward, Tokyo Prefecture (tm Tokyo Tohoku-bu (Tokyo Northeast), ca. Lat. 35°42'N., Long. 139°50'E.). Tokyo formation, Pleistocene. Hypotype.—IGPS. coll. cat. no. 22251.

Locality and geological horizon.—IGPS loc. no. Ch-25.—Roadside cutting at Somei, Tako-machi, Katori-gun, Chiba Prefecture (tm Narita, Lat. 35°44′02″N., Long. 140°27′ 36″E.). Narita formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 7899-A.

Locality and geological horizon.—IGPS loc. no. Ch-33.—Roadside cutting at Ôtake, near Shimosa-Manzaki railway station, Habu-mura, Inba-gun, Chiba Prefecture (tm Narita, Lat. 35°48′27″N., Long. 140°16′42″E.). Narita formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 7899-B.

Locality and geological horizon.—IGPS loc. no. Ch-34.—Roadside cutting west of Narita-machi, Inba-gun, Chiba Prefecture (tm Narita, Lat. 35°46'32"N., Long. 140°18' 58"E.). Narita formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 7899-C.

Locality and geological horizon.—IGPS loc. no. Ch-35.—Roadside cutting at Usui, Usui-mura, Inba-gun, Chiba Prefecture (tm Sakura, Lat. 35°43′47″N., Long. 140°10′ 52″E.). Narita formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 7899-D.

Locality and geological horizon.—IGPS loc. no. Ch-36.—Roadside cutting at Hagiwara, Rokugô-mura, Inba-gun, Chiba Prefecture (tm Sakura, Lat. 35°47′47″N., Long. 140°12′48″E.). Narita formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 7899.

Locality and geological horizon.—IGPS loc. no. Ch-37.—Roadside cutting at south of Kioroshi, Kioroshi-machi, Inba-gun, Chiba Prefecture (tm Sakura, Lat. 35°49′40″N., Long. 140°09′30″E.). Narita formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 7899-E.

Locality and geological horizon.—IGPS loc. no. Ch-38.—Roadside cutting at Ôyatsu, Koito-mura, Kimitsu-gun. Chiba Prefecture (tm Futtsu, Lat. 35°18′26″N., Long. 139° 59′24″E.). Kiyokawa formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 73749-A.

Locality and geological horizon.—IGPS loc. no. Ch-39.—Cliff of the River Yôrô, at Komagome, Takataki-mura, Kimitsu-gun, Chiba Prefecture (tm Anegasaki, Lat. 35° 22'N., Long. 140°09'13"E.). Yabu formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 73749-B.

Locality and geological horizon.—IGPS loc. no. Ib-22.—Roadside cutting at Shironaka, Kuga-mura, Tsukuba-gun, Ibaragi Prefecture (tm Ryûgasaki, Lat. 35°56'37"N., Long. 140°05'46"E.). Narita formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 7899-F.

There are numerous specimens referred to this species at the writer's disposal,

ranging from 16 mm to 72 mm in longitudinal diameter.

Full-grown specimens generally attain 60 mm or more in longitudinal diameter of test. Marginal outline of test rounded pentagonal or subcircular, not regularly rounded, undulating, broadly notched in ambulacra, especially in the postero-lateral ambulacra (I and V), outline of test somewhat re-enteringly curved to the effect that the posterior interambulacrum (5) becomes slightly prominent; transverse diameter being slightly larger or lesser than the longitudinal one; the greatest breadth in the postero-lateral interambulacra (I and 4) or just posterior to the apical system. Interambulacral medial space depressed on the aboral surface and forming shallow grooves, and there is a slight depression around the petaloid area; ambulacral area outside the petaloid area higher than distal part of petals and nearly as high or more or less lower than the apical system. Apical system rather large, situated at central, with four genital pores. Ambulacra much wider than interambulacra at the ambitus, width of frontal ambulacrum (III) being one and half times the adjoining interambulacrum (2 or 3).

Petaloid area rather small, its total length being about 0.6 of longitudinal diameter; petals generally subequal in length and width, their distal ends more or less open and slightly depressed; frontal petal (III) being generally widely open. Number of



Fig. 47 [22]. Ambulacral structure of Scaphechinus mirabilis A. AGASSIZ, 1863, ×2.5.
A part of the frontal ambulacrum (III) on aboral surface, showing the arrangement of extra-petaloid pores.

pore-pairs of petals being about 70 in 18 mm length, about 65 in 16 mm, and about 45 in 9 mm, respectively, and several supernumerary small pores being often on the prolongation of poriferous zones (text-fig. 47 [22]). Ambulacral plates outside the petals numbering eight in a column from distal end of the petal to the ambitus, being much higher and wider than petaloid plates and greatly curved at the middle part, in the adult specimens. Poriferous zones broad, almost as wide as or slightly narrower than half interporiferous zone, thus differ from the typical *Echinarachnius*; a ridge between two pore-pairs with 10 or 11 tubercles in a row in 2 mm width. Series of pores divergent at first and become convergent at about half the length of petals, and re-divergent distally.

Oral surface evenly flat. Peristome rather small, situated at central, rounded decagonal in outline; in young specimens, adorally each ambulacral furrow has a fairly conspicuous, well limited, but delicate, median keel, and its inner end scarcely bends downwards; while in adult specimens it is not so conspicuous as that of young specimens. Oral ambulacral furrows distinct, and dividing at distal end of basicoronal ambulacral plates into two diverging main branches, which have a varying number of small sidebranches distally, mainly on the outer side; main stem of the furrows does not continue beyond the branching point (text-fig. 48 [23]). Basicoronal row rather large, its longitudinal diameter (including the peristome) being about 0.3 of longitudinal diameter of test; usually all the first post-basicoronal interambulacral plates being separated from basicoronal interambulacral plates, so that the first row of post-basicoronal ambulacral plates of each ambulacrum is in lateral contact with the plates of the adjacent ambulacrum (discontinuous arrangement); variation of arrangement of coronal plates rarely



Fig. 48 [23]. Structure of oral surface of Scaphechinus mirabilis A. AGASSIZ, 1863, $\times 0.8$.

occurs in some interambulacral areas, particularly in the antero-lateral areas (2 and 3), that is the interambulacral plates of the basicoronal row are in contact with the succeeding plates of columns (continuous arrangement). Periproct small, marginal, in a small notch. Interambulacral plates on the aboral surface high, there are 11 plates from the apical system to the ambitus. Coronal plates on the oral surface rather few; in each ambulacral column there are four post-basicoronal plates; in inter-ambulacral areas, there are two post-basicoronal plates to a column in posterior area (5), two in anterior and three in posterior columns in postero-lateral areas (1 and 4), and three post-basicoronal plates to a column in antero-lateral areas (2 and 3). Internal radiating partition walls extending from periphery inwards half of distance in each interambulacrum and there are abundant and heavy concentric buttresses covering a greater part of the floor (NISIYAMA, 1940, fig. 4 on pl. 43).

This is a common species of Japan, ranging from Hokkaido at the north to Kyushu at the south, and the commonest and most widely distributed one of the *Scaphechinus*. In fossil state, it is more common in younger deposits rather than the late Pliocene, and remarkable increase in individual number is noticed with the increase in age of formations.

The deep purplish or with violet tinge and the pentagonal form of the test which is somewhat pointed behind characterize this species. The depression in the interambulacral spaces on the aboral surface and a slight depression around the petaloid area appear when the test reaches about 30 mm in length and a somewhat pentagonal outline of the test is also seen in young individuals. This species generally attains a large size, especially in the mild waters of central Japan, the largest of the present series (both fossil and living) measures 88 mm in transverse diameter. Among the known species of the genus from Japan, only severals are known to attain such size as the present one.

The developmental process of change in the ambulacral and interambulacral plates system on the oral surface of the test of this species, from the data observed from the Recent specimens from the west coast of Shimane Prefecture (GISM coll. cat. nos. 3364, 3365, 3366 and 3368) as shown in the text-figures (text-figs. 49 [24]-50 [25]), is summarized as follows. In a specimen measures 5 mm in transverse diameter (text-



Fig. 49 [24]. Ontogeny of oral surface of *Scaphechinus mirabilis* A. AGASSIZ, 1863. a. 5 mm in test-diameter; b. 9 mm in ditto; c. 18 mm in ditto; d. 32 mm in ditto.



Fig. 50 [25]. Structure of aboral surface of Scaphechinus mirabilis
A. AGASSIZ, 1863 (in the young individuals).
a. 5 mm in test-diameter; b. 7 mm in ditto; c. 9 mm in ditto.

fig. 49 [24]a) the peristome large, its diameter being about 0.18 of longitudinal diameter of test, and adorally each ambulacral furrow has a fairly conspicuous, well limited median keel, and its inner end scarcely bends downwards. The basicoronal row is relatively large, its diameter (including the peristome) being about 0.5 of longitudinal diameter of test; the basicoronal ambulacral plates are comparatively broad contrast to those of the larger specimens, and the breadth of basicoronal ambulacral area (in a pair of the plates) being about 0.5 of the basicoronal interambulacral area. The first post-basicoronal plates comparatively small contrast to those of the larger specimens, and the basicoronal interambulacral plates are barely in contact with first post-basicoronal interambulacral plates of both columns in the areas 1, 2, :3 and 4, except the posterior area (5), in which the plate is in contact with a column (5a) of the subsequent plates. On the oral surface, there are from three to four post-basicoronal ambulacral plates in each ambulacral area, and two post-basicoronal interambulacral plates to a column. The oral ambulacral furrows are indistinct, minute pores arranged nearly parallel to median line of the basicoronal ambulacral plates, and there is no trace of bifurcation of the furrows at the distal end of the plates.

In a specimen measures 9.0 mm in transverse diameter (text-fig. 49 [24]b) the peristome also relatively large, its diameter being about 0.14 of longitudinal diameter of the test, and adorally each ambulacral furrow has a median keel. The basicoronal row is relatively large, its diameter (including the peristome) being about 0.34 of longitudinal diameter, and the basicoronal ambulacral plates are large compared to the larger specimens, but small compared to the smaller specimens. The first postbasicoronal plates are also comparatively small, but relatively larger than those of the smaller specimens. In the posterior interambulacral area (5) the first post-basicoronal interambulacral plates have been pushed dorsally so that the first post-basicoronal ambulacral plates of the postero-lateral areas (I and V) are in contact with each other (the discontinuous arrangement); the basicoronal interambulacral plates are in contact (except the posterior area (5)) subsequent plates of the interambulacrum; in the postero-lateral area (1 and 4) they scarcely in contact with one plate of the posterior column, and in the antero-lateral areas (2 and 3) they moderately in contact with two plates of the both columns. On the oral surface, there are two post-basicoronal plates to a column in the posterior area (5), two in the anterior and three in posterior columns of the posterior-lateral areas (1 and 4), and three in each column of the antero-lateral areas (2 and 3); there are three to five post-basicoronal ambulacral plates to a column. The oral ambulacral furrows rather indistinct, minute pores arranged to each side and nearly parallel to median line of the basicoronal ambulacral plates, and trace of bifurcation is indicated at the distal end of the plates.

In a specimen measures 18 mm in transverse diameter (text-fig. 49 [24]c) the peristome becomes comparatively small as compared to that of the smaller specimens, its diameter being about less than one-tenth of longitudinal diameter, and also adorally each ambulacral furrow has a median keel. The basicoronal row also becomes comparatively small, its diameter (including the peristome) being less than 0.3 of longitudinal diameter of the test. The arrangement of coronal plates on the oral surface in this stage is characterized by the plates of the basicoronal row being become small in comparison to the subsequent plates of following rows, and in the interambulacral areas they are more or less (but least in the antero-lateral areas) separated from the basicoronal interambulacral plates, so that the first post-basicoronal ambulacral plates of each ambulacrum are in lateral contact with the plates of the adjacent ambulacrum. The contact line of two first post-basicoronal ambulacral plates of the adjacent ambulacra in the interambulacral areas (i.e., the degree of discontinuous arrangement) (text-fig. 49 [24]d) is the longest in the posterior interambulacral area (5), those in the postero-lateral areas (1 and 4) are about half of that of the posterior area (5), and those in the antero-lateral areas (2 and 3) are about one-third the posterior area (5). The basicoronal ambulacral plates become comparatively small compared to the adjoining interambulacral plates. The oral ambulacral furrows also become more or less distinct, and the two side-branches of the furrows also become more or less longerthan those of the smaller specimens. On the oral surface, there are four post-basicoronal ambulacral plates to a column in the postero-lateral areas (I and V), and from four to five post-basicoronal ambulacral plates to a column in the antero-lateral areas. (II and IV) and the frontal area (III). In the interambulacral areas, there are two post-basicoronal plates to a column in the posterior area (5), two in anterior and three in posterior columns of the postero-lateral areas (1 and 4), and three in each column of the antero-lateral areas (2 and 3), as usual.

As for the ambulacral and interambulacral plates system on the oral surface of fossil specimens derived from the Byôritsu formation (Pliocene) of Formosa, HAYA-SAKA and MORISHITA (1947-a, pp. 95-96) noticed that-" Thus, in none of the specimens. the interambulacrum (5) is continuous. As in the interambulacrum (5), in all of the specimens examined, the distance between the first and second interambulacral plates is always the greatest. This fact indicates that the process of change of interambulacral plates from continuous to discontinuous takes place with growth, and,. consequently, it is assumed that the interambulacrum (5) is the most progressive of all, as NISIYAMA remarked." Although there is no citation on the size of test, the ratio of continuous types of interambulacral plates on the oral surface of these fossil specimens seems to be larger than the Recent specimens from the central Japan. In the Pliocene specimens from Formosa there is one continuous type proportined to three discontinuous type in other than the posterior area (5), while in the Recent specimens of large size there seems to be one continuous type proportioned to five or more discontinuous type. The large proportion of the continuous type of the Formosan fossil can be considered whether it may be the local variation or the older geological age (i. e., the less specialized type), but it cannot be settled until the close examination of the numerous Recent specimens from various localities on the ambulacral and interambulacral plates system on the oral surface.

The writer (1940, pp. 837-839) described as to the variation in the marginal outline of this species and the stoutness of the test, which may be apparently related to both age and habitat. Although the fossil specimens from the Byôritsu formation of Formosa are assigned to Scaph. mirabilis, especially to forma scutella (NISIYAMA, 1940,. p. 838), there are found slight differences from the living specimens in the features. of test. In the Formosan fossil specimens, the interambulacral depression on the aboral surface and a depression around the petaloid area are shallower, the width of poriferous zones of the petals is narrower, and the elevation of petaloid portion of the ambulacra is smaller than in the living Schaph. mirabilis. They may probably have descended from such a form having more or less round test with rather thick margin, a small petaloid area, a small degree of depression of interambulacral spaces on the aboral surface and around the petaloid area, and with more or less distinct. ambulacral furrows which bifurcated at the distal end of the basicoronal ambulacral plates. The genital pores of young individuals of the Byôritsu forms seem to be formed somewhat earlier than in the living forms. This species occurs as fossil at: about Lat. 24°30'N., in Formosa.

Scaphechinus mirabilis tenuis (YOSHIWARA, 1898)

Echinarachnius tenuis Yoshiwara, 1898, p. 61.—Yoshiwara, 1900, p. 392 (in Japanese).— Lambert and Thiéry, 1925, p. 583.—Echinarachnius (Scaphechinus) mirabilis tenuis Yoshiwara: Nisiyama, 1940, p. 839, pl. 43, fig. 5, text-fig. 63.—Scaphechinus tenuis (Yoshiwara) Mortensen, 1948-c, p. 378, pl. 62, fig. 4 (pro parte).—Echinarachnius (Scaphechinus) mirabilis tenuis Yoshiwara: Morishita, 1950, p. 256(?).—Scaphechinus tenuis (Yoshiwara): Utinomi, 1954, p. 354 (pro parte).—Echinarachnius mirabilis tenuis Yoshiwara: Morishita, 1955, p. 234, pl. 9, figs. 3-4 (?).—Morishita, 1960, p. 58.—Scaphechinus mirabilis tenuis (Yoshiwara): Nisiyama, 1965, pp. 79, 85.

There is no authentic fossil specimen of this form at the writer's disposal, although MORISHITA reported its occurrence from the Pliocene of Ishikawa Prefecture.

Locality and geological horizon (after MORISHITA, 1955, p. 234).—Hutamata, Asakawa-mura, Kahoku-gun, Ishikawa Prefecture (Lat. 36°35'N., Long. 136°50'E., near Kanazawa City). Omma Sandstone, Pliocene.

The description of fossil specimens of this form from the Pliocene of Ishikawa Prefecture is not given by MORISHITA, but from the figures of the aboral and oral surfaces given by him (1955, pl. 9, figs. 3-4) it may be described as follows—

Test small, 45 mm in longitudinal diameter and 44 mm in the transverse. Marginal outline of test subcircular, not regularly rounded, undulating, broadly notched in ambulacra, notches being much greater in the postero-lateral ambulacra (I and V) than in anterior ones; transverse diameter slightly smaller than the longitudinal, the greatest breadth being immediately posterior to the centre of test. Apical system moderate in size, situated at central, 22.5 mm from the anterior margin.

Petaloid area rather small, its total length being about 0.5 of longitudinal diameter of test; petals rather short and wide, subequal in length and width, their length less than twice the width, and widely open at their extremities; poriferous zones seem to be rather narrow, being narrower than half the interportierous zones.

Peristome central, rather large, over 3 mm in diameter. Basicoronal row rather small, its diameter (including the peristome) being 0.22 of longitudinal diameter of test; shape of basicoronal interambulacral plates being elongated rhombic; first post-basicoronal ambulacral plates rather small; there are from four to five post-basicoronal ambulacral plates in a column of ambulacral areas. Oral ambulacral furrows rather distinct and seem to trifurcating at the distal end of second post-basicoronal ambulacral plates on median line, at least in the areas I, II and III, while in the areas IV and V the trifurcating point is obscure. Periproct probably marginal in a rather broad notch of the posterior margin.

From this description and figures of the fossil form, especially on the features of the oral surface, it cannot be safely assigned to *Scaph. mirabilis tenuis*, and the true systematic position of this fossil form is necessity of a future elucidation.

Scaph. mirabilis tenuis possesses some characteristics of both Scaph. mirabilis and Scaph. brevis (IKEDA, 1963) (Echinarachnius brevis IKEDA, 1936-a, p. 1231, text-figs. a-c.—Echinarachnius (Scaphechinus) brevis IKEDA: NISIYAMA, 1940, p. 843, pl. 43, figs. 7-9, text-fig. 65.—Echinarachnius brevis IKEDA: MORISHITA, 1955, p. 234, pl. 8, figs. 1-2). The specimens from off Taitô-zaki, Pacific side of Chiba Prefecture, north of the type-locality, are fairly well in accordance with YOSHIWARA's description (1898, p. 61), and comparing the specimens with the young individuals of Scaph. brevis from the Onahama Bay, the type-locality of that species, the writer finds that this form (tenuis) may be more related to Scaph. mirabilis than to Scaph. brevis. The tenuis and brevis differ from each other in the position of the periproct, the position of the apical system, the colour of test, and in the stage of the outside opening of genital pores, although they are accordance with in a strongly wavy contour of the posterior margin. In large individuals of this form (tenuis), more than 35 mm in longitudinal diameter, the depression of interambulacral spaces on the aboral surface and a slight depression around the petaloid area, which are characteristics of Scaph. mirabilis, are evident on the test, and the coat of radioles is more dense than in Scaph. brevis; but the colour of test is usually lighter than that of *mirabilis*. The edge of test is more or less thinner than that of *mirabilis*, and it may be due to the more or less deeper habitat than that of the typical mirabilis. When Scaph. mirabilis and Scaph. tenuis are laid side by side, the differences recognized between them lead the writer in taking the latter as a subspecies of the former. This subspecies is known only from the east coast of Chiba Prefecture in the living.

Scaphechinus griseus (MORTENSEN, 1927)

- Echinarachnius griseus MORTENSEN, 1927-a, p. 195, pl. 1, figs. 1-4, text-figs. 2a, 2f.—MORTENSEN, 1929, p. 477.—IKEDA, 1939, pl. 2, figs. 3-5.—IKEDA, 1940, p. 4.—Echinarachnius (Scaphechinus) griseus MORTENSEN: NISIYAMA, 1940, p. 841, pl. 43, fig. 6, text-fig. 64.—Scaphechinus griseus (MORTENSEN) MORTENSEN, 1948-c, p. 379.—Echinarachnius griseus MORTENSEN: MORISHITA, 1955, p. 234, pl. 9, figs. 1-2.—Scaphechinus griseus (MORTENSEN): UTINOMI, 1960, p. 345, pl. 40, fig. 19.—Scaphechinus griseus (MORTENSEN): NISIYAMA, 1965, pp. 79, 85.
- Non Echinarachnius griseus: IKEDA, 1935-a, pl. 4, figs. 1-4 (= Scaphechinus brevis (IKEDA, 1936)).

Locality and geological horizon.—IGPS loc. no. Ak-1.—Sea cliff near Anden, Iriaimura, Minami-Akita-gun, Akita Prefecture (tm Funakawa, Lat. 39°58′05″N., Long. 139°51′05″E.). Shibikawa formation, Pliocene. Hypotype.—IGPS coll. cat. no. 60330-B.

Locality and geological horizon.—IGPS loc. no. Ch-40.—Small cliff of small hill at Mandano, Satomi-mura, Ichihara-gun, Chiba Prefecture (tm Ôtaki, Lat. 35°19′16″N., Long. 140°07′14″E.). Kiyokawa formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 73749-C.

A well preserved specimen measures 43 mm in longitudinal diameter, 45 mm in transverse one, and about 6.5 mm in height. Marginal outline of test subcircular, not regularlarly rounded, the transverse diameter being somewhat larger than the longitudinal; the largest breadth being in the postero-lateral interambulacra (I and 4); in the ambulacra, especially in the postero-laterals (I and V), outline of test somewhat re-enteringly curved to the effect that the posterior interambulacrum (5) becomes slightly prominent. Edge of test flat and rather thin, aboral surface very gently rising from the edge towards the highest point anterior to the apical system, which is slightly eccentric in front, a little nearer to the anterior than the posterior extremity; this eccentricity is made more conspicuous through the fact that the highest point of test just anterior to the apical system, in the frontal ambulacrum (III).

Apical system situated at 20 mm from the anterior margin, rather large, 4 mm wide and 4.5 mm long, with four genital pores.

Petaloid area rather large, its total length being about 0.63 of longitudinal diameter of test; petals rather long and wide, their length more or less twice the width; frontal petal (III) more or less differs from other paired petals in shape. Frontal petal (III) 11.5 mm long and 7 mm wide, slightly wider than others, broadly open distally; poriferous zones (having about 42 pore-pairs on each side) rather narrow, 1.2 mm in width at the broadest part; interporiferous zone rather broad, half interporiferous zone 2.3 mm in width at the broadest part, being nearly twice as wide as the poriferous zone; inner series of pores at first diverge, then slightly converge at middle part of the petal and diverge again distally; outer series of pores more divergent from beginning of the petal, more or less converge at halfway to length of the petal and diverge to large extent again distally. Antero-lateral petals (II and IV) 12 mm long by 6 mm wide; poriferous zones (having about 45 pore-pairs on each side) 1.2 mm in width at the broadest part; inner series of pores at first diverge and somewhat converge at middle part of the petals and again diverge near the distal ends; outer series of pores more divergent from beginning of the petals, converge to some degree at halfway to length of the petals and since continue almost parallel to the inner series. Postero-lateral petals (I and V) 12 mm long and nearly 6 mm in width, similar to the antero-lateral petals in form, but slightly narrower than them. Shape of the petals mainly as in Echinarachnius parma (LAMARCK, 1816), especially in the poriferous zones, but rather not as in Scaph. mirabilis or brevis; they are, however, subjected to some variations in minor details.

Oral surface almost flat. Peristome slightly eccentric anteriorly, situated at about 20 mm from the anterior margin, just as in the apical system, rather small, about 2.5 mm in diameter. Basicoronal row rather large, its diameter (including the peristome) being nearly 0.3 of longitudinal diameter of test; basicoronal interambulacral plates large, about 5 mm long and 4 mm wide; basicoronal ambulacral plates (in a pair) lancet-shaped, about 5 mm long and 1.5 mm wide; first post-basicoronal ambulacral plates exceedingly large, and quitely separated post-basicoronal interambulacral plates from the basicoronal interambulacral plates (discontinuous arrangement); contact line of ambulacral plates I2a and V2b in the posterior interambulacrum (5) is the longest, about 9 mm long; contact line of ambulacral plates I2b and II2a and that of V2b and IV2b are about 8 mm long, respectively; and contact line of ambulacral plates II2b and III2a and that of III2b and IV2a are about 5 mm long, respectively (or more or less variable in length in individuals). There are four post-basicoronal ambulacral plates to a column in each area; and in the interambulacral areas, there are two postbasicoronal plates to a column in the areas 1, 4, and 5, and three in anterior and two in posterior columns of the antero-lateral areas (2 and 3). This ambulacral and interambulacral plates system more or less differs from that of Scaph. mirabilis or brevis. Oral ambulacral furrows bifurcate at distal end of the basicoronal ambulacral plates in median area; two side-branches generally subdivided, more or less, distally to the edge of test. Periproct distinctly supramarginal, evidently apart from the posterior edge. Tuberculation on the test very fine and close, and glassy knobs occurring between tubercles on the oral side so small as to be hardly observable, particularly in

fossil specimens. Internal radiating partition walls stouter than *Scaph. mirabilis*, but the concentric buttresses lesser and more delicate than that species.

This species was originally described on the living specimens from Yamagata Prefecture, northern Japan. As for the radioles and pedicellariae, MORTENSEN, (1927-a, p. 196) described—" The spines (radioles) of the aboral side are rather slender, with well differentiated, widened terminal part. Pedicellariae of the usual bivalve type." These features cannot be applied for fossil specimens, but the characters on the test of these fossil specimens make the specimens safely assigning to *Scaph. griseus*.

This species is readily distinguished from *Scaph. mirabilis*, by (1) the slight eccentric position of the apical system and peristome, a little nearer to the anterior margin, (2) the distinctly supramarginal position of the periproct, which is situated at 3 mm from the posterior edge in a specimen of 44 mm in longitudinal diameter of the test, (3) the thinner and flat edge of the test, (4) lacking the depression of interambulacral spaces on the aboral surface and a slight depression around the petaloid area, (5) the greyish or greyish green colour of the test and radioles contrasting to the dark purplish colour of those of *Scaph. mirabilis*, and (6) by the ambital outline of the test. The shape of the radioles of aboral side is somewhat different from that of *mirabilis* being more or less specialized. This species has also some characteristics of *Ech. parma* in the aboral surface and in the shape of the petals on one hand, however, it also has some characteristics of *Scaph. mirabilis* in the mode of bifurcation of the oral ambulacral furrows, the large basicoronal row, and in the discontinuous arrangement of interambulacral plates on the oral surface, on the other hand.

Scaphechinus griseus seems to be distributed from about Lat. 50°N. (IGPS coll. cat. no. 61256) or more north to about Lat. 38°N. (MCZ 5022—paratype), in small depths, and several specimens hardly distinguishable from this species are known to occur in the Kiyokawa formation (Pleistocene) at about Lat. 35°20'N., in Chiba Pre-fecture, central Japan.

Genus Pseudoastrodapsis DURHAM, 1953

Nipponaster Durham, 1952-b, p. 844 (non Niponaster LAMBERT, 1920).

- Pseudoastrodapsis Durham, 1953-b, p. 756 (pro Nipponaster Durham, 1952).—Durham, 1955,. p. 168, text-figs. 16e, 32c.
- Astrodapsis: NISIYAMA, 1948, p. 601 (non CONRAD, 1857).
- Orthotype.—Astrodapsis nipponicus NISIYAMA, 1948, p. 602, pl. 88, figs. 1-6, 8, 10-15 (Suenomatsuyama formation of Iwate Prefecture, Japan).

Small to moderate sized, more or less inflated, echinarachniid echinoids; oral surface moderately flattened, aboral surface arched, margin of the ambitus rounded; outline somewhat elongated or rounded. Petals long, widely open distally, length about three-fourths the radius of test; pore-pairs conjugate; petals elevated, with intervening interambulacral depressions. Apical system slightly anterior or central in position, with four genital pores. Peristome central, large, subpentagonal, with large interambulacral projections ("buccal tubes"?); periproct submarginal or inframarginal, large, situated usually at junction of sutures between second and third pairs of post-basicoronal interambulacral plates. Oral ambulacral furrows simple, unbranched, or rarely branching distally. Basicoronal plates of moderate size, interambulacral plates much larger than the ambulacral plates. Interambulacral areas on the oral surface very narrow, about one-fourth width of the ambulacral areas at the ambitus; post-basicoronal interambulacral plates in contact with the basicoronal interambulacral plates in the areas 1, 2, 3 and 4, and moderately separated in the posterior area (5). On the oral surface there are from four to five post-basicoronal plates to a column in interambulacral areas 1, 2, 3 and 4, three plates to a column in the posterior area (5); six or seven post-basicoronal ambulacral plates to a column in each ambulacral area (from DURHAM, 1952 and 1955).

From the upper Miocene to Pliocene of Japan and Sakhalin.

The narrow interambulacral areas and the ambulacral and interambulacral plates system on the oral surface, widely opened petals, and the more distinctly inframarginal periproct, readily separate Pseudoastrodapsis from Astrodapsis CONRAD, 1857 (CONRAD, 1857, p. 315.—Haplotype.—Astrodapsis antiselli CONRAD, 1857, p. 315.—CONRAD, 1857-a, p. 196, pl. 10, figs. 1-2.—Richards, 1935, pp. 62, 63, pl. 7, figs. 1a-b.—Durham, 1952-b, p. 845, text-fig. 1A.-DURHAM, 1955, text-fig. 22A on p. 105). Even though the general characters of *Pseud. nipponicus* show considerable convergence with the typical Astrodapsis from the Pacific coast of North America, evalution of the plate arrangement does not indicate a particularly close relationship, other than that they both belong in the general Echinarachnius-group of the North Pacific region. Comparison of the plates on the oral surface of *Pseud. nipponicus* with the most primitive species of Astrodapsis, Ast. brewerianus (RÉMOND, 1863) (Echinarachnius brewerianus RÉMOND, 1863, p. 53.—Astrodapsis brewerianus (RÉMOND) KEW, 1920, p. 91, pl. 13, figs. 5a-c.— GRANT and HERTLEIN, 1938, p. 70, pl. 16, figs. 7-8, pl. 20, figs. 4-5.-DURHAM, 1952-b, p. 845, text-fig. 1F.-DURHAM, 1955, text-fig. 22F on p. 105.-Briones substage of California), in which the post-basicoronal interambulacral plates are also in contact with the basicoronal interambulacral plates in the areas 1, 2, 3 and 4, but the ambulacral and interambulacral plates system on the oral surface of that species demonstrates the lack of affinity of the Japanese or western Pacific species with the Californian genus Astrodapsis.

DURHAM (1952-b, p. 846; 1955, p. 168) stated that the species of *Astrodapsis* recorded from Sakhalin and Kamtchatka are to be referred to this or some closely allied genus. There are at least three fossil species referred to this genus from the North Pacific coast of Sakhalin, Hokkaido, and North Japan.

Pseudoastrodapsis nipponicus (NISIYAMA, 1948)

(Text-fig. 45 [20])

Astrodapsis nipponicus NISIYAMA, 1948, p. 602, pl. 88, figs. 1-6, 8, 10-13.—Nipponaster nipponicus (NISIYAMA) DURHAM, 1952-b, p. 844, text-fig. 1D.—Pseudoastrodapsis nipponicus (NISI-YAMA) DURHAM, 1953-b, p. 756.—DURHAM, 1955, p. 168, text-figs. 16e, 32e.—Morishita, 1960, p. 59.—NISIYAMA, 1965, p. 79.

Holotype.--IGPS coll. cat. no. 60326a.-Paratypes.--IGPS coll. cat. nos. 60326, 22034.--Standard Univ. Paleo. Type Coll., no. 7952.--Coll. Mus. Paleo., Univ. California, no. 30131.--California Acad. Sci., Paleo. Type Coll., and U.S. Nat. Mus.

Locality and geological horizon.-IGPS loc. no.-Iw-15.-In a fine conglomeratic

sandstone at the southern margin of the tributary of the Mabechi-gawa, about 150 metres east of the bridge connecting Kita-Fukuoka-machi and Itsuka-machi, Ninohegun, Iwate Prefecture (tm Ichinohe, Lat. 40°13′48″N., Long. 141°18′56″E.). Suenomatsuyama formation, Mio-Pliocene (or Miocene) (YABE and HATAI, 1941, p. 49.— HATAI and NISIYAMA, 1952, p. 338). Holotype and paratypes.

Locality and geological horizon.—IGPS loc. no. Iw-16.—Nekobuchi (precise locality unknown to the writer), Nisatai-mura, Ninohe-gun, Iwate Prefecture (tm Ichinohe, ca. Lat. 40°17'N., Long. 141°18′40″E.). Suenomatsuyama formation, Mio-Pliocene. Para-types.—IGPS coll. cat. no. 22034.

Locality and geological horizon.—IGPS loc. no. Iw-17.—A point near Kintaichi railway station (precise locality unknown to the writer), Kintaichi-mura, Ninohe-gun, Iwate Prefecture (tm Ichinohe, ca. Lat. 40°19'N., Long. 141°18'E.). Suenomatsuyama formation, Mio-Pliocene. Hypotype.—IGPS coll. cat. no. 22047.

There are nearly thirty specimens referred to this species at the writer's disposal, ranging from 16 mm to 26 mm in longitudinal diameter of test. Holotype, 24 mm in longitudinal diameter, 22 mm in transverse one, and 8 mm in height. This species is characterized by having long, elevated, widely open petals, peristome with rather large interambulacral projections, periproct submarginal, situated at junction of sutures between second and third pairs of post-basicoronal interambulacral plates, and simple but stout internal radiating partition walls.

The arrangement of coronal plates on the oral surface of this species shows a considerable differences, as examined by DURHAM (1952-b, p. 845, text-fig. 1), from that of *Astradapsis* species. The ambulacral areas (or plates) on the oral surface very broad, about four times as wide as the interambulacral areas (or plates) near the subambital region, while in the typical *Astrodapsis* (viz., *Ast. antiselli* or *Ast. salina-sensis* (RICHARDS, 1935, p. 61, pl. 7, figs. 2a-c.—DURHAM, 1955, text-fig. 22B on p. 105)) the width of ambulacral areas on the oral surface is about one and half times as wide as the interambulacral areas. The basicoronal row of moderate size, but the basicoronal interambulacral plates usually much prolonged than the basicoronal ambulacral plates, and the basicoronal ambulacral plates elongate and narrow, and are in contact with the basicoronal interambulacral plates in the areas 1, 2, 3 and 4, only moderately separated in the posterior area (5). In the typical *Astrodapsis*, the post-basicoronal interambulacral plates in the basicoronal interambulacral plates in the basicoronal interambulacral plates in the basicoronal interambulacral plates in the areas 1, 2, 3 and 4, only moderately separated in the posterior area (5). In the typical *Astrodapsis*, the post-basicoronal interambulacral plates being not in contact with the basicoronal interambulacral plates being not in contact with the basicoronal interambulacral plates being not in contact with the basicoronal interambulacral plates being not in contact with the basicoronal interambulacral plates in the areas are broad and low.

This species superficially resembles Ast. tumidus RÉMOND, 1863 (RÉMOND, 1863, p. 52.—KEW, 1915, pp. 366, 367, 370, pl. 39, figs. 7a-c, pl. 40, figs. 1a-b, 2.—CLARK and TWITCHELL, 1915, p. 202, pl. 95, figs. 3a-b, pl. 108, fig. A.—GRANT and HERTLEIN, 1938, p. 77, pl. 16, fig. 6), from the Miocene (middle Delmontian stage) of California, but is easily distinguished from that species by its shorter and straight petals, the more arched profile, the depressed apical system, and by the highest point, and decidedly by the features of the oral surface of the test. It is also distinguished from the Californian species by the position of the periproct, which is far apart from the posterior edge.

The main developmental trends of this species observed in the specimens available for study are -(1) increase in the degree of elevation of ambulacra and of depression

of interambulacra, (2) increase in the degree of depression of the apical system, and (3) slight increase in breadth. Distinct depression of the interambulacral areas on the aboral surface is not observed until the test diameter reaches 18 mm, but well marked depression of the areas has developed when the test attains about 20 mm or more in longitudinal diameter. These changes seem to appear suddenly in growth stages between 18 mm and 20 mm in longitudinal diameter of the test.

Associated fauna.—The associated fauna of this species is as follows.—Chlamys cosibensis (YOKOYAMA), Patinopecten kimurai nakosoensis MASUDA, Patinopecten kimurai yudaensis MASUDA, Panope japonica (A. ADAMS), Neptunea modesta (KURODA), Coptothyris adamsi (DAVIDSON), etc.

Pseudoastrodapsis intermedius NISIYAMA, n. sp. (Pl. 16, figs. 9-12, 14)

Holotype.---IGPS coll. cat. no. 73803.

Locality and geological horizon.—IGPS loc. no. Te-13.—In the fine conglomeratic sandstone at Sanpô-zawa near the Shôwa coal-mine, Numata-mura, Uryû-gun, Teshio, Hokkaido (tm Ebishima, Lat. 43°59'N., Long. 141°57′52″E.). Kawabata formation, Miocene.

There are several specimens referred to this new species at the writer's disposal, but the preservation of them is not in good condition, the best preserved one is selected as the holotype.

Test small, stout, ovoid in marginal outline; margin thick, depressions in the postero-lateral ambulacra (I and V); aboral surface moderately arched; moderate depressions in the interambulacral areas. Oral surface more or less concave to the peristome. Ambulacra petaloid adapically; petals slightly elevated, broad, and widely open at their extremities; pores conjugate, inner series of pores at first diverge widely and then contract slightly at about two-thirds the distance from the apical system to the margin and near the distal end of the petals; outer series of pores at first more diverge than the inner series and then converge markedly at the middle part, close to the inner series, and diverge again distally; interporiferous zones wide, being about three times as wide as the poriferous zones. Peristome central, small, subcircular in outline, with prominent adoral projections. Periproct small and round, situated at 2 mm from the posterior margin. Apical system being a little eccentric to anterior and slightly sunken. Oral ambulacral furrows broad, straight, and extend nearly to the margin, not branching distally. Test covered with small tubercles of nearly the same size on the both surfaces, which have sunken scrobicules.

Dimensions of holotype.—26 mm in longitudinal diameter, 22 mm in transverse one, and 4 mm in height.

Distinction.—This new species superficially resembles Astrodapsis brewerianus (RÉMOND, 1863) (loc. cit.), from the Miocene (Briones substage) of California, but may be distinguished from that species by its straighter petals, the depressed apical system, and by the position of the periproct. This species also superficially resembles Astrodapsis cierboensis KEW, 1920 (KEW, 1920, p. 94, pl. 14, figs. 1a-c.—GRANT and HERT-LEIN, 1938, p. 71, pl. 16, fig. 1), from the Cierbo formation (above the Ast. brewerianus)

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zone and below the Ast. tumidus zone) of California, but differs from that species in having shorter and narrower petals, the less elevated petals and less depressed interambulacra, and in the position of the periproct. In the position of the periproct, this species resembles *Pseud. nipponicus*, from the Suenomatsuyama formation of Iwate Prefecture, but is distinguished from that species by the less elevated petals, the less depressed interambulacra, and by the less elevated test.

Pseudoastrodapsis nitidiusculus NISIYAMA, n. sp.

(Pl. 16, figs. 15-17, Pl. 17, figs. 2-3, 6)

Holotype.—IGPS coll. cat. no. 73805.

Locality and geological horizon.—Exact locality unknown to the writer, probably the middle part of Hokkaido. Formation unknown, probably the upper Miocene or lower Pliocene.

Seven specimens referred to this new species at the writer's disposal, ranging from 31 mm to 45 mm in longitudinal diameter. Holotype, 38 mm in longitudinal diameter, 35 mm in transverse one, and 9 mm in height.

Test of medium size; subcircular in marginal outline; margin rather thin; depressions prominent in the postero-lateral ambulacra (I and V); aboral surface strongly arched from the extremities of the petals to the highest point; marked depressions in the interambulacral areas, especially in the posterior interambulacrum (5). Oral surface evently concave to the peristome. Ambulacra broad; petaloid area large, 30 mm in length, its total length being 0.78 of longitudinal diameter of test; petals prominently elevated, widely open at their extremities and extending about threefourths of distance to margin of test; pores conjugate; inner series of rounded pores after first diverging extend in almost straight lines, converging slightly about threefourths the distance to the margin; outer series of transversely elongated pores diverge at first and then converge markedly about three-fourths the distance to the margin, at that point they become more or less round and continue parallel with the inner series to the distal end of the petals. Frontal petal (III) widely open at its extremity, but more or less differs from the others, in that it is wider and slightly less elevated than the other paired petals. Apical system situated at 18 mm from the anterior margin, or little eccentric to anterior. Peristome sunken, small, subcentral, and subcircular in outline, with adoral projections. Periproct small, elongated transversely, situated at 1.5 mm from the posterior margin. Oral ambulacral furrows distinct, broad, straight and pointed to the ambulacral depressions. Tubercles small, crowded, and similar over both surfaces. Arrangement and shape of coronal plates on the oral surface are very similar with those of *Pseud. nipponicus*, the type-species, in the much narrower interambulacral areas and in the number of plates to a column.

Distinction.—This new species superficially resembles Astrodapsis whitneyi RÉMOND, 1863 (RÉMOND, 1863, p. 52.—CLARK and TWITCHELL, 1915, p. 201, pl. 95, figs. 2a-c.—Kew, 1920, p. 111, pl. 16, figs. 1a-b, pl. 17, fig. 2.—GRANT and HERTLEIN, 1938, p. 77, pl. 16, fig. 9.—DURHAM, 1955, text-fig. 22D on p. 105), from the Miocene (middle Delmontian stage) of California, but differs from that species in having the broader petals, the thicker margin of test, and in the position of the periproct. This species also superficially resembles Ast. major KEW, 1920 (KEW, 1920, p. 102, pl. 15, figs. 1a-c), from the Jacalitos formation (Pliocene) of California, but is easily distinguished from that species by the smaller and more rounded test, the smaller peristome, and by the position of the periproct. In the position of the periproct, this species resembles *Pseud. nipponicus*, but is ditinguished from that species by the more elevated petals, the more depressed interambulacra, and by the more arched test.

Besides occurring in Honshu and Hokkaido, *Pseudoastrodapsis* may also occurs in the Neogene formations of Sakhalin and Kamtchatka, as reported by two Russian authors under the names of Californian species, which are shown in the annexed list.

1. Astrodapsis tumidus RÉMOND: KHOMENKO, 1931, pp. 27, 115, pl. 1, fig. 4.— "North of Okha on the right bank of rivulet draining into the Nautu Gulf, Eastern Sakhalin. Nutovo series, middle Pliocene." This species may be identical with *Pseudoastrodapsis nipponicus* (NISIYAMA, 1948) or its closely allied species.

2. Astrodapsis pabloensis KEW: KHOMENKO, 1931, p. 106.—" Coast of Baron Korf Gulf, Kamtchatka. Middle Miocene." This species probably closely related to *Pseud*. *intermedius* NISIYAMA.

3. Astrodapsis whitneyi RÉMOND: ARGAMAKOVA, 1934, pp. 28, 41.—" Boatassin district, Sakhalin. Upper Notovo series, Pliocene." This species may be identical with *Pseud. nitidiusculus* NISIYAMA, or its closely allied species.

The species-correlation of the Californian *Astrodapsis* and the northwestern Pacific *Pseudoastrodapsis* will be summarized as follows.—

Formation of	Californian	N.W. Pacific
California	Astrodapsis	Pseudoastrodapsis
Jacalitos	A. jacalitosensis	
	A. spatiosus	D
Poncho Rico	A. saliansensis	P. nitidiusculus
Neroly	A. tumidus	P. nipponicus
Dierbo	A. cierboensis	P. intermedius
Briones	A. brewerianus	

Genus Allaster NISIYAMA, n. gen.

Type-species.—Allaster rotundatus NISIYAMA, n. sp.

Test small, depressed and rounded; apical system a little eccentric in front, with four genital pores, and distinctly depressed inner portion of petals. Petals with relatively small number of plates and widely open distally; elevation of petals and depression of interambulacral areas on the aboral surface not prominent; margin of test thick. Oral ambulacral furrows simple. Periproct marginal. Internal structure consists of strong radiating partition walls which connect the roof for one-fourth the distance from periphery to the peristome, and without concentric buttresses. Tuberculation scrobicular of rather large size.

This genus is distinguished from the young forms of the genera *Pseudoastrodapsis* and *Astrodapsis*, when compared with one another, by the distinctly depressed apical system which is not so eccentric in front, the flattened test, and by the form of petals.

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Allaster is also distinguished from Kewia, a primitive genus of the Echinarachniusgroup, by the depressed apical system, the position of the periproct, and by the markedly thicker margin. The depressed apical system, thick margin of the test, and shape of the petals of this genus may indicate a primitive character of some species of *Pseudoastrodapsis*, and from such primitive form some species of *Pseudoastrodapsis* may have sprung off. The arrangement of coronal plates on the oral surface is not detected.

Allaster rotundatus NISIYAMA, n. sp.

(Pl. 17, fig. 5, Pl. 18, figs. 1, 4)

Holotype.--IGPS coll. cat. no. 73768.

Locality and geological horizon.—IGPS loc. no.—Hd-12.—In the calcareous conglomeratic sandstone near Nishô bridge, Nishô-mura, Saru-gun, Hidaka, Hokkaido (tm Saruta, Lat. 47°39′20″N., Long. 142°12′10″E.). Takinoue formation, Oligo-Miocene (MURATA, 1933, pp. 12-13.—HUZIOKA, 1941, pp. 964-966).

There are two specimens and several fragmentaries at the writer's disposal, ranging from 14 mm to 20 mm in longitudinal diameter.

Test small, stout, circular in marginal outline; margin thick; aboral surface rather depressed. Oral surface more or less concave to the peristome. Apical system situated at 10 mm from the anterior margin, madreporite pentagonal in outline, 2 mm long and 2 mm wide, with rather large genital pores and numerous madreporic pores, distinctly depressed below the inner portion of petals.

Ambulacra petaloid adapically; petaloid area rather large, 13 mm in length; petals widely open at the extremity; frontal petal (III) 5.5 mm long, 4 mm wide at the distal end, having 19 pore-pairs in each side; antero-lateral petals (II and IV) about 6 mm long, and about 4 mm wide at the distal ends, having 20 pore-pairs in each side; postero-lateral petals (I and V) about 6 mm long, and 4 mm wide at distal ends, having about 20 pore-pairs in each side; inner series of pores straight, outer series slightly incurved at the middle part of the petals. Peristome sunken, subcentral, rounded subpentagonal in outline. Periproct rather small, marginal in position.

Oral ambulacral furrows distinct near the peristome and not reach the margin, not branching distally. Internal structure consists of pairs of stout radiating partition walls in each interambulacrum close to the ambulacra, they extend to roof at about one-fourth the distance from the periphery to the peristome. Tuberculation distinct, similar on the both surfaces, rather coarse and somewhat regularly placed.

Dimensions of holotype.—20 mm in longitudinal diameter, 20 mm in transverse one, and 3 mm in height.

Remarks.—The depressed apical system, circular test in marginal outine, shape of the petals, and thick margins are the combination of conspicuous features of this species. In comparison with young specimens of *Pseudoastrodapsis*, it is easily distinguishable from them by the conspicuous features described above. Although the holotype of this species attains 20 mm in longitudinal diameter of the test, it is not so young individual as judged from its small size, as the well-developed outside genital pores are distinctly observable when the test attains 16 mm in longitudinal diameter. The occurrence of this species may be contemporaneous with some species of the genus *Kewia*, such as *Kewia elongata* (NISIYAMA, 1940) or *K. nipponica* (NAGAO, 1928).

Family Astriclypeidae Stefanini, 1912

Astriclypeinae Stefanini, 1912, pp. 747, 748, 749 (partim).—Mortensen, 1948-c, p. 398 (partim). —Astriclypeidae Stefanini: Durham, 1955, p. 175 (family; partim).

Monophorinae LAHILLE, 1895, p. 551 (pro parte).—LAMBERT and THIÉRY, 1921, p. 324 (proparte).—MORTENSEN, 1948-c, p. 419 (pro parte).

Mellitinae STEFANINI, 1912, p. 749 (partim).—Mellitidae STEFANINI: DURHAM, 1955, p. 171. Type-genus.—Astriclypeus VERRILL, 1867.

Test of usually large forms, very flat, low discoidal, without posterior lobules or indentations; oral side usually very flat. Petals well-formed, usually moderately closed; pores conjugate, outer member of pore-pairs elongated, a few primary porepairs outside the petals. There are lunules or marginal slits in the ambulacra or in the posterior interambulacrum (5), or in the both areas, never in the antero-lateral inter-ambulacra (2 and 3). Basicoronal row fairly small, interambulacral plates more or less larger than ambulacral plates. Paired interambulacra usually not in contact with basicoronal plates, rarely the posterior interambulacrum (5), on the oral surface. Interambulacra on the oral surface widening toward the ambitus, and about as wide as ambulacra at the ambitus. Apical system subcentral, with four or five genital pores. Peristome subcentral, small, round, mostly with the edge rather abruptly sunken. Periproct on oral surface, generally between peristome and posterior margin of test, usually with a central anal rostrum. Oral ambulacral furrows bifurcating just outside basicoronal plates, with more or less developed lateral branches, and terminating adorally in a small projection over the peristome. A complicate structure of internal supports in the test. Aboral primary radioles usually club-shaped, oral primaries generally simple; miliary radioles usually simple, terminating in a glandular bag. Pedicellariae bivalved or trivalved, ophicephalous pedicellariae may occur. Tubefeet with a pair of spicules in sucking disc. Larva with a skeleton of basket type, usually complicate.

From the Oligocene to Recent.

The occurrence of lunules or marginal slits in ambulacra or the posterior interambulacrum (5) extending through the test, permitting the free passage of water between the oral and aboral surfaces, is a remarkable feature of this family. MORI-SHITA (1963, pp. 136-137) has summarized the discussions on the functions of the lunules and ecological observations on the lunuled scutellids contributed by many authors, such as IKEDA (1939, 1941), KENK (1944), HYMAN (1958), and others. He stated (1963, p. 137) that, although the nature of the lunules being not certain, they must be concerned with the locomotion for certain reason, and the forming of them must be owing to the excessive indentation; and he further stated that the lunules must have some close relation with the life of lunuled scutellids, and the specialization into various forms seems to have taken place along the process of evolutionary trends. The writer believes this specialization of various forms with certainty.

The forms (except the Monophoraster) with lunules or marginal slits in ambulacra

or in the posterior interambulacrum (5) of the family should be subdivided, as was done by STEFANINI (1912), NISIYAMA (1935), and DURHAM (1955), on account of their morphological features and their geological and geographical distribution. The genera *Echinodiscus* (with *Amphiope*) and *Astriclypeus*, which are regarded as probably descendants of the scutellids of the late Tethys Sea, forming one group, the Astriclypeinae; besides the lacking of the posterior interambulacral lunule in these genera, the pedicellariae are three-valved and ophicephalous pedicellariae alone present. The genera *Encope*, *Mellita*, and *Mellitella*, which are regarded by DURHAM (1955, p. 116) as probably descendants of the Central American protoscutellids, forming another group, the Mellitinae; all the forms with a lunule in the posterior interambulacrum (5) and ambulacral lunules, the pedicellariae are bivalved, but no ophicephalous pedicellariae. The writer thinks thus the subfamily Astriclypeinae is well formed. The fossil representatives of this subfamily are in our collection.

Subfamily ASTRICLYPEINAE STEFANINI, 1912

Astriclypeinae Stefanini, 1912, p. 747.—Mortensen, 1948-c, p. 398.—Astriclypeidae Stefanini: Durham, 1955, p. 175 (family).

Test usually of large size, with lunules or marginal slits in the ambulacra, but none in the interambulacra, and posterior edge of test not indented. Four genital pores. Posterior interambulacrum (5) discontinuous on oral surface, antero-lateral interambulacra may be discontinuous. Interambulacra about as wide as ambulacra at ambitus. Basicoronal interambulacral plates larger than ambulacral plates. Periproct on oral surface. Oral ambulacral furrows bifurcating at just outside basicoronal plates. Pedicellariae three-valved and ophicephalous pedicellariae present.

From the Oligocene to Recent.

The subfamily comprises two genera *Echinodiscus* (with *Amphiope*) and *Astriclypeus*, and they are discriminated from one another as shown by the following key.

Key to the genera and subgenus of the subfamily Astriclypeinae.

- 1. Five lunules, one in each ambulacrum Astriclypeus Only two lunules or marginal slits, in the postero-lateral ambulacra (I and V) ... 2
- 2. Lunules, or marginal slits, narrow, longitudinal Echinodiscus Lunules broad, round, or transverse oval Amphiope. There are fossil representatives of the genera Echinodiscus (with Amphipe) and

Astriclypeus in our collection.

Genus Echinodiscus LESKE, 1778

Echinodiscus LESKE, 1778, p. 195 (pro parte), non p. xix.—GRAY, 1825, p. 428 (pro parte).—GRAY, 1855-a, p. 19 (pro parte).—A. AGASSIZ, 1872-74, pp. 112, 531.—DUNCAN, 1889-a, p. 159.—H. L. CLARK, 1911, p. 605.—H. L. CLARK, 1914, p. 70.—H. L. CLARK, 1925, p. 169.—NISIYAMA, 1935, p. 137, foot-note.—H. L. CLARK, 1946, p. 351.—MORTENSEN, 1948-c, p. 398 (complete synonymy).—TERMIER and TERMIER, 1953, p. 926.—DURHAM, 1955, p. 176, text-figs. 4a, 5e-f, 8b, 32a.—MORISHITA, 1963, pp. 131, 132.

- Logotype.—Echinodiscus bisperforatus LESKE, 1778, p. 197 (132), pl. 21, figs. A-B.—MORTENSEN, 1948-c, p. 406, pl. 53, figs. 2, 6-8, pl. 71, figs. 6-9, 18, text-figs. 202b, 241a, 242a-b (from the Philippines to Red Sea). [H. L. CLARK, 1911, p. 605.—Action of International Commission on Zoological Nomenclature.—Bull. Zool. Nomencl., vol. 4, 1950, p. 5357.
- Echinoglycus 'VAN PHELSUM': LESKE, 1778, pp. 197, 199, 201, 204 ("Egelkoek" PHELSUM, 1774, pp. 26, 34) (fide Durham, 1955, p. 76).
 - Logotype.—Echinoglycus irregularis LESKE, 1778, p. 197.=Echinodiscus bisperforatus LESKE, 1778, p. 197. [DURHAM, 1955, pp. 175, 176].
- Lobophora AGASSIZ, 1841-b, p. 62 (non Lobophora Curtis, 1825, nec Serville, 1839).—AGASSIZ and DESOR, 1847, p. 136 (pro parte).—DESOR, 1855-58 (57), p. 235.—DUJARDIN and HUPÉ, 1862, p. 564.
- Logotype.—Lobophora biforis (LAMARCK) AGASSIZ, 1841-b, p. 64, pl. 12, figs. 1-11.—Echinus biforis GMELIN, 1788-93 (91), p. 3188 (Coast of Madagascar).—Echinodiscus biforis (GMELIN)
 A. AGASSIZ, 1872-74, pp. 113, 532, pl. 13b, figs. 5-6, pl. 37, figs. 4-6.=Echinodiscus bisperforatus Leske, 1778, p. 197. [Desor, 1855-58 (57), p. 235].
- Tretodiscus POMEL, 1883, p. 71 (pro Lobophora AGASSIZ, 1831, non CURTIS, 1825).—FOURTAU, 1904-a, p. 523.—Tetrodiscus POMEL: LAMBERT and THIÉRY, 1921, p. 323 (corruption of Tretodiscus POMEL, 1883).—Tretodiscus POMEL: GRANT and HERTLEIN, 1938, p. 94, footnote.

Orthotype.-Echinodiscus biforis (GMELIN) A. AGASSIZ, 1872-74, pp. 113, 532.

- Non Echinodiscus Breynius: Lambert, 1907-c, p. 124 (Breynius, 1732, p. 63, pl. 7, pre-Linnean).—Lambert and Thiéry, 1914, p. 311.—Lambert and Thiéry, 1925, p. 580.
 - Logotype.—Echinodiscus orbicularis LESKE, 1778, pl. 45, figs. 6-7.—Laganum orbiculare (LESKE) AGASSIZ, 1841-b, p. 120, pl. 22, figs. 16-20. [LAMBERT, 1907-c, p. 124].

Test of medium to very large size (up to ca. 180 mm length), low discoidal; with two lunules or marginal slits in postero-lateral ambulacra; oral side flat, aboral surface slightly arched; outline varying; mostly truncate at posterior end; margin thin. Petals well-defined, but rather short; more or less distinctly closed distally; petals subequal or more or less variable in length; pores conjugate, no small isolated pores

continuing pore-series distally. Oral ambulacral furrows bifurcating just outside basicoronal plates, with more or less developed lateral braches (textfig. 51 [26]). Apical system central, with four genital pores. Peristome central, small, round, slightly sunken; periproct on oral surface, situated at between first and second post-basicoronal plates, covered with fairly conspicuous plates without radioles. Basicoronal row of rather moderate size; interambulacral plates larger than ambulacral plates. Usually first pair of post-basicoronal ambulacral plates separates post-basicoronal interambulacral plates from basicoronal plates. In interambulacra from two to four post-basicoronal plates to a column on oral surface; ambulacral area usu-



Fig. 51 [26]. Structure of oral surface of *Echinodiscus auritus siamensis* MORTENSEN, 1948, \times ca 0.6 (drawing from HAYASAKA, 1948).

ally with five or six post-basicoronal plates to a column on oral surface. Posterior interambulacrum (5) slightly wider, other interambulacra about same width as ambulacra at ambitus. Primary radioles of aboral side short, with club-shaped widened distal part, forming a dense, perfectly uniform coat; miliary radioles about as long as primaries, terminating in a glandular bag; radioles of oral side longer, not distinctly

club-shaped. Pedicellariae of tridentate, ophicephalous, and triphyllous types, in general three-valved (mainly after MORTENSEN, 1948-c, and DURHAM, 1955).

From the Oligocene to Recent.

The generic distinction between Echinodiscus and Amphiope, by the form of lunules. and length of petals, seems to be more or less artificial. In the course of development of lunules two different ways are observable-(1) the one way arises depressions on the oral side of the test which by resorption ultimately perforate both the oral and aboral plates and attain the full size of the lunules, as in the case of Astriclypeus, and (2) the other way arises as notches in the test-margin which become deeper with the growth of the test and ultimately are close in at the distal end, as in the case of ambulacral lunules of Mellitella. The resorptive process seems to occurred in the Oligocene (as in Amphiope) and it persists to the Recent, and the second process occurred somewhat lately in geological age and observable in the Recent forms. The differences of the form of lunules, in Echinodiscus elongate longitudinally and in Amphiope elongate transversely, and the differences of the length of petals, in Echinodiscus the long anterior and short posterior petals and in Amphiope the equally developed petals, are somewhat attractive. DURHAM (1955, p. 176) stated that specimens from the Miocene of India (Echinodiscus) have the lunules more ovate than the Pliocene and Recent species, a characteristic that indicates the close relationship to Amphiope. The two names, Echinodiscus and Amphiope, should be united into one and the latter may be separated as a subgeneric rank of the former. Further the poriferous zones of petals are broad, incurved and instead of divergent distally they tend to become closed distally in contrast to the divergent poriferous zones of petals in many species. of scutellid genera of the North Pacific region. This genus is the oldest occurrence of the family and is notable as the only one among the Astriclypeidae which has retained the ophicephalous pedicellariae (H. L. CLARK, 1914, p. 70.-KOEHLER, 1922, p. 129.—MORTENSEN, 1948-c, p. 399). The Recent species of Echinodiscus range from Gulf of Suez through the Indian Ocean to north as Ryukyu Islands and south as to-New Guinea, in small depth, usually less than 50 metres.

There are two fossil species of this genus in our collection.

Echinodiscus chikuzenensis NAGAO, 1928

Echinodiscus chikuzenensis NAGAO, 1928, p. 17, pl. 1, figs. 15–17.—Мокізніта, 1956, р. 194.— Мокізніта, 1960, р. 59.—Nisiyama, 1965, р. 79.

Holotype.—IGPS coll. cat. no. 35952.—Paratypes.—IGPS coll. cat. no. 35951.

Locality and geological horizon.—IGPS loc. no. Fu-33.—Beach rocks west of Hachiman-zaki and about 300 metres north of Waita, Shimagô-mura, Onga-gun, Fukuoka Prefecture (tm Orio, Lat. 33°54′02″N., Long. 130°46′35″E.). Wakita formation, Oligo-Miocene (or Oligocene). Holotype.—IGPS coll. cat. no. 35952.

Locality and geological horizon.—IGPS loc. no. Fu-34.—Beach rocks of Tôminohana (Myôken-saki) about 400 metres northwest of the contact point of the two road at Iwaya, Ashiya-machi, Onga-gun, Fukuoka Prefecture (tm Orio, Lat. 33°56'N., Long. 130°41'E.). Yamaga formation, Oligo-Miocene (or Oligocene). Paratypes.—IGPS coll. cat. no. 35051.—GISM coll. cat. no. 3508. Locality and geological horizon (after MORISHITA, 1956, p. 194).—Nango-mura, Minami-Naka-gun, Miyazaki Prefecture (ca. Lat. 31°30'N., Long. 131°20'E.). Nichinan Group (Oligocene). Hypotype.—No. GK-L 4739 in Geol. Inst., Kyushu Univ.

This species is characterized by broadly oval test which is nearly as broad as long, and broader and truncated posteriorly, relatively small petaloid area, the narrow, elongated and somewhat lanceolated lunules and their longer diameter being less than three times the shorter one, with their longer axis concordant with the median line of the ambulacra, and by moderately distant from the extremity of the petals, the distance is 6 mm long. The anterior petals (III, II and IV) are longer and the posterior petals (I and V) are short as usual in *Echinodiscus*. This species closely resembles *Echinodiscus desori* DUNCAN and SLADEN, 1883 (DUNCAN and SLADEN, 1883, p. 60, pl. 12, figs. 7-10.—DUNCAN and SLADEN, 1885-a, p. 328, pl. 51, figs. 1-2), from the Gaj (or Gaji) series (Miocene) of western India, as stated by the original author, but is distinguished from that species by the broader and shorter frontal petal (III).

This species seems to be confined in its distribution to Kyushu and in the Ashiya group or its equivalent.

Echinodiscus transiens NISIYAMA, n. sp.

(Pl. 17, fig. 1)

Holotype.—IGPS coll. cat. no. 73773.

Locality and geological horizon.—IGPS loc. no. Yg-25.—A point west of Nishiyama, Hikoshima, Shimonoseki City, Yamaguchi Prefecture (tm Kokura, Lat. 33°56'24"N., Long. 130°53'34"E.). Yamaga formation, Oligo-Miocene (or Oligocene).

There are two specimens, holotype and paratype, of this species at the writer's disposal, ranging from 96 mm to 104 mm in transverse diameter, and the adoral surfaces are attached to sandstone matrix.

Test large, rather thin, with a flat or somewhat concave oral surface, aboral surface gently raises from the thin margin to the highest point, which is situated at just behind the apical system; transversely oval in marginal outline, transverse diameter greater than the longitudinal one, ratio being about 1:0.86, the greatest breadth lies at some distance behind the apical system; rounded anteriorly, broader and truncated posteriorly; margins broadly and deeply notched in the anterior ambulacra (II, III, and IV) and more or less notched in the posterior interambulacrum (5), as in outline of *Ech. bisperforatus truncatus* (AGASSIZ, 1841) (*Lobophora truncata* AGASSIZ, 1841-b, p. 66, pl. 11, figs. 11-16).

Apical system lying a little eccentric anteriorly, about 42 mm from the anterior margin, rather small, 7 mm wide and 5 mm long, madreporite central and pentagonal in outline as usual, genital pores four and small.

Petaloid area rather large, nearly as long as or somewhat larger than half the test-radius; frontal petal (III), the longest of all, about 25 mm long and 14 mm wide at the middle part of the petal, distal end perfectly closed; poriferous zones about .3.5 mm wide at the middle part of the petal, with 66 pore-pairs in each side; anterolateral petals (II and IV), 23 mm long and 12 mm wide near the distal end, where the .broadest, and perpectly closed, poriferous zones about 3 mm wide at the broadest part, with 85 pore-pairs in each side, angle between median line of the frontal petal and that of the antero-lateral petal being about 70° on each side; postero-lateral petals. (I and V), 22 mm long, the shortest of all, and 12 mm wide at near the distal end, where the broadest, and perfectly closed, poriferous zones 3.5 mm wide at the broadest part, with 56 pore-pairs in each side; interporiferous zones of all petals rather uniform, and about 5 mm wide at the middle part of the petals; the long anterior and short posterior petals as usual in *Echinodiscus*.

Two postero-lateral ambulacral lunules large, and elliptical in outline, 18 mm long and 15 mm wide, placed longitudinally on the elongation of median lines of the ambulacra (I and V), distance between extremities of petals and lunules about 4 mm. Peristome, oral ambulacral furrows, and periproct not accessible.

Distinction.—This new species closely resembles *Ech.* (*Amphiope*) formosus YOSHI-WARA, 1901, from the Miocene formation of Formosa and Ryukyu Islands, in the form of petals and lunules, but is distinguished from that species by the marginal outline of test and by the placement of the lunules. This species is also related to *Ech.*. *chikuzenensis* NAGAO, 1928 (loc. cit.), from the Ashiya group of northern Kyushu, but differs from that species in the outline of test and in the form of lunules.

The form of lunules of this species is similar to that of the subgenus $Amphiope_{.}$ than to the typical *Echinodiscus*, but the placement of the lunules is longitudinally on the elongation of median lines of the postero-lateral petals (I and V) refers this species to the genus *Echinodiscus*.

The three species, *Ech. chikuzenensis*, *Ech. transiens*, and *Ech. (Amphiope) formosus*,. seem to be much related to one another, especially in the former two. There arises a question whether they should be each as a separate species or as subspecies of one species, but here they are regarded as distinct species respectively. The three specieslived in the subtropical or tropical seas from the Oligocene to Miocene of Formosa,. Ryukyu Islands and as north as western Japan.

Subgenus Amphiope AGASSIZ, 1840

Amphiope Agassiz, 1840-a, pp. 6, 17 (Species included-perspicillata Ag., bioculata Desm.).— Agassiz, 1841-b, p. 72.—Agassiz and Desor, 1847, p. 136.—Desor, 1855-58 (57), p. 235.— POMEL, 1883, p. 71.—LAMBERT, 1907-e, p. 49—LAMBERT and THIÉRY, 1921, p. 322.—Nisi-YAMA, 1935, p. 137, foot-note.—GRANT and HERTLEIN, 1938, p. 94, and foot-note.—MORTENsen, 1948-c, p. 413 (complete synonymy).—TERMIER and TERMIER, 1953, p. 926.—DURHAM. 1955, p. 177, text-figs. 16d, 32b (genus).—MORISHITA, 1963, pp. 131, 132.

Logotype.—Amphiope bioculata (DESMOULINS) AGASSIZ, 1840-a, p. 6.—AGASSIZ, 1841-b, p. 73, pl. 11, figs. 1-5 (Tertiary of France). [LAMBERT, 1907-e, p. 49].

Differs from typical *Echinodiscus* mainly in the shape of the lunules, which are round or transverse oval or more or less broadly oval, not long and narrower as in typical *Echinodiscus*. As a consequence of the shape of the lunules the ambulacral plates are arranged more or less distinctly in a circle around them. In the typical species of this subgenus, the basicoronal row more or less larger than that of the typical *Echinodiscus*, the innermost post-basicoronal interambulacral plates more elongated and larger, the petals are equally developed, and there are two or three post-basicoronal interambulacra plates to a column on the oral surface. These features, however, cannot be regarded as criteria for generic distinction between them.

From the Oligocene to Miocene of the circum-Mediterranean countries, India, and Ryukyu Islands.

There is a fossil species referred to this subgenus in our collection.

Echinodiscus (Amphiope) formosus YOSHIWARA, 1901

Echinodiscus formosus YOSHIWARA, 1901, p. 62.—TOKUNAGA, 1903, p. 14, pl. 1, figs. 1-2, pl. 2, fig. 2.—Amphiope formosa (TOKUNAGA) LAMBERT, 1904-a, p. 129.—LAMBERT and THIÉRY, 1921, p. 323.—MORISHITA, 1963, p. 138, pl. 6, fig. 2 (reproduced from TOKUNAGA, 1903).— Echinodiscus (Amphiope) formosus YOSHIWARA: NISIYAMA, 1965, p. 79.

There is no authentic specimen of this species at writer's disposal. This species is characterized by having ovoidal test as in *Ech.* (*Amphiope*) placenta DUNCAN and SLADEN, 1885 (DUNCAN and SLADEN, 1885-a, p. 329, pl. 51, fig. 7, pl. 52, figs. 1-3, 8), from the Miocene of India, relatively large petaloid area, subequally developed petals, and broad, short, elliptical lunules which are close to the distal ends of the posterolateral petals (I and V). The distance from the extremity of the petal to lunule being only 5 mm, with their longer axis making an angle of about 30° with the median line of the ambulacra. This peculiar placement of the lunules in this species stands it between the subgenus *Amphiope* and the typical *Echinodiscus*, but the obliqueness of lunules should be referred this species to the subgenus *Amphiope*.

Genus Astriclypeus VERRILL, 1867

Astriclypeus VERRILL, 1867-71 (67), p. 311.—A. AGASSIZ, 1872-74, pp. 93, 538.—POMEL, 1883, p. 71.—DUNCAN, 1889-a, p. 163.—MEISSNER, 1904, p. 1384.—H. L. CLARK, 1911, p. 605.— STEFANINI, 1912, p. 749.—H. L. CLARK, 1914, p. 72.—LAMBERT and THIÉRY, 1921, p. 323.—H. L. CLARK, 1925, p. 171.—NISIYAMA, 1935, p. 132.—GRANT and HERTLEIN, 1938, p. 94, foot-note.—MORTENSEN, 1948-c, p. 414 (complete synonymy).—MORISHITA, 1952, p. 109.— TERMIER and TERMIER, 1953, p. 927.—DURHAM, 1955, p. 175, text-figs. 1m, 32d—MORISHITA, 1963, pp. 131, 132.

Haplotype.—Astriclypeus mannii VERRILL, 1867-71 (67), p. 311.—Astriclypeus manni VERRILL: A. AGASSIZ, 1872-74, pp. 93, 539, pl. 13d, figs. 2-4 (China and Japan).

- Crustulum Troschel, 1868, p. 1.—Troschel, 1869, p. 15.—Troschel, 1869-a, p. 52.
- Haplotype.—Crustulum gratulans TROSCHEL, 1868, p. 1.=Astriclypeus mannii VERRILL, 1867-71 (67), p. 311.

Test of large size, flattened, rounded outline, only slightly truncated posteriorly, somewnat subdiscoidal, oral side perfectly flat. Test very strong and heavy; internal structure of usual type (NISIYAMA, 1935, text-figs. 1a-b on p. 134), pillars arranged so as to show in sections a more or less distinct star-shaped arrangement, in marginal part calcification so strong that it is almost quite compact; no internal pillars separating buccal cavity from intestinal space. Petals well-defined, rather broad, more or less open distally, pore-series more or less markedly truncated at their distal end in living specimens; furrow conjugated outer and inner pore narrow, but deep and sharply limited. Five ambulacral lunules, but none in posterior interambulacrum (5). Oral ambulacral furrows bifurcating at distal end of basicoronal ambulacral plates; two main branches pass rather closely among each side of lunules, sending out of varying number of side-branches along their interradial side, these side-branches being again more or less distinctly branched distally; adorally each ambulacral furrow has a fairly conspicuous, well limited median keel that bends downwards at its inner end; pores along this keel usually large. Apical system subcentral, with four genital pores, which may be placed somewhat out in interambulacra, particularly postero-lateral pores (1 and 4). Periproct about midway between peristome and posterior margin, situated at usually between first and second post-basicoronal interambulacral plates, covered by a number of small, naked plates, and its central part raised so as to form an anal rostrum. Peristome central, fairly deeply sunken. Basicoronal plates small; post-basicoronal interambulacral plates separated from basicoronal plates by first pair of post-basicoronal ambulacral plates. Interambulacra with 3 or 4 post-basicoronal plates to a column on oral surface, with areas windened toward ambitus so that they are slightly wider than ambulacral areas at ambitus; ambulacral areas with 6 or 7 postbasicoronal plates to a column on oral surface; first post-basicoronal ambulacral plates with about twice or more altitude of subsequent plates. A single interambulacral perignathic process, fused auricle, short, curved and bends backwards. Teeth strongly keeled; pyramids laterally extremely flaring, with wing-like extensions, pits in top of pyramids; brace and epiphyses conspicuously small, compases absent; foramen magnum extremely shallow. Aboral primary radioles only moderately club-shaped; miliaries between them terminate in a large, glandular skin-bag; primaries of oral side less distinctly club-shaped; no marked difference between ambulacra and interambulacral radioles. Pedicellariae of tridentate and triphyllous types; ophicephalous pedicellariae present in youngs only. Colour in living a uniform brown (mainly after NISIYAMA, 1935, MORTENSEN, 1948-c, and DURHAM, 1955).

Astriclypeus is a genus restricted in its present distribution mainly to Japan and also sporadically in a China and Indo-China, being represented by a single living species Astriclypeus mannii VERRILL, 1867.

The genus Astriclypeus appeared in the lower Miocene (probably the Burdigalian epoch) in the North China Sea or the neighbouring area and the species Ast. integer YOSHIWARA, 1899 (see below) may be its first representative. The occurrences of Echinodiscus (Amphiope) and Scutaster (PACK, 1909, p. 278—Haplotype.—Scutaster andersoni PACK, 1909, p. 278, pl. 23, fig. 2.—KEW, 1920, p. 135, pl. 26, figs. 2a-b) seem to be more or less older than the Astriclypeus, as the Scutaster appeared first in the Vaqueros formation of California (Scut. vaquerosensis LOEL and COREY, 1932, p. 179, pl. 5, figs. 1a-b, 3), the formation is mostly correlated to the Aquitanian series, and as a few species of the subgenus Amphiope were reported from the Oligocene formations of the circum-Mediterranean countries.

The comparison of the geological and geographical distribution of the two genera *Echinodiscus* (with *Amphiope*) and *Astriclypeus* indicates an interesting relation of their distribution. The Recent species of *Echinodiscus* live in the Indo-West Pacific waters between Red Sea and eastwards as north as Ryukyu Islands (Latitude 27° North (*Ech. tenuissimus* (AGASSIZ, 1847) was reported from there), and Torres Strait, but they have never been discovered from the Japanese Seas. The fossil *Echinodiscus* (with *Amphiope*) was found in the Palaeogene formation of Kyushu and Neogene of Formosa and Ryukyu Island and as north as at Latitude 34° North (Hikoshima on the western-

most part of the Inland Sea). A living species of *Echinodiscus* (*Ech. auritus siamensis* MORTENSEN: HAYASAKA, 1948, p. 19, pl. 4, figs. 1a-b, pl. 5, figs. 1a-b—as *Ech. auritus* LESKE) occurs in Formosa, while *Astriclypeus mannii* is not found there. *Astriclypeus* is found in the Miocene and Pliocene formations of Japan and Formosa, ranging from Latitude 23° North, but its northwards extention seems to be regressive, as in the Recent seas it occurs at Latitude 35° North on the Pacific side in the northern limit.

The two genera *Echinodiscus* (particularly the subgenus *Amphiope*) and *Astriclypeus* are much alike morphologically as well as in the radioles and pedicellariae, and have more or less related geographical distribution. The writer once suggested that a probability of derivation of Astriclypeus from a Echinodiscus (Amphiope)-like ancestor, with getting an available specimen that having intermediate characters between of Amphiope and Astriclypeus (NISIYAMA, 1935, pp. 138-140, text-fig. 2-reproduced by MORISHITA, 1963, pl. 5, fig. 2); the specimen is derived from the lower Neogene of Formosa. This probability or possibility is believed by MORTENSEN (1949-c, p. 146) with certainty, and is repeated by DURHAM (1955, p. 176). This probability may be confirmed by the fact that derived from the development of ambulacral lunules in the young specimens of Astriclypeus. As to the development of the lunules in the young specimens, MORTENSEN (1948-c, p. 418) stated-" In a dredging outside the Biological Station, at depth of ca. 20 fms., I got, however, a quite young specimen, only 13×13 mm, which I cannot hesitate in identifying as a young Astriclypeus manni. It offers the most unexpected feature that only the two posterior lunules are present, they are quite short and broad, oval, so that this species so to say passes through an Amphiope-stage. On the oral side the first indication of the lunule of the frontal ambulacrum is visible; but it is still only a depression, the test not yet perforated. Of the two antero-lateral lunules there is still no trace", while in quite young specimens, less than 9 mm in test-diameter, there are no traces of lunules. Whereas, in a young specimen of fossil Astriclypeus, from the Tôgane formation (Miocene) of Shimane Prefecture (GISM coll. cat. no. 3202), the writer observed the development of the five lunules. The specimen ca. 20 mm in test-diameter, adapical part of interambulacra prominently raised and consequently proximal part of petals depressed; measurements of the specimen are as follows: length of petals ca. 4 mm; width of petals ca. 1.5 mm; number of pore-pairs on each side ca. 24; lunule (III) 1.3 mm long and 1 mm wide; lunule (IV) 1.2 mm long and 1 mm wide; lunule (V) 2 mm long and 1.5 mm wide; distance between extremities of petals and lunules ca. 2 mm; distance from extremity of lunules to margin ca. 1.5 mm or more. In this specimen, the postero-lateral lunule (V) is the longest, frontal lunule (III) slightly longer than the antero-lateral lunule (IV), which is the shortest of all. This trend of development seems to be coincide with the development of lunules, as described by MORTENSEN (loc. cit.), in a young specimen of 13 mm in test-diameter, and it seems to persist to the adult individuals of the living form (confer-NISIYAMA, 1935, p. 144).

Through an examination of living and fossil specimens of the genus *Astriclypeus*, the writer has had an idea that there have been three orthogenetical tendencies are recognizable in the evolutionary trends of this genus, they are, (1) progress of the resorption in the lunules, (2) increase of the podial pores in the petals, increase of the height of second post-basicoronal and subsequent ambulacral plate, and decrease

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in the size of the basicoronal row compared to the test-diameter, and (3) completion of the Astriclypeus-type petals from the ancestor-like petals (the petals such as in the Echinodiscus (Amphiope)). The degree of resorption of the lunule is measured by the distance from the extremity of petals to the lunules, as the larger the degree of the resorption the distance is smaller. In the living specimens of nearly adult or fullgrown Ast. mannii, the writer has found that the distance from the extremity of petals. to the lunules being usually less than 3 mm (this measurement needs a caution because of the margin of lunules is more or less oblique and sloping). But in the fossil Astriclypeus of the Miocene age it measures usually more than 6 mm. This difference of distance leads the writer to believe that it may be taken as a main criterion for subspecific distinction in the genus Astriclypeus, and also it seems to the writer that the smaller the progress of the resorption in the lunules the more older the geological occurrence. The shape of the lunules seems to be related to the degree of resorption of them, as a whole, as the smaller the progress of the resorption the shorter the length of the lunules. The shape of the lunules, however, being also more or less related to the age and size of individuals, and even in the living specimens of Ast. mannii it is more or less variable from elongate oval to slit-like form. Morishita (1952, pp. 111-112) regarded the shape of the lunules is the most important feature for the classification of species (or subspecies), by the measurements of the specimens from the different localities.

The number of podial pores in the petals is usually correlated with length of them, but in general speaking it becomes larger with the younger the geological age. In *Ast. integer* (110 mm in test-diameter) the number of podial pores in a series is 37, in *Ast. mannii ambigenus* (76 mm in test-diameter) the number is about 60, in *Ast. mannii* (104 m in test-diameter) from the Pliocene the number is 60 (HAYASAKA, 1947, p. 117), and in the living *Ast. mannii* of 102 mm in test-diameter the number is 68 and 121 mm in test-diameter 82. The tendency of increase of podial pores in the petals in the evolutionary trends of this genus is thus roughly recognizable.

The basicoronal row on the oral surface of the Miocene forms is generally larger than that of the living form, as it is indicated by bifurcating point of the oral ambulacral furrows. In a specimen of 76 mm in transverse diameter of *Ast. mannii ambigenus* the oral ambulacral furrows bifurcate at about 4 mm from the margin of the peristome; while in a living specimen of 121 mm in transverse diameter they bifurcate at about 2 mm from the margin of the peristome. In fossil forms, e. g., *Ast. mannii ambigenus* and *minoensis*, the periproct lying nearer to the posterior margin than the living form; in a specimen of 38 mm test-radius of *Ast. mannii ambigenus* the periproct situated at 24 mm from the peristome, while in a living specimen of 60 mm test-radius of *Ast. mannii* it situated at 30 mm from the peristome. This larger distance of the periproct from the peristome in the Miocene forms than in the living form indicates comparatively larger basicoronal and first post-basicoronal ambulacral rows than the living form.

The petals of the living *Ast. mannii* are characterized by their distal end, which open distally and the pore-series are more or less markedly truncated, and the wide poriferous zones are slightly incurved and then divergent distally. Whereas the petals of the Miocene forms are more or less tend to closed distally and the pore-series make rounded tips, and the poriferous zones are incurved and almost do not diverge distally as in the genus *Echinodiscus* (*Amphiope*). This feature of the petals also seems to indicate the probably derivation of *Astriclypeus* from an *Echinodiscus* (*Amphiope*)-like ancestor.

Species of Astriclypeus are discovered in the Miocene formations from Hokkaido to North Formosa (cf. MORISHITA, 1963, p. 130), viz., Kunnui (Ôanzaigawa) formation of Shiribeshi in Hokkaido, Tanosawa formation of Aomori Prefecture, Kadonosawa formation of Iwate Prefecture, Nishikurosawa formation of Akita formation, Tsugawa formation of Niigata Prefecture, Moniwa (Hatadate) formation of Miyagi Prefecture, Nokogiriyama formation of Chiba Prefecture?, Yatsuo Subgroup of Toyama and Ishikawa Prefectures, Katsuragawa formation of Yamanashi Prefecture, Shiroyama sandstone of Shizuoka Prefecture, Shukunohora Sandstone member of Gifu Prefecture, Shôbara formation of Hiroshima Prefecture, Tôgane formation of Shimane Prefecture, and Kaizan formation of Formosa; in the Pliocene formations of Shikoku and Formasa, viz., Kônomine formation of Kôchi Prefecture and Byôritsu formation of Formosa; and in the Pleistocene Ryukyu Limestone in Ryukyu Islands.

The specimens from the Pliocene and Pleistocene formations are safely referred to the typical *Ast. mannii*. The Miocene forms, however, differ in minor details from the typical one, and these forms may be regarded as two or three distinct subspecies of the typical one.

In Hiroshima, Gifu, Toyama, Ishikawa, Yamanashi, Niigata, Akita, Aomori Prefecture, and in Hokkaido, the Miocene forms of Astriclypeus occur associated with *Miogypsina kotoi* and *Operculina complanata japonica*, the characteristic higher foraminifers in Japan; and in Shimane, Shizuoka, Chiba, Miyagi, and Iwate Prefectures, where the *Miogypsina—Operculina* zone is not exactly known, they occupy a little higher zone than the *Lepidocyclina* (*Nephrolepidina*)—zone. The Pliocene Ast. mannii from Kôchi Prefecture occurs associated with *Operculina complanata* (DEFRANCE), and the Pleistocene form from Ryukyu Islands occurs together with *Operculina bartschi* CUSHMAN (HANZAWA, 1935-a, p. 22, pl. 2) and *Operculinella venosa* (FICHTEL and MOLL) (HANZAWA, 1935-a, p. 23, pl. 1, figs. 31-41). The fossil forms of Astriclypeus seem to have been, as in the living form, dwelling in a shallow water, in a view of their associated fauna, and under a warm current.

Astriclypeus mannii integer YOSHIWARA, 1899

Astriclypeus integris Yoshiwara, 1899, p. 1, pls. 1-2.—Astriclypeus integer Yoshiwara: Toku-NAGA, 1903, p. 15, pl. 1. figs. 3-4, pl. 2, figs. 3-4.—LAMBERT and THIÉRY, 1921, p. 324.— NISIYAMA, 1935, p. 141.—HAYASAKA, 1947, p. 115, pl. 15, fig. 2, pl. 16, figs. 1-2.—MORISHITA, 1960, p. 60.—MORISHITA, 1963, p. 138, pl. 5, fig. 1 (reproduced from Tokunaga, 1903 from Formosa).—Astriclypeus mannii integer Yoshiwara: NISIYAMA, 1965, p. 79.

There is no authentic specimen of this fossil subspecies at the writer's disposal. This is reported from Mizuho-mura, Minami-Tsuru-gun, Yamanashi Prefecture.

Astriclypeus mannii integer is characterized as a subspecies by the distance from the extremity of the petals to the lunules and the oval form of the lunules, as well as by the smaller number of the podial pores in the petals. It is very regrettable that the feature of the oral ambulacral furrows, the position of the periproct and the arrangement of coronal plates on the oral surface are not detected in the specimens; hence there remains a question whether these structures are quite similar to or how differ from those of the living form. To all appearances, this subspecies seems to be very different from the living form in the features as stated above, but intermediate forms between this subspecies and the living form are frequently found from several localities with progress of researches of geology and paleontology. It cannot be drawn the specific distinction between the fossil *Ast. integer* and the living *Ast. mannii*, and therefore the former may be placed in a subspecific rank of the latter, as the writer (NISIYAMA, 1935, p. 144) did so.

The specimen from the Katsuragawa formation (Miocene) of Yamanashi Prefecture (the holotype) seems to be a very peculiar form, and is characterized by having the small number of podial pores in the petals (37 in a large specimen measuring 110 mm in test-diameter) and the oval-form of the lunules (the ratio of width and length of them being 0.64). The Miocene forms from many localities referred to this subspecies by TOKUNAGA (1903, p. 16) and other authors are more or less differing from the typical one; e.g., the Miocene form from the Neogene of Formosa, described and figured by HAYASAKA (1947, p. 116, pl. 16, figs. 1-2), having number of podial pores in the petals being over 50, the ratio of width and length of the lunules ranges from 0.32 to 0.52, and the distance from the extremity of petals to the lunules measures 12 mm? to 6 mm.

If the subspecific range of *Ast. mannii integer* were taken as very wide and with regard the form of lunules only as distinguishing criterion for the subspecific distinction in this genus, the almost of the Miocene forms with oval-form of the lunules would be regarded as this subspecies. The ratio of width and length of the lunules of the living *Ast. mannii*, in the writer's measurements, ranges from 0.35 to 0.17 and generally much smaller than that of the Miocene forms (e.g., Table on p. 111 of MORISHITA, 1952—the ratio ranges from 0.40 to 0.67). *Astriclypeus mannii integer* must be restricted to include only the form from the type locality and of the original description.

Astriclypeus mannii ambigenus NISIYAMA, 1935

Astriclypeus manni ambigenus NISIYAMA, 1935, p. 140, pl. 8, figs. 1–3, text-figs. 3a-c.—Durham, 1955, p. 176.—Morishita, 1960, p. 60.—Morishita, 1963, p. 138.—NISIYAMA, 1965, p. 79.

Locality and geological horizon.—IGPS loc. no.—Ao-13.—Tanosawa, near the railway station, Ôdose-mura, Nishi-Tsugaru-gun, Aomori Prefecture (tm Ajigasawa, Lat. 40°45′07″N., Long. 140°02′03″E.). Tanosawa formation, Miocene. Holotype.—Saito Ho-on Kai Museum, reg. no. 6165.

Locality and geological horizon.—IGPS loc. no.—Ao-18.—Hotatezawa, about 3 kilometres northwest of Shin'yu hot spring, a tributary of the Sasanai-gawa, Iwasaki-mura, Nishi-Tsugaru-gun, Aomori Prefecture (tm Fukaura, Lat. 40°35'N., Long. 140°01'E.). Tanosawa formation, Miocene. Paratypes.—Saito Ho-on Kai Museum, reg. no. 6162.

Locality and geological horizon.—IGPS loc. no.—Ni-11.—A point southwest of Kamagui, Takekoshi-mura, Iwafune-gun, Niigata Prefecture (tm Shiono-machi, Lat. 38°13′24″N., Long. 139°34′12″E.). Tsugawa formation, Miocene. Hypotype.—IGPS coll.
no. 57302-A.

Locality and geological horizon.—IGPS loc. no.—Mi-54.—Road-side cutting at west of Kagitori, Sendai City, Miyagi Prefecture (tm Sendai, Lat. 38°13′08″N., Long. 140° 50′16″E.). Hatatate formation, Miocene. Hypotype.—IGPS coll. cat. no. 57302-B.

Locality and geological horizon.—IGPS loc. no.—Ak-53.—Beach rocks under sea cliff west of Nishikurosawa and east of Hirasawa, Kitaura-machi, Minami-Akita-gun, Akita Prefecture (tm Toga, Lat. 39°58′45″N., Long. 139°44′16″E.). Nishikurosawa formation, Miocene. Hypotype.—IGPS coll. cat. no. 57302-C.

Locality and geological horizon.—IGPS loc. no.—Iw-32.—Stream-side of the valley, about 200 metres southeast of the bridge at south of Nisatai, Nisatai-mura, Ninohegun, Iwate Prefecture (tm Ichinohe, Lat. 40°18'N., Long. 141°19'24"E.). Kadonosawa formation, Miocene. Hypotype.—Geol. Inst., Univ. Tokyo.

Locality and geological horizon.—IGPS loc. no.—Sr-15.—The basin of the River Ôanzai, Kaminokuni-mura, Hiyama-gun, Shiribeshi, Hokkaido (tm Kaminokuni, Lat. 41°44′29″E., Long. 140°06′28″E.). Kunnui (Ôanzaigawa) formation, Miocene. Hypotype.— IGPS coll. cat. no. 57302-D.

There are several specimens referred to this subspecies at the writer's disposal. Ast. mannii ambigenus is well characterized as a subspecies by the distance from the extremity of the petals to the lunules, the form of the lunules, the large basicoronal plates and low second post-basicoronal ambulacral plates, as well as by the number of the podial pores in the petals and the feature of the oral ambulacral furrows. A comparison of this subspecies with the living Ast. mannii and fossil Ast. mannii integer gives us very interesting result, for it is clear that this subspecies evidently possessed some of the characters of both the living mannii and the fossil integer. Comparing this subspecies with the living mannii it is found that this subspecies has more primitive features which are shown by the less resorption of the lunules, the greater length of the distance from the extremity of the petals to the lunules, the oval-form of the lunules, the large basicoronal plates, as well as by some neanic features of the petals in Ast. mannii and smaller number of the petal pores, and by the position of the periproct; with *integer* this subspecies has more or less specialized features, which are indicated by the larger number of the podial pores and more progressed resorption of the lunules. Through an examination of numerous living specimens of Ast. mannii, the writer has found the comparative constantness of the distance from the extremity of petals to lunules as being less than 3 mm; whereas the Miocene forms at the writer's disposal have a greater distance, from 5 mm to 9 mm, than the living form.

The holotype and two paratypes from Aomori Prefecture seem to be more or less young ones, as are indicated by the form of lunules and smaller size of the test. The large one is apparently an adult form, as the lunules are more elongated, about 20 mm in longitudinal and 6 mm in transverse diameter (the ratio of width and length being 0.30); the petals are about 20 mm long and 10 mm wide and the number of podial pores being over 50, but the distance from the extremity of petals to the lunules is usually constant, about 6 mm in length. The specimens from other localities resemble the type-specimens in their general features, and can be referred to this subspecies. This subspecies seems to be a Miocene representative of northern Japan.

Astriclypeus mannii minoensis MORISHITA, 1952

Astriclypeus manni minoensis Morishita, 1952, p. 113, pl. 11, fig. 1.—Morishita, 1953-b, p. 63, pl. 6, figs. 1-2.—Morishita, 1954-a, p. 227.—Morishita, 1960, p. 60.—Morishita, 1963, p. 138.—Nisiyama, 1965, p. 79.

Locality and geological horizon (after MORISHITA).—Shukunohara, Hiyoshi-mura, Toki-gun, Gifu Prefecture. Shukunohara Sandstone, Miocene. Holotype.—No. JC 75000, deposited in Geol. Inst., Kyoto Univ.

Locality and geological horizon.—IGPS loc. no.—Sm-14.—Platform near the sea shore of Senjôjiki, about 600 metres northwest of Tôganeura, Kokubu-mura, Naka-gun, Shimane Prefecture (tm Hamada, Lat. 34°56′33″N., Long. 132°06′35″E.). Tôgane formation, Miocene. Hypotypes.—GISM coll. cat. nos. 3165, 3202.

There are eleven specimens of various sizes at the writer's disposal, they are derived from the Tôgane formation (Miocene) of Shimane Prefecture, aside from the type-locality, and can be referred to this subspecies in the general features. The supplementary description of this subspecies may be given as follows.

Test attains large size, over 130 mm in longitudinal diameter, thin and very flat, proportion of thickness to the longitudinal diameter being about 0.07, gently elevated from thin margin towards centre, oral surface slightly concave towards the peristome. Ambital outline usually subpentagonal, sharpened anteriorly and slightly truncated posteriorly. Petaloid area rather flat and small, its total length being about 0.4 of the longitudinal diameter of test (in Ast. mannii, its total length being about 0.5 of the longitudinal diameter). Petals rather broad and short (the ratio of width to length being from 0.54 to 0.63); interporiferous zone broad (proportion of width of interporiferous zone to width of petals being from 0.41 to 0.52), broader than that of the living Ast. mannii (in the latter, the proportion being from 0.3 to 0.38), poriferous zones proportionally narrow, and the inner series of pores became distinctly close distally, not as in the living form, thus the form of petals more or less differs from that of the living Ast. mannii. Number of podial pores in the petals numerous, over 60 in a petal of 23 mm in length, this number more or less approaches that of the living form. Lunules remarkably narrow, even in a small specimen of about 72 mm in longitudinal diameter, the postero-lateral lunules (I and V) measure 14 mm in length and 2 mm in width (ratio of width to length being 0.14), in a moderate-sized specimen of about 94 mm in longitudinal diameter, the postero-lateral lunules measure 23 mm in length and 3 mm in width (the ratio being 0.13), and in a large specimen of about 120 mm in longitudinal diameter, the lunules measure 24 mm in length and 3.5 mm in width (the ratio being 0.14); the ratio of width to length of the postero-lateral lunules (I and V) in this subspecies is smaller than that of the living Ast. mannii (in the latter, the ratio is averaged 0.24); the postero-lateral lunules usually exceed in length those of the anterior lunules (II, III, and IV), and the two lunules are placed not in strict prolongation of the median lines of the petals but making a small degree to those lines, as in the case of the living form. Distance from the extremity of petals to the lunules in the specimens at the writer's disposal measure from 5 mm to 6 mm and broader than that of the living form; in his statement on this point, MORISHITA (1952, p. 113) described "the interval of the ambulacral petal and the

lunule is narrower (than that of Ast. mannii)", but in comparison of this subspecies (MORISHITA, 1952, fig. 1 on pl. 11) and the figure of the living Ast. mannii (fig. 2 on pl. 11) there can be found that the distance of this subspecies is broader (about 5 mm) than that of Ast. mannii (about 2 mm or 3 mm). This feature may be regarded as a point distinguishing this subspecies from the living Ast. mannii and Ast. mannii integer.

Apical system subcentral and similar in form and structure to that of the living Ast. mannii. Peristome subcentral, just as in the apical system. Periproct lying between the peristome and the posterior margin on the oral side; in a moderate-sized specimen of about 94 mm in longitudinal diameter, it situated at about 28 mm from the peristome and about 19 mm from the posterior margin, thus it is decidedly nearer to the posterior margin than that of the living Ast. mannii; ratio of length between the peristome and the periproct to length between the periproct and the posterior margin, in Ast. mannii ambigenus being about 1:0.6, in this subspecies being about 1:0.7, and in the living Ast. mannii being about 1:1; thus, the position of periproct in this subspecies is like to that of Ast. mannii ambigenus. Oral ambulacral furrows bifurcate more widely to the paristome than the living form and more or less narrowly than the fossil Ast. mannii ambigenus, about 3.5 mm from the peristomial margin, at the distal end of basicoronal ambulacral plates; the two main stems around each lunule and give off side-branches, the greatest width between the two main stems being about 11 mm and more or less narrower than that of the living form. On the oral side, the lunules continue, but not reaching to, the peristome as narrowing and shallowing grooves, and the grooves decidedly longer than those of Ast. mannii ambigenus. Basicoronal row relatively larger than that of the living Ast. mannii of same size, the basicoronal interambulacral plates measure 8 mm in length and 5 mm in width.

This subspecies is distinguished from both the living Ast. mannii and the fossil Ast. mannii ambigenus, by the thinner test, the form of petals, the narrower lunules, and by the position of periproct, as well as the size of basicoronal row. Ast. mannii minoensis may stand as a valid subspecies of the Miocene representative of western Japan at that time.

Astriclypeus mannii VERRILL, 1867

(Pl. 17, fig. 4, Text-fig. 53 [28])

Mellita new species? A. AGASSIZ, 1863-a, p. 358 (China Seas, in Latitude 23° North).

Astriclypeus mannii VERRILL, 1867-71 (67), p. 311.—Astriclypeus manni VERRILL: A. AGASSIZ, 1872-74, pp. 93, 529, pl. 13d, figs. 2-4.—YOSHIWARA, 1900, p. 343 (in Japanese).—YOSHIWARA (TOKUNAGA), 1907, pl. 10, figs. 11-12.—H. L. CLARK, 1914, p. 72, pl. 125, figs. 13-15.—H. L. CLARK, 1925, p. 171.—TORTONESE, 1933-a, p. 151.—NISIYAMA, 1935, p. 134, text-figs. 1a-b.—IKEDA, 1939, pl. 2, figs. 8-11, pl. 3, figs. 6-7, pl. 12, fig. 9, pl. 13, figs. 4-6.—HAYASAKA, 1947, p. 116, pl. 12, fig. 2, pl. 13, fig. 1, pl. 14, fig. 1, pl. 15, fig. 1—MORTENSEN, 1948-c, p. 416 (complete synonymy), pl. 50, figs. 1-3, pl. 62, fig. 1, pl. 72, figs. 17-18, 20-21, text-figs. 219c, 221, 244a.—MORISHITA, 1952, p. 111, pl. 11, fig. 2.—UTINOMI, 1954, p. 355.—DURHAM, 1955, p. 175, text-figs. 1m, 32d.—MORISHITA, 1960, p. 60.—MORISHITA, 1963, p. 138, pl. 4, figs. 1a-b (Recent).—NISIYAMA, 1965, pp. 79, 85.

Crustulum gratulans TROSCHEL, 1868, p. 1, pl. 1.—TROSCHEL, 1869, p. 15.—TROSCHEL, 1869-a, p. 52.

Locality and geological horizon.—Wanga, Byôritsu-gun, Shinchiku-shû (Wanwa, Miaolichu, Hsinchuhsien), Formosa. Byôritsu formation, Pliocene. Hypotype.—IGPS coll. cat. no. 61258-C.

Locality and geological horizon.-Hakushaton, Byôritsu-gun, Shinchiku-shû (Paishatung, Miaolichu, Hsinchuhsien), Formosa. Byôritsu formation, Pliocene. Hypotype.-IGPS coll. cat. no. 61258-D.

Locality and geological horizon.—A point on the Okinawa Island (precise locality unknown), Ryukyu Islands. Ryukyu Limestone, Pleistocene. Hypotype.—IGPS coll. cat. no. 8315.

Locality and geological horizon.—IGPS loc. no.—Ko-21.—Road-side cutting near the junction of the tributary and the small river, a short distance east of the road at Tôdani, north of Tônohama, Yasuda-machi, Aki-gun, Kôchi Prefecture (tm Aki, Lat. 33°26′43″N., Long. 133°58′20″E.). Kônomine (Ananai) formation, Pliocene. Hypotype.— IGPS coll. cat. no. 61258-E.

This is a characteristic echinoid of Japan and recorded from central and southern Japan (from Bôsô Peninsula to Kagoshima Gulf) in depth of 0-35 metres, and also from China and Cambodja, Indo-China.

There are several fossil specimens of this species at the writer's disposal. The measurements of the specimen from the Ryukyu Limestone (Pleistocene) of Okinawa Island are given below to show the relative dimensions of the species.

Length 100 mm or more; width 100 mm or more; height 16 mm; length of petal III, 22 mm; length of petals II and IV, 20 mm; length of petals I and V, 21 mm; width of petals, 11 mm; poriferous zones of the petals are rather narrow and slightly incurved distally, there are 13-15 primary tubercles on a ridge between two pore-pairs; interporiferous zones are rather broad, about 5 mm wide at the broadest part, which lies on one-fifth length of the petals from the distal extremity, and petals open distally in about 2 mm apart; the podial pores of the zones are numerous, counting over 60 in a pore-series.

Length of frontal lunule (III), 14 mm; width of the lunule, 4 mm; length of left antero-lateral lunule (II), 14 mm; width of the lunule, 4 mm; length of right anterolateral lunule (IV), 14 mm; width of the lunule, 3 mm; length of left postero-lateral lunule (I), 15.5 mm; width of the lunule, 5 mm; length of right postero-lateral lunule (V), 15 mm; width of the lunule, 4.5 mm; the ratio of width to length of the lunules being from 0.21 to 0.32. The distance between the extremity of petals and lunules being less than 2.5 mm.

The measurements of a large, typical, living specimen from central Japan are as follows.--

Longitudinal diameter of the test, 121 mm Transverse diameter of the same, 121 mm Height of the test, 18 mm Ratio of thickness to diameter of test, 0.15 Length of frontal petal (III), 28 mm Width of the petal, 16 mm Ratio of width to length of the petal, 0.57 Length of antero-lateral petals (II and IV), 26 mm Width of the petals, 16 mm Ratio of width to length of the petals, 0.61 Length of postero-lateral petals (I and V), 28 mm Width of the petals, 16 mm Ratio of width to length of the petals, 0.57 Width of the poriferous zone, 5 mm Width of the interporiferous zone, 6 mm Number of podial pores on a series in petal (III), 68 Number of podial pores on a series in petals (II and IV), 66 Number of podial pores on a series in petals (I and V), 72 Number of primary tubercles on a ridge between two pore-pairs, 18-21 Length of frontal lunule (III), 19 mm Width of the lunule. 6 mm Ratio of width to length of the lunule, 0.32 Length of antero-lateral lunules (II and IV), 18 mm Width of the lunules, 5 mm Ratio of width to length of the lunules, 0.28 Length of postero-lateral lunules (I and V), 22 mm Width of the lunules. 5 mm Ratio of width to length of the lunules, 0.23 Distance between the extremity of petal and lunule in area III. 1 mm Distance between the extremity of petals and lunules in areas II and IV, $2\,\mathrm{mm}$ Distance between the extremity of petals and lunules in areas I and V, 2 mm Size of the apical system, $9 \times 9 \text{ mm}$ Distance between the apical system and the anterior margin, 60.5 mm Distance between the peristome and the anterior margin, 63 mm Distance between the periproct and the posterior margin, 30 mm Oral ambulacral furrows bifurcating at about 2-2.5 mm from the margin of peristome.

In comparison of the measurements of the specimen from the Ryukyu Limestone (Pleistocene) with those of the living specimen, it is found that the specimen from the Ryukyu Limestone can be safely identical with the living species, *Astriclypeus mannii* VERRILL, 1867. The specimens from the uppermost horizon of the Byôritsu formation (not older than the youngest Pliocene), described by HAYASAKA and at the writer's disposal, are also safely assigned to this species in their general features.

The ambulacral and interambulacral plates system (the arrangement of the plates) on the oral side of the test of the living *Ast. mannii* may be described as follows (text-fig. 53 [28]). The basicoronal row quite small, its diameter (including the peristome) being about one-tenth or less the longitudinal diameter of test; the basicoronal interambulacral plate is much higher and broader than the adjacent ambulacral plates (in a pair), twice or more as wide as them, the oral end of the ambulacral plates has a conspicuous median keel that bends downwards at the end. The basicoronal row is encircled by a ring of large first post-basicoronal row consisting of ten ambulacral plates and by all the interambulacral areas being separated from the basicronal inter-



Fig. 52 [27]. Structure of oral surface of *Encope grandis* AGASSIZ, 1841, × ca 0.7 (from DURHAM, 1955).



Fig. 53 [28]. Structure of oral surface of Astriclypeus mannii VERRILL, 1867, $\times 0.44$.

ambulacral plates; plates Ia and Vb are the largest, plates of IIIa and IIIb the smallest, and the plates of IIb and IVb are also large but being a little smaller than the largest, and the rest plates are moderate in size between the largest and the smallest; the following rows of ambulacral plates are rather low in comparison to the first postbasicoronal row and approximately subequal in height; there are six post-basicoronal plates in each ambulacral column. The lunule (III) begins with the distal end of second post-basicoronal plate, the lunule (II) begins with middle point of second postbasicoronal plate, but the lunule (IV) with middle point of third post-basicoronal plate, the lunules (I and V) begin with at least middle point of third post-basicronal ambulabral plates. The post-basicoronal interambulacral plates are more or less broader and higher than the post-basicoronal ambulacral plates; there are four post-basicoronal plates in the interambulacral areas 1, 3, 4 and 5, on the oral surface, only three plates of a column in 2b. The periproct lies at the junction of a suture between first and second post-basicoronal interambulacral plates in the area (5), as in the genus Echino*discus* (with *Amphiope*). This position of the periproct differs from that of the genus *Encope*, i. e., in that genus (text-fig. 52 [27]) the periproct on the oral surface between posterior interambulacral lunule and the peristome and situated at the inner margin of first pair of the post-basicoronal plates. The oral ambulacral furrows bifurcate at the distal part of the basicoronal ambulacral plates very close to the peristome, the two main branches pass rather closely along each side of the lunules, sending out 5-6 of side-branches along their internadial side onto the interambulacral areas.

Astriclypeus mannii VERRILL, 1867, the living representative of the genus, is characterized by its small distance between the extremity of the lunule to petal, large number of podial pores in the petals, small size of the basicoronal row compared to diameter of the test, and by the form of petals, in which the distal ends are somewhat open and the poriferous zones are slightly incurved and then divergent distally.

Order SPATANGOIDA CLAUS, 1876

Spatangoideae CLAUS, 1876, p. 386 (pro parte).—Spatangideae CLAUS, 1880, p. 364 (suborder).— Spatangoida AGASSIZ: DUNCAN, 1889-a, p. 205.—HAWKINS, 1920, p. 459.—Spantangoida DUNCAN: LAMBERT and THIÉRY, 1924, p. 401.—Spatangoida AGASSIZ: MORTENSEN, 1950-a, p. 1.—Spatangoida DUNCAN: NISIYAMA, 1954, p. 329 (in Japanese).—Spatangoida CLAUS: DURHAM and MELVILLE, 1957, p. 261 (partim).—PHILIP, 1965, p. 59.

Spatangina JACKSON, 1912, p. 204 (suborder; non Spatangina GRAY, 1855).—H. L. CLARK, 1917, p. 91 (suborder; pro parte).

Type-family.—Spatangidae GRAY, 1825.

Forms of oval or more or less elongate shape, often with a frontal notch and test becomes conspicuously heart-shaped. Ambulacra more or less petaloid adapically, or quite rudimentary, not impressed or impressed, not all similar. Apical system elongate, disjunct or compact. No distinct floscelle; phyllodes may be conspicuous, but no bourrelets. Posterior interambulacrum (5) usually different from paired interambulacra on oral side, forming a more or less highly specialized plastron. Apical system and peristome usually anterior or sometimes opposite; periproct posterior or inframarginal, never contiguous with apical system. No branchial slits; masticatory apparatus, absent, at least in adults. Fascioles of very varying development, but lacking in some mainly older, more primitive forms (mainly after MORTENSEN, 1950-a).

From the Jurassic Period to Recent.

MORTENSEN (1950-a, p. 5) subdivided the order into three suborders, mainly based on the structure of plastron; viz., the Protosternata with simple or feebly differentiated plastron, the Meridosternata with meridosternous plastron, and the Amphisternata with amphisternous plastron. This suborder subdivisions are followed mainly by NISIYAMA (1954, pp. 329-330) and PHILIP (1965, pp. 59-60). While DURHAM and MEL-VILLE (1957, pp. 260-261) separated the order into two distinct orders mainly based on the structure of apical system; viz., the Holasteroida with elongate or disjunct apical system and feebly differentiated or meridosternous plastron and the Spatangoida with compact apical system and amphisternous plastron. MORTENSEN (1950-a, pp. 12-13) claimed, mainly after BEURLEN (1934, pp. 161-174), that the family Holasteridae with intercalary apical system and meridosternous plastron are the descendants of the family Collyritidae with disjunct apical system and feebly differentiated plastron, and that the family Toxasteridae, the old and primitive spatangoins, with amphisternous plastron and a rather compact apical system, are derived from the family Disasteridae with the oculars II and IV are not in contact in the midline and with a feebly differentiated plastron. DURHAM and MELVILLE (1957, p. 261) accept the first hypothesis (the derivation of the Holasteridae from the Collyritidae), but are difficult to accept the second (the derivation of the Toxasteridae from the Disasteridae). They seek for the probable derivation of the amphisternous spatangoids (the spatangoins) from some nucleolitoid stock of the Cassiduloida.

Whether the amphisternous spatangoids (the spatangoins) have derived from the Nucleolitidae of the Cassiduloida, as suggested by DURHAM and MELVILLE, or the Disasteridae, as stated by BEURLEN and MORTENSEN, the apical system of them seems to have nothing to do with the descent line of evolution; the common character of them is that they evidently possess an amphisternous plastron. The writer, here, regards the character of the plastron, as proposed by MORTENSEN, e.g., the simple or undifferentiated, the meridosternous or the amphisternous, not of the apical system being as a cirterion of separating the suborders under the order Spatangoida. The suborders are discriminated from one another as shown by the following key.

Key to the suborders of the order Spatangoida.

Suborder URECHINOINA H.L. CLARK, 1925

Urechinina H. L. CLARK, 1925, p. 185.—NISIYAMA, 1954, p. 330 (in Japanese).

Meridosterni Lovén, 1883, p. 91.—Meridosternata (Lovén) Mortensen, 1907, p. 39.—Mortensen, sen, 1927-b, p. 340.—Mortensen, 1950-a, p. 37.—Meridosternina Mortensen: Philip, 1965, p. 60.

Holasteroida DURHAM and MELVILLE, 1957, p. 260 (order; pro parte).

Type-family.—Urechinidae DUNCAN, 1889.

The suborder Urechinoina are characterized by the structure of their plastron, the labrum (the primordial (basicoronal) interambulacral plate) joining at its posterior end only a single plate no. 2; the plates of the two series a and b of the interambulacrum (5) being displace to a varying degree, squeezing themselves in between one another, as that at last they form only a single regular series. Fascioles are of irregular occurrence and seem to be of no great classificatory value.

From the upper Jurassic (Malm) to Recent.

This suborder comprising the following five families, the Holasteridae PICTET, 1857, Urechinidae DUNCAN, 1889, Calymnidae MORTENSEN, 1907, Pourtalesiidae A. AGASSIZ, 1881, and Stenonasteridae LAMBERT, 1922. These families are those recognized by MORTENSEN (1950-a) and PHILIP (1965) in their usage of the suborder Meridosternata (or Meridosternina). These families are discriminated from one another as shown by the following key.

Key to the families of the suborder Urechinoina.

-4. Adoral end of the antero-lateral interambulacra (2 and 3) meridoplaceous (i.e., in each one the primordial interambulacral plate is followed by a single plate (2))
Adoral end of the antero-lateral interambulacra (2 and 3) amphiplaceous (i.e., the primordial interambulacral plates abutting against two about equalsized plates

no. 2) Calymnidae.

The Holasteridae seem to have their flourishing age in the Cretaceous Period, especially the upper half (Senonian), but continue sparingly in the Eocene and the Miocene; they are also represented in the Recent seas by the genera *Stereopneutes* MEIJERE, 1904 (1904, p. 147) and *Sternopatagus* MEIJERE, 1902 (1902, p. 10). The Urechinidae and the Pourtalesiidae, as well as the small family Calymnidae, comprise only Recent forms being in a flourishing condition. The small family Stenonasteridae are probably confined to the upper Cretaceous and seem to represent a separate line from the Disasteridae. The ideal relationships of these families are shown in the table of phylogeny of the superorder Atelostomata by DURHAM and MELVILLE (1957, p. 266).

There are fossil representatives of the family Holasteridae in our collection.

Family Holasteridae Pictet, 1857

Holasteridae PICTET, 1854-73 (57), p. 276 (pro parte).—Holasteridae ZITTEL, 1879, p. 532 (pro parte).—Holasteridae LAMBERT, 1917, p. 2.—LAMBERT and THIÉRY, 1924, p. 401.—Holasteridae ZITTEL: MORTENSEN, 1950-a, p. 38.

Type-genus.—Holaster AGASSIZ, 1836.

Echinocorythidae GREGORY, 1900-b, p. 321 (pro parte).—H. L. CLARK, 1917, p. 124.—Сооке, 1942, p. 38.—Wright and Wright, 1949, p. 455.

Urechinoinan echinoids (with meridosternous plastron) of very varying size and shape, with at least the paired ambulacra biporous (double), simple, flush with test or subpetaloid and more or less sunken. Paired interambulacra amphiplaceous (i. e., the primordial interambulacral plate is followed by two plates). Apical system intercalary, antero-lateral oculars (II and IV) meeting in aboral midline, separating thus anterior .(2 and 3) from posterior genital plates (1 and 4) (mainly after MORTENSEN, 1950-a).

From the upper Jurassic (Malm) to Recent.

It seems highly probable that there is very close relation between the older Holasteridae and the younger Urechinidae. The biporous ambulacra characterize the Holasteridae as more primitive than the uniporous ambulacra of the younger Urechinidae, on one hand, and the antero-lateral interambulacra (2 and 3) are amphiplaceous characterize the older Holasteridae as more primitive than the Urechinidae, which have all the interambulacra are meridoplaceous, on the other hand. The character of the apical system, as well as the general shape of the test being the same in both these families, it seems most probable that the Urechinidae are the descendants of the Holasteridae. The Holasteridae, in turn, are the probable descendants of the family Collyritidae of the Collyritoina.

This family should be subdivide into two subfamilies, the Holasterinae and Stegasterinae, mainly by the presence or absence of the oral groove.

Type-genus.—Echinonocorytes [BREYNIUS] LESKE, 1778.

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Subfamily HOLASTERINAE PICTET, 1857

Holasterinae MORTENSEN, 1950-a, p. 47.

This subfamily is characterized, as against the subfamily Stegasterinae (MORTEN-SEN, 1950-a, p. 58), by the peristome not being placed at the end of a deep, sharply limited oral groove.

There are fossil representatives of the genera *Holaster* and *Cardiaster* in our collection, which are described herein.

Genus Holaster AGASSIZ, 1836

Holaster Agassiz, 1836, p. 183 (16).—Agassiz, 1839, p. 9.—Agassiz 1840-a, p. 15.—Agassiz and Desor, 1847, p. 26.—D'Orbigny, 1853-55 (53), p. 71.—Pomel, 1883, p. 45.—Duncan, 1889-a, p. 207.—Lambert, 1917, p. 2.—Lambert and Thiéry, 1924, p. 401.—Smiser, 1935, p. 66.—Cooke, 1946, p. 233.—Mortensen, 1950-a, p. 47 (complete synonymy).—Cooke, 1955, p. 107.—Cooke, 1959, p. 65.

Logotype.—Spatangus nodulosus GOLDFUSS, 1826-1833 (29), p. 149, pl. 45, fig. 6 (Cenomanian of Germany).—Holaster carinatus D'ORBIGNY, 1853-55 (53), p. 104, pl. 818, figs. 1-7. [SAVIN, 1905, p. 37].

Holasteropsis Elbert, 1902, p. 115.

Haplotype.—Holasteropsis credneriana Elbert, 1902, p. 115, pl. 4.

Forms of moderate size, of ovoid outline, somewhat heart-shaped because of a frontal depression. Test usually rather high convex, sometimes flattened above, oral side flattened; posterior end usually truncate. Frontal ambulacrum (III) somewhat sunken, with small pores, not petaloid; paired ambulacra subpetaloid, not sunken, not closed distally; pores elongate, comma-shaped, in circumflex, not conjugate. Apical system central, with four genital pores; elongated intercalary, antero-lateral oculars (II and IV) meeting broadly in midline so as to separate anterior from posterior genital plates (1 and 4); according to this structure of apical system paired ambulacra somewhat distant from each other at apex. Periproct on truncate posterior end, elongate oval; peristome anterior, semi-circular or transversely elliptical, usually not labiate. Plastron meridosternous, plates alternating. Some larger tubercles may be scattered irregularly over aboral side. No fascioles.

This primitive urechinoid genus ranges from the Valanginian to Maastrichtian of the world-wide distribution, comprising about over sixty species, and flourished in the Cenomanian of Europe. The abundant occurrence of a species of this genus from the Cretaceous in northern Japan is noteworthy.

Holaster clypeatulus NISIYAMA, 1950

Holaster clypeatulus Nisiyama, 1950-а, р. 35, pl. 4, figs. 8-9, text-figs. 1-3.—Nisiyama, 1965,. р. 79.

Holotype.—IGPS coll. cat. no. 72980.

Locality and geological horizon.—IGPS loc. no.—It-5.—Sea cliff a short distance east of shrine at Raga, Tanohata-mura, Shimohei-gun, Iwate Prefecture (tm Iwaizumi, Lat. 39°56′12″N., Long. 141°56′36″E.). Hiraiga Sandstone (*Orbitolina*-horizon), lower-Cretaceous (probably Aptian and Albian). YABE and YEHARA, 1913.

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There are several specimens of this species at the writer's disposal, the best preserved one is selected as the holotype. This species seems to belong to the speciesgroup of *Holaster nodulosus* (LAMBERT and THIÉRY, 1924, p. 402), and similar to *Holaster laevis* (BRONGNIART) (LORIOL, 1873, p. 319, pl. 27, fig. 1), an Albian species of France and Belgium, but is easily distinguished from that species by the smaller breadth compared to the length, and by the lower test. *Hol. clypeatulus* also resembles *Hol. simplex* SHUMARD, 1853 (CLARK, 1893, p. 76, pl. 38, figs. 1a-g, pl. 39, figs. 1a-d.— ADKINS and WINTON, 1920, p. 51, pl. 8, figs. 5-6, pl. 9, figs. 18-19.—*Holaster laevis* (BRONGNIART): COOKE, 1946, p. 234, pl. 34, figs. 1-3.—*Holaster simplex* SHUMARD: COOKE, 1955, p. 107, pl. 24, figs. 6-8), from the Fort Worth formation of Texas, but differs from that species in having the more anterior position of the apical system and longer postero-lateral ambulacra (I and V).

Genus Cardiaster FORBES, 1850

Cardiaster Forbes, 1850-a, p. 442.—D'Orbigny, 1853-55 (53), p. 123.—Desor, 1855-58 (58), p. 344.—Dujardin and Hupé, 1862, p. 591.—Loriol, 1873, p. 335.—Wright, 1864-82 (78), p. 293.—Pomel, 1883, p. 46.—Duncan, 1889-a, p. 209.—Lambert, 1893, p. 96.—Lambert and Thiéry, 1924, p. 405.—Smiser, 1935, p. 67.—H. L. Clark, 1946, p. 360.—Mortensen, 1950-a, p. 51 (complete synonymy).

Logotype.—*Cardiaster granulosus* (GOLDFUSS) D'ORBIGNY, 1853-55 (53), p. 131, pl. 826 (Aturian of Europe). [LAMBERT and THIÉRY, 1924, p. 406].

Forms of medium size, heart-shaped, with deep frontal notch; test moderately high arched, slightly truncate posteriorly; oral side flat. Frontal ambulacrum (III) deeply sunken, adjoining interambulacra (2 and 3) forming rather sharp keels. Pores of frontal ambulacrum (III) smaller than those of paired ambulacra, the latter being comma-shaped, placed "en chevron" as in the genus *Holaster*; pores of anterior series somewhat smaller than posterior ones. Apical system subcentral, elongate, as in *Holaster*, with four genital pores. Periproct on posterior end, elongate oval; peristome eccentric in front, slightly labiate. Plastron consists of alternating plates much as shown in *Holaster intermedius* (MUNSTER) (D'ORBIGNY, 1853-55 (53), p. 81, pl. 810, as *Hol. ihardyi*—Hauterivian). Tuberculation in the main uniform, but with a few larger tubercles aborally. A marginal fasciole, passing under periproct (mainly after MORTEN-SEN, 1950-a).

From the Cretaceous (Cenomanian-Senonian) to ? Tertiary of almost world-wide distribution.

This genus is distinguished from an allied genus *Holaster* by the deeper frontal groove and by possessing a marginal fasciole. The occurrence of a species of this genus from the Senonian of Japan is noteworthy.

Cardiaster perorientalis NISIYAMA, n. sp.

(Pl. 18, figs. 6-7)

Holotype.--IGPS coll. cat. no. 73747.

Locality and geological horizon.—IGPS loc. no. Eh-51.—Beside a bridge at Narufuji, Kôfuji-mura, Kita-Uwa-gun, Ehime Prefecture (tm Uwajima, Lat. 33°16'N., Long. 132°40′34″E.). Miyakura (Furushiroyama) formation, Senonian-Maastrichtian. YABE, 1927, p. 78.—MATSUMOTO, 1953, p. 98.

There are three specimens of this new species at the writer's disposal, the best preserved one is selected as the holotype.

Test moderate, oblong, heart-shaped, anterior part broad and posterior part constricted, with deep frontal notch; rather low, height about one-third the length, highest point a little anterior to apical system, which situated in subcentral; a slight median carina extends posterior in posterior interambulacrum (5). Oral surface rather flat, except peristomial region.

Frontal ambulacrum (III) lies in deeply sunken anterior groove, adjoining interambulacra (2 and 3) forming rather sharp keels, rather narrow and long, about 19 mm long and 4 mm wide at broadest point and at distal end it slightly narrowed; each poriferous zone consists of about 50 pore-pairs and 4 or 5 pairs near distal end become apart gradually; pores small and round, each pore-pair placed horizontally along suture line. Antero-lateral ambulacra (II and IV) rather long and broad, subpetaloid part widely open distally, 4 mm wide at the broadest point, rather flush with aboral surface; diverge from each other and then slightly turn backwardly near ambitus, angle between median lines of each subpetal being about 100°; poriferous zones rather broad, 2 mm wide at broadest point in posterior series, consisting of more than 50 pore-pairs, distal end of each poriferous zone becomes close together; pores being elongate or comma-shaped, placed "en chevron", those of outer zone usually somewhat elongated and of anterior series somewhat smaller than posterior ones. Postero-lateral ambulacra (I and V) rather long and broad, subpetaloid part widely open distally, diverge from each other at about 70°; poriferous zones rather broad, about 2 mm wide at broadest point in anterior series, consisting of more than 25 pore-pairs, distal end of each poriferous zone becomes close together; pores as in antero-lateral ambulacra and of anterior series somewhat smaller than those of posterior ones.

Apical system elongate, subcentral, situated at about 22 mm from anterior margin of groove, with four genital pores. Periproct rather small, elongate oval, situated at posterior end. Peristome rather large, transverse oblong, slightly labiate, situated at about seven-ninths from posterior end. Tuberculation not well preserved. A marginal fasciole narrow but rather distinct, running above ambitus and passing under periproct.

This new species is much similar to *Card. orientalis* STOLICZKA, 1873 (STOLICZKA, 1873, p. 22 (92), pl. 4 (14), figs. 1-2), from the Senonian of southern India, in its general features, but is distinguished from that species by the deeper anterior groove, the longer subpetals and by the anterior position of the peristome.

The occurrence of this Japanese species, *Card. perorientalis*, which closely related to the Indian Senonian species, *Card. orientalis*, is very interesting. Because it seems highly probable that it offers a material to do with geographical distribution of the genus *Cardiaster* on one hand and a geological correlation of both regions on the other hand.

Suborder SPATANGOINA CLAUS, 1876

Spatangina JACKSON, 1912, p. 204 (suborder; non Spatangina GRAY, 1855).-H.L. CLARK, 1925,

p. 192.—NISIYAMA, 1954, p. 330 (in Japanese). Amphisternata Lovén: Mortensen, 1907, p. 90.—Mortensen, 1927-b, p. 319.—Mortensen, 1950-a, p. 174.—Amphisternina Mortensen: Philip, 1965, p. 60. Spatangoida Cluas: Durham and Melville, 1957, p. 261 (order). Type-family.—Spatangidae Gray, 1825.

The essential character of this suborder is that of the plastron, viz., that the labrum (the primordial interambulacrum plate (5_1)) joins at its posterior end two large, equally developed sternal plates (amphisternous). Other characters are found in the apical system which is usually compact and never opposite the peristome, and the petals are usually impressed and not all similar. Fascioles generally present and of very constant arrangement, as a whole.

Whether the ancestor of the Spatangoina (the amphisternous spatangoids of authors) can be found in the Disasteridae, as speculated by BEURLEN and MORTENSEN, or in the Nucleolitidae, as suggested by DURHAM and MELVILLE, it has no direct proof to decide the problem. The amphisternous plastron is a striking feature of this group and it makes a rather clear distinction of this group from the meridosternous condition of plastron in other group. The differences of apical system and petals, as pointed out by DURHAM and MELVILLE (1957, pp. 260-261), between the Spatangoina and the Urechinoina (the meridosternous spatangoids) are also more or less distinct. The other important features detected in the Spatangoina are the fascioles, the structure of peristome, and the form of petals. The interplay of these features leads to great complexity in the form and structure of the Spatangoina. It is still possible, however, to classify the various forms into families according to a general scheme. An excellent modern classification is that proposed by MORTENSEN (1950-1951), partly following the usage adopted by LAMBERT and THIÉRY (1924-1925), and against the former simple classification of JACKSON (1913) and of H.L. CLARK (1917, 1925). The classification of the Spatangoina here limited, according to MORTENSEN (1950-a, p. 180), must be based in the main on the fascioles, although the origin and relation of these structures are not definitely known to us at present. In that way a clear distinction and practical use of the various groups become possible. As for this family subdivisions PHILIP (1965, p. 60) stated that—"The work of KERMACK (1954) and NICHOLS (1958), on the evolution of the Chalk Micrasters, suggested that fascioles (on which the family classification of amphisternous spatangoids is largely based) are not such an important taxonomic feature. It is, however, impossible to suggest any other basis for the family subdivision of the suborder". He listed the families those are recognized by MORTENSEN (1950-51) in his restricted usage of this suborder. MORTEN-SEN classified this suborder into the following families, viz., the Palaeopneustidae A. AGASSIZ, 1904, Palaeostomatidae Lovén 1867, Aeropsidae LAMBERT, 1896, Loveniidae LAMBERT, 1905, Brissidae GRAY, 1855, Micrasteridae LAMBERT, 1920, Spatangidae GRAY, 1825, Schizasteridae LAMBERT, 1905, Toxasteridae LAMBERT, 1920, Hemiasteridae H.L. CLARK, 1917, and Pericosmidae LAMBERT, 1905. DURHAM and MELVILLE (1957, p. 261 and text-fig. 9 on p. 266) erected the family Maretiidae LAMBERT, 1905, without commentation. These families and subfamilies are discriminated from one another as shown by the following key (mainly after MORTENSEN, 1950-a, 1951).

Key to the families and subfamilies of the suborder Spatangoina.

1.	Petals imperfectly developed, or quite rudimentary 2
	Petals well developed 3
2.	Peristome non-labiate; large forms; ambulacra subpetaloid, usually not rudimen-
	tary; fasciole lackingAsterostomatidae
	Peristome labiate; large, usually long-spined forms; ambulacra subpetaloid, usually
	not rudimentary; fasciole variable or lacking Palaeopneustidae
	Peristome labiate; small forms; ambulacra rudimentary aborally Palaeotropinae
3.	Peristome non-labiate; mouth opening central 4
	Peristome labiate; mouth opening not central 5.
4.	Peristome covered with five large plates Palaeostomatidae
	Peristome covered with small plates only Aeropsidae
5.	Subanal fasciole present 6.
	No subanal fasciole present 11
6.	Inner fasciole present
	No inner fasciole present 8.
7.	Large radioles (tubercles) with deep inner ampullae Loveniidae
	No inner ampullae Echinocardiinae
8.	Peripetalous fasciole present Brissidae
	No peripetalous fasciole present
9.	Apical system ethmophract Micrasteridae
	Apical system ethmolytic 10,
10.	Plastron wholly covered with radioles (tubercles) Spatangidae
	Plastron more or less extensively naked Maretiidae
11.	A latero-anal fasciole present Schizasteridae
	No latero-anal fasciole present 12.
12.	Peripetalous fasciole present 13
	No peripetalous fasciole present Toxasteridae
13.	Only the peripetalous fasciole present; apical system ethmophract
	Hemiasteridae
	A marginal fasciole present; apical system ethmolytic Pericosmidae.

Fasciole Family	Subanal	Internal	Peripetalous	Latero-anal	Marginal
Micraestridae	×				· · · ·
Hemiasteridae			×		
Spatangidae	×				
Loveniidae	×	×	(×)		
Pericosmidae			×		×
Schizasteridae			×	×	
Brissidae	×		×		
Palaeopneustidae	(×)		(×)		(x)
Palaeostomatidae			(×)		
Aeropsidae			(×)		

The distribution of the fascioles in the families.

() represents irregular occurrence.

There are fossil representatives of the families, Palaeopneustidae, Aeropsidae (incertae sedis), Toxasteridae, Spatangidae, Maretiidae, Loveniidae, Schizasteridae, Pericosmidae, and Brissidae, in our collection.

Family PALAEOPNEUSTIDAE A. AGASSIZ, 1904

Palaeopneustidae A. Agassiz, 1904, p. 150.—H. L. Clark, 1917, p. 138.—H. L. Clark, 1925, p. 195.—Grant and Hertlein, 1938, p. 111.—H. L. Clark, 1946, p. 362.—Mortensen, 1950-a, p. 181.

Type-genus.—Palaeopneustes A. AGASSIZ, 1873.

Antillasterinae LAMBERT in LAMBERT and THIÉRY, 1924, p. 439.

Type-genus.—Antillaster LAMBERT, 1909.

Mainly large forms of ovoid or round outline. Ambulacra adapically more or less conspicuously petaloid or subpetaloid, but not sunken and usually not rudimentary. Phyllodes usually strongly developed. Apicel system ethmolytic, or rarely ethmophract. Peristome more or less conspicuously labiate. Primary radioles usually strongly developed. Fascioles (subanal, peripetalous and marginal(?)) variable or lacking. All the different types of pedicellariae (tridentate, rostrate, triphyllous and ophicephalous in the living) may be present (mainly after MORTENSEN, 1950-a). From the Senonian to Recent.

The family Palaeopneustidae probably relate to the family Asterostomatidae, as already suggested by MORTENSEN (1950-a, p. 185). The two families are common in the form of test, the mode of petals, and in the flattened adoral side; but differ from each other in the peristome, i.e., in the Palaeopneustidae it is prominently labiate and in the Asterostomatidae not labiate. While the Recent smaller forms of the Palaeopneustidae seem to be related to the Maretiidae in their general features.

The limitation of this family is not satisfactory, and hence the classification of the family has much disputed among many authors. The larger forms of the family, such as the genera *Archaeopneustes* GREGORY, 1892, *Heterobrissus* MANZONI and MAZZETTI, 1880, *Palaeopneustes* (the type-genus), and *Linopneustes* A. AGASSIZ, 1881, seem to form a distinct and natural group among the Palaeopneustidae in general features and also be regarded as the center of its family. LAMBERT and THIÊRY (1924), MORTENSEN (1950), and H. L. CLARK (1917, 1925) agree on the assignment of these genera into the family Palaeopneustidae, except the genus *Linopneustes*; the genus was referred to the family Spatangidae by H. L. CLARK (1917, 1925), but he included the two species belonging to this genus into the genus *Palaeopneustes*, and it is to be considered that there is no discordance of assignment of these genera in the Palaeopneustidae among these authors.

To the family Palaeopneustidae MORTENSEN (1950-a, pp. 181-283) referred numerous Recent and fossil genera, the Recent genera, *Plesiozonus, Homolampas, Argopatagus, Phrissocystis, Linopneustes, Elipneustes, Archaeopneustes, Heterobrissus, Palaeopneustes, Platybrissus, Eurypatagus,* and others; the fossil genera *Pharaonaster, Stomatoporus, Megapneustes,* and others. Of the fossil genera the writer here intends to refer the genus *Niponaster* LAMBERT, 1920, to the family Palaeopneustidae. This genus was originally placed in the family Stenoasteridae (the urechinoins) by LAMBERT and THIÉRY (1924, p. 426), in general appearance, particularly in the condition of the

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plastron. MORTENSEN (1950-a, p. 169) followed the two French authors and referred it to the family Stenonasteridae as incertae sedis. However, MORISHITA (1955-a, pp. 99-100) has clarified the amphisternous character of the plastron and recognized it is not allied to *Stenonaster*, but to the Spatangoina; MORISHITA, nevertheless, did not state to what family it belongs. In its general features, the mode of ambulacra, and in the labiated peristome, which is much similar to that of *Palaeopneustes*, this genus may be referred to the family Palaeopneustidae than to any other families of the Spatangoina, and it represents the oldest genus (from the Senonian) of the family. The important genera of the family Palaeopneustidae are discriminated from one another as shown by the following key (mainly after MORTENSEN, 1950-a, p. 1888).

Key to the important genera of the family Palaeopneustidae.

1.	A more or less conspicuous frontal depression 2
	No frontal depression 10
2.	No primary tubercles (radioles). Only three genital pores Plesiozonus
	Primary tubercles (radioles) present on the aboral side. Four or three genital pores
3.	Only some few large tubercles (radioles), on the aboral side; their areoles deeply
	sunken, forming internal pouches Homolampas
	Primary radioles (tubercles) on the aboral side without deeply sunken areoles 4
4.	Petals rudimentary 5
	Petals well formed 6
5.	Subanal fasciole present Argopatagus
	No subanal fasciole Phrissocystis
6.	Subanal fasciole present
	No subanal fasciole (or unknown) 8
7.	A marginal fasciole present Linopneustes
	A peripetalous fasciole present Elipneustes
8.	Periproct supramarginal
9.	Interporiferous zones broad, tuberculated Pharaonaster
	Interporiferous zones narrow, not tuberculated Stomaporus
10.	Ambulacra I and V on the oral side covered with tubercles (radioles) 11
	Ambulacra I and V on the oral side naked, or minutely tuberculated $\ldots 12$
11.	Periproct inframarginal Archaeopneustes
	Periproct marginal Heterobrissus
12.	Test round, or nearly round. Frontal ambulacrum (III) petaloid, not different from
	the paired petals. Apical system central. A marginal fasciole present(?)
	Niponaster
	Test elongate. Frontal ambulacrum (III) not petaloid, different from the paired
	petals. Apical system central or anterior
13.	Periproct submarginal or marginal. Only three genital pores Palaeopneustes
	Periproct marginal 14
14.	Petals tending to close distally. Subanal fasciole distinct only in the young

Petals not tending to close distally. No peripetalous fasciole Eurypatagus. There are fossil representatives of the genera Palaeopneustes, Pharaonaster, and Niponaster, in our collection.

Genus Palaeopneustes A. AGASSIZ, 1873

Palaeopneustes A. Agassiz, 1873, p. 188.—A. Agassiz, 1874, p. 13.—Pomel, 1883, p. 30.— Duncan, 1889-a, p. 223.—A. Agassiz, 1904, p. 178.—H. L. Clark, 1917, p. 143.—Lambert and Thiéry, 1924, p. 446.—H. L. Clark, 1925, p. 196.—Grant and Hertlein, 1938, p. 112.— Mortensen, 1950-a, p. 189 (complete synonymy).

Haplotype.—Palaeopneustes cristatus A. AGASSIZ, 1873, p. 188.—A. AGASSIZ, 1874, p. 14, pl. 4, figs. 1–3, text-figs. 8–15 (off Barbados, West Indies).

Large forms of high rounded-conical shape, with flat oral side; no frontal depression. Ambulacra flush with test, distinctly petaloid, but open distally; at distal ends of petals ambulacra conspicuously widened. Frontal ambulacrum (III) narrow, not at all petaloid, pore-pairs very small, pores placed vertically one above other, or they may coalesce; pores continue throughout ambulacra, which quite flat. On oral side postero-lateral ambulacra (I and V) naked; there is no adproctal widening of plates of ambulacra Ia and Vb adjoining episternal plates. Phyllodes not strongly developed; labrum forms a prominent lip, posteriorly prolonged to middle of adjoining ambulacral plates no. 3, but not very narrow. Apical system central, ethmolytic, with only three genital pores. Periproct generally supramarginal, on obliquely truncated posterior end, rarely marginal or slightly inframarginal. Tubercles of aboral side rather numerous, small, none of them distinctly primaries. Radioles straight, short, not exceeding a length of 5-10 mm, forming a rather dense, uniform covering; a distinct apical tuft of somewhat larger, erect radioles; radioles more or less thorny, terminating in a simple, usually not hyaline point; miliary radioles straight. A marginal fasciole may present (in young specimens), but no subanal fasciole. Pedicellariae of tridentate, rostrate, triphyllous and ophicephalous types (mainly after MORTENSEN, 1950-a).

This genus is very interesting and perplexing one among the primitive member of the Spatangoina. The two Pacific species, *Pal. fragilis* MEIJERE, 1904 (MEIJERE, 1904, p. 175, pl. 9, figs. 90-93, pl. 21, figs. 427-432, pl. 22, figs. 433-437) and *Pal. spectabilis* MEIJERE, 1904 (MEIJERE, 1904, p. 172, pl. 8, figs. 86-90, pl. 21, figs. 422-426), were originally by MEIJERE and later assigned to this genus by H. L. CLARK (1917, pp. 144-146). They were removed from this genus and transferred to the genus *Linopneustes* by MORTENSEN (MORTENSEN, 1948-b, pp. 114-116; 1950-a, pp. 203-220), thus there remains only a West Indian (the type) species in this genus.

This genus has no subanal fasciole and is distinguished from the genus *Linopneustes* in this point; further it differs from that genus in the arrangement of plates on the oral surface, i.e., in this genus the first interambulacral plate (labrum) broad and short, and some plates adjoining the sternum not adproctally prolonged so as no space of development of subanal fasciole (text-fig. 54[29]), while in that genus from 6th to 8th ambulacral plates adproctally prolonged to make a space of development of subanal fasciole (text-fig. 55[30]). *Palaeopneustes* is also distinguished from its ally



Fig. 54 [29]. Palaeopneustes cristatus A. AGASSIZ, 1873. An ambulacrum (I) and an interambulacrum (5) on the oral surface, $\times 0.66$ (after A. AGASSIZ, 1904).

Archaeopneustes by the less development of phyllodes in the postero-lateral ambulacra (I and V), the more or less bare adoral ambulacra, and by the supramarginal periproct, in that genus (textfig. 56(31)) the periproct is distinctly inframarginal. This genus also has resemblance with the genus *Elipneustes* in outline, but differs from that genus in the arrangement of plates on the oral surface, especially in the form and prologation of the labrum, and in lacking of the subanal fasciole.

Palaeopneustes holmani GRANT and HERTLEIN, 1938 (1938, p. 112, pl. 25, figs. 1-2), from the Repetto formation (lower Pliocene) of California, is referred to the genus *Megapetalus*, by ZULLO and DUR-HAM (1962, p. 524). The find of some fossil species of this genus from the Pliocene and Miocene of northern and western Japan is very interesting both in taxonomy and geographical distribution of the genus. The West Indian and North Pacific species may be regarded as the congener in their general features, and probably not came from diferent sources by convergence, but would be from

same source by divergence. They perhaps occurred in the North Pacific from unknown source during the Miocene or earlier epoch and the North Pacific was probably the center of their distribution. The comparatively stout and long-lived larvae



Fig. 55 [30]. Linopneustes murrayi (A. AGASSIZ, 1879). An ambulacrum (I) and an interambulacrum (5) on the oral surface, $\times 0.66$ (after A. AGASSIZ, 1881 and 1904).



Fig. 56 [31]. Archaeopneustes hystrix (A. AGASSIZ, 1880). An ambulacrum (I) and an interambulacrum (5) on the oral surface, $\times 0.66$ (after A. AGASSIZ, 1904).

of them seem to be widely distributed from there to other region during the Miocene and Pliocene when the Canal Zone was still under shallow sea, larvae of certain species were migrated into the West Indian sea from the Pacific side; after this migration the Canal Zone uplifted from shallow sea as highly land, the North Pacific species became extinct by unknown unfavourable condition or other reasons, but the West Indian species seems to have inherited from the migrant to the present.

A Japanese fossil species at the writer's disposal does not quite agree in the generic diagnosis from the typical species in some smaller features. It has a inframarginal periproct and short frontal ambulacrum (III), contrasting to the supramarginal periproct and long and subequal length of frontal ambulacrum of the typical species. However, the form of labrum and the arrangement of plates on the oral surface are not so different as to separate them into two genera, i. e., in the species 5th and 6th plates of the postero-lateral ambulacra (I and V) are joining periproctal region as in the typical species. That only regarding with the position of periproct it recalls the genera *Archaeopneustes* and *Hypospatangus*, but it differs from the former genus by the bare oral ambulacra and the less developed phyllodes, and is distinguished from the latter in the arrangement of plates on the oral side and shorter frontal ambulacrum (III). A Japanese fossil species, as describes below, is taken as the type-species of a subgenus, *Oopneustes*, differing from the typical subgenus.

Subgenus Oopneustes NISIYAMA, n. subgen.

Type-species.—Palaeopneustes (Oopneustes) priscus NISIYAMA, n. sp.

This subgenus differs from the typical one in having a inframarginal periproct, narrower and shorter frontal ambulacrum (III), and in the position of apical system, which is very eccentric in front.

Palaeopneustes (Oopneustes) priscus NISIYAMA, n. sp.

(Pl. 19, figs. 1-2, Pl. 21, fig. 4, Text-figs. 57 [32]-59 [34])

Holotype.--IGPS coll. cat. no. 7098.

Locality and geological horizon.—In some place of Kawasaki-mura (exactly locality unknown), Shibata-gun, Miyagi Prefecture. Probably Tsunaki formation, Miocene.

Test large, rounded-oval in marginal outline, anterior part round, posterior part more or less constricted, 142 mm in longitudinal diameter, rather low, 63 mm in height, broadest point lies slightly anterior to middle of test, 140 mm in transverse diameter; aboral surface arched, anterior slope rounded and posterior slope rather straightly rising from margin to highest point, which is eccentric in front, just posterior to apical system; ambital margin of ambulacra slightly concave; adoral surface flat, especially from line transversely crosses labrum to posterior end; peristomal region depressed adorally.

Apical system eccentric anteriorly, situated at 45 mm from anterior margin rather small, about 6 mm wide and 8 mm long, ethmolytic, madreporite extends beyond, centrally, and separates genital plates (2) and (4) also ocular plates (I) and (V), and passes into posterior interambulacrum (5); genital pores three, lacking in genital (2).

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Ambulacra diverse, nearly flush on aboral surface. Frontal ambulacrum (III) small and short, rather apetalous, at least 60 plates in a column on aboral side; pore-pairs continue to about 30th plate from apical system to ambital margin, pores of a pair small, rounded and rather distinct, pores placed rather vertically one above other; beyond ambital region pores coalesce to become unipore; plates near ambital region rather low, 2.5 mm high and 8 mm broad, unipore placed centrally; interporiferous zone rather broad and distinct. Antero-lateral ambulacra (II and IV) rather broad and slightly depressed in median area; they diverge at about 140° at first and then at middle of petals they slightly curved backwardly and innerwardly, cross ambitus at line of apical system; at least 65 plates in a column on aboral side; aborally subpetaloid and quite open distally; pore-pairs rather distinct, outer pores of pairs



Fig. 57 [32]. Palaeopneustes (Oopneustes) priscus NISIYAMA, n. sp. Aboral view, ×055.

somewhat elongate, the inner round; interporiferous zone broad and distinct; plates rather low, 2.5 mm and 10 mm wide at ambital region, and bear a central unipore. Postero-lateral ambulacra (I and V) long and broad; they diverge at about 100° at first, and then slightly curved at middle of petaloid area; at least 60 plates in a column on aboral side; adapically outer member of pairs elongate, inner round; interporiferous zones broad and distinct; plates rather high, 6 mm high and 17 mm wide at ambital region, and bear a unipore.

Oral surface rather flat, except periproctal region. Labrum large and broad, about 30 mm high and 17 mm wide; following second plates in posterior interambulacrum (5) very long and large, over 50 mm long and 20 mm wide on each side; 3rd plates on each side rather low, about 25 mm wide and 18 mm high; 4th plates on each side somewhat smaller than 3rd plates; 5th and 6th plates joining periproctal region; arrangement of plates in posterior interambulacrum (5), as a whole, much resembles that of *Pal. cristatus* (A. AGASSIZ, 1904, pl. 95-MCZ 7826), but slightly less in number



Fig. 58 [33]. Palaeopneustes (Oopneustes) priscus NISIYAMA, n. sp. Oral view, $\times 0.5$.

of plates. Ambulacral plates on oral surface rather narrow; plates in right posterior ambulacrum (I) consist of 11 on each side, and not prolonged periproctally. Phyllodes rather well developed; frontal ambulacrum (III) of four plates on each side, in postero-lateral ambulacra (I and V) 5 plates, and in antero-lateral ambulacra (II and IV) 8 plates, join in combination of phyllodes.

Peristome eccentric anteriorly, situated at about 30 mm from anterior margin, depressed, and semilunular. Periproct on adoral surface, rather small, transversely oval, 10 mm wide and 6 mm high. Interambulacral plates large and broad, about 20 mm wide and 10 mm high at 10th plate from apical system in area 2b, and seems to be 18 tubercles in four rows on plate. Tuberculation on oral surface and any fasciole not preserved on the specimen, but adoral ambulacral plates seem to be quite bare.



Fig. 59 [34]. Palaeopneustes (Oopneustes) priscus NISIYAMA, n. sp. Side view, $\times 0.5$.

Distinction.—This interesting new species resembles *Pal. cristatus* (loc. cit.), a Recent species of the West Indies, but it distinguished from that species by the form of test and the arrangement of plates in the posterior interambulacrum (5) on the oral surface, and decidedly by the position of periproct. This species also super-

ficially resembles *Plesiozonus hirsutus* MEIJERE, 1904 (1904, p. 178, pl. 7, figs. 83-86, pl. 22, figs. 438-453), a Recent species from the Flores Sea, in the outline of test and in the position of periproct, but is easily distinguished from that species by having broad and distinct interporiferous zone in subpetaloid areas, simple ambulacral plates on the aboral surface, in that species the distal part of aboral ambulacral plates are occluded, and by having bared aboral ambulacral plates. This species has also superficial similarity to *Heterobrissus niasicus* (DÖDERLEIN, 1902) (*Archaeopneustes niasicus* DÖDERLEIN: DÖDERLEIN, 1906, p. 245, pl. 32, fig. 1), a Recent species from Indian Ocean, in the outline, but is distinguished from that species by the adoral ambulacral plates being bare and by the position of periproct. The assignment of that species, however, to the genus *Heterobrissus* is not certain, as MORTENSEN (1950-a, p. 202) was in doubt as to its assignment to that genus, and he intends to refer that species whether to the *Archaeopneustes* or to the *Palaeopneustes*.

The following fossil species, from the Neogene formations of Japan, can be referred to the typical *Palaeopneustes* in general features.

Palaeopneustes psoidoperiodus NISIYAMA, n. sp.

(Text-figs. 60 [35] a-c)

Palaeopneustes sp. nov., AOKI (now NISIYAMA) 1933, text-fig. 65a on p. 50.

Palaeopneustes cf. cristatus A. Agassiz: Morishita, 1953, p. 27, pl. 3, fig. 1(?).-Morishita, 1960, p. 61.

Holotype.—IGPS coll. cat. no. 73780.

Locality and geological horizon.—IGPS loc. no.—Fk-61.—Road-side cutting leads to Harano-machi from Kashima, about 500 metres north of Shiozaki, Mono-mura, Sômagun, Fukushima Prefecture (tm Sôma-Nakamura, Lat. 37°41'N., Long. 140°58′42″E.). Nakamura formation, Pliocene (KAMADA). Holotype.

Locality and geological horizon.—IGPS loc. no.—Fk-62.—Road-side cutting immediately north of shrine at Takami, Mano-mura, Sôma-gun, Fukushima Prefecture (tm Sôma-Nakamura, Lat. 37°41′15″N., Long. 140°58′43″E.). Nakamura formation Pliocene. Paratype.—IGPS coll. cat. no. 73781.

Locality and geological horizon.—IGPS loc. no.—Fk-63.—Sea cliff about 400 metres north of Kabaniwa, Isobe-mura, Sôma-gun, Fukushima Prefecture (tm Sôma-Nakamura, Lat. 37°45′N., Long. 141°00′31″E.). Nakamura formation, Pliocene. Paratype.—IGPS coll. cat. no. 73780-A.

Locality ane geological horizon.—IGPS loc. no.—Fk-64.—Road-side cutting at a large tree south of Yamanobuta-ura, Isobe-mura, Sôma-gun, Fukushima Prefecture (tm Sôma-Nakamura, Lat. 37°45′54″N., Long. 140°58′49″E.). Nakamura formation, Pliocene. Paratype.—IGPS coll. cat. no. 73782.

Locality and geological horizon.—IGPS loc. no.—Fk-65.—Road-side cutting at Koizumi, Nakamura-machi, Sôma-gun, Fukushima Prefecture (tm Sôma-Nakamura, Lat. 37°48′18″N., Long. 140°55′34″E.). Nakamura formation, Pliocene. Paratype—IGPS coll. cat. no. 73783.

Locality and geological horizon (after MORISHITA).—Sendo, Isobe-mura, Nishi-Kubiki-gun, Niigata Prefecture. Nadachi formation, Pliocene.

Several specimens of this new species at the writer's disposal, all are not in good preservation, but the best preserved one is selected as the holotype.

Test of moderate or large-size, ovoid in marginal outline, anterior part round, posterior part constricted, about 105 mm in longitudinal diameter, 92 mm in transverse one, broadest point lies middle of test, rather high, about 45 mm in highest; aboral surface moderately arched, subconical, highest point situated central, just on apical system; oral surface somewhat concave, especially peristomial region and postero-lateral ambulacra (I and V) depressed, and periproctal region inclined inwardly.

Apical system small, about 4 mm wide and 6 mm long, central, situated at about 52 mm from posterior margin. Ambulacra diverge, nearly flush on aboral surface, subpetaloid and open distally. Frontal ambulacrum (III) narrow, apetalous, about 10 mm wide at ambitus; ambulacral plates rather high, 3 mm high and 5 mm wide at ambital region; pore-pairs continued from apical system to half way of anterior margin; pores of pairs small, round and closed; beyond pore-pairs to anterior margin pores coalesce, and a centrally placed unipore on each plate. Antero-lateral ambulacra (II and IV) broad, about 16 mm wide at ambital region, straight, diverge each other about 120°; pore-pairs rather distinct, outer member of pairs elongate, inner round; interporiferous zones distinct and broad; ambulacral plates rather low, about 5 mm high and 8 mm wide at ambital region, and plate beyond pore-pairs to ambital margin



Fig. 60 [35]. Palaeopneustes psoidoperiodus NISIYAMA, n. sp., \times 0.6. a. Aboral view of holotype; b. Oral view of the same; c. Side view of the same.

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bears a central unipore. Postero-lateral ambulacra (I and V) also broad, about 20 mm wide at ambital region, straight, diverge each other at angle about 70°; pores of pairs distinct, outer member of pairs elongate, inner round; interporiferous zones broad and distinct; ambulacral plates rather row, 3 mm high and 10 mm wide at ambital region, and plate beyond pore-pairs to ambital margin bears a central unipore.

Labrum large and broad, about 20 mm long and 17 mm wide; following second plates in posterior interambulacrum (5) very long but rather narrow, about 40 mm long and 12 mm wide on each side; 3rd plates on each side very low, about 10 mm high and 15 mm wide; 4th plates on each side as large as or somewhat smaller than 3rd plates on each side; 5th and 6th plates join adproctal region. Ambulacral plates in postero-laterals (I and V) on oral surface not prolonged adproctally, and mould and cast specimens (with fragments) at the writer's disposal prove that there are no trace of tubercles on ambulacra; plates high; highest measures 13 mm, but narrow, 11 plates in a column. Phyllodes as in *Pal. cristatus*.

Peristome very eccentric anteriorly, situated at about 20 mm from anterior margin, depressed, semilunular in outline, about 22 mm wide and 5 mm high. Periproct small, oval in outline, 6 mm wide, situated at margin on inwardly inclined truncation.

Interambulacral plates large and broad, especially in postero-lateral areas (1 and 4), about 25 mm wide and 15 mm high above ambitus. Tuberculation on both aboral and oral surfaces not well preserved.

Distinction.—This new species resembles *Pal. cristatus* (loc. cit.) in the form of phyllodes and the position of the apical system, but differs from that species in having narrower ambulacra on the oral surface, the smaller periproct, and the larger second plates in the posterior interambulacrum (5). This species has similarity to *Pal. priscus* in the arrangement of plates on the oral surface, but is distinguished from that species by the central position of the apical system, the longer frontal ambulacrum (III) on the aboral surface, and by the more elongate form of marginal outline of test.

MORISHITA's specimen from the Pliocene of Niigata Prefecture (as *Palaeopneustes* cf. cristatus A. AGASSIZ) seems to be more related to this species than to the West Indian Recent species. His specimen, as judged from the figure and description, is differing from *Pal. cristatus* in having longer (i. e., having more numerous pore-pairs in spite of smaller size of the test) and narrower aboral ambulacra, moreover, the height of his specimen is smaller than that of *Pal. cristatus* and it accords nearly with that of *Pal. psoidoperiodus*. In the features of the aboral side, this species recalls *Heterobissus hemingi* (ANDERSON, 1899) (*Palaeopneustes hemingi* ANDERSON, 1899, p. 7.—*Archaeopneustes hemingi* (ANDERSON): KOEHLER, 1914, p. 52, pl. 4, figs. 1-2, pl. 5, figs. 1-2, 4-5, 8, pl. 18, figs. 1-11), a Recent species from the Indian Ocean, but is easily distinguished from that species in having the peristome more eccentric anteriorly, less developed phyllodes, and bared oral ambulacral plates. It seems to the writer that specific identification of the Palaeopneustids only from the aboral features leads to misidentification.

Palaeopneustes periturus NISIYAMA, n. sp.

(Text-figs. 61 [36] a-c)

Archaeopneustes cf. hystrix (A. Agassiz): Morishita, 1953, p. 28, pl. 3, figs. 2-3(?).—Morishita, 1960, p. 61.

Holotype.—IGPS coll. cat. no. 73785.

Locality and geological horizon.—IGPS loc. no.—Ch-87.—River side of the Minatogawa, about 300 metres south of Onda, Tamaki-mura (Kazusa-machi), Kimitsu-gun, Chiba Prefecture (tm Futtu, Lat. 35°13′10″N., Long. 139°55′57″E.). Kiwada formation, Pliocene.

There are several fragmentary specimens of this new species at the writer's disposal, some of them are badly preserved moulds and others of casts, and the writer somewhat succeeded in gluing the fragments together, so that one gets an idea of what it looked like when rather complete.

Test of moderate-size, elliptical in marginal outline, anterior and posterior parts round, about 97 mm in longitudinal diameter, 82 mm in transverse one, broadest point lies middle of test, anterior groove slightly and broadly depressed; test low, about .32 mm in height; aboral surface slightly arched, rising from rather thin margin to highest point, which eccentric anteriorly, just anterior to apical system; adoral surface flat, except peristomial region, which decidedly depressed orally.



Fig. 61 [36]. Palaeopneustes periturus NISIYAMA, n. sp., $\times 0.66$. :a. Aboral view of holotype; b. Oral view of the same; c. Side view of the same.

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Apical system eccentric in front, situated at about 37 mm from anterior margin, rather small, 4 mm wide and 7 mm long, ethmolytic. Frontal ambulacrum (III) small and short, slightly and broadly notched in margin, rather apetalous; pores of pairs small, round and close, and placed vertically one above other; ambulacral plates rather high, about 4 mm high and 5 mm wide at ambital region; interporiferous zone rather distinct. Antero-lateral ambulacra (II and IV) rather broad, straight, and diverge each other about an angle 120°; pores of pairs rather distant, outer member of pairs elongate, inner round; ambulacral plates rather low, about 3 mm high and 8 mm wide at ambital region, plates near ambital region bear a central unipore. Postero-lateral ambulacra (I and V) broad and long, about 18 mm wide at ambital region, rather straight, diverge from each other at an angle about 60°; pores of pairs distant, outer member of pairs elongate, inner round; interporiferous zones broad and distinct; ambulacral plates rather low, about 3 mm high and 9 mm wide at ambital region, and plates near ambital region bear a central unipore.

Labrum long and rather narrow, about 19 mm long and 11 mm wide, but is the Palaeopneustid-type not the Linopneustid; following second plates in posterior interambulacrum (5) long and narrow, about 40 mm long and 12 mm wide on each side; 3rd plates on each side very low, about 10 mm high and 15 mm wide; 4th plate in 5b as large as 3rd plate of 5b, that of 5a very low, about 6 mm high and 15 mm wide; 5th plates on each side very low, about 4 mm high and 11 mm wide, with 6th plates. on each side touch periproctal margin as in normal of the Palaeopneustid-type. Postero-lateral ambulacra (I and V) on oral surface rather narrow, about 15 mm wide at broadest point and lacking any tubercles in preserved parts, 11 plates in a column; ambulacral plates high, highest plate measures 12 mm; plates side of sternum not prolonged adproctally. Phyllodes as normal in that genus. Peristome very eccentric in front, situated at about 15 mm from anterior margin, and about 15 mm wide and 3 mm high. Periproct small, oval in outline, 7 mm wide, situated at margin on inwardly inclined truncation. Interambulacral plates large and broad, especially in postero-lateral areas (1 and 4), about 25 mm wide and 9 mm high above ambitus. Tuberculation in postero-lateral areas on oral surface large, sunken scrobicules, in antero-lateral areas somewhat smaller than those in antero-laterals.

This new species resembles *Pal. psoidoperiodus*, but is distinguished from that species by the eccentric apical system, the narrower labrum and by the more elongate form in marginal outline of the test. This species is also related to *Pal. cristatus* in the form of phyllodes and in marginal outline of test, but differs from that species in having the eccentric apical system and larger second plates in the posterior interambulacrum (5).

The labrum of this species is more or less narrower than that of *Pal. cristatus* or *Pal. psoidoperiodus*, but it is not so elongate as that of *Linopneustes murrayi* (A. AGASSIZ, 1879) (*Palaeopneustes murrayi* A. AGASSIZ, 1879, p. 210.—*Linopneustes murrayi* (A. AGASSIZ) A. AGASSIZ, 1881-a, p. 168, pl. 25), and in this species only the 5th and 6th plates of the posterior interambulacrum (5) touch the periproctal region and having no pores as usual of the Palaeopneustid-type; moreover, there are no trace of marginal (or peripetalous) and subanal fascioles, which characterize the genus *Linopneustes*. This species may be safely referred to the genus *Palaeopneustes* in its features.

MORISHITA (1953, p. 28) reported an occurrence of Archaeopneustes cf. hystrix (A. AGASSIZ) from the Pliocene formations of Shizuoka and Miyazaki Prefectures. By judging from his description and figures, the aboral side only, his specimens cannot be referred to the genus Archaeopneustes. In his statement, "The posterior paired ambulacra on the oral side naked" being contrast to "Ambulacra I and V on the oral side covered with tubercles" on the genus Archaeopneustes and the position of periproct seems to be at the posterior end, while in Archaeopneustes it is distinctly inframarginal. It seems to the writer that these specimens much relate Pal. periturus or Pal. psoidoperiodus than the West Indian Recent species. In the Pliocene epoch, the species of the genus Palaeopneustes were widely distributed from northeastern to southwestern Japan.

Palaeopneustes lepidus NISIYAMA, n. sp.

(Pl. 20, figs. 1, 4, Pl. 21, fig. 1)

Holotype.—IGPS coll. cat. no. 8076.

Locality and geological horizon.—IGPS loc. no.—Is-68.—Road-side cutting at Tsumukô, Nanao City, Ishikawa Prefecture (tm Nanao, Lat. 37°03′18″N., Long. 136° 57′12″E.). Nanao formation, Miocene.

There is a rather well preserved specimen of this new species at the writer's disposal; however, the arrangement of plates on the oral side is not precisely detected.

Test of rather large-size, ovoidal in marginal outline, anterior part well rounded, posterior part slightly truncated, about 126 mm in longitudinal diameter, 102 mm in transverse one, broadest point lies a little posterior to middle of test in postero-lateral interambulacral area (1 and 4), rather low, about 60 mm in height; aboral surface moderately arched, anterior surface moderately rising as rounded curve towards apical system, posterior surface less rounded; highest point situated just anterior to apical system; oral surface flat, peristomial region depressed adorally and periproctal region inclined inwardly.

Apical system small, about 4 mm wide and 6 mm long, situated at about 56 mm from anterior margin, slightly eccentric in front; ethmolytic, with three genital pores. Ambulacra diverge, nearly flush on aboral surface and slightly or not depressed proximally, and widely open distally. Frontal ambulacrum (III) narrow, apetalous, about 12 mm at ambitus, at least 50 plates in a column on aboral side; pore-pairs continued to about 40th plate from apical system to ambital margin; pores of pairs small, close, round and placed vertically one above other; beyond pore-pairs to anterior margin pores coalesce and a centrally placed unipore on each plate. Anterolateral ambulacra (II and IV) broad, about 18 mm wide at ambital margin, straight, diverge each other at angle about 120°; at least 52 plates in a column on aboral surface; subpetaloid adapically and quite open distally; plates rather high, about 3.5 mm high and 9 mm wide at ambital region; pore-pairs rather distant, outer member of pairs more or less elongate, inner round; plates beyond pore-pairs bear a central unipore; interporiferous zones broad and distinct. Postero-lateral ambulacra (I and V) long and broad, about 24 mm wide at ambital margin; they diverge at an angle about 65° at first and then slightly curved outwardly at a distance about two-thirds length of ambulacra from apical system; at least 52 plates in a column on aboral surface; subpetaloid adapically and quite open distally; plates rather low, about 3.5 mm high and 12 mm wide at ambital region and plates beyond pore-pairs bear a central unipore.

Adoral surface rather flat, except peristomial region. Labrum large and broad, about 18 mm high and 18 mm wide, of the Palaeopneustid-type; following interambulacral and adjoining ambulacral plates not well preserved, but in general features they seem to be the Palaeopneustid-type. Phyllodes rather well developed; in frontal ambulacrum (III) 4 plates on each side, in antero-lateral ambulacra (II and IV) 7 plates, and in postero-lateral ambulacra (I and V) 2 or 3 plates join in phyllodes (they are perforated by large penicillate tube-feet). Peristome eccentric in front, situated at about 23 mm from anterior margin, depressed, semilunular in outline, about 22 mm in transverse diameter. Periproct large, transversely oval, about 14 mm wide and 9 mm long, situated on obliquely truncated posterior end, and visible from oral side.

Distinction.—This new species resembles *Pal. cristatus* in outline of the test, but is distinguished from that species by having longer pore-paired areas in the ambulacra, broader interporiferous zones, and by the narrower peristome with well developed labrum. *Pal. lepidus* has relation with *Pal. psoidoperiodus* in general features, but differs from that species in having larger periproct and narrower peristome, and the less developed postero-lateral phyllodes.

Associated fauna.—Patinopecten (Kotorapecten) kagamianus (YOKOYAMA), Gloripallium crassivenium (YOKOYAMA), Nanaochlamys notoensis (YOKOYAMA), Cosmopolitodus hastalis (AGASSIZ), Megaselachus megalodon (CHARLESWORTH), etc.

In future researches the occurrence of fossil species of the related genera, such as Archaeopneustes, Heterobrissus, and Linopneustes, from Japan will be expected.

Genus Pharaonaster LAMBERT, 1920

Pharaonaster Lambert, 1920-b, p. 26 (168).—Lambert and Thiéry, 1924, p. 441.—Checchia-Rispoli, 1941, p. 236.—Mortensen, 1950-a, p. 238.—Kier, 1957, p. 875.

Orthotype.—Macropneustes ammon DESOR in AGASSIZ and DESOR, 1847, p. 115.—LORIOL, 1880, p. 71, pl. 10, fig. 2 (Eocene of Egypt).

Forms of fairly large-size, of ovoid outline, inflated, but with a broad, shallow, frontal depression. Test low arched, gently sloping at both ends, not distinctly truncate posteriorly; oral side apparently flat, posterior interambulacrum (5) gently inflated. Frontal ambulacrum (III) different from other paired ones, non- or subpetaloid, somewhat depressed, with small, distinct pores. Paired ambulacra petaloid, petals long, reaching border of test, with round conjugate pores; open distally, not sunken; interporiferous zone broad, with tubercles like those of interambulacra, and poriferous zones equal in width. Apical system slightly anterior, with four genital pores, ethmolytic (in *Phar. migliorinii* CHECCHIA-RISPOLI, 1941, p. 388, pl. 1, figs. 1–2). Peristome somewhat anterior, labiate (in *Phar. migliorinii*). Some larger tubercles scattered all over aboral side. Peripetalous fasciole well developed, passing straight between ends of petals (and a subanal fasciole present-KIER, 1957, p. 875).

This genus differs from *Hypsospatangus* POMEL, 1883 (POMEL, 1883, p. 31.—Type-species.—*Hyp. meneghini* (DESOR) : LAUBE, 1862, p. 32, pl. 7, fig. 1—Oligocene of Vicen-

tin) in having the longer and opened paired petals, and from the genus *Megapneustes* 'GAUTHIER, 1899 (GAUTHIER, 1899, p. 678.—Type-species.—*Meg. grandis* GAUTHIER, 1899, p. 681, pl. 2, figs. 5-6.—Eocene of Egypt) in having the shorter paired petals, which are flush on the aboral surface. *Pharaonaster* also resembles *Stomaporus* COTTEAU, 1888 (COTTEAU, 1888, p. 977.—Type-species.—*Stom. hispanicus* COTTEAU, 1889, p. 23, pl. 3, figs. 1-4.—Eocene of Alicante) in general shape and in the mode of paired petals, but is distinguished from that genus in the interporiferous zones, which are very wide and tuberculated in this genus, while are very narrow and being not tuberculated in that genus.

LAMBERT and THIÉRY (1924, p. 442) enumerated three species under the genus Pharaonaster, besides the type-species; of the species Macropneustes fischeri LORIOL, 1880 (LORIOL, 1880, p. 74, pl. 9, fig. 10) was made the type-species of a separate genus, Thebaster (CHECCHIA-RISPOLI, 1941, p. 392); the two others Hypsospatangus japonicus LORIOL, 1902 and Macropneustes mortoni (CONRAD) (CLARK and TWITCHELL, 1915, p. 155, pl. 72, figs. 1-1d.—Eocene of U.S. A.) are imperfectly known. Hyp. japonicus reported from the Neogene of Hokkaido and has a peripetalous fasciole.

Pharaonaster japonicus (LORIOL, 1902)

Hypsospatangus japonicus LORIOL, 1902-a, p. 32, pl. 3, figs. 8-8a.—TOKUNAGA, 1903, p. 23.— Pharaonaster japonicus (LORIOL) LAMBERT and THIÉRY, 1924, p. 442.—AOKI (now NISI-YAMA), 1933, text-figs. 64a-b (reproduced from LORIOL, 1902).—MORTENSEN, 1950-a, p. 239.—MORISHITA, 1960, p. 61.—NISIYAMA, 1965, p. 80.

There is an imperfectly preserved specimen referable to this species at the writer's disposal. The greater part of aboral side of the specimen is broken away and the adoral side is so firmly covered with matrix that the detailed observation on the specific features could not be made clear.

Referred specimen.—The National Science Museum, Tokyo, fossil coll. cat. no. 1868. Locality and geological horizon.—Unknown to the writer, owing to the lacking .any mention on the label.

A specimen at hand, probably came from the Tertiary of Hokkaido, measures about 87 mm in longitudinal diameter, about 80 mm in transverse one, and about 37 mm in height. Preserved part of apical system seems to be ethmolytic and madreporite more or less squeezed by subsequent deformation after fossilization. Ambulacra on aboral surface more or less depressed and not quite flush as in typical species, *Ph. ammon* (KIER, 1957, p. 875, pl. 105, fig. 1). Frontal ambulacrum (III) rather apetalous, narrow, 10 mm in width above ambital margin; plates rather low, 5 mm wide and 22 mm high above ambital margin, each plate near ambital margin carrying from three to five primary tubercles (sunken scrobicules) on innerside and one on outerside of pore-pair; interporiferous zone wide, about 5 mm wide above ambital margin and covered with primary tubercles, which are as large as those on interambulacra; porepairs very small, round, placed vertically one above other, close, and pores of a pair separated by a peduncle. Paired ambulacra subpetaloid adapically, long, open distally and straight, rather narrow, 12 mm in width above ambital margin; plates low, 6 mm wide and 1.5 mm high above ambital margin, each plate near ambital margin carrying

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from two to three primary tubercles perradial (inner) side of pcre-pair; interporiferouszone broad, about 6 mm wide above ambital margin and covered with primary tubercles resembling those on interambulacra in size and form; poriferous zones rather narrow, about 3 mm wide above ambital margin, pores of a pair conjugate, outer pore of a pair elongate, inner round, and each pair carrying a few miliary tubercles on proximal side. Tuberculation small and close; primary tubercles more numerous than those of type-species and not prominent.

Preserved part of peripetalous fasciole narrow but rather distinct, runs a little above ambital margin and slightly curves adapically in postero-lateral interambulacra (1 and 4) and in posterior interambulacrum (5); this feature of fasciole more or less differs from that of typical species. Radioles on adoral side as in the description given by LORIOL (1902-a, p. 32). Presence or absence of a subanal fasciole not certained. In its general features, this species is similar to *Ph. ammon*, particularly in the feature of interporiferous zone, the apical system, and in the peripetalous fasciole. This species, however, differs from that species in having more or less depressed paired ambulacra. This difference is so slight that it seems probable that the two species, *Ph. ammon* and *Ph. japonicus*, belong to the same genus. This suggestion, however, can be tested only when more specimens are available for study. It is very interesting fact that a species of Egyptian genus has distributed as eastwards as Hokkaido.

Genus Niponaster LAMBERT, 1920

Niponaster Lambert, 1920-b, p. 26 (168).—Lambert and Thiéry, 1924, p. 426.—Mortensen, 1950-a, p. 169.—Morishita, 1955-a, p. 99.—Saito, 1959, p. 83.

Orthotype.—Niponaster hokkaidensis LAMBERT in LAMBERT and THIÉRY 1924, p. 426.— Ananchytinarum sp. indet., JIMBO, 1894, p. 45, pl. 9, fig. 8 (Cretaceous of Hokkaido).

Niponaster is a somewhat puzzling genus; it was referred originally by MORTENSEN (1950-a, p. 169) to the family Stenoasteridae as incertae sedis, probably owing to the doubtful characters of the adoral side. On the question concerns the true character of the adoral side of Niponaster hokkaidensis was not settled, till MORISHITA (1955-a, p. 99) has clarified the amphisternous condition of the plastron. MORISHITA (1955-a, p. 15, fig. 3) illustrated the adoral side of this species with a short mention, as follows .-- "The posterior interambulacrum forms sternum and amphisternous." MORISHITA'S specimen was formerly reported by SASAI (1936, p. 600) as an European. species, Ananchytes ovatus (LESKE), from the Minato shale (upper Cretaceous) of Awaji Island, and after re-examination of the specimen he identified it as Niponaster hokkaidensis. From the figure and description given by MORISHITA (1955-a) and from the examination on preserved part of the adoral side of a specimen at the writer's. disposal, it is now clear that the plastron of Niponaster is strictly amphisternous as in the genus Palaeopneustes, but not as in the genera Stenonaster (MORTENSEN, 1950-a,. text-fig. 127a), Brightonia (KIER, 1957, text-fig. 13a), and Leviechinus (KIER, 1957, textfig. 14a) of the family Stenoasteridae. Thus the genus Niponaster must be referred to a member of the amphisternous spatangoids (the Spatangoina) from the condition. as described above.

In the mode of ambulacra on the aboral surface, the labiated peristome, the posterolateral ambulacra (I and V) on the oral surface, the structure of plastron, and in the general form the genus Niponaster can be referred to the family Palaeopneustidae. The revised diagnosis is written as follows.

Test of rather large-size, fairly strong, high and rounded-oval in outline. Adoral surface flat, peristomial region more or less depressed adorally. No frontal depression. Ambulacra subpetaloid adapically, flush with aboral surface, long, straight, open distally; frontal ambulacrum (III) similar paired ones. (?)A narrow marginal fasciole near ambitus. Apical system subcentral, compact, ethmophract, with four genital pores. Peristome eccentric in front; labrum well formed, and the second sternal plates moderate in size. Postero-lateral ambulacra (I and V) on oral surface covered with small tubercles. Periproct inframarginal, rather large, and oval in outline. From the upper Cretaceous (Senonian) of Japan.

This genus has similarity with the genus Archaeopneustes in the test without a frontal depression, the antero-lateral ambulacra on the oral side covered with minute tubercles, and in the inframarginal periproct; but differs from that genus in having the compact and ethmophract apical system, which seems to be an unique feature in the family, and in having a narrow marginal fasciole, if there were really it. Niponaster also resembles Megapetalus in the unspecialized anterior ambulacrum (III) which is similar in character to the paired ambulacra and in the antero-lateral ambulacra are minutely tubercluated on the oral surface, but differs in having the ethmophract apical system and the well developed phyllodes. In the presence (?) of a marginal fasciole this genus resembles Linopneustes, but it differs from that genus in lacking of a frontal depression on the test, lacking of a subanal fasciole, and in the character of the apical system.

This genus comprises two species, *Nip. hokkaidensis* and *Nip. nakaminatoensis*, from the upper Cretaceous of Japan, and it is very interesting to the writer that these specialized forms (except the apical system) have already occurred as old as the upper Cretaceous epoch.

Niponaster hokkaidensis LAMBERT, 1924

(Text-figs. 62 [37] a-b)

Ananchytinarum sp. indet., JIMBO, 1894, p. 45, pl. 9 (25), fig. 8.

Niponaster hokkaidensis LAMBERT in LAMBERT and THIÉRY, 1924, p. 426.—MORTENSEN, 1950-a, p. 170, text-fig. 132 (reproduced from JIMBO, 1894).—MORISHITA, 1955-a, p. 99, pl. 15, figs. 1-3.—NISIYAMA, 1965, p. 80.

Ananchytes ovatus: SASAI, 1926, p. 600 (non LESKE, 1778).

Hypotype.—The National Science Museum, fossil coll. cat. no. 376.

Locality and geological horizon.—In vicinity of Senhôshi, Kusuri, Hokkaido (the precise locality unknown to the writer). Probably from the Upper Yezo group (MATSUMOTO, 1953, p. 22) of Hokkaido.

A specimen at the writer's disposal, from the upper Cretaceous of Hokkaido, is not good state in preservation. Specimen measures about 86 mm in longitudinal diameter, 80 mm in transverse one, and 37 mm in height. Test rounded oval in marginal outline, greatest breadth lies at middle of test, aboral surface arched from thick margin to highest point, which situated just at apical system; apical system central. Adoral surface flat, except peristomial region that being more or less depressed orally; margin passed into thick ambital region; no frontal depression.

Ambulacra subpetaloid adapically, flush with surface, open distally, long, and nearly reach to ambital margin; frontal ambulacrum (III) not well differentiate from other ambulacra, but more or less narrower than the others. Ambulacra straight and gradually widened toward distal ends; paired ambulacra nearly equal in shape and length, at least 30 pore-pairs from apical system to ambital margin, about 15 mm wide above ambital region; plates low, about 1.5 mm high and 7.5 mm wide above ambital margin; poriferous zones runs in rather equal width (except the proximal part); interporiferous zones gradually widened toward distal ends; poriferous zone



Fig. 62 [37]. Niponaster hokkaidensis LAMBERT, 1924.

- a. Structure of the posterior interambulacrum (5) and adjoining ambulacra, × 0. 6.
- b. Tuberculation on the posterolateral ambulacral plates on the oral side, $\times 1.5$.

5 mm wide near ambital region, outer pore of a pair elongate or comma-shaped, inner rounded oval; interporiferous zone 5 mm wide at ambital region.

Phyllodes fairly well developed, with 5 penicillate tube-feet in each series on antero-laterals (II and IV), 3 penicillate tube-feet in each series on postero-laterals (I and V), and the those on frontal ambulacrum (III) not preserved. Peristome very eccentric in front, situated at about one-fourth the length of test from anterior margin, semilunular in outline, about 30 mm in width. Labrum rather well developed, about 12 mm wide and 17 mm high; following second plates in pair moderate in size, about 18 mm high and 10 mm wide on each side, 3rd plates low and wide, about 8 mm high and 12 mm wide. Preserved part of postero-lateral ambulacra (I and V) on oral side narrow, the plates fully

covered with close and minute tubercles; tubercles numbering about 10 or more in four square milimetres.

MORISHITA (1955-a, p. 100) sliped to describe detailed feature on the oral side of his specimen from the island of Awaji. It is observable, from the figure (fig. 3 on pl. 15) of oral side, that the labrum is long and broad, probably over 10 mm in width and 15 mm in length, the anterior part probably missing; the following second plates in pair measure about 18 mm in length and 10 mm in width (the right half is more or less narrower than left half and this is probably due to subsequent deformation), the 3rd plates about 8 mm long and 10 mm wide, and from 5th to 7th (?) plates on each side join the periproctal region; the second sternal plates more or less smaller than those of *Palaeopneustes*, but in its general feature of sternum it seems to be the Palaeopneustid-type. The periproct is oval in outline, about 10 mm wide and 8 mm long, inframarginal.

There is a doubt as to the identity of the species between the specimen from

Hokkaido and that from Awaji Island, because slight differences are found in the ambulacra on the aboral surface and in the labrum; the difference, however, in the ambulacra seems to be due to the difference of expression and the difference in the labrum also due to the missing of anterior part in Awaji specimen. It seems highly probable that the specimen from Hokkaido and that from Awaji Island should belong to the same species; but this suggestion can be tested only when more specimens are available for study.

Niponaster nakaminatoensis SAITO, 1959

(Text-figs. 64 [39] a-b)

Niponaster nakaminatoensis SAITO, 1959, p. 81, pl. 2, figs. 1-5, text-figs. 1-2.-NISIYAMA, 1965, p. 80..

There is no authentic specimen of this species at the writer's disposal. SAITO (loc. cit.) reported this species from the upper part of the Nakaminato formation (upper Cretaceous) of Ibaraki Prefecture, with well-written description and good illustrations. As for the tubercles of this species, SAITO (1959, p. 81) described that— "Ambulacral and interambulacral plates minutely tuberculated, tubercles being more numerous on the latter than on the former; tubercles marked by a depressed ring (sunken scrobicule), 1 mm in diameter, and a small dot-like central pit (perforate). Near the peristome, smaller secondary tubercles (miliaries) appear on the ambulacral plates, in alternation with the primary ones." This description indicates that the postero-lateral ambulacra (I and V) are covered with minute tubercles on the oral surface, as one of the characteristic features of this genus. The oral features of this.

Fig. 63 [38]. Megapetalus lovenioides H.L. CLARK, 1929, showing the structure of the posterior interambulacrum (5) on the oral side, $\times 1.2$ (from ZULLO and DURHAM, 1962).



Fig. 64 [39]. Niponaster nakaminatoensis SAITO, 1959.

- a. Structure of the posterior interambulacrum (5) on the oral surface, $\times 0.7$.
- b. A set of ambulacral plates, $\times 6$ (after SAITO, 1959).

species more or less resemble those of *Megapetalus lovenioides* H. L. CLARK, 1929 (textfig. 63 [38]), from the Miocene formation of California; but it differs from that species in the position of periproct, i.e., in this species the periproct lies on a distance onetwelveth length from the posterior margin, while in that species it is quite inframarginal. This species is said to be distinct from *Nip. hokkaidensis* in the relative breadth of poriferous and interporiferous zones, i.e., it is just in reverse condition between the two species. This species also differs from *Nip. hokkaidensis* in having the narrower labrum and sternum and in the position of periproct, which is in that species just inframarginal. It seems represent a distinct species from *Nip. hokkaidensis*.

Family AEROPSIDAE LAMBERT, 1896

Aeropsidae LAMBERT, 1896, p. 324.—MEIJERE, 1904, p. 243.—Aeropsidae H.L. CLARK, 1917, p. 133.—Aeropsidae LAMBERT: LAMBERT and THIÉRY, 1924, p. 426 (pro parte).—Aeropsidae H.L. CLARK: H.L. CLARK, 1925, p. 193.—Aeropsidae LAMBERT: MORTENSEN, 1950-a, p. 322.

Type-genus.—Aeropsis MORTENSEN, 1907.

Forms of mainly moderate or small-size, of rather varying shape. Frontal ambulacrum (III) strongly petaloid, with very large tube-feet; paired ambulacra fairly developed, not petaloid or subpetaloid adapically. A conspicuous peripetalous fascioles surrounding frontal part of test; no other fascioles. Peristome circular, with small plates surrounding central mouth in living forms. Plastron amphisternous as usual in the Spatangoina (mainly after MORTENSEN, 1950-a).

From the upper Cretaceous to Recent.

This family has been insituted for some Recent and fossil genera which are superficially quite dissimilar but agreeing in the peculiar character of the peristome and in the peripetalous fasciole. Among the genera referred to this family, *Aceste* THOMSON, 1877, in its shape, recalls *Schizaster* AGASSIZ, 1836, and *Aeropsis* MORTENSEN, 1907, in the shape and in the position of the peripetalous fasciole, also recalls *Prenaster* DESOR, 1853, of the family Schizasteridae. The genera of the Aeropsidae are distinguished from those of the Schizasteridae in the absence of a latero-anal fasciole that being a main character of the latter family. The resemblance between these genera of the Aeropsidae and those of the Schizasteridae seems to be superficial and not being relational. The family Aeropsidae may be a special small branch of the Spatangoina of unknown origin, as suggested by MORTENSEN (1950-a, p. 326).

There is a fossil representative of the genus *Cottreaucorys* (incertae sedis) in our collection.

Genus Cottreaucorys LAMBERT, 1920

Cottreaucorys Lambert, 1920-b, p. 26 (168).—Lambert and Thiéry, 1924, p. 430.—Lambert, 1931, p. 76.—Mortensen, 1950-a, p. 355.

Orthotype.—Homoeaster blayaci COTTREAU, 1910-a, p. 428, pl. 14, figs. 7-19, text-fig. 2 (Maastrichtian of Algeria).

MORTENSEN (1950-a, p. 335) separated *Cottreaucorys* from *Homoeaster* and raised the former as a generic rank, to which the writer agrees.

Small form of elongate ovoid outline, somewhat pointed posteriorly, with merest indication of a frontal depression. Test rather high, posterior end forming a rather pronounced rostrum below periproct. Ambulacra subpetaloid, short, simple, with small pores. A conspicuous peripetalous fasciole passing anteriorly low down at ambitus. Apical system anterior, with four genital pores; probably ethmophract. Periproct high up on very obliquely posterior end of test. Peristome anterior, pentagonal, without prominent lip, but labrum long, and second sternal plates also long and narrow (mainly after MORTENSEN, 1950-a).

From the upper Cretacaous (Maastrichtian) of Algeria.

As described in the diagnosis, this genus is characterized by its elongate test, rostrate posterior part, small anterior groove, the pentagonal peristome, high ambulacral plates with round pores of pairs, and by a very broad peripetalous fasciole. This curious genus is known only from a single Maastrichtian species, and is distinguished from the genus *Homoeaster* by having rostrate posterior part of the test, the higher ambulacral plates and by the higher position of the periproct. In its general shape this genus resembles the Recent *Aeropsis rostrata* (NORMAN, 1876). It is regrettable that there is no information about the apical system of this genus; but the structure of plastron coincides with that of the Recent forms.

Subgenus Cordastrum NISIYAMA, n. subgen.

Type-species.—Cottreaucorys (Cordastrum) sulcatus NISIYAMA, n. sp.

This subgenus differs from the typical one by having a very broad and deep frontal groove, well defined and somewhat depressed paired petals, lower ambulacral plates in the petaloid areas, supramarginal position of the periproct, and the mode of a peripetalous fasciole. *Cordastrum* is also distinguished from the genus *Homoeaster* by having the rostrate posterior part of the test, well defined petals, and by a supramarginal periproct.

This subgenus comprises only a single species from the upper Cretaceous of Japan, which is described below.

Cottreaucorys (Cordastrum) sulcatus NISIYAMA, n. sp.

(Pl. 18, figs. 10-11, Pl. 20, fig. 2, Text-figs. 65 [40] a-c)

Holotype.--IGPS coll. cat. no. 73746.

Locality and geological horizon.—IGPS loc. no.—Eh-52.—A bridge beside at Narufuji, Kôfuji-mura, Kita-Uwa-gun, Ehime Prefecture (tm Uwa-jima, Lat. 33°16'N., Long. 132°40'34"E.). Miyakura (Furushiroyama) formation, Senonian-Maastrichtian. YABE, 1927, p. 78 and MATSUMOTO, 1953, pp. 84, 98.

There is only a single specimen at the writer's disposal, it is comparatively wellpreserved although some detailed structures on the test are not well observed.

Test rather small, 21 mm in longitudinal diameter, 20 mm in transverse one, and about 14 mm in height. Test somewhat cordate in marginal outline, rounded and broad in anterior part and rostrate and narrowed in posterior part, anterior margin

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notched by a broad and deep frontal groove, which about 4 mm wide and 1.5 mm deep; greatest breadth lies about 8 mm from anterior margin; aboral surface well arched and round, anterior slope well rounded and gradually passed to highest point, which lies on subcentral part of test; anterior half of posterior slope round, but posterior half more or less depressed at about middle of slope; margin thick and round, posterior one thinner than anterior; oral surface slightly concave to peristome, which distinctly depressed, and posterior half of sternum slightly convex.

Apical system eccentric in front, situated at about 5 mm from anterior margin, rather small, may be ethmophract, and there may be four genital pores.

Frontal ambulacrum (III) in a deep groove; subpetaloid area rather small, about 1.5 mm wide and 4 mm long; ambulacral plates rather low, pores of pairs small and round, arranged in regular series; there are about 20 pore-pairs in each column. Antero-lateral subpetals (II and IV) rather long and broad, about 8 mm long and 2 mm wide at middle of petals; they diverge each other at first about 140° and near distal end of subpetals slightly curved backwardly; subpetals more or less depressed; pores of pairs small and round, rather distant, there are about 25 pore-pairs in each column; interporiferous zone very narrow. Postero-lateral subpetals (I and V) short, about 4 mm long and 2 mm wide at middle of subpetals, more or less depressed and slightly



Fig. 65 [40]. Cottreaucorys (Cordastrum) sulcatus NISIYAMA, n. sp., $\times 2.6$. a. Aboral view of holotype; b. Oral of the same; c. Side view of the same.
curved inwardly; pores of pairs small, round, and rather distant, there are about 18 pore-pairs in each column; interporiferous zone very narrow.

Peristome eccentric in front, situated at about 7 mm from anterior margin, rather small, about 2 mm wide and 1.5 mm high, pentagonal in outline, depressed; no phyllodes. Sternum rather narrow, 6 mm wide at broadest point, but convex at its posterior part. Periproct small, about 0.5 mm wide and 0.8 mm high, situated at supramarginal, oval in outline, longitudinally placed.

Labrum narrow and long, about 1.5 mm wide and 3 mm long; following second plates in pair broad and long, about 4.5 mm high and 2.2 mm wide on each side, 3rd plates broad and short, about 2 mm high and 3 mm wide on each side, 4th and 5th plates contracted posteriorly and merge into ambital margin on both sides. Arrangement of interambulacral plates on oral surface seems to be rather regular, and interambulacral plates much wider than adjoining ambulacral plates; postero-lateral ambulacra (I and V) one-fourth or one-fifth as broad as postero-lateral interambulacra (1 and 4). Preserved part of a peripetalous fasciole distinct but rather narrow, being apparently well circumscribing all subpetals. Tubercles not well preserved.

Distinction.—This new species resembles *Cottreaucorys blayaci* (COTTREAU, 1910) (loc. cit.) in elongate test and rostrate posterior part, but is easily distinguished from that species in having wider and deeper anterior groove, somewhat depressed paired subpetals, the lower ambulacral plates, supramarginal position of the periproct, and in having shorter labrum and wider sternal plates.

It is a very interesting fact that this curious echinoid, which in the general shape recalls the Maastrichtian species, *Cott. blayaci* of Algeria, occurred in the upper Cretaceous (Senonian) of Japan. The two regions, Algeria and Japan, are quite remoteand there is no record of occurrence of allied forms in intermediate region. The Japanese form seems to be more or less older or almost equal in the geological agethan the Algerian form, but the deeper frontal groove and the depressed subpetals of the former indicate that it is more specialized than the latter. But that the structure of plastron in both forms does not at once decide whether the former is more specialized or the latter is. The find of this Japanese form puts forward a problem on echinoid evolution and taxonomy.

Family TOXASTERIDAE LAMBERT, 1920

Toxasteridae LAMBERT, 1920-b, p. 16 (158) (subfamily).—LAMBERT and THIÉRY, 1924, p. 435.— MORTENSEN, 1950-a, p. 337. Theorem and Thiery, 1940

Type-genus.—Toxaster AGASSIZ, 1840.

Peristome usually transverse or more or less subpentagonal; labrum more or less distinctly developed. Ambulacra more or less petaloid adapically; frontal ambulacrum (III) in a shallow or more or less deep groove; paired subpetals (or petals) flush with test or more or less sunken and flexuous; pore-pairs usually unequal. Apical system ethmophract, with four genital pores. Tubercles small, perforate and crenulate. Usually adetes (no fascioles).

From the upper Jurassic to Cretaceous (Senonian), rarely to Recent (*Isopatagus* MORTENSEN, 1948).

The family Toxasteridae are characterized generally by the absence of fascioles, and it indicates the family as primitive member of the Spatangoina. This is in accordance with their occurrence in the oldest geological time (as old as the upper Jurassic) among the Spatangoina. On the other hand the traces of "multiple narrow fasciolepseudomarinal fasciole" appeared in the species of *Washitaster* or *Heteraster*. The genus (or subgenus) *Washitaster* was referred by MORTENSEN, (1951, p. 202) to the family Pericosmidae on account of possessing this fasciole, but it is now evident that it closely relates to *Heteraster* of the family Toxasteridae. As for the derivation of the family Toxasteridae, there is no fully assured suggestion that indicating the source from which they are derived.

To the family Toxasteridae LAMBERT and THIÉRY (1924, pp. 435-438) referred the following fossil genera, Toxaster AGASSIZ, 1840 (with subgenera Miotoxaster POMEL, 1883 and Pliotoxaster FOURTAU, 1907), Aphelaster LAMBERT, 1920, Heteraster D'ORBIGNY, 1853, and Enallopneustes POMEL, 1883. As for these genera it seems highly probable that Toxaster, Aphelaster, and Heteraster form a natural group and the centre of the family, but Enallopneustes differs from the typical ones by the feature of petals and having a distinct marginal fasciole. To this family MORTENSEN (1950-a, pp. 340-360) referred the following fossil genera, Toxaster, Isomicraster, Isaster, Aphelaster, Mokotibaster, Heteraster, Miotoxaster, Palmeraster, and Epiaster, and a Recent genus Isopatagus. The last genus is established by MORTENSEN (1948-b, p. 113) and referred to the family Micrasteridae, but it is referred by himself (MORTENSEN, 1950-a, p. 339) to this family on account of the total absence of fascioles; by the same reason MORTENSEN (1950-a, loc. cit.) transferred such genera, Isomicraster LAMBERT, 1901, Isaster DESOR, 1858, and Epiaster D'ORBIGNY of the family Micrasteridae in usage of LAMBERT and THIERY, to the family Toxasteridae. To this family the writer further refers two fossil genera from Japan, the Allotoxaster and Paraheteraster; the former resembles the genus Aphelaster and the latter recalls Heteraster.

The important genera of the family Toxasteridae are discriminated from one another as shown by the following key.

Key to the important genera of the family Toxasteridae.

1.	Frontal ambulacrum (III) in the main likes the paired petals 2
	Frontal ambulacrum (III) different from the paired petals 6
2.	A distinct frontal depression 3
	No, or at most a very indistinct, frontal depression 4
3.	Apical system somewhat posterior Toxaster
	Apical system centralIsomicraster
4.	Petals long, continuing to the edge of the test 5
	Petals short, not continuing to the edge of the test Isaster
5.	Forms of circular outline; edge of test rather sharp; no frontal depression
	Aphelaster
	Forms of oval outline; edge of test round and thick; frontal depression more or
	less large Allotoxaster
6.	Pores of frontal ambulacrum (III) alternatingly small, round, and elongate slits7

7.

8.

Genus Toxaster AGASSIZ, 1840

Toxaster Agassiz, 1840-a, p. 15.—Desor, 1855-58 (58), p. 350 (pro parte).—Pomel, 1883, p. 43.—Savin, 1903, p. 81.—Lambert, 1920-a, pp. 5, 29.—Lambert and Thiéry, 1924, p. 435.—Mortensen, 1950-a, p. 340 (complete synonymy).—Cooke, 1955, p. 99.

Logotype.—Toxaster retusus (LAMARCK): COTTEAU, 1857-78, p. 117, pl. 61, figs. 1-6 (Hauterivian of France).—LAMBERT, 1920-a, p. 6. [POMEL, 1883, p. 44].

Echinospatangus [BREYNIUS] D'ORBIGNY, 1853-55 (53), pp. 30, 149, 151 (Echinospatangus BREYNIUS, 1732—pre-Linnean).—LORIOL, 1873, p. 340.—WRIGHT, 1864-1882 (74, 78), pp. 192, 280.—DUNCAN, 1889-a, p. 219.

Type-species.—Echinospatangus cordiformis BREYNIUS: D'ORBIGNY, 1853-55, p. 155, pl. 80.= Toxaster retusus (LAMARCK): LAMBERT, 1920-a, p. 6.

Test of small to medium size, generally oval in marginal outline, in general rather low, truncate posteriorly. Frontal ambulacrum (III) broad, but not deep, and not sharply limited; pores more or less elongate slits. Paired petals long, somewhat flexuous, open distally; pores elongate slits. Interporiferous zones tuberculated. No fascioles. Apical system somewhat posterior, ethmophract, with four genital pores. Periproct on truncate posterior end. Peristome anterior, subpentagonal, without prominent lip.

The Cretaceous (Valanginian-Cenomanian, or Senonian) of the circum-Mediterranean countries and North America.

This primitive genus differs from *Isomicraster* (LAMBERT, 1901, p. 595.—*Orthotype.*— *Isomicraster stolleyi* LAMBERT, 1901, p. 959.—*Epiaster gibbus*: SCHLÜTER, 1869, pl. 2, fig. 1) in the position of the apical system, and comprises numerous species from the Cretaceous System.

Toxaster sanchuensis TANAKA, 1965

Toxaster sanchuensis TANAKA, 1965, p. 131, pl. 15, figs. 5a-b, 6a-b, pl. 16, figs. 1a-c, 2a-c, text-figs. 3a-c.

No specimens of this species are available for study. TANAKA (1965, pp. 132-133) reported this species from the following localities and geological horizons.

Locality and geological horizon.-About 800 metres northwest of Sebayashi, Naka-

zato-mura, Tano-gun, Gumma Prefecture. Lower part of Ishido formation, Neocomian. Locality and geological horizon.—About 600 metres north of Shiroi, Ueno-mura, Tano-gun, Gumma Prefecture. Lower part of Ishido formation, Neocomian.

Locality and geological horizon.—About 2.5 kilometres northwest of Shiroi, Uenomura, Tano-gun, Gumma Prefecture. Lower part of Ishido formation, Neocomian. Holotype (GSJ 6124), paratypes (GSJ 6110-6113).

Locality and geological horizon.-Upper course of the Honya, Minami-Maki-machi, Shigaraki-gun, Gumma Prefecture. Lower part of Ishido formation, Neocomian.

This species resembles *Tox. peroni* LAMBERT, 1920 (*Tox. peroni* LAMBERT, 1920-b, p. 18, pl. 2, fig. 6), from the Neocomian of Morocco, in the features of pore-pairs in the frontal ambulacrum (III) and the depressed paired ambulacra, but differs from that species in having the much narrower petals. *Tox. sanchuensis* also resembles *Tox. gibbus* AGASSIZ (D'ORBIGNY, 1853-55, p. 160, pl. 841), from the Barremian and Aptian of the circum-Mediterranean region, but differs from that species in having the shorter petals. This species is similar to *Tox. collegnoi* SISMONDA (D'ORBIGNY, 1853-55, p. 169, pl. 846.—*Pliotoxaster collegnoi* (SISMONDA) LAMBERT and THIÉRY, 1924, p. 437), from the Aptian of the circum-Mediterranean region, but differs from that species in having the narrower anterior sulcus and less flexuous antero-lateral petals. This species seems to have close relation to the above mentioned species from the circum-Mediterranean region.

Genus Aphelaster LAMBERT, 1920

Aphelaster LAMBERT, 1920, p. 9.—LAMBERT, 1920-a, p. 22.—LAMBERT, 1920-b, p. 14.—LAMBERT and THIÉRY, 1924, p. 437.—MORTENSEN, 1950-a, p. 355.—TANAKA and SHIBATA, 1961, p. 69. Orthotype.—Aphelaster integer [GAUTHIER MS] LAMBERT, 1920, p. 9, pl. 3, figs. 1a-c (Hauterivian of South France).

Forms of moderate size, of circular outline. Test subconical, with flat oral side; no frontal depression, and posterior end not truncate; edge of test rather sharp and thin. Ambulacra petaloid, all alike; petals long and continuing to edge of test; pores transversely elongate; frontal ambulacrum (III) somewhat narrower than paired ones. No fascioles. Apical system central, compact, ocular IV proceeding inwards so as to meet the madreporite, thus separating genitals 3 and 4; genital pores four. Periproct just a little above margin of test; peristome subpentagonal, anterior. Plastron amphisternous; sternal plates small in number.

Lower Cretaceous of South Europe and Japan.

This peculiar genus is characterized, in the main, by having the test circular in outline and the primitive feature in the apical system, in which the genitals 3 and 4 separated by the prolonged ocular IV. The primitive feature of the apical system as such is also represented by *Toxaster* (*Eotoxaster*) africanus (COQUAND) and its allied species, but *Aphelaster* is distinguished from those forms by the marginal outline of test and feature of petals that equally developed.

There is a characteristic species of the genus, besides the type-species, from the Japanese Cretaceous.

Aphelaster serotinus TANAKA and SHIBATA, 1961

Aphelaster serotinus Tanaka and Shibata, 1961, p. 70, pl. 10, figs. 1-6, text-figs. 1-2.—Tanaka, 1965, p. 133.—Nisiyama, 1965, p. 80.

No specimens of this species are available for study. TANAKA and SHIBATA (1961, pp. 71-72) and TANAKA (1965, p. 133) reported this species from the following localities and geological horizons.

Locality and geological horizon.—Ishido, Saku-machi, Minami-Saku-gun, Nagano Prefecture. Lower part of Ishido formation, Neocomian. Holotype (GSJ 6092), paratypes (GSJ 6063, 6095).

Locality and geological horizon.—About 800 metres southeast of Yoshikawa, Tasukawa-mura, Arita-gun, Wakayama Prefecture. Arita formation, Barremian. Paratype (GSJ 6010).

Locality and geological horizon.—Suhara Pass, north of Yuasa-machi, Arita-gun, Wakayama Prefecture. Arita formation, Barremian. Paratype (GSJ 6038).

Locality and geological horizon.-Tasukawa, Katsura-machi, Katsura-gun, Tokushima Prefecture. Hanoura formation, Barremian.

This species is characterized by having the peculiar shape of pores of pairs, i.e., the outer pore more or less elongate but wider and rounded at its both ends while narrower in the middle part, the inner elongated uniform in width and its inner end bent towards abapically in the middle of the petal (TANAKA and SHIBATA, 1961, text-fig. 2 on p. 71), the anteriorly eccentric peristome, and the interporiferous zones of paired ambulacra being dotted with a longitudinal series of tubercles. This species differs from *Aph. integer* (loc. cit.) in having the less flexuous paired ambulacra and more petaloid all the ambulacra.

As for the oral features of this species TANAKA and SHIBATA (1961, p. 70) only shortly mentioned on the peristome and plastron. It is observable, however, from their good illustrations of oral side (Pl. 10, figs. 1b, 2b, and 4b), that the labrum is short and narrow, probably 4 mm long and 2 mm wide, and slightly emarginate; sternal plates gradually widened toward the posterior margin and symmetrical in size on both sides; the following second plates in a pair measure about 5 mm wide and 5 mm long, the 3rd plates in a pair about 13 mm long and 13 mm wide, 4th plates in a pair about .5 mm long and 17 mm wide, and 5th plates in a pair 18 mm wide. Phyllodes seem to be more or less well developed, with less than 5 pencillate tube-feet in the each series on the antero-lateral ambulacra (II and IV).

This species may be regarded as more specialized than the type-species of the Hauterivian as may be expected of a later representative (the Barremian) of this genus. TANAKA and SHIBATA (1961, p. 71) stated that the specimens of this species were always obtained from a muddy facies and that the fact may indicate that it lived in muddy layers on the sea-floor.

Genus Allotoxaster NISIYAMA, n. gen.

Allotoxaster NISIYAMA (MS), 1954, p. 330 (in Japanese).

Type-species.—Toxaster tosaensis LORIOL, 1902-a, p. 36, pl. 3, fig. 7 (Torinosu Limestone of Sakawa, Kôchi Prefecture).

S. NISIYAMA

Small sized form in the main oval outline, anterior part wide and posterior one narrow; test high, obliquely truncate anteriorly; frontal depression broad, but slightly depressed on anterior margin; oral surface convex, especially plastron inflated; margin of test round and thick. Ambulacra subpetaloid adapically, nearly flush on aboral surface; subpetals more or less unequal, poriferous zones more or less depressed; subpetals long, open distally, and continuing to edge of test, with pores oval or more or less elongate. No fascioles. Apical system central, ethmophract?. Peristome small, non-emarginate, and eccentric in anterior. Periproct oval, acuminate on posterior extremity. Plastron amphisternous?. Tubercles and radioles unknown. Upper Jurassic (Callovian-Tithonian) of Japan.

The type-species of this genus was originally referred to the genus *Toxaster* (loc. cit.), but the frontal depression of that genus broader and deeper, the paired petals are distinctly flexuous, the ambulacral pores elongated slit-like, and the apical system posterior in the latter while it is central in the former; only one feature, however, in common with the both genera that having no fascioles. Thus the type-species, *Tox. tosaensis*, cannot be referred to genus *Toxaster*, but should be referred to the other genus on account of the features as described above.

LAMBERT and THIÉRY (1924, p. 437) referred Tox. tosaensis to the genus Aphelaster (loc. cit.). As to this assignment, MORTENSEN (1950-a, p. 355) stated that this species was referred to Aphelaster in consideration of all petals resemblance, but the species tolerably differs from Aph. integer although the structure of the apical system is unknown; and in such circumstances, MORTENSEN persisted that it is too soon to include Tox. tosaensis in Aphelaster as LAMBERT and THIÉRY did. The Japanese species conspicuously differs from Aph. integer in the features, i.e., the frontal depression is broader and more or less deeper in the Japanese species while in that species there is no frontal depression and the petals are all alike in the latter and more or less. unequal in the former, and also the structure and location of the peristome of the former are much differ from those of the latter. It is very unfortunate that the structure of the apical system of the Japanese species is unknown, whereas its structure characterized the genus Aphelaster. Tox. tosaensis also cannot be referred to the genus Aphelaster. TANAKA and SHIBATA (1961, p. 70) stated that they consider that Tox. tosaensis should be removed from Aphelaster approving of MORTENSEN's and NISIYAMA'S opinions.

A only representative of this genus was reported from the upper Jurassic system of Japan.

Allotoxaster tosaensis (LORIOL, 1902)

Toxaster tosaensis LORIOL, 1902-a, p. 36. pl. 3, fig. 7.—TOKUNAGA, 1903, p. 18.—Aphelaster tosaensis (LORIOL) LAMBERT and THIÉRY, 1924, p. 437.—AOKI (NOW NISIYAMA), 1933, text-figs. 63a-c (reproduced from LORIOL, 1902).—'Aphelaster' tosaensis (LORIOL): MOR-TENSEN, 1950-a, p. 355.—'Allotoxaster' tosaensis (LORIOL) NISIYAMA, 1954, text-figs. 384a-c on p. 330 (reproduced from LORIOL, 1902).—TANAKA and SHIBATA, 1961, p. 70.— NISIYAMA, 1965, p. 80.

No specimens of this species are available for study. This species is reported from the Torinosu Limestone at Torinosu, Sakawa-machi Kôchi Prefecture.

This is a rather small sized and globular form, it measures about 35 mm in longitudinal diameter, about 32 mm in transverse diameter, and about 20 mm in height. LORIOL (1902-a, p. 36) compared this species with *Tox. subcavatus* (GAUTHIER) (COULON, 1894, p. 69, pl. 4, figs. 11-12), from the Neocomian of Algeria, but distinguished from that species by having the less depressed ambulacra and smaller eccentricity to anterior of peristome.

LAMBERT and THIÉRY (1924, p. 437) referred this species to the genus *Aphelaster* with a mention, but without any note on its assignment, as—" Autre espèce: *A. tosaensis* DE LORIOL (*Toxaster*) du Cretace du Japon, 864, p. 36, pl. 3, fig. 7", and hence it is very hard to find the responsibility of this generic reference. As for this assignment of the species, MORTENSEN (1950-a, p. 355) stated that " It differs, however, quite considerably in the shape (frontal depression is larger) from the genotype (type-species), and its apical system is unknown (the specimen is an internal mould); it is thus only the fact that the petals are all alike that indicates its possible relation to *Aphelaster*." There are no positive data for the reference of this species to the genus *Aphelaster*. The genus *Aphelaster* (from the Hauterivian) seems to be a small side-branch of the family Toxasteridae, and it has undergone a specialization of the apical system, which characterized the genus, but rather has retarded in the development of the frontal groove and the location of the peristome.

This species seems to be the oldest representative of the family Toxasteridae, and it seems less specialized than the typical *Toxaster* (from the Valanginian) in the general features. These less specialized features are found in the slight depression of the frontal groove, all alike and straight petals, and in the oval ambulacral pores and the central position of the apical system; these features contrast to the specialized features of the typical *Toxaster*, which are found in the broader and deeper depression of the frontal groove, the paired petals are flexuous, the elongate slit-like ambulacral pores and in the posteriorly eccentric position of the apical system. It may be considered that *All. tosaensis* should be separated from the both *Toxaster* and *Aphelaster* as a distinct form, and furthermore it seems to fit well the geological sequence.

Genus Heteraster D'ORBIGNY, 1853

- Heteraster D'ORBIGNY, 1853-55 (53), p. 175.—DESOR, 1855-58 (58), p. 355.—LORIOL, 1873, p. 354 (with Enallaster D'ORBIGNY, 1853).—DUNCAN, 1889-a, p. 220 (with Enallaster).—LAMBERT and THIÉRY, 1924, p. 437 (with Enallaster).—NISIYAMA, 1950, p. 42 (with Enallaster).—MORTENSEN, 1950-a, p. 246 (with Enallaster).—COOKE, 1955, p. 100.
 - Type-species.—Spatangus oblongus BRONGNIART, 1821, p. 555, pl. 7, figs. A, B, C.—Heteraster oblongus (BRONGNIART) D'ORBIGNY, 1853-55 (53), p. 176, pl. 847 (Aptian-Albian of France).—DEVRIÈS, 1954, text-figs. 1a-d on p. 40.
- Enallaster D'ORBIGNY, 1853-55 (53), p. 181.—DESOR, 1855-58 (58), p. 357.—POMEL, 1883, p. 44.— Сооке, 1946, p. 230 (with Heteraster).—Тамака and Окиво, 1954, p. 221.—Сооке, 1955, p. 101.
 - Type-species.—Hemipneustes greenovi FORBES, 1852-b, pl. 5.—WRIGHT, 1864-82 (78), p. 290, pl. 64, figs. 2a-f, 3a-d (Blackdown, Devonshire; Gault or upper Greensand, Albian-Cenomanian).

Small to medium sized forms of in the main oval outline; test in general rather low, truncate posteriorly. Frontal depression broad, but not deep, and not, or more or less, sharply limited; the pore-pairs irregular, composed of two types, the larger type of the round or oval and the outer pore slit-like and it more or less placed obliquely to the suture set in primary plate and smaller type set in demi-plate of round or oval pore-pair. Paired petals usually long, almost flush with the test, somewhat flexuous, open distally; the pores more or less elongate and partly irregular as in the frontal ambulacrum (III); interporiferous zones tuberculated. No fascioles. Apical system somewhat posterior, usually ethmophract or tends to become ethymolitic, with four genital pores. Periproct on the truncate posterior end. Peristome anterior, subpentagonal, without a prominent lip.

From the lower Cretaceous (Barremian to Cenomanian) of the circum-Mediterranean countries, Asia, and America.

This genus differs from the related genus *Toxaster* in the character of the ambulacral pores, i.e., in this genus the pore-pairs are irregular, the larger type of the inner pore round or oval and the outer pore slit-like, being placed more or less obliquely to the suture set in primary plate, and smaller type set in demi-plate, but in that genus the pores been elongate oval or slit-like and arranged regularly.

The systematic rank of *Enallaster* has been much disputed. D'ORBIGNY (1853-55 (53), feuille 11, p. 175, pls. 847, 848) established *Heteraster* and meanwhile he also proposed the genus *Enallaster* (1853-55 (53), feuille 12, p. 181, pl. 849) because of the supposed difference in the character of the frontal ambulacral pores of these two forms. LORIOL (1873, p. 354) regarded that the feature and arrangement of frontal ambulacral pores in the *Heteraster* are the extreme case and an aberrant condition in the *Enallaster* and combined *Enallaster* with *Heteraster*. This procedure is followed by DUNCAN (1889-a, p. 220) and others. LAMBERT and THIÉRY (1924, p. 437) united the two names into one genus and they prefer the name *Heteraster* as a valid name on account of



Fig. 66 [41]. Ambulacral structure of ambulacra (III) and (IV) of *Heteraster oblongus* (BRONGNIART, 1821) (enlarged), (after HAWKINS, 1920).

the preceding page when published; this is followed by MORTENSEN (1950-a, p. 246) and others. COOKE (1946, p. 230) prefers the name Enallaster and distinction between the *Enallaster* and *Heteraster* may be considered as only a subgeneric level. TANAKA and OKUBO (1955, p. 221) follow COOKE's, and the feature and arrangement of the frontal ambulacral pores in *Heteraster* are the specialized and extreme case of those in *Enallaster*, and vice versa; but they seem to prefer the name Enallaster. COOKE (1955, p. 100) separated Heteraster from Enallaster based on the differences in the apical system, the ambulacral pores in the frontal ambulacrum, and in the postero-lateral petals between them, and he regarded that these differences may be important enough to justify the retention of Heteraster and Enallaster as separate genera or at least subgenera.

The original figure of ambulacral pores in the

frontal ambulacrum (III) of Het. oblongus given by D'ORBIGNY (1853, pl. 847) is more or less inaccurate. From that figure we can only state that the pore-pairs are irregular, the inner pores are round or oval, but the outer pores transversely slit-like, and of varying length. Thus they differ at glance from those in the frontal ambulacrum of Enal. greenovi (WRIGHT, 1878, pl. 64, figs. 2a-f), and this difference causes some authors being hesitation to accept the identify of Enallaster with Heteraster, otherwise the two species are much alike in the generic characters. The true nature of the pore-pairs in the frontal ambulacrum (III) and in the antero-lateral petals (II and IV) of Het. oblongus is noticed by HAWKINS (1920, p. 479, pl. 69, fig. 2) (reproduced here, text-fig. 66 [41]), and DEVRIÈS (1954, pp. 343-345, figs. a-d) clearly shows its nature and well illustrated after a careful observation on well preserved specimens of this species from the Aptian of Algeria. The pore-pairs in the frontal ambulacrum, according to DEVRIÈS figures and description, are composed of two types; three or two pairs of pores are normal (or larger) type in this species, that the inner pore of round or oval and the outer pore of slit-like and more or less placed obliquely to the suture, and intercalate a pair of "abnormal" (or smaller) type, which is oval or round or not so transversely elongated and its outer pore placed inner (or in other words, nearer to the perradial suture) side than the outer pore of the normal (or larger) type. The plate composed of this "abnormal" (or smaller) type does not extend to the adradial suture, i. e., the demi-plate, against the primary plates composed of the normal type of pore-pairs. This feature of ambulacral pores is also found in Toxaster villei (DEVRIÉS, 1955, text-fig. 1e on p. 40). The distinction of *Enallaster* from *Heteraster* by the differences of pore-pairs in the frontal ambulacrum seems to be not so large that the two entitled the separate generic ranks, as expected from the distinction by the original figures of Het. oblongus and Enal. greenovi. In some species of "Enallaster" the pairs of slit-like pores placed more or less or slightly "en chervon" type as those of paired petals of Cardiaster (loc. cit.), and more or less or slightly oblique to transverse suture of the plates. This slight obliquity of outer slit-like pores of pore-pairs is also found in the frontal ambulacral pores of Heteraster. TANAKA (1965, p. 133) united Heteraster with Enallaster, to which the writer agrees under the circumferences as described above.

Distinction of the species under a genus by the differences of the frontal ambulacral pores may be found in the genus *Paraster*, in which *Par. gibberulus* with the pores of frontal ambulacrum placed obliquely to the ambulacral suture, and the other species *Par. compactus* with the pores not placed obliquely but nearly horizontal, while the two species being otherwise much alike in other characters, e. g., the globiferous pedicellariae with terminal opening surrounded by a member of short teeth in both species. In the genus *Heteraster*, if each species with a definite alternation type of the frontal ambulacral pores, which are smaller, round or oval, and larger, transversely elongate or slit-like, and they were different from each species, it should be regarded as a criterion of the specific distinction. This alternation of type may be simply formularized as follows—the number of the larger type, the pairs of elongate or slit-like pores, is represented by the Roman numeral and that of smaller type, the pairs of small and round pores, is represented by the Arabian numeral, and further the numerals are expressed in the form of ratio, as II: 1, it means that a pair of smaller type situates among the two sets of larger type. Thus the species with the alternation type of III:1 is clearly discriminated from a species with alternation type of I:1, notwithstanding some irregularities are found throughout the whole length of the frontal ambulacrum (III).

This genus (with *Enallaster*) dates back to the Barremian and ranges to the Cenomanian, and comprising no less than twenty species from widely separated countries. No less than three species of this genus are known to the Japanese Cretaceous System.

Heteraster nexilis NISIYAMA, 1950

Heteraster nexilis NISIYAMA, 1950, p. 42, text-figs. 1-3.—Enallaster cf. nexilis (NISIYAMA) TANAKA and Okubo, 1954, p. 224, pl. 7, fig. 8.—Heteraster cf. nexilis NISIYAMA: TANAKA, 1965, p. 135, pl. 16, fig. 5, text-fig. 5.—Heteraster (Enallaster) nexilis NISIYAMA: NISIYAMA, 1965, p. 80.

Holotype.—IGPS coll. cat. no. 72979.

Locality and geological horizon.—IGPS loc. no. Tk-1.—Cliff along the River Naka, about 800 metres west of Komo, Hanoura-machi, Naka-gun, Tokushima Prefecture (tm Awa-Tokushima, Lat. 33°56′30″N., Long. 134°35′16″E.). Hanoura formation, Barremien. NISIYAMA, 1950, p. 42 and MATSUMOTO, 1953, p. 82.

Locality and geological horizon.—IGPS loc. no. Wa-1.—Cliff 200 metres north of the bridge on main road, and about 700 metres southwest of Yoshikawa, Tasukawamura, Arita-gun, Wakayama Prefecture (tm Kainan, Lat. 34°02′30″N., Long. 136°11′ 24″E.). Arita formation, Barremian. MATSUMOTO, 1953, p. 75 and TANAKA and OKUBO, 1954, p. 222.

Locality and geological horizon (after TANAKA, 1965).—About 800 metres northwest of Sebayashi, Nakazato-mura, Tano-gun, Gumma Prefecture. Lower part of Ishido formation, Neocomian (GSJ 6127).

Locality and geological horizon (after TANAKA, 1965).—Ishido, Saku-machi, Minami-Saku-gun, Nagano Prefecture. Lower part of Ishido formation, Neocomian (GSJ 6105).

This species is similar to *Het. obliquatus* (W. B. CLARK, 1893, p. 89, pl. 40, figs. 1a-1), a Trinity species of Texas, in outline of test and position of the apical system, but is distinguished from that species in narrower anterior sulcus and the type of alternation of pore-pairs in the frontal ambulacrum, and in having longer posterolateral petals (I and V). This species is characterized by having the irregularity of alternation type of pore-pairs in the frontal ambulacrum, i.e., in proximally I:1, proximally to middle II:1 to III:1, and middle to distally III:1 to II:1, while in *H. obliquatus* it is a regular type of I:1, and pores of smaller type divided by a small bead. TANAKA (1965, p. 136, text-fig. 5) made clear that the apical system is ethmophract and the posterior genitals (1 and 4) are broadly in contact, while in *Het. obliquatus* the posterior genitals nearly separated by the madreporite.

Heteraster yuasensis (TANAKA and OKUBO, 1954)

Enallaster yuasensis TANAKA and OKUBO, 1954, p. 223, pl. 7, fig. 6.—Heteraster yuasensis (TANAKA and OKUBO) TANAKA, 1965, p. 136, pl. 16, figs. 6a-c, 7, text-figs. 6a-d.—Heteraster (Enallaster) yuasensis (TANAKA and OKUBO) NISIYAMA, 1965, p. 80. Locality and geological horizon (after TANAKA and OKUBO, 1954).—Southeast of Yoshikawa, Tasukawa-mura, Arita-gun, Wakayama Prefecture. Arita formation, Barremian. Holotype (GSJ 6007).

Locality and geological horizon (after TANAKA and OKUBO, 1954).—East of Subara, Tasukawa-mura, Arita-gun, Wakayama Prefecture. Arita formation, Barremian.

Locality and geological horizon (after TANAKA, 1965).—About 800 metres northwest of Sebayashi, Nakazato-mura, Tano-gun, Gumma Prefecture. Lower part of Ishido formation, Neocomian (GSJ 6127).

Locality and geological horizon (after TANAKA, 1965).—Ishido, Minami-Saku-gun, Nagano Prefecture. Lower part of Ishido formation, Neocomian (GSJ 6105).

There is no authentic specimen referable to this species at the writer's disposal. This species may be characterized by having the broad test, the indistinct frontal indentation, the shallow and narrow frontal ambulacral groove, in the type of alternation of the frontal ambulacral pores and the pore-pairs of paired petals. The type of alternation is I:1 at the middle of the frontal ambulacrum, but varies proximally and distally; these slit-like pores set slightly "en chevron" and slightly oblique to transverse suture of the plate. The labrum is slightly emarginate and the sternal plates are nearly symmetrical, equal in size and shape as in *Aphelaster serotnus* (loc. cit.). It may be a distinct species among *Heteraster*, and it is desirable to investigate on much more complete and numerous specimens in future.

Heteraster cf. obliquatus (CLARK, 1893)

Enallaster cfr. obliquatus CLARK: TANAKA and OKUBO, 1954, p. 223, pl. 7, fig. 5.

No specimens of this species are available for study. TANAKA and OKUBO (1954, p. 223) reported this species from the following localities and geological horizons.

Locality and geological horizon.—Southwest of Obara, Kawamata-mura, Yatsushirogun, Kumamoto Prefecture. Yatsushiro formation, Albian.

Locality and geological horizon.—East of Suhara, Tasukawa-mura, Arita-gun, Wakayama Prefecture. Arita formation, Barremian.

The two authors compared this species with *Het. obliquatus* (CLARK, 1893) (*Enallaster obliquatus* CLARK, 1893, p. 79, pl. 40, figs. 1a-1.—COOKE, 1955, p. 102, pl. 25, figs. 7-13), from the Trinity group of Texas, but more or less differs in more elongate test and more slit-like ambulacral pores of the frontal ambulacrum. The type of alternation and shape of pore-pairs in the frontal ambulacrum of this conferred species are akin to *Het. yuasensis*, but differ from that species in having the longer frontal groove that attaining to the frontal margin of test. The figures (TANAKA and OKUBO, 1954, pl. 7, figs. 5a-b) of their specimen are not in good state, the more detail observations need for well preserved specimens.

Heteraster cf. boehmi (LORIOL, 1904)

Enallaster cf. böhmi LORIOL: TANAKA and OKUBO, 1954, p. 224, pl. 7, fig. 7.

No specimens of this species are available for study. TANAKA and OKUBO (1954, p. 224) reported this species from the following localities and geological horizons.

Locality and geological horizon.—East of Subara, Tasukawa-mura, Arita-gun, Wakayama Prefecture. Arita formation, Barremian.

Locality and geological horizon.—Southwest of Obara, Kawamata-mura, Yatsushiro-gun, Kumamoto Prefecture. Yatsushiro formation, Albian.

The original description of *Het. boehmi* has appeared in the "LORIOL, 1904, p. 49, pl. 4, figs. 7-10" on the specimens from the lower Cretaceous (exact stage unknown to the writer, probably Albian) of Honduras. The specimens of TANAKA and OKUBO are more or less deformed by the subsequent disfigurement; however, it may be assumed that this conferred species is characterized by having the II:1 type of alternation of the frontal ambulacral pores and the depressed paired petals. It is much desirable to investigate on new and well preserved specimens.

It is very interesting fact that the two Albian or rather Aptian species, *Het. obliquatus* and *H. boehmi*, from Texas, U.S.A. and Honduras, are in common with, though their identification is not strictly accurate, the Barremian series of Japan. If their identification would be correct, it offers an interesting problem that concerning on the evolution and migration of the echinoid fauna, i.e., the two regions are so separate and the Japanese species are obviously older occurrence than the American ones in geological age.

Genus Paraheteraster NISIYAMA, n. gen.

Type-species.—Washitaster? macroholcus NISIYAMA, 1950, p. 44, text-figs. 4-6.—TANAKA and Okubo, 1954, p. 221, pl. 7, figs. 1a-1c, 2 (Arita formation of Wakayama Prefecture).

Test rather low, less than half the test-length, of elongate oval or elliptical outline, but with a conspicuous frontal groove; posterior end rather truncate. Vertex at near the posterior end. Frontal ambulacrum (III) deeply and conspicuously sunken, sharply limited, often biconvex and with the sides nearly straight; pores of pairs small, numerous, sometimes up to 90 pore-pairs on each side, without a peduncular granule, generally arranged in two series, but often being irregularly alternatingly small and close, round and elongate, and large oval and slit-like, wider pairs. Antero-lateral ambulacra (II and IV) long, subpetals flexuous, widely open distally, scarcely sunken; pore-zones more or less unequal, the anterior series somewhat rudimentary, with small, round or elongate pores, the posterior series with outer pores transversely elongate; pore-pairs numerous, up to 60 on each series. Postero-lateral ambulacra (I and V) much shorter than the antero-lateral ones, the subpetals with both pore-series alike those of the antero-laterals, the outer pores more or less transversely elongate. Apical system small, depressed, greatly eccentric in posterior, ethmophract, with four genital pores. Periproct oval, high up on the rather truncated posterior end. Peristome anterior, small, transversely oval, lies in the recurved end of the frontal groove; labrum slightly emarginate; plastron amphisternous, sternal plates nearly symmetrical, equal in size and shape. Small sunken scrobicules and numerous microscopic granules. Marginal (or peripetalous) fasciole (pseudomarginal fasciole of COOKE) (in one species, Par. barremicus) slender and multiple.

Lower Cretaceous (from the Barremian to Albian) of Japan.

This genus is closely related to the genus Washitaster (LAMBERT, 1927, p. 271.-

Orthotype.—Hemiaster riovistae ADKINS, 1920, p. 115, pl. 6, fig. 4, pl. 8, figs. 2-3, 5.— Weno formation; Riovista, Texas), in the form of test, position and mode of the apical system, form of the petals and in the position of the periproct, and particularly in the deep and conspicuously sunken frontal groove. In the type-species (COOKE, 1955, pl. 26, figs. 10-13, in USNM-the writer examined it) of Washitaster, which was referred by MORTENSEN (1951, p. 202) to the family Pericosmidae as incertae sedis, the pores of the frontal ambulacrum (III) of the same regular shape throughout, obliquely placed to the suture of plates, round, separated by a peduncular granule (or bead); while in *Paraheteraster* the pores are not separated by a bead and often being irregularly alternatingly small, close, and large wider pairs. Washitaster is also characterized by having multiple granular bands or pseudomarginal fasciole; because of having this fasciole Enallaster bravoensis (BÖSE, 1910, p. 168, pl. 41, figs. 5-10, pl. 42, figs. 2-12, pl. 43, figs. 1-2, 6-7) is assigned to Washitaster, and in this species (COOKE, 1955, pl. 27, figs. 5-12, in USNM-the writer examined it) the pores of the frontal ambulacrum are alternation of II:1 type at the middle part as in *Heteraster*; COOKE (1955, pp. 102, 104) regarded Washitaster as a subgenus of Enallaster (he separated Enallaster from Heteraster as a distinct genus). The differences of pore-pairs in the frontal ambulacrum (III) may be regarded as a generic (or subgeneric) distinction among the Spatangoina; e.g., the separation of Ova from Schizaster and likewise Diploporaster from Paraster—the formers having the pore-pairs of irregular series in the frontal ambulacrum and the latters having the pore-pairs in a single series with a peduncular granule. Among the species referring here to the genus



Fig. 67 [42]. Ambulacral structure of *Heteraster* and *Paraheteraster*. a. Frontal; b. Antero-lateral petal; c. Postero-lateral petal.

- A. Heteraster oblongus (BRONGNIART, 1821) (after DEVRIÈS, 1954).
- B. Paraheteraster macroholcus (NISIYAMA, 1950).
- C. Paraheteraster barremicus (TANAKA and OKUBO, 1954).
- D. Paraheteraster japonicus (TANAKA and OKUBO, 1954). (Enlarged; C, D., after TANAKA and OKUBO, 1954).

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Paraheteraster, the pores in the frontal ambulacrum of one or two species are not irregularly alternate but rather regular shape in two series on each side and placed nearly parallel to the suture of plates, but the pore-pairs have no peduncular granule and close set in great number, probably owing to plate-complexity to compressure of plate-growth (Text-fig. 67 [42]). The Japanese species of this group have deep frontal ambulacrum and its sides are more or less overhanging and the pore-pairs are crowded, sometimes irregularly bigeminal and parallel to the transverse suture of plates; these features are contrasting to the comparatively shallow frontal ambulacrum and the sides are not overhanging and the pore-pairs are spaced, unigeminal and at rather large angles to the transverse suture of plates of the species of Washitaster. Great variation in the arrangement of the pores in the frontal ambulacrum obtains in only one case, the living Echinocardium cordatum (PENNANT, 1777), among the Spatangoina; i.e., some specimens with the frontal pores arranged in a single regular series and others with the pores are to a varying degree irregular of the almost size, but there are no peduncular granule among them in both cases, and these specimens being otherwise so totally alike that it would have no sense to separate them into two species or subspecies. The Japanese species of Paraheteraster, however, is not the case; different species show distinctions in the arrangement of the pores in the frontal ambulacrum, while no evidence of great variation has been obtained from the specimens examined.

It seems highly probable that the lower Cretaceous (from the Hauterivian to lower Albian) Spatangoina are regarded to be a group having rather undifferentiated features that lately differentiate into distinct features along many lines, i.e., the frontal pores and the pseudomarginal fasciole. Enallaster wenoensis ADKINS, 1920 (ADKINS, 1920, p. 112, pl. 5, fig. 3.—Enallaster texanus (ROEMER) COOKE, 1946, p. 231 (partim)) has pseudomarginal fasciole as in Washitastaster riovistae (ADKINS, 1920) and likewise in Paraheteraster barremicus (TANAKA and OKUBO, 1954), but in the typical Heteraster (or Enallaster) there is no fasciole to occur. Thus Enal. wenoensis may be more or less related to the species of Paraheteraster, but through the structure of the peristome, the smaller number of the frontal ambulacral plates, a shallow frontal ambulacrum and the structure of paired petals of this species, it cannot be safely referred to Paraheteraster. The both species, Enal. wenoensis and Parah. barremicus may represent two divergent developments decended from different sources by convergency in appearance of pseudomarginal fasciole in the different areas and different ages. The pseudomarginal fasciole of both species may not indicate the genetic relation but of the 'parallelism' development. From the Japanese Cretaceous following three species of this genus are reported to occur.

Paraheteraster macroholcus (NISIYAMA, 1950)

(Pl. 18, figs. 3, 12-13, pl. 21, fig. 3)

Washitaster (?) macroholcus NISIYAMA, p. 45, text-figs. 4-7.—Washitaster macroholcus (NISIYAMA) TANAKA and OKUBO, 1954, p. 221, pl. 7, figs. 1-2, text-figs. 5-7.—Heteraster macroholcus (NISIYAMA) TANAKA, 1965, p. 133, pl. 16, figs. 3, 4a-b, text-figs. 4a-d.

Holotype.—IGPS coll. cat. no. 72981.

Locality and geological horizon.—IGPS loc. no.—Wa-1.—Cliff about 200 metres north of the bridge on main road, northeast of Yuasa-machi, Arita-gun, Wakayama Prefecture (tm Kainan, Lat. 34°02′30″N., Long. 136°11′24″E.). Arita formation, Barremian. MATSUMOTO, 1953, p. 74.

Locality and geological horizon (after TANAKA and OKUBO, 1954).—Pass about 600 metres southwest of Yoshikawa, Tasukawa-mura, Arita-gun, Wakayama Prefecture. Arita formation, Barremian.

Locality and geological horizon (after TANAKA, 1965).—Upper course of the Honya, Minami-Maki-machi, Shigaraki-gun, Gumma Prefecture. Lower part of Ishido formation, Neocomian.

The original description of this species is somewhat inadequate, and it is emended by TANAKA and OKUBO (1954, p. 221) and TANAKA (1965, p. 133) on the results of their investigation obtained from several new materials from the type-locality and others.

This species is superficially similar to Washitaster longisulcus (ADKINS and WIN-TON, 1920) (Enallaster longisulcus ADKINS and WINTON, 1920, p. 55, pl. 9, figs. 4, 8-10.— COOKE, 1946, p. 232, pl. 33, fig. 6), from the Washita group of Texas, in outline of the test, form of the paired petals, and in position of the apical system, but is easily distinguished from that species through the arrangement of the frontal pores, the deeper and well limited frontal groove, the form of the peristome, and through the greater number of pore-pairs in petals as well as the coarser and small-sized tuberculation. Paraheteraster macroholcus (NISIYAMA, 1950) is also seemingly related to Washitaster riovistae (ADKINS, 1920), from the Weno formation of Texas, but is easily distinguished from that species by the arrangement of frontal ambulacral pores, the more posterior position of the apical system, and larger number of pore-pairs in petals; that species has a pseudomarginal fasciole, which characterized the genus Washitaster in thought of some authors. The frontal ambulacral pores of the two American species are of the same regular shape throughout the area, round, and separated by a granule, and obliquely placed to the transverse suture of plates, and thus they are easily discriminated from the Japanese species in this point.

Paraheteraster barremicus (TANAKA and OKUBO, 1954)

Washitaster barremicus TANAKA and OKUBO, 1954, p. 220, pl. 7, fig. 3, text-fig. 7. Heteraster macroholcus (NISIYAMA)?: TANAKA, 1965, p. 133.

Locality and geological horizon (after TANAKA and OKUBO, 1954).—Southwest of Yoshikawa, Tasukawa-mura, Arita-gun, Wakayama Prefecture. Arita formation, Barremian.

No specimens of this species are available for study. This species may be characterized by its frontal ambulacral pores, which are slit-like and set closely, the outer ones are longer than the inner, placed parallel to suture line of plates, more or less similar to the arrangement of the frontal pores in species of the genus *Toxaster*, and to be expected to happen some irregularities of the arrangement of pore-pairs in whole length of the ambulacrum. This character of the species prevents its assignment to the genus *Washitaster*. Another characteristics of this species may be found

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in the pore-pairs of paired petals, i.e., the anterior poriferous series composed of pairs small, elongate pores, whereas the outer one is longer than the inner, and the posterior series consisting of pairs of slit-like outer pores and small inner pores; this feature of the pore-pairs in the paired petals is more or less similar to that of species of *Heteraster*.

The occurrence of a curious fasciole, the pseudomarginal fasciole, in the Barremian *Parah. barremicus* from Japan, is in accordance with the characteristics of the Albian species of different genera, e.g., *Washit. riovistae*, *Was. longisulcus*, and *Was. weno-ensis*, but the occurrence of the fasciole in the Japanese species is obviously earlier in geological time than in the American species.

Paraheteraster japonicus (TANAKA and OKUBO, 1954)

Washitaster japonicus TANAKA and OKUBO, 1954, p. 220, pl. 7, fig. 4.

Locality and geological horizon (after TANAKA and OKUBO, 1954).—North of Tsuzura, Shimo-Matsukuma-mura, Yatsushiro-gun, Kumamoto Prefecture. Yatsushiro formation, Albian.

There are no authentic specimens referable to this species at the writer's disposal. This species is characterized by its arrangement of the frontal ambulacral pores, which are similar, oval or round and near together, parallel to the transverse suture of the plates. In its arrangement of the frontal pores, this species very closely resembles *Parah. macroholcus*, but in that species some irregularities found in a pair of small, closer, oval pores situates among from two to several pairs of large, oval, pores being placed widely, while in this species it is regularly arranged. The present species is also similar to *Parah. macroholcus* on the feature of pore-pairs in the paired petals; i. e., the anterior poriferous series provided with minute round pores, and the posterior poriferous series consisting of round in the inner zone and large oval or elongate pores in the outer zone. *Parah. japonicus*, as a whole, seems to be very closely related to *Par. macroholcus* in spite of the different geological horizons.

The Japanese genus *Paraheteraster* and the North American genus *Washitaster* are agree in several points; the both genera are nearly equal in the ethmophractic apical system, the pore-pairs in the paired petals, the form of the paired petals, the location of the apical system, and in the deeply and conspicuously sunken frontal groove; moreover, the inter-relationships of one species to the other in each genus seem to be nearly correspondent between the *Paraheteraster* and *Washitaster*. The correlation of the species in the both genera may be tabled as follows.

Japan	Texas, U.S.A.
Par. macroholcus (Barremian)	Was. longisulcus (Albian)
Par. barremicus (Barremian)	Was. riovistae (Albian)
Par. japonicus (Albian)	5

By considering the differentiation of ambulacral pores among the Spatangoina based on the paleontological datum and with regarding the feature of the frontal ambulacral pores only, *Washitaster* from Texas seems to be more specialized than *Paraheteraster* from Japan, and it fairly well agrees with the fact that *Washitaster* has occurred in later geological time (Albian) than the Japanese Paraheteraster (Barremian).

Family Hemiasteridae H. L. Clank, 1917

Hemiasteridae H. L. Clark, 1917, p. 159 (pro parte).—H. L. Clark, 1925, p. 197 (pro parte).— Grant and Hertlein, 1938, p. 113 (pro parte).—Mortensen, 1950-a, p. 374.

Hemiasterinae LAMBERT, 1920-b, p. 16.—LAMBERT and THIÉRY, 1924, p. 498 (pro parte).— SMISER, 1935-a, p. 86.

Type-genus.—Hemiaster DESOR, 1847.

Peristome transverse, labrum more or less well developed. Ambulacra more or less petaloid adapically; petals usually straight or more or less curved; frontal ambulacrum (III) more or less differentiated from the paired petals. Apical system usually ethmophract or rarely ethmolytic, with usually four, rarely three or two penital pores. A peripetalous fasciole present, but no other fascioles. From the lower Cretaceous to Recent.

This family is characterized by having only a peripetalous fasciole, but no other fascioles. The family Hemiasteridae have already developed, though their occurrence is as old in as the lower Cretaceous (the Aptian), the more or less deepen petals, the labiated peristome, the regular series of the frontal ambulacral pores, which are minute and oblique to transverse suture, the primitive ethmolytic apical system in some forms, and the distinct peripetalous fasciole. These features are contrasting to the less specialized features of the typical Toxasteridae, which have less developed superficial paired ambulacra, the peristome being not well labiate, the frontal ambulacral pores are elongate slit-like in two series, the ethmophractic apical system, and total absence of fascioles. The origin of the family Hemiasteridae is not clear, but when the features of the two families, Hemiasteridae and Toxasteridae, are compared with each other, it seems probable that the source of the Hemiasteridae in the typical Toxasteridae or their allies, in which fascioles not yet defined. The sequence of geological age in the both groups is not controversy. There is, however, no direct proof of this consideration that the Hemiasteridae have been derived from the typical Toxasteridae.

The family Hemiasteridae were established by H. L. CLARK (loc. cit.) with taking the main character as the lacking of a subanal fasciole and separating from the Spatangidae, which characterize the presence of a subanal fasciole being taken as the character. LAMBERT and THIÉRY (loc. cit.) take the presence of a peripetalous fasciole alone as the main character of their Hemiasterinae. MORTENSEN (loc. cit.) well defined the family Hemiasteridae, with taking the presence of a peripetalous fasciole as the main character. This agrees with the idea of LAMBERT and THIÉRY. In thus defining the family Hemiasteridae MORTENSEN safely referred to this family the following genera: viz., Hemiaster DESOR, 1847, Distefanaster CHECCHIA-RISPOLI, 1902, Ditremaster MUNIER-CHALMAS, 1885, Hernandezaster SANCHEZ ROIG, 1949, Heterolampas COTTEAU, 1862, Somaliaster HAWKINS, 1935, Vomeraster LAMBERT, 1920, Trachyaster POMEL, 1869 and Opissaster POMEL (though with some doubt as to Vomeraster), and the Recent genera Sarsiaster MORTENSEN, 1950 and Sinaechinus HAYASAKA, 1948 (referring this genus to the family is very doubtful). The important genera of the family Hemiasteridae are discriminated from one another as shown by the following key.

Key to the important genera of the family Hemiasteridae.

1.	Genital pores two 2
	Genital pores four
2.	Genital plate (3) lacking Distefanaster
	Genital plate (3) present 3
3.	Frontal depression distinctOpissaster
	Frontal depression faint 4
4.	Test low. Posterior petals about half the length of the anterior onesSarsiaster
·	Test high. Posterior petals only about one-third the length of the anterior ones
	Ditremaster
5.	Apical system ethmophract. A more or less distinct frontal depression
	Hemiaster
	Apical system ethmolytic. Petals short, the posterior much shorter than the
	anterior Trachyaster.
	There is a fossil representative of the genus <i>Hemiaster</i> in our collection.

Genus Hemiaster DESOR, 1847

Hemiaster DESOR in AGASSIZ and DESOR, 1847, p. 16.—FORBES, 1852-a, p. 24.—D'ORBIGNY, 1853-55 (53), p. 220.—D'ARCHIAC and HAIME, 1853-54 (53), p. 220.—DESOR, 1855-58 (58), p. 367.—STOLICZKA, 1873, p. 10 (81).—LORIOL, 1873, p. 370.—A. AGASSIZ, 1872-74, p. 585 (pro parte).—WRIGHT, 1864-82 (75), p. 261.—LORIOL, 1875, p. 91.—ZITTEL, 1879, p. 540.—DUNCAN and SLADEN, 1882-a, p. 78.—POMEL, 1883, p. 42.—COTTEAU, 1885-89 (87), p. 400.—DUNCAN and SLADEN, 1888, p. 327.—DUNCAN, 1889-a, p. 229 (pro parte).—DELAGE and HÉROUARD, 1903, p. 271 (pro parte).—SAVIN, 1903, p. 22.—MEISSNER, 1904, p. 1390 (pro parte).—BATHER, 1904, p. 297.—SAVIN, 1905, p. 118.—LAMBERT, 1907-c, p. 101.—STEFANINI, 1908-a, p. 11.—LAMBERT, 1915-b, p. 155.—H.L. CLARK, 1917, p. 165.—JACKSON, 1922, p. 73.—LAMBERT and THIÉRY, 1924, p. 498 (pro parte).—H. L. CLARK, 1925, p. 200.—SANCHEZ ROIG, 1926, p. 124.—LAMBERT, 1931, p. 113.—SMISER, 1936, p. 477.—GRANT and HERTLEIN, 1938, p. 117.—COOKE, 1946, p. 222.—H.L. CLARK, 1946, p. 364.—MORTENSEN, 1950-a, p. 378 (complete synonymy).—COOKE, 1959, p. 67.

Logotype.—Spatangus bufo BRONGNIART in CUVIER and BRONGNIART, 1822, p. 389 (Cretaceous of France).—Hemiaster bufo (BRONGNIART): D'ORBIGNY, 1853-55 (53), p. 277, pl. 873, figs. 1-10 (Normandie and numerous localities in France; characteristic of the Cenomanian). [SAVIN, 1903, p. 22.—LAMBERT, 1907-c, p. 101].

Leucaster GAUTHIER, 1887-a, p. 242.

Haplotype.-Leucaster remensis GAUTHIER, 1887-a, p, 243. pl. 7, figs. 8-12 (Senonian of Reme).

Small to moderately sized, ovoid or cordiform, with short, high test, somewhat sloping anteriorly, abruptly truncate posteriorly. Frontal depression inconspicuous. Paired petals well developed, straight, or slightly curved, not very long; antero-lateral petals (II and IV) sunken, diverging, and more or less distinctly longer than the postero-lateral ones (I and V); pores of the petaloid parts conjugated, the outer ones usually the longest. Pores of the frontal ambulacrum (III) oblique and arranged in regular series. A peripetalous fasciole well developed, but no other fascioles. Apica 1

system central, ethmophract, in some cases, however, the madreporite separates the posterior genitals and reaches the posterior oculars, but no separate the oculars, with four genital pores. Periproct at the upper end of the truncate posterior end; peristome anterior. In the Recent forms the pedicellariae of five types usually present, globiferous, tridentate, rostrate, ophicephalous, and triphyllous; tube-feet of frontal ambulacrum (III) terminating in a large disc supported by rosette-plates; tube-feet at the subanal region large and penicillate like the adoral tube-feet (mainly after MORTEN-SEN, 1950-a). From the lower Cretaceous (Aptian) to Recent of the world-wide distribution.

This genus has a close relation with Trachyaster POMEL, 1869 (POMEL, 1869, p. 14.—Type-species.—Trachyaster globosus POMEL, 1869, p. 14.—POMEL, 1887, p. 109, pl. A, figs. 9-13.—Pliocene of Algeria) in the form of the paired petals, outline of the test, and in the anterior groove, but differs from the latter in having a ethmophractic apical system, while in the latter it is ethmolytic. Systematic position of Trachyaster has been much disputed. COTTEAU (1885-89 (87), p. 400) applied the name for those species of *Hemiaster* which have ethmolytic apical system; BATHER (1904, p. 297) suggested that *Trachyaster* should be treated as a provisional subgeneric rank for ethmolytic Hemiaster. LAMBERT and THIÉRY (1924, p. 507) regarded Trachyaster as a separate genus from Hemiaster, and MORTENSEN (1950-a, p. 396) likewise maintained it as a separate genus, and lastly KIER (1957, p. 880) considers it as a subgenus of Hemiaster as BATHER already suggested. Difference of opinions have proposed by authors on this point probably due to the structure of apical system in *Hemiaster*; i.e., in some case it is more or less modified from the typical ethmophractic structure and having four genital pores and the structure seems to be nearer to the ethmolytic apical system, with four genital pores, of Trachyaster.

The genus Opissaster POMEL, 1883 (POMEL, 1883, p. 37.—Orthotype.—Opissaster polygonalis POMEL, 1883, p. 73.—POMEL, 1887, p. 106, pl. A, figs. 1-5.—Tortonian of Algeria) also resembles Hemiaster, as both genera have short, high tests, with well-developed paired petals. The genus Hemiaster in general, however, does not have a conspicuously frontal groove, and its paired petals are shallower and straight; while they are usually flexuous in Opissaster. The apical system of Hemiaster is ethmophractic with four genital pores, while it is ethmolytic with two or three genital pores in Opissaster.

Species of this genus are very abundant and there are about 260 species mentioned in literature of the genus *Hemiaster*. Because of this large number of species, several attempts have been made to divide the genus into sections. LAMBERT and THIÉRY (1924, pp. 498-505) divide the genus into seven sections, and MORTENSEN into eight sections, whose type-species are as follows, respectively.

- Hemiaster bufo (BRONGNIART, 1822) (loc. cit.)
- Hemiaster leymeriei DESOR: D'ORBIGNY, 1853-55 (53), p. 232, pl. 875.
- Hemiaster fourneli DESHAYES: COTTEAU, PERON, and GAUTHIER, 1879, p. 58, pl. 2.
- Hemiaster coranguinum (GREGORY, 1892).—Pericosmus coranguinum GREGORY, 1892-c, p. 615, pl. 2, figs. 3-4.
- Hemiaster aumalensis Coquand, 1862, p. 249, pl. 26, figs. 9-11.

Hemiaster prunella DESOR: D'ORBIGNY, 1853-55 (53), p. 242, pl. 881.

Hemiaster hickmanni KOEHLER, 1914, p. 142, pl. 7, figs. 4-10. Hemiaster enormis GAUTHIER, 1889-a, p. 18, pl. 1, figs. 12-13.

These sections are distinguished mainly on the minor differences in the petals.

The genus *Hemiaster* dates back to the Aptian (the lower Cretaceous) and gradually took a racial development, from the Cenomanian to the Senonian the course of development seems to be maintained as usually, in the Senonian it attained the climax of development, and then gradually took a declined course, notwithstanding nearly 10 species still living in the present seas, and a Recent species was discovered for the first time in 1874.

There is a fossil species of Hemiaster in our collection.

Hemiaster uwajimensis MORISHITA, 1962

(Pl. 18, figs. 2, 5, 9)

Hemiaster uwajimensis Morishita, 1962, p. 114, pl. 1, figs. 1-7.—Nisiyama, 1965, p. 80.

Locality and geological horizon.—IGPS loc. no. E-52.—A bridge beside at Narufuji, Kôfuji-mura, Kita-Uwa-gun, Ehime Prefecture (tm Uwajima, Lat. 33°16'N., Long. 132° 40°34"E.). Miyakura (Furushiroyama) formation, Senonian-Maastrichtian. YABE, 1927, p. 78.—MATSUMOTO, 1953, pp. 84, 98. Hypotype.—IGPS coll. cat. no. 73747.

Locality and geological horizon (after MORISHITA, 1962).—Asakawa, Yoshida-machi, Kita-Uwa-gun, Ehime Prefecture. Yoshida group, upper Cretaceous. Holotype.—No. ESN 30001 in Inst. Earth Sci., Nagoya Univ. Paratypes.—Nos. ESN 30002-ESN 30007 in Inst. Earth Sci., Nagoya Univ..

There are four specimens referred to this species at the writer's disposal. The best preserved one measures about 18 mm in longitudinal diameter, about 20 mm in transverse one, and 12 mm in height.

Test small, rounded quadrate in outline, short, wider than long, not sharply constricted posteriorly, anterior part not greatly widened, sides more or less evenly rounded, rather high, more than half the length as much, the broadest point lies at middle of the test, the highest point situated at near centre just anterior to apical system, anterior slope steeper than the posterior, posterior part abruptly truncated. Frontal depression wide but very shallow. Oral side nearly flat, plastronal region slightly inflated and peristomial region depressed adorally.

Frontal ambulacrum (III) lies in a very shallow groove continuing from apical system over the ambitus to peristome, rather long and wide, widening from proximal part to the middle and from the middle to distal passing parallel, about 9 mm long and about 2.4 mm wide at the broadest point; each poriferous zone consisting of about 20 pore-pairs within the fasciole, pore-pairs outside the fasciole become wider apart each other and obsolete; pores of pairs small, close, round, oblique and arranged in regular series placing near adradical suture, but a peduncular granule between pores of a pair indistinct.

Antero-lateral petals (II and IV) rather long and broad, about 8 mm long and about 3.5 mm wide at the widest point, sunken, widest at the middle, diverge from each other, an angle between mid-line of each petal being about 110°, width of anterior

pore-series and the posterior not much different; interporiferous zones rather narrow, about 1 mm wide; each poriferous zone comprises about 27 pore-pairs within the fasciole, by which distal part of petals terminated; pore-pairs conjugate, outer pores of pairs longer than the inner, slit-like. Postero-lateral petals (I and V) short, but rather broad, widest at the middle, about 4.5 mm long and 3 mm wide, a little over half the length of antero-laterals, not curved; diverge from each other, an angle between mid-line of each petal being about 60°; interporiferous zones narrow; each poriferous zone comprising about 20 pore-pairs within the fasciole; pore-pairs conjugate, the outer pores of pairs longer than the inner; width of outer pore-series and that of the inner not much different.

On aboral surface, postero-lateral interambulacra (1 and 4) and posterior interambulacrum (5) gently inflated, and antero-lateral interambulacra (2 and 3) more or less inflated. Apical system small, 0.6 mm long and 0.7 mm wide, a little eccentric in posterior, situated at 10 mm from the anterior margin; posterior genital pores (1 and 4) large and distinct, right anterior genital pore (2) smaller than the posterior ones, but left anterior pore (3) concealed under matrix and invisible; it may be ethmophract.

Peristome much eccentric in anterior, situated at about 2.5 mm from the anterior extremity, very wide, about 3 mm wide and 1 mm high, being three times as wide as high. Sternum broad, slightly inflated; labrum wide. Periproct small, longitudinally elongated, situated high on oblique posterior truncation and partially visible from above. Peripetalous fasciole, in preserved part, a wide band, passing around the extremities of petals; it curved slightly forwards the ambitus in the antero-lateral interambulacra (2 and 3) and crosses anterior groove some distance above the ambitus, and curves more or less towards the apical system in the postero-lateral interambulacra (1 and 4), but passes rather straight between the postero-lateral petals (I and V), where crossing the posterior interambulacrum (5). No other fascioles present. Tubercles and radioles are not well preserved to describe.

This species is characterized by its small and rounded quadrate outline, very eccentric in anterior position of the peristome, and large angle between the mid-line of petal (II) and of petal (IV), and is easily distinguished from all the Senonian species of this genus by its specific characters. This species resembles *Hemiaster similaris* STOLICZKA, 1873 (STOLICZKA, 1873, p. 10 (80), pl. 1 (11), fig. 1), from the Senonian of southern India, but differs from that species in the smaller and wider test, the location of the peristome, and in the form of antero-lateral petals (II and IV). *Hemiaster uwajimensis* is like *Hem. aumalensis* COQUAND, 1862 (loc. cit.), a Cenomanian species, but differs from the latter in having the smaller test and in the diverging antero-lateral petals.

Family Spatangidae Gray, 1825

(Emended by MORTENSEN, 1950)

Spatangidae GRAY, 1825, p. 430 (pro parte).—GRAY, 1855-a, p. 38 (pro parte).—A. AGASSIZ, 1872-74, p. 561 (pro parte).—WRIGHT, 1864-82 (75), p. 260 (pro parte).—ZITTEL, 1879, p. 536 (pro parte).—DUNCAN, 1889-a, p. 216 (pro parte).—GREGORY, 1900-b, p. 321 (pro

parte).—Meissner, 1904, p. 1388 (pro parte).—H. L. Clark, 1917, p. 197 (pro parte).—H. L. Clark, 1925, p. 212 (pro parte).—Grant and Hertlein, 1938, p. 126 (pro parte).—Mortensen, 1950-a, p. 181.—Mortensen, 1951, p. 1 (complete synonymy).

Spatangoides AGASSIZ in AGASSIZ and DESOR, 1847, p. 5 (pro parte).—D'ORBIGNY 1853-55 (53), p. 148 (pro parte).—DESOR, 1855-58 (58), p. 350.—LORIOL, 1873, p. 399 (pro parte).

Spatangides POMEL, 1883, p. 27 (pro parte).—Spatangidées COTTEAU, 1885-89 (85), p. 15 (pro parte).

Prospatangidae LAMBERT, 1905-a, p. 34 (pro parte).—LAMBERT and THIÉRY, 1924, p. 435. Type-genus.—Spatangus [O.F. MÜLLER] GRAY, 1825.

Peristome transverse, labrum and sternum fully developed, the latter wholly tuberculated. Ambulacra well developed, petaloid adapically, but paired petals not sunken and with rather few pore-pairs. Main character is the presence of a subanal fasciole, but no other fascioles. Primary radioles without internal ampullae. From the Eocene to Recent.

In the presence of only a subanal fasciole the family Spatangidae are in common with the Micrasteridae, the Maretiidae, and some genera of the Palaeopneustidae, and it may indicate, in this matter, affinities of the Spatangidae with the all or one of these families. The family Spatangidae are distinguished from the family Micrasteridae through having the ethmolytic apical system (in that family it is ethmophract) and well differentiated tubercles (radioles) on the aboral surface (in that family they are not well differentiated), and this family should be regarded as a representative of further specialization than the family Micrasteridae. From the family Maretiidae, this family is distinguished by lacking of internal ampullae to the aboral primary tubercles (though in that family the internal ampullae are not necessary distinct) and in the sternum, which is fully covered with tubercles (radioles), but the two families are in common with having the ethmolytic apical system. This family is also distinguished from some genera of the Palaeopneustidae having a subanal fasciole by the form of petals and the feature of sternum. The genera of the Palaeopneustidae having a subanal fasciole, in the presence of large aboral primary tubercles combined with the character of the ethmolytic apical system and in the extensively naked sternum, recall the Maretiidae. The Maretiidae also have affinities with the Loveniidae in the presence of internal ampullae to the aboral primary tubercles and non-crenulate aboral primary tubercles. The affinities of some genera of the Palaeopneustidae having a subanal fasciole seems more nearer to the Maretiidae than to the Spatangidae.

The family Spatangidae are dating back to the Eocene and their origin is not quite certain. The probable derivation of the Spatangidae seeks for from the Micrasteridae or the Toxasteridae. A derivation of this family from the Hemiasteridae suggested by DURHAM and MELVILLE (1957, text-fig. 9 on page 266) seems to be improbable, as a peripetalous fasciole of the Hemiasteridae has already appeared early in the Aptian and a subanal fasciole of the Spatangidae has appeared in the Eocene, and a peripetalous fasciole of the Hemiasteridae becomes very distinct in the Tertiary and it represent a main character of that family. If the Spatangidae, the Maretiidae, and some genera of the Palaeopneustidae were derived from different sources, the occurrence of a subanal fasciole should be regarded as independent origin and not indicate relationships of these families.

To the family Spatangidae as here limited the writer refers the following genera,

Spatangus [O. F. MÜLLER] GRAY, 1825 and Oppenheimia COSSMANN, 1900. The two genera are discriminated from each other as shown by the following key.

Key to the genera of the family Spatangidae.

Genus Spatangus (O. F. MÜLLER) GRAY, 1825

- Spatangus O. F. MÜLLER, 1776, p. 236 (Sp. purpureus and Sp. pusillus).—GRAY, 1825, p. 430.— AGASSIZ, 1840-a, pp. 2, 16.—AGASSIZ and DESOR, 1847, p. 6.—GRAY, 1855-a, p. 46.—DESOR, 1855-58 (58), p. 419.—A. AGASSIZ, 1872-74, pp. 158, 564.—LORIOL, 1875, p. 131.—ZITTEL, 1879, p. 546.—CARUS, 1884, p. 102.—DUNCAN, 1889-a, p. 251.—BELL, 1892, p. 164.—MEISSNER, 1904, p. 1396.—MORTENSEN, 1907, p. 120.—H. L. CLARK, 1908, p. 308.—H. L. CLARK, 1917, p. 233.—H. L. CLARK, 1925, p. 224.—MORTENSEN, 1932-e, p. 356.—GRANT and HERTLEIN, 1938, p. 131.—MORTENSEN, 1951, p. 6 (complete synonymy).—COOKE, 1959. p. 80.
 - Haplotype.—Spatangus purpureus O. F. MÜLLER, 1776, p. 236.—A. AGASSIZ, 1872-74. pp. 158, 331, 565, pl. 11, figs. 19-22, pl. 14a, fig. 1, pl. 19a, figs. 5-6, pl. 26, figs. 24-27, pl. 32, figs. 17-18, pl. 34, figs. 3-4, pl. 38. fig. 16, pl, 38, figs. 34-35 (Norway, Mediterranean Sea). [Genus validated as of GRAY 1825 by Opinion 209 of the International Commission on Zoological Nomenclature].
- Prospatangus LAMBERT, 1902, p. 55.—LAMBERT, 1915-b, p. 192.—VADÀSZ, 1915, p. 156.—LAMBERT and THIÉRY, 1924, p. 459.
- Orthotype.—Prospatangus purpureus (O.F. MÜLLER) LAMBERT, 1902, p. 55.—Spatangus purpureus O.F. MÜLLER: A. AGASSIZ, 1872-74, pp. 158, 331, 565.
- Non Spatangus [KLEIN] LAMBERT, 1907-c, p. 112 (KLEIN, 1734, p. 33—pre-Linnean).—LAMBERT and THIÉRY, 1925, p. 530.
 - Type-species.—Spatangus canaliferus LAMARCK, 1816, p. 31.—Schizaster canaliferus (LA-MARCK: A. AGASSIZ, 1872-74, pp. 157, 609, pl. 23a, figs. 1-3, pl. 33, fig. 7 (Mediterranean Sea).

Medium sized of broad oval outline, with a fairly deep frontal groove, test usually more or less distinctly heart-shaped; usually asymmetrical, the right side from aboral view extending beyond the left side. Aboral side of test regularly arched, more or less high; oral side flat, sternum more or less convex. Paired ambulacra form very distinct petals, nearly closed distally, at least ten distal pore-paires developed in anterior series of antero-lateral petals (II and IV), not sunken. Pores of frontal ambulacrum (III) small, distant, in regular single series, peduncular granule between pores of a pair not distinct; frontal tube-feet small, without a distinct terminal disc. Apical system subcentral, with four genital pores, ethmolytic; madreporite extends rather far beyond the posterior oculars (I and V), widening there into a conspicuous plate. Peristome anterior; peristomial region usually distinctly sunken, with fairly conspicuous phyllodes; labrum prominent. Sternum generally narrow, may form a fairly conspicuous keel. Subanal plastron broad or shield-shaped with or without a well marked re-entering angle in upper adproctal band. Sternum wholly covered by tubercles (radioles). Periproct on truncate posterior end. Subanal fasciole present, but no other fascioles. Primary tubercles in varying numbers on aboral side in interambulacral areas outside petals, in some forms lacking entirely in postero-lateral interambulacral

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areas (1 and 4). Two or three penicillate tube-feet to each side within subanal fasciole. Primary aboral radioles curved, smooth; radioles of plastron only slightly widened distally. Tridentate pedicellariae in two or three different forms; globiferous and ophicephalous pedicellariae only exceptionally found, mainly in young specimens (mainly after MORTENSEN, 1951). From the Eocene to Recent.

The use of name Spatangus for an echinoid is very old, e.g., ARISTOTLE said to used this name for an echinoid in Greek as " $\delta \sigma \pi \alpha \tau \dot{\alpha} \gamma \gamma \sigma \varsigma$ ". O. F. MÜLLER was the first to use this name for a genus in a post-Linnean usage, but he have no generic description. The first author who established a genus Spatangus in really modern sense is GRAY (1825, p. 430); he put under the genus Spatangus is named as only a single species Sp. purpureus LESKE (1778, p. 235, pl. 43, figs. 3, 5), which was based on MÜLLER'S Sp. purpureus.

LAMBERT (1902, p. 55.—1907-c, p. 112) considered *Spatangus* as dating from KLEIN (1734, p. 33.—pre-Linnean and non-binominal author) and regarded *Sp. canaliferus* LAMARCK (1816, p. 31) as the type-species of the genus; and he further maintained that the type-species generally was understood as *Spatangus*, e. g., *Sp. purpureus*, does not rightly belong there, and he proposes to name those forms *Prospatangus*.

The numerous fossil species, some seventy species, are enumerated by LAMBERT and THIÉRY in their work (1924, pp. 460-464). In that work LAMBERT and THIÉRY divided the fossil species besides the living ones into five subgenera, viz., *Phymapatagus* LAMBERT, 1910, *Mazzettia* LAMBERT and THIÉRY, 1915, *Platyspatus* POMEL, 1883 and *Granospatagus* LAMBERT, 1915, besides their typical "*Prospatangus*" (*Spatangus* of authors). As for *Mazzettia* MORTENSEN does not accept it as a *Spatangus* at all, as it has no fasciole, and he regarded it as a Palaeopneustid (MORTENSEN, 1950-a, 235; 1951, pp. 5, 6), to which the writer quite agrees. The subgenera and their type-species are as follows, respectively.

Spatangus sens. strict	Spatangus	purpureus O.F. Müller
Phymapatagus	Spatangus	(Phymapatagus) britannus MICHELIN
Platyspatus	Spatangus	(Platyspatus) chitonosus Sismonda
Granopatagus	Spatangus	(Granopatagus) lonchophorus Meneghini

To this last subgenus, which seems to be the best characterized, are referable the Recent species, *Sp. inermis* MORTENSEN, 1913 and *Sp. paucituberculatus* A. AGASSIZ and H. L. CLARK, 1917, in their characters.

In the discriminating of the species from one another under the genus *Spatangus*, the feature of subanal plastron and the existence and absence of primary tubercles in the ambulacra outside the petals and in the interambulara are usually regarded as criteria with the number of pore-pairs within the subanal fasciole and form of test.

This genus dates back to the Eocene and including some seventy fossil species, which are rather widely distributed as well as the living species.

There are two species of fossil representatives of this genus in our collection, the one can be identified with the living species from Japan, and the other is left unnamed to the deficient condition of the specimen. Spatangus pallidus H. L. CLARK, 1908

(Pl. 22, figs. 1-6)

Spatangus pallidus H. L. CLARK, 1908, p. 307.—H. L. CLARK, 1917, p. 239, pl. 146, fig. 18, pl. 149, fig. 5, pl. 157, figs. 1-4.—Prospatangus pallidus (H. L. CLARK) LAMBERT and THIÉRY, 1924, p. 463.—Spatangus pallidus H. L. CLARK: H. L. CLARK, 1925, p. 224.—MORTENSEN, 1951, p. 19.

Locality and geological horizon.—IGPS loc. no.—Ch-1.—About 100 metres east of shrine on main road at Jizôdô, Makuta-mura, Kimitsu-gun, Chiba Prefecture (tm Anegasaki, Lat. 35°21′07″N., Long. 140°06′02″E.). Jizôdô formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 7976.

Locality and geological horizon.—IGPS loc. no.—Ch-65.—At the northern foot of Sengen-yama, near Umadate, Toda-mura, Ichihara-gun, Chiba Prefecture (tm Anegasaki, Lat. 35°22′30″N., Long. 140°03′20″E.), Jizôdô formation, Pleistocene. Hypotype.— IGPS coll. cat. no. 8422.

There are six specimens referred to this species at the writer's disposal, but they are not well preserved, in two of which is preserved a greater part of the aboral surface of the test.

A comparatively well preserved specimen measures about 60 mm in longitudinal diameter and about 58 mm in transverse one, and over 36 mm in height; test cordate in marginal outline, with a rather deep and broad frontal groove, right side of the groove from aboral view extending beyond the left side as usual of the genus, the greatest width just back of apical system, width nearly equal to or a little smaller than the length, and the greatest height a trifle further back of apical system on somewhat carinate posterior interambulacrum (5).

Frontal ambulacrum (III) in a depressed groove, its ambulacral plates rather high; the pores small and distant, in regular single series on each side. Antero-lateral petals (II and IV) a trifle sunken, about 20 mm long and 7 mm wide, there are about 15 porepairs in anterior poriferous-series and about 22 in the posterior; pores of a pair large and elongate, in a shallow groove. Postero-lateral petals (I and V) somewhat longer and narrower, about 22 mm long and 6 mm wide, scarcely sunken; there are about 20 pairs of pores in anterior poriferous-series and 24 in the posterior; pores of a pair as in the antero-lateral petals.

Posterior end of test truncate, a trifle oblique, with slope downwards and forwards. Periproct not accessible. Adoral surface of test seems to flat on each side of sternum, but sternum conspicuously keeled. Labrum not preserved; peristome sunken. On aboral surface, primary tubercles, in preserved part, few and conspicuous; there are about 17 or 18 small ones in posterior interambulacrum (5) and seem to arranged in 6 or 7 groups of two or three each; there are about 12 slightly larger ones in postero-lateral interambulacra (1 and 4), and in antero-lateral interambulacra (2 and 3) from 35 to 40 tubercles along the margin of frontal ambulacrum and gradually passing into secondaries to near the ambitus. Subanal fasciole partly preserved, about 1.5 mm wide, and enclosing two ambulacral pores (penicillate tube-feet) on left side preserved.

The specimen here described is larger and having more or less larger number

of primary tubercles on the aboral surface than the type-specimen described by H. L. CLARK (1908, p. 307) from the Sagami Sea, but it is probably due to the growth-length of the test.

This species is known to distribute from the Sagami Sea (H. L. CLARK, 1908, p. 307) to Oze-Zaki, Japan (H. L. CLARK, 1917, p. 240.—MORTENSEN, 1951, p. 19) in small depth, from 5 to 48 fathoms deep. This species closely resembles Sp. luetkeni A. AGASSIZ, 1872 (A. AGASSIZ, 1872, p. 57.—H. L. CLARK, 1917, p. 238, pl. 146, fig. 17, pl. 157, figs. 5-6), from the northern Japan, but is distinguished from that species in having the conspicuous keeled sternum, the higher test, and only two pore-pairs on each side within the subanal fasciole. As for the specific validity of this species MORTENSEN (1951, p. 19) stated that—"It would seem closely related to Sp. lütkeni (? altus); but the fact that it has only two pore-pairs to each side within the subanal fasciole, shown in pl. 149, fig. 5 of CLARK's work (1917), prevents identifying it with any of these species."

Spatangus sp.

(Pl. 21, fig. 2)

Lacality and geological horizon.—IGPS loc. no.—Kn-1.—Sea cliff at Shiba, Kanazawa-machi, Totsuka Ward, Yokohama City, Kanagawa Prefecture (tm Yokohama, Lat. 35°20'N., Long. 139°38'N.). Koshiba formation, Pliocene. Hypotype.—IGPS coll. cat. no. 22244.

There is only a single specimen at the writer's disposal. The oral side of the specimen is quite broken out and somewhat deformed to lateral asymmetry. The specimen measures about 33 mm in longitudinal diameter and also 23 mm in transverse one. Test is rather low; apical system central, situated at 16.5 mm from the anterior margin, rather large, ethmolytic, with four genital pores. Frontal ambulacrum (III) in rather broad groove; antero-lateral petals (II and IV) long and narrow, about 10 mm long and 2 mm wide, with about eight pore-pairs in anterior pore-series and about twelve pairs in the posterior; postero-lateral petals (I and V) rather short and wide, about 9 mm long and 2.5 mm wide, with thirteen pairs of pores in anterior pore-series and about eleven pairs in the posterior. On aboral surface, there is no primary tubercles in postero-lateral interambulacrum (5), and about 15 small primary tubercles in each antero-interambulacrum (2) or (3) along the margin of frontal groove.

It seems evident that this specimen has relation with the northern Japanese Sp. luetkeni A. AGASSIZ, 1872 (loc. cit.), but it differs from that species in lacking the large tubercles in the postero-lateral interambulacra (1 and 4) and in the form of petals. In lacking the large tubercles in the postero-lateral interambulacra, this specimen resembles the Hawaiian and Japanese Sp. (Granopatagus) paucituberculatus A. AGASSIZ and H. L. CLARK, 1907 (A. AGASSIZ and H. L. CLARK, 1907-a, p. 253.—H. L. CLARK, 1917, p. 237, pl. 146, fig. 19, pl. 157, figs. 7-9.—MORTENSEN, 1951, p. 19, pl. 2, fig. 3), but is distinguished from that species by the form of petals. This specimen may represent a new species, but unfortunately it is very incomplete to full recognition of a distinct species.

Family MARETHDAE LAMBERT, 1905

Maretiinae LAMBERT, 1905-a, p. 162 (groupe).—LAMBERT and THIÉRY, 1924, p. 456 (tribus).— MORTENSEN, 1951, p. 21 (subfamily).—Maretiidae LAMBERT: DURHAM and MELVILLE, 1957, pp. 261, 266.
Tupo groups Maretia Court 1955.

Type-genus.—Maretia GRAY, 1855.

Peristome transverse, labrum and sternum fully developed, the latter being more or less extensively naked. Ambulacra petaloid adapically, but with rather few porepairs. Apical system ethmolytic, with four or three genital pores. A subanal fasciole developed, but no other fascioles present. Areoles of aboral primary tubercles moderately sunken, forming more or less developed internal ampullae or none. From the Eocene to Recent.

This family covers the same ground of the subfamily Maretiinae in the strict usage of MORTENSEN (1951, pp. 6, 21), and comprises, as in dealt with the problem under the family Spatangidae, different forms-the ones being related to the Spatangidae on one hand and the others related to the Loveniidae on the other hand. To the subfamily Maretiinae as he limited MORTENSEN referred the following genera, viz., Laevipatagus NOETLING, 1885, Atelospatangus KOCH, 1885, Hemimaretia MORTENSEN, 1950, Paramaretia MORTENSEN, 1950, Maretia GRAY, 1855, Pseudomaretia KOEHLER, 1914 (with Goniomaretia H.L. CLARK, 1917), and Nacospatangus A. AGASSIZ, 1873. The genus Laevipatagus, according to MORTENSEN (1951, p. 5), is an intermediate form between Spatangus and Pseudomaretia. Pseudomaretia is also rather intermediate between Maretia and Spatangus in respect to the tuberculation of the sternum. The Nacospatangus was referred to the Family Palaeopneustidae by H. L. CLARK (1917, p. 149), while to the subfamily Maretiinae by LAMBERT and THIERY (1924, p. 465) and also by MORTENSEN (1951, pp. 5, 74), and its relation with two families is not clear to the writer. The existence of internal ampullae to the aboral primary tubercles of Hemimaretia and young individuals of Maretia recalls Lovenia in this respect, and that indicates relationship with the Loveniidae, and also non-crenulate aboral primary tubercles of some genera of the Maretiidae recall the Loveniidae. The family Maretiidae differ from the Loveniidae in lacking an internal fasciole and in development of the internal ampullae, and from the Spatangidae in having the internal ampullae of aboral primary tubercles, but less developed than in the Loveniidae.

The important genera of this family are discriminated from one another as shown by the following key.

Key to the important genera of the family Maretiidae.

1.	A pair of large prominence (peristomial tuberosity) adorally in the anterior inter-
	ambulacra; no primary tubercles on the aboral side. Antero-lateral petals
	fully or more or less developed Laevipatagus
	No large prominence adorally; primary tubercles more or less developed on the
	aboral side. Antero-lateral petals fully or more or less developed 2
2.	Genital pores four 3
	Genital pores three

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3.	Anterior plates-series of antero-lateral petals well developed. Globiferous pedi-
	cellariae lacking Maretia
	Anterior plates-series of antero-lateral petals rudimentary (or degenerate). Glo-
	biferous pedicellariae present Paramaretia
4.	A fairly number of primary aboral radioles (tubercles), not in horizontal series,
	with well developed inner ampullae; phyllodes of rudimentary condition
	Hemimaretia
	Only very few primary aboral radioles (tubercles), arranged in a horizontal series
	near the ambitus, or none at all, internal ampullae developed only in the
	young, slightly developed or none; phyllodes more or less well developed \dots 5
5.	Pores of paired petals rudimentary (or degenerate) proximally Nacospatangus
	Pores of paired petals developed proximally as well as middle part
	Pseudomaretia.
	There is a fossil representative of the genus Maretia in our collection.

Genus Maretia GRAY, 1855

- Maretia GRAY, 1855-a, p. 48.—A. AGASSIZ, 1872-74, pp. 139, 568.—BOLAU, 1873, p. 4.—TENISON-WOODS, 1878, p. 173.—ZITTEL, 1879, p. 545.—COTTEAU, 1880-a, p. 74.—LORIOL, 1883-a, p. 48.—COTTEAU, 1885-89 (85), p. 16.—DUNCAN, 1889-a, p. 252.—COTTEAU, 1890, p. 51.— BITTNER, 1891, p. 144.—MEISSNER, 1904, p. 1396.—LAMBERT, 1906, p. 47.—HOFFMANN, 1914, p. 263.—H. L. CLARK, 1917, p. 246.—FOURTAU, 1920, p. 83.—LAMBERT and THIÉRY, 1924, p. 458.—H. L. CLARK, 1925, p. 226.—SANCHEZ ROIG, 1926, p. 110.—GRANT and HERTLEIN, 1938, p. 133.—H. L. CLARK, 1946, p. 379.—MORTENSEN, 1951, p. 21 (complete synonymy).—COOKE, 1959, p. 80.
 - Haplotype.—Spatangus planulatus LAMARCK, 1816, p. 31 (Habite les mers australes).— Maretia planulata (LAMARCK): A. AGASSIZ, 1872-74, pp. 140, 570, pl. 19b, figs. 7-12, pl. 25, figs. 33-34, pl. 26, figs. 21-22, pl. 37, figs. 13-17 (Kingsmills, China, East Indian Islands, Mauritius).
- Hemipatagus Desor, 1855-58 (58), p. 416.—Cotteau, 1863-a, p. 309.—Zittel, 1879, p. 546.—
 Pomel, 1883, p. 29.—Duncan, 1889-a, p. 252.—Lambert, 1909-a, p. 107.—Lambert, 1915b, p. 188.—Lambert and Thiéry, 1924, p. 1942, p. 52.
- Haplotype.—Spatangus hoffmannii GOLDFUSS, 1826-33 (29), p. 152, pl. 47, fig. 3.—Hemipatagus hoffmannii (GOLDFUSS): EBERT, 1889, p. 63, pl. 8, figs. 3-6 (Chattian of Bünde). Tuberaster PERON and GAUTHIER, in COTTEAU, PERON and GAUTHIER, 1876-91 (85), p. 46.
- Haplotype.—Tuberaster tuberculatus PERON and GAUTHIER, 1010-01 (00), p. 40. Haplotype.—Tuberaster tuberculatus PERON and GAUTHIER, in COTTEAU, PERON and GAUTHIER, 1876-91 (85), p. 46.—COTTEAU, 1885-89 (86), p. 660, pl. 360, figs. 5-10 (non ZIT-TEL).—Hemipatagus gauthieri LAMBERT and THIÉRY, 1924, p. 457 (Oligocene of Algeria).

Forms of moderate size; test low, arched, or very low, flattened above, more or less fragile. Frontal ambulacrum (III) simple, flush with test, sinking into a slight or more marked depression at anterior edge and test becomes heart-shaped. Frontal tube-feet small and inconspicuous. Paired ambulacra forming conspicuous petals which closed distally; pore-pairs of anterior series of antero-laterals fully developed; adorally paired ambulacra form a conspicuous phyllode. Subanal fasciole well developed. Large tubercles aborally in paired interambulacra, but none in posterior interambulacrum (5); tubercles perforate, crenulate (?); areoles of aboral tubercles moderately sunken, forming slightly developed internal ampulae or none. Peristome anterior; labrum more or less prominent, posteriorly prolonged to about end of third adjoining ambulacral plates. Sternum and adjoining ambulacra very bare, carrying only scattered miliary radioles and pedicellariae. Periproct at upper edge of posterior end of test. Apical system ethmolytic, with four genital pores. Radioles of frontal depression curved, strongly thorny along the concave side; radioles on oral side of paired interambulacra with a more or less conspicuous widening at the base; miliary radioles curved. Pedicellariae of tridentate, rostrate, ophicephalous, and triphyllous types, but one of globiferous types. Sphaeridia open, more or less sunken grooves; in paired ambulacra they continue along the tube-feet of phyllodes (mainly after MORTENSEN, 1951). From the Eocene to Recent.

Maretia is distinguished, as shown in a key of the genera, from the related Paramaretia (MORTENSEN, 1950, p. 160.—Orthotype.—Par. multituberculata MORTENSEN, 1950, p. 160.—MORTENSEN, 1951, p. 47, pl. 4, figs. 5-9, pl. 5, figs. 1-2, pl. 6, figs. 1-3, pl. 45, figs. 3, 5, 8, 10, 12-22, text-figs. 19, 20a-c, 21-22) by having well developed anterior plates-series of the antero-lateral petals (II and IV), while in the latter genus anterior plates-series of the petals are rudimentary. From the genera Hemimaretia (MORTENSEN, 1950, p. 160.—Orthotype.—Hem. elevata (DÖDERLEIN) MORTENSEN, 1951, p. 53, pl. 1, fig. 4, pl. 44, figs. 5-7, 21, text-figs. 23-24) and Pseudomaretia (KOEHLER, 1914, p. 107.—Orthotype.—Pseud. alta (A. AGASSIZ): MORTENSEN, 1951, p. 58, pl. 3, figs. 12-14, 16-20, pl. 46, figs. 1-6, 8-11, 13, 19-20, text-figs. 25, 26a-c, 27a, 28, 30) Maretia differs in having four genital pores, while those genera having only three genital pores.

The geographical distribution of the living species of this genus is almost confined to the Indo-West Pacific Oceans. Fossil species date back to the Eocene and comprising about thirty-five in number, and seem to more widely distributed than the living species, but none is known from the Australian regions.

There is a single species, Mar. planulata (LAMARCK, 1816), of fossil in our collection.

Maretia planulata (LAMARCK, 1816)

(Pl. 25, fig. 4)

- Spatangus planulatus LAMARCK, 1816, p. 31.—MICHELIN, 1845, p. 179 (7).—AGASSIZ and DESOR, 1847, p. 7.—Maretia planulata (LAMARCK) GRAY, 1855-a, p. 48.—Hemipatagus planulatus (LAMARCK) MICHELIN, 1862, p. 6.—Maretia planulata (LAMARCK): A. AGASSIZ, 1863, p. 27.—Spatangus planulatus LAMARCK: MARTENS, 1866, p. 180, pl. 33, fig. 1.—Maretia planulata (LAMARCK): A. AGASSIZ, 1863, p. 27.—Spatangus planulatus LAMARCK: MARTENS, 1866, p. 180, pl. 33, fig. 1.—Maretia planulata (LAMARCK): A. AGASSIZ, 1872-74, pp. 140, 570, pl. 19b, figs. 7-12, pl. 25, figs. 33-34, pl. 26, figs. 21-22, pl. 27, figs. 13-14.—LOVÉN, 1874, pl. 3, fig. 40, pl. 42.—A. AGASSIZ, 1881-a, p. 173, pl. 38, fig. 23, pl. 40, figs. 54-55, pl. 41, figs. 17-20.—LORIOL, 1883-a, p. 48.—LOVÉN, 1883, pl. 8, figs. 64, 78-79.—MARTIN, 1888-87 (85), p. 286.—LORIOL, 1893, p. 377.—KOEHLER, 1895, p. 416.—BELL, 1902, p. 233.—MEIJERE, 1904, p. 190, pl. 23, figs. 478-480.—YOSHIWARA (TOKUNAGA), 1907, pl. 19, figs. 11-14.—HOFFMANN, 1914, p. 263, pl. 6, figs. 3-5.—GERTH, 1922, p. 286 (512).—LAMBERT, 1922, p. 31.—LAMBERT and THIÉRY, 1924, p. 458.—WANNER, 1931, p. 455.—JEANNET and MARTIN, 1937, p. 277.—MORTENSEN, 1948-b, p. 131.—MORTENSEN, 1951, p. 27 (complete synonymy), pl. 4, figs. 1-5, 10-11, pl. 5, figs. 3-17, pl. 44, figs. 1-4, 18, 26-27, 29, 32-33, text-figs, 6a-b, 7a-b, 8, 10, 13a, 14, 53b.
- Spatangus praelongus HERKLOTS, 1854, p. 9, pl. 2, fig. 6.—Hemipatagus praelongus (HERK-LOTS) DESOR, 1855-58 (58), p. 418.—Atelospatangus praelongus (HERKLOTS) LAMBERT and THIÉRY, 1924, p. 458.—WANNER, 1931, p. 455.

- Spatangus affinis HERKLOTS, 1854, p. 10, pl. 2, fig. 5 (pro parte).—Hemipatagus affinis (HERK-LOTS) DESOR, 1855-58 (58), p. 418 (pro parte).—Maretia affinis (HERKLOTS) LAMBERT and THIÉRY, 1924, p. 458 (pro parte).
- Hemipatagus muscareignarum MICHLEIN, 1862, p. 6, pl. 16, figs. 2a-i.—Maretia muscareignarum (MICHELIN) LAMBERT and THIÉRY, 1924, p. 458.
- Maretia variegata GRAY, 1866, p. 190.
- Maretia fasciata LAMBERT, in LAMBERT and THIÉRY, 1924, p. 458.
- Maretia ovata ('LESKE') MEISSNER, 1904, p. 1397.—H.L. CLARK, 1917, p. 248.—H.L. CLARK, 1925, p. 226.—STOCKLEY, 1927, p. 117, pl. 21, figs. 8a-b.—H.L. CLARK, 1932, p. 219.—TORTONESE, 1933-a, p. 168, pl. 13, fig. 58.—CURRIE, 1938, p. 87, pl. 9, figs. 3a-b.—H.L. CLARK, 1938, p. 437.—NISIYAMA, 1942, p. 24 (in Japanese).—H.L. CLARK, 1946, p. 380.

Locality and geological horizon.—Northern part of Angaur Island, Palao Island Group, Micronesia, South Sea Islands. Younger Angaur Limestone, Pleistocene. Hypotype.—IGPS coll. cat. no. 73826.

There is only a single specimen of internal mould of this species at the writer's disposal, the anterior part of test is broken due to corrosion and the preserved part is not good state in preservation. The specimen measures about 30 mm in transverse diameter, about 37 mm in longitudinal one of the preserved part, and about 14 mm in height. From lateral view, aboral surface almost flat and slightly down towards the anterior part, adoral surface also flat on the anterior part, labrum more or less produced and then makes more or less a convex curve adorally and terminated a rounded end, where it coincides with the posterior end of sternum. From posterior view, both margins rather round and gradually rising to the highest point; periproct lies a little, about one-fourth of height, below the highest point. Frontal ambulacrum (III) preserved only a small part, especially on aboral surface, proximal part of the petal very narrow. Antero-lateral petals (II and IV) rather flush on the surface and closed distally, narrow and rather short, about 15 mm long and 3 mm wide at the broadest point; number of plates in the petal 15 in a column; pore-pairs of anterior series of the petals fully developed and pores situated near distal suture of the plates. Posterolateral ambulacra (I and V) on the aboral surface rather long but narrow, about 22 mm long and 3.5 mm wide at the middle part and flush with the surface; petals closed distally; number of plates in the petal 20 in a column; pores of pairs situated near distal suture of the plates; plates outside the petal 12 in a column and rather abruptly widened toward the margin. Plates in posterior interambulacrum (5) broad and high, number of the plates 12 in a column. Apical system rather small, about 1.5 mm wide and 2 mm high, with four genital pores. Trace of 2 or 3 large tubercles aborally preserved in the postero-lateral interambulacra (1 and 4). At least two tubefeet to each side enclosed by the subanal fasciole. The very low and flattened test and the number of tube-feet within the subanal fasciole of this specimen its reference safely with the living Mar. planulata (LAMARCK, 1816).

As for the specific name of this species, H. L. CLARK (1917, p. 266), after MEISSNER (1904, p. 1397), preferred the name *ovata*, as this name is derived from "*Spatangus ovatus*" of LESKE, 1778 (pl. 49, figs. 12-13), to which he identified with LAMARCK's "*Spatangus planulatus*" and holds superior the former than the latter by the rule of priority. But MORTENSEN (1948-b, p. 132) rejected the name *ovata* and takes the universally used name *planulata* for this species. LAMBERT and THIÉRY (1924, p. 458)

stated on this matter, as—"CLARK donne à cette espèce de nom de M. ovata LESKE (Spatangus) 1452, p. 248, mais l'identité du type de SEBA (tab. XV, fig. 28-29) et de l'expèce de LAMARCK n'est pas réellement démonstrée."

Maretia planulata is widely distributed and seems to be rather varied species, and many synonymous names are given for varied forms by many authors. One of the synonymous names, Mar. fasciata LAMBERT, 1924 (in LAMBERT and THIÉRY, 1924, p. 458), is given for a Philippine form by LAMBERT, his description of this form is as follows—M. fasciata LAMBERT, des Philippines, se distingue du M. planulata par sa petite taille, sa coloration fasciée, surtout ses tubercules scrobiculés plus rares et plus inégaux." But the differences between Mar. fasciata and Mar. planulata in sense of LAMBERT seem to fall into within the variational limit of one and same species. The smaller height, fasciated colouration of the test and arrangement and number of the scrobiculated tubercles, which are accounted for the features of Mar. fasciata by LAMBERT, are found in some specimens of Mar. planulata from other localities than the Philippines. H. L. CLARK (1925, p. 226) and MORTENSEN (1948-b, p. 131) being not recognized LAMBERT's Mar. fasciata for the Philippine form and the both authors identified it with Mar. planulata of widely distributed species.

In the living this species distributes mainly in the Indo-West Pacific, from East Africa (Mozambique to Madagascar) to Fiji and the Gilbert Islands (but apparently not farther east), and from the Sagami Sea, Japan, to Port Jackson, Australia; in the Red Sea it is known only from the southernmost part. It ranges from ebb-zone to about 60 metres in bathymetrical distribution. This species dates back at least to the upper Miocene of the East Indies (Java), and occurs in the Pliocene of East Indies (Java) and North Africa (Zanzibar) and in the Pleistocene of the Farsan Islands in the Red Sea. The occurrence of this species from the Pleistocene of the Palao Islands is noteworthy to indicate the northeastern range of the species in the geological distribution.

Family LOVENIIDAE LAMBERT, 1905

Lovenidae LAMBERT, 1905-a, p. 162 (subfamily; pro parte).—LAMBERT and THIÉRY, 1924, p. 447 (subfamily; pro parte).—Loveniidae LAMBERT: MORTENSEN, 1950-a, p. 181.—MORTENSEN, 1951, p. 83.

Breyninae LAMBERT, 1905-a, p. 162 (tribus; pro parte).—LAMBERT and THIÉRY, 1924, p. 466 (pro parte).

Type-genus.—Breynia DESOR, 1847.

Peristome transverse, labrum and sternum well developed, the latter covered with tubercles or almost quite naked. Apical system ethmolytic, with four or three genital pores. Ambulacra petaloid adapically, petals usually short and pointed distally. Large and deeply sunken primary tubercles, with sunken areoles and the internal ampullae, usually present at least within a peripetalous fasciole. An "inner" or "internal" fasciole present. surrounding only the frontal ambulacrum (III) and the apical system, and a subanal fasciole.

The presence of an "internal" or "inner" fasciole is an unique feature in this family, it is easily and distinctly demarcated the family from other Spatangoins. The

Type-genus.—Lovenia DESOR, 1847.

presence of a subanal fasciole in this family is in common with the families, e.g., the Maretiidae, Micrasteridae, Brissidae, Spatangidae and a part of the Palaeopneustidae. But the origin of this fasciole, like a peripetalous fasciole, would took place the different lines of development, and the presence of a subanal fasciole in itself alone cannot afford definite proof on the relationship of the Loveniidae to other families providing with this fasciole. The occurrence of a peripetalous fasciole in one genus (Breynia) of this family is in common with the families, e.g., the Hemiasteridae, Pericosmidae, Schizasteridae, Brissidae, a part of the Aeropsidae, a part of the Palaeopneustidae, and a part of the Palaeostomatidae. But the origin of a peripetalous fasciole also has took place the different lines of development and it does not indicate the relationship of the Loveniidae to other families providing with this fasciole. The presence of the internal ampullae of the large aboral primary tubercles, one of the main characters of this family, is found to developed in one genus (Hemimaretia) and in the young individuals of *Maretia* of the Maretiidae; it seems to suggest a relationship between the Maretiidae and the Loveniidae. Similar development of the internal ampullae of the tubercles is also found in some genera, i.e., Homolampas, of the Palaeopneustidae; but in Homolampas an internal fasciole does not developed. The true relationship of this family to other Spatangoins are not ascertained on sound ground in the present state of our knowledge.

Regarding the classification of the family LAMBERT and THIÉRY ascribed to the tribus Breyninae (1924, pp. 466-472) Vasconaster LAMBERT, 1915, Lovenia DESOR, 1847 (with a subgenus Pseudolovenia A. AGASSIZ and H. L. CLARK, 1907), Breynia DESOR, 1847, Blaviaster LAMBERT, 1920, Gaultieria DESOR, 1847, Echinocardium GRAY, 1825, and Amphidetus AGASSIZ, 1836, which are characterized by having an internal fasciole. LAMBERT and THIERY's tribus Brevninae cover almost the same ground of the Loveniidae, which is emended and relimited by MORTENSEN (loc. cit.), except for some fossil genera, as far as the Recent forms are concerned. In the family Loveniidae, as in the strict usage of MORTENSEN, it is generally regarded that the genera Lovenia, Pseudolovenia and Breynia are related to one another as they are placed together in LAMBERT and THIÉRY'S tribus Breyninae. The perplexing genus Echinocardium differs markedly from the typical Loveniids in that the primary aboral tubercles are small and that it has no sunken areoles or inner ampullae, showing a contrast to the well-developed sunken areoles of the typical Loveniids; although the genus was referred by LAMBERT and THIERY to their tribus Breyninae for the reason that it has a typical internal fasciole besides a subanal one, being in accord with the main character of this tribus or the Loveniidae. COOKE (1942, p. 59) has established a family Echinocardiidae, as comprising *Echinodardium* as the type-genus, *Lovenia* and *Vasconaster* LAMBERT, 1915 (this is regarded as a synonym of Lovenia by MORTENSEN, 1915, pp. 88, 89). MORTENSEN (1951, p. 88) suppressed the Echinocardiidae as a subfamily rank of the Loveniidae. The writer merely follows this treatment of the subfamily Echinocardiinae, and the two subfamilies, the Loveniinae and the Echinocardiinae, of the Loveniidae are distinguished from each other by the feature of the primary aboral tubercles.

As for fossil genera referable to the family Loveniidae MORTENSEN (1951, op. cit.) enumerated the following three genera. viz., *Megapetalus* H. L. CLARK, 1929, *Chuniola*

GAGEL, 1903, and Verbeekia FRITSCH, 1887, as incertae sedis. Megapetalus has close relation with Palaeopneustes in the general features and should be referred to the Palaeonpneustidae, and Verbeekia closely resembles Brissopsis of the Brissidae in the shape of petals. Chuniola may be left incertae sedis under the Loveniidae.

The Recent genera of the family, viz., *Lovenia*, *Pseudolovenia*, *Breynia* and *Echino-cardium*, are discriminated from one another as shown by the following key.

Key to the Recent genera of the family Loveniidae.

- No peripetalous fasciole present; sternum almost quite naked 3

Genus Breynia DESOR, 1847

- Breynia DESOR, in AGASSIZ and DESOR, 1847, p. 12.—D'ARCHIAC and HAIME, 1853-54 (53), p. 215.—GRAY, 1855-a, p. 45.—DESOR, 1855-58 (58), p. 408.—COTTEAU, 1863-a, p. 305.—A. AGASSIZ, 1872-74, pp. 45, 578.—BOLAU, 1873, p. 10.—ZITTEL, 1879, p. 544.—POMEL, 1883, p. 27.—DUNCAN and SLADEN, 1883, p. 66.—DUNCAN and SLADEN, 1884, p. 228.—DUNCAN and SLADEN, 1885-a, p. 342.—DUNCAN, 1889-a, p. 262.—COTTEAU, 1889-94 (94), p. 670.— MEISSNER, 1904, p. 1400.—HOFFMANN, 1914, p. 265.—H. L. CLARK, 1917, p. 250.—LAMBERT and THIÉRY, 1924, p. 467.—H. L. CLARK, 1925, p. 228.—H. L. CLARK, 1946, p. 381.—HAYA-SAKA, 1947, p. 110.—MORTENSEN, 1951, p. 128 (complete synonymy).—TERMIER and TERMIER, 1953, p. 945.
- Haplotype.—Spatangus crux-andreae LAMARCK, 1816, p. 31.—Spatangus australasiae LEACH, 1815, p. 68, pl. 82 (Australia).—Breynia australasiae (LEACH): A. AGASSIZ, 1872-74, pp. 95, 578, pl. 15a, figs. 7-9, pl. 25, fig. 32, pl. 26, fig. 20 (East coast of Australia, shallow water form).

Large form of ovoid outline; test usually quite stout, low arched, flattened below. Paired ambulacra form conspicuous petals adapically, usually pointed distally, triangular in outline, flush with test; pore-series end abruptly at internal fasciole, plates within the fasciole having only minute microscopic pores, or even none at all proximally. Frontal ambulacrum (III) simple, somewhat sunken; a broad, but not very deep depression in frontal edge of test. Adorally ambulacra do not form a very conspicuous phyllodes. Three fascioles present, an internal, a peripetalous, and a subanal fasciole. Peripetalous fasciole not bending inwards between petals; subanal fasciole has an obtuse anterior angle, posterior band straight; subanal plastron subtriangular. A number of large primary tubercles on aboral side, from nearly 10 to as many as 30 in an area, within peripetalous fasciole, but only in paired interambulacra, but none in posterior interambulacrum (5). Tubercles non-crenulate (but in fossil species, *Br. carinata* and *Br. meslei*, the tubercles crenulate), have very deep areoles, with well developed inner ampullae. Tubercles of oral side small, perforate, crenulate, usually elegantly formed, their areoles not at all deepened, and they have no inner ampullae. Primary aboral radioles slightly curved, smooth, or with few small thorns. Pedicellariae of five usual types, but globiferous pedicellariae found only in one species (*Br. desorii*). Sphaeridia in simple grooves, sometimes in considerable number of adoral tube-feet (mainly after MORTENSEN, 1951). From the Oligocene to Recent of the Indo-Malayan regions.

By the presence of three fascioles, viz., the internal, the peripetalous, and the subanal, this genus is distinguished markedly from all other Spatangoins having various kinds of fascioles, and it brings the most characteristic feature of this genus. This genus is generally regarded to have a close relation with *Lovenia* (DESOR in AGASSIZ and DESOR, 1847, p. 10.—Type-species.—*Spatangus elongatus* GRAY in EYRE, 1845, p. 436, p. 6, fig. 2), and the both genera are in common with also the presence of internal ampullae at the aboral primary tubercles. But in the latter genus the large primary tubercles with internal ampullae occur on the oral side and the absence of a peripetalous fasciole.

The living species of this highly specialized genus was long supposed to be monotypic and to be the characteristic of Australian Seas; however, GRAY's *desorii* is distinctly distinguished from the type-species (*australasiae*), and the following living species are referred to this genus hitherto.

- Breynia australasiae (LEACH, 1815): GRAY, 1851, p. 131. Known with certainty only from East Australia, from the Queensland coast to Port Jackson.
- Breynia desorii GRAY, 1851, p. 131.—MORTENSEN, 1951, p. 139, pl. 11, figs. 3-5, pl. 12, figs. 1, 17, 12, pl. 14, figs. 1, 2, 6-7, pl. 49, fig. 21, text-fig. 70b.

Known with certainty only from West Australia, from Swan River to Mermaid Strait.

- Breynia elegans MORTENSEN, 1948-b, p. 138.—MORTENSEN, 1951, p. 142, pl. 11, figs. 6-7, pl. 14, fig. 10, pl. 49, figs. 6, 8, 22, 31, text-figs. 63, 68, 69b, 71c, 72-73. Known from Kei Islands and Tawi-Tawi Islands, Philippine Islands, in 60-85 metres depth.
- 4. Breynia vredenburgi ANDERSON, 1907, p. 145, pl. 5.—H. L. CLARK, 1917, p. 251. Known only from Port Blair, Andaman Islands. A shallow water form.

As for fossil species, a number of species have been referred to this genus. LAMBERT and THIÉRY (1924, p. 467) enumerated six fossil species under the genus *Breynia*, and MORTENSEN (1951, pp. 129-131) enumerated and discussed the fossil species, which are referred to the genus, before and after the publication of LAMBERT and THIÉRY'S work. The following fossil species can be safely referred to the genus *Breynia* on their characteristic features on test.

- 1. Breynia carinata HAIME, in D'ARCHIAC and HAIME, 1853-54 (53), p. 216, pl. 15, figs. 4a-c. Oligocene and Miocene of western Sind.
- Eupatagus magnus HERKLOTS, 1854, p. 13, pl. 2, fig. 7f.—Breynia magna (HERKLOTS) MARTIN, 1880, p. 5.—GERTH, 1922, p. 515. Miocene of Java.
- 3. Breynia meslei GAUTHEIR, in COTTEAU, 1889-94 (94), p. 671, pls. 363-364. Oligocene?

of Egypt.

- 4. Breynia multituberculata VREDENBURG, 1906-a, p. 271, pl. 38.—(Breynia carinata multituberculata VREDENBURG, 1906). Oligocene of India.
- 5. Breynia sundaica GERTH, 1922, p. 514, pl. 62, fig. 5. Miocene of Java.
- Spatangomorpha paucituberculata GERTH, 1922, p. 513, pl. 62, fig. 6.—Breynia paucituberculata (GERTH) JEANNET and MARTIN, 1937, p. 278. Miocene of Madura.
- Breynia australasiae var. aroensis CURRIE, 1924, p. 64, pl. 4, fig. 6.=Breynia desorii GRAY, 1851. Pliocene? of Aru Island.
- 8. Breynia birmanica VREDENBURG, 1932, p. 413, pl. 30, figs. 1a-b. Oligocene of Burma.
- 9. Breynia cordata HAYASAKA, 1947, p. 122, pl. 10, figs. 1a-b, pl. 11, fig. 1. Pliocene of Formosa (Taiwan).
- 10. Breynia testudinaria HAYASAKA, 1947, p. 125, pl. 1, figs. 2a-b. Pliocene of Formosa (Taiwan).

It seems highly probable that some of these fossil species may represent ancestors of the living forms, which are descended from the predecessors of the geological time, or almost identical with the living species.

There are good fossil representatives of this genus from Formosa (Taiwan) in our collection.

Breynia carinata HAIME, 1853

Breynia carinata HAIME in D'ARCHIAC and HAIME, 1853-54 (53), p. 216, pl. 15, figs. 4a-c.— DUNCAN and SLADEN, 1883, p. 66, pl. 10, figs. 1-4.—DUNCAN and SLADEN, 1885-a, p. 343, pl. 54, figs. 1-8, pl. 55, figs. 1-8.—LAMBERT and THIÉRY, 1924, p. 467.—HAYASAKA, 1948-a, p. 114, pl. 4, fig. 4.—MORTENSEN, 1951, p. 130, text-figs. 6a-b.

There is no authentic specimen of this species at the writer's disposal, although HAYASAKA reported an occurrence of this species from the Nankô (Kaizan) formation (Miocene) developed near Shuinantung, along the coast of Chilung City, Formosa, together with *Astriclypeus integer* YOSHIWARA, 1899 (not typical *integer*), *Echinolampas jacquemonti* D'ARCHIAC and HAIME, 1853, and *Moira obesa* NISIYAMA, 1935.

The specimen figured by HAYASAKA fairly coincides with the figures of this named species from the Miocene of Kach (DUNCAN and SLADEN, 1883, pl. 10, figs. 1-4), but somewhat differs from the Oligocene form of the western Sind. The slight difference between the specimens from the Miocene and from the Oligocene is already noticed by LAMBERT and THIÉRY (1924, p. 467). By considering the wide range of variation of this species in the form of the test, course of the internal fasciole and in the form of petals, as is elaborately explained and illustrated by DUNCAN and SLADEN (1885-a, p. 343, pl. 54, figs. 3-8, pl. 55, figs. 1-8, but figs. 1-2, and 9 on plate 54 omitted), the difference in the Oligocene and Miocene forms should be fall into mere variation of a single species. It may perhaps, however, be doubted whether the remarkably broader specimens represented in plate 54, figs. 1-2, and 9 are actually the same species as the other (other figures on plate 54 and 55), more slender specimens of the normal form.

S. NISIYAMA

Br. carinata HAIME, 1853, the Indian Oligocene and Miocene species occurs as fossil in nearly same age in Formosa seems to be most probable. The Indian common fossil species Br. carinata, which ranges as east as Formosa, seems to be recall in its general shape and the number of the aboral primary tubercles the living Br. desorii (loc. cit.), but differs from that species in having only six pore-pairs (tube-feet) on each side included in the subanal fasciole, while in that species at least eight porepairs to each side within the fasciole, and in the internal fasciole being broader and less prolonged backwards of the apical system. Also Br. carinata offers the interesting feature, as is noticed by MORTENSEN, that the aboral primary tubercles are crenulate. In this feature it may be considered as being more primitive than the Recent species. HAYASAKA has a comparison this species with Br. australasiae var. aroensis CURRIE (1924, p. 64, pl. 4, fig. without number) from the Pliocene? of Aru Islands; that fossil variety is identified with the living Br. desorii by MORTENSEN (1951, p. 139), the writer believes it with certainty. In comparing that fossil variety with Br. carinata, CURRIE (1924, loc. cit.) noticed the difference in shape of the internal fasciole, that it is less drawn out to the posterior than in *carinata*, as is less prolonged backwards of the apical system in carinata. At any rate, Br. carinata seems to be closely related to the living Br. desorii from the West Australian region.

Breynia cordata HAYASAKA, 1947

Breynia australasiae subsp. nov. Аокі (now Nisiyama), 1933, p. 52, text-fig. 69a. Breynia cordata Науазака, 1947, p. 122, pl. 10, figs. 1a-b, pl. 11, fig. 1.

Locality and geological horizon.—About 800 metres east of Jôtsûshôwan, Tsûshôshô, Byôritsu-gun, Shinchiku-shû (Hsinchuhsien), Formosa. Byôritsu formation, Pliocene. Hypotype.—IGPS coll. cat. no. 73739.

Locality and geological horizon (after HAYASAKA, 1947).—Wanwa, Chunanchiu, Hsinchuhsien, Taiwan (Formosa). Byôritsu formation, Pliocene. Holotype and paratype.

There are four specimens referred to this species at the writer's disposal, range from about 78 mm to about 113 mm in longitudinal diameter. This species is fully described and well illustrated by HAYASAKA (loc. cit.). The following is the supplementary description of the species on the specimens at the writer's disposal.

Large one measures 95 mm in longitudinal diameter, 90 mm in transverse one, and about 33 mm in height; ratio of length to breadth being about 1:0.95, and that of length to height being about 1:0.35. Apical system slightly eccentric in front, situated at about 38 mm from the anterior margin, ratio of length of test to the length from anterior margin to apical system being 1:0.4, the value somewhat smaller than that of *Br. australasiae* and nearly usual as that of *Br. carinata*. Peripetalous fasciole well preserved, crosses posterior interambulacium (5) and runs almost parallel to the ambitus, passing by a short distance from distal ends of postero-lateral petals (II and IV); area within the peripetalous fasciole about three-fourths of test-length. Internal fasciole rather broad, in a very shallow groove; it forms posteriorly a wide angle between closely approximated poriferous zones of postero-lateral ambulacra of Ia and Vb, and crosses these zones, dividing, as in usual, from minute pairs of pores at
about sixth interradial plate from the apical system; the fasciole then passes forwards and outwards to reach the outer poriferous zones of the postero-lateral petals (I and V), thence it pursues the same line, and shortly crosses posterior poriferous zones of the antero-lateral petals (II and IV), at spots on a line drawn a cross the apical system; from these places the fasciole passes narrower forwards, and crosses the frontal ambulacrum (III) about midway between the peripetalous fasciole to the apical system, it measures 22 mm wide and 30 mm long. Subanal fasciole well marked and broad, about 1.5 mm wide at the broadest point, convexity of path forwards to keel at junction of culminating point of sternum; at least six ambulacral pore-pairs (tube-feet) to each side within the subanal fasciole; in the number of these pore-pairs this species in accord with the living *Br. australasiae* and the fossil *Br. carinata*.

Frontal ambulacrum (III) long and narrow; in a rather shallow groove; ambulacral plates rather high; pores minute, in regular series on each side, pore-pairs oblique to transverse suture of the plates; there are nearly 20 pore-pairs from the internal fasciole to apical system. Antero-lateral petals (II and IV) nearly transverse in parts external to the internal fasciole, especially anterior poriferous zones, which slightly curved so as to bring outer ends more to front; posterior poriferous zones wide apart from the anterior ones and close to the internal fasciole; within the internal fasciole the petals triangular in outline, base at the fasciole and apex to ocular plates; petals outside the fasciole also triangular in outline, about 14 mm wide at the base and about 20 mm long, with 9 large pore-pairs in the anterior and 14 pore-pairs in the posterior poriferous zone; pore-pairs within the internal fasciole small, over 11 pore-pairs in posterior poriferous zone. Postero-lateral petals (I and V) longer than the anterolateral ones, closed; beyond the internal fasciole, outer poriferous zones long, scarcely curved, being slightly bent near it, with 15 large pore-pairs; inner poriferous zones, beyond the internal fasciole, shorter than the outer, slightly curved, and come close to the outer poriferous zones so as to close the petals, with 14 large pore-pairs; within the internal fasciole, the outer poriferous zones with over 10 small pore-pairs.

Peristome situated at about 26 mm from the margin of frontal groove, rather small, reniform in outline, about 14 mm wide and 5 mm high; each ambulacrum at peristomial region perforated by from 2 to 4 large penicillate pores on each side, thus the ambulacra form a not very conspicuous phyllode. Labrum has a narrow posterior prolongation, about 15 mm long, and reaching almost to end of third plate of adjoining ambulacra. Sternum rather narrow and small, with two culminating points about 10 mm apart. Periproctal region deeply sunken, and below the periproctal region a subcarinate ridge quite abruptly rises to form a sharp peak, but the details of periproct not observable.

Aborally, within the peripetalous fasciole, in each postero-lateral interambulacrum (1 or 4) there are 12 large primary tubercles, which have very deep areoles, arranged in roughly three rows; and in each antero-lateral interambulacrum (2 or 3) there are 9 similar large primary tubercles arranged roughly in three rows, but none in posterior interambulacrum (5). Tubercles seem to be non-crenulate.

This specimen resembles figure 9 on plate 54 of DUNCAN and SLADEN'S Br. .carinata in outline, but is distinguished from that species by the form of petals, but the number of pore-pairs (tube-feet) to each side within the subanal fasciole agrees in the both species.

One of the small specimens, of about 80 mm in longitudinal diameter, resembles. Br. australasiae var. aroensis (loc. cit.), which is now referred to the living Br. desorii, from the Pliocene? of Aru Islands, in general outline, but differs from that species in the narrower petals, in the number of aboral large primary tubercles within the peripetalous fasciole, and in the number of pore-pairs to each side within the subanal fasciole.

It seems probable that this upper Pliocene species, from the Byôritsu formation of Formosa, of its nearest relation would bring to the living species, e.g., Br. australasiae or its allies, and the writer once regarded it as a subspecies of Br. australasiae (AOKI (now NISIYAMA), 1933, text-fig. 69a on page 52), as that species was not definitely known to the writer at that time, but it is not the case. Br. cordata seems neither to have the nearest akin to the living Br. australasiae (MCZ no. 7269, from Lord Howe Island, Australia, the writer examined them), nor Br. desorii, and nor Br. elegans (loc. cit.); but it seems to have affinity with an undescribed species from the Pacific Ocean of MORTENSEN (1951, p. 131) in the small number of aboral primary tubercles. The Pliocene species of Formosa, Br. cordata, in the meantime, has almost beyond doubt affinity with the Indian Oligocene and Miocene as well as the Formosan Miocene species, Br. carinata, in the general appearance and in the number of pore-pairs within the subanal fasciole, and it may be regarded that the former is probably derived from the latter by considering the geological sequence and same region of the both species. It is speculated that Br. cordata may be linked between the Miocene species Br. carinata and the living form in thought as the unnamed species of MORTENSEN.

It is very interesting fact that this species occurs as fossil together with an allied *Br. testudinaria* HAYASAKA, 1947 (see below), and the other echinoids such as *Scaphe-chinus mirabilis* A. AGASSIZ, 1863, and *Astriclypeus mannii* VERRILL, 1867; all of them seem to be rather exotic genera for Formosa, and the latter two are still living flour-ishingly off the coast of central Japan.

Breynia testudinaria HAYASAKA, 1847

Breynia australasiae subsp. nov. AOKI (now NISIYAMA), 1933, text-fig. 69b on p. 52. Breynia testudinaria HAYASAKA, 1947, p. 125, pl. 11, figs. 2a-b. Breynia carinata: COOKE, 1954, p. 49, pl. 12, figs. 5-6 (non D'ARCHIAC and HAIME, 1953).

Locality and geological horizon.—About 800 metres east of Jôtsûshôwan, Tsûshôshô, Byôritsu-gun, Shinchiku-shû (Hsinchuhsien), Formosa. Byôritsu formation, Pliocene. Hypotype.—IGPS coll. cat. no. 73790.

Locality and geological horizon (after HAYASAKA, 1947).—Wanwa, Chunanchiu, Hsinchuhsien, Formosa (Taiwan). Byôritsu formation, Pliocene. Holotype.

Locality and geological horizon (after COOKE, 1954).—USGS 17440, near mouth of small stream emptying into Katena-kô at Nakaosu, on road opposite Nakaosu Primary School, Okinawa. Basal part of Naha limestone, Pliocene. Hypotype.—USNM 561569.

There are three specimens referable to this species at the writer's disposal, range from about 85 mm to 118 mm in longitudinal diameter of test.

Large one at the writer's disposal measures 118 mm in longitudinal diameter, and 88 mm in transverse one and about 36 mm in height; ratio of length to breadth being about 1:0.74 and that of length to height being about 1:0.3; thus it may be much narrower and lower than *Br. cordata* and approaches very closely to the specimen of HAYASAKA'S *Br. testudinaria*. Distal ends of the antero-lateral petals (II and IV) placed more front than in *Br. cordata* and of the postero-lateral petals (I and V) closer together than in *Br. cordata*. Labrum seems to be more elongate than in *Br. cordata*, about 20 mm long, and sternum much narrower, about 15 mm wide at the broadest point being proportioned to the length, than in *cordata*, and the periproctal region deeply sunken below the posterior truncation as in *Br. cordata*. It is very doubtful whether it may be a distinct species separated from *Br. cordata*, or may be regarded as a subspecies of that species, and further or may fall within the range of variation of that species. But the shape of the test, shape of the petals, and the structure of the labrum of this form seem to make it a distinct species from *Br. cordata*.

COOKE (1954, pp. 49-50) regarded the individual variation of *Br. carinata* as being very wide and the East Indian and Formosan fossil species, e. g., *Br. magna, cordata*, and *testudinaria*, should be, but with some doubt, became synonyms of *carinata*. He identified large specimens from the upper Pliocene of Okinawa with *Br. carinata*. But, in the specimen figured by COOKE (USNM 561569—the writer examined it) the primary tubercles seem to be non-crenulate; this feature is contrasting to the crenulate tubercles, one of the characteristics of *Br. carinata*, and the number and arrangement of aboral primary tubercles within the peripetalous fasciole, shape of test, shape of petals, and shape of sternum much alike *Br. testudinaria*.

It is very interesting to see that *cordata* and elongate form (*testudinaria*) of the allied echinoids occur as fossils in the same horizon and the same locality side by side and the number of each form is not very different from each other. Whether the difference in form of the two types is due to whether difference of species or to sexual diamorphism is not quite certain; the difference due to sexual diamorphism is observable on the genital pores in the living specimens of this genus, but in these fossil forms the genital pores are not well preserved.

Subfamily ECHINOCARDIINAE COOKE, 1947

Echinocardiidae Сооке, 1942, p. 59 (family; pro parte).—Echinocardiinae Сооке: Mortensen, 1950-a, p. 181 (emend.).—Mortensen, 1951, pp. 89, 149. Type-genus.—Echinocardium Gray, 1825.

The subfamily Echinocardiinae differ from the other subfamily Loveniinae in the feature of the aboral primary tubercles, as they are rather inconspicuous and lacking the deep areoles and the internal ampullae. In the presence of a typical internal fasciole this subfamily can be leaded to associate with the family Loveniidae. Besides the presence of an internal and a subanal fasciole as usual of the Loveniidae, forms of this subfamily having an anal fasciole, which issues from the subanal fasciole and passing upwards along each side of the periproct, as in the genus *Metalia* of the Brissidae, and the feature is not found in the typical Loveniinae.

At our present knowledge only the single genus Echinocardium (including the

genus *Amphidetus* AGASSIZ, 1836, of authors) belongs to this subfamily, and no fossil genera are known which can be safely referred to the subfamily with certainty.

Genus Echinocardium GRAY, 1825

- Echinocardium GRAY, 1825, p. 430 (8) (original list of species.—Spatangus atropos LAMARCK, Sp. pusillus LESKE, E. sebae=Echinus guinensis cordiformis SEBA, 1758).—GRAY, 1851, p. 131.—GRAY, 1855-a, p. 42.—DESOR, 1855-58 (58), p. 406.—A. AGASSIZ, 1872-74, pp. 104, 349.— LOVÉN, 1874, p. 55, pls. 3, 12, 39.—ZITTEL, 1879, p. 544.—A. AGASSIZ, 1881-a, 173.—POMEL, 1883, p. 28 (partim).—CARUS, 1884, p. 102.—COTTEAU, 1885-89 (87), p. 119.—DUNCAN, 1889-a, p. 261.—Bell, 1892, p. 168.—MEISSNER, 1904, p. 1399.—MORTENSEN, 1907, p. 132.—H. L. CLARK, 1917, p. 261.—LAMBERT and THIÉRY, 1924, p. 468 (partim).—H. L. CLARK, 1925, p. 232.—MORTENSEN, 1932-e, p. 356.—COOKE, 1924, p. 59.—MORTENSEN, 1951, p. 149 (complete synonymy).—TERMIER and TERMIER, 1953, p. 945.—COOKE, 1959, p. 78.
 - Logotype.—Spatangus pusillus LESKE, 1778, p. 230, pl. 24, figs. C, D, E.=Echinus cordatus PENNANT, 1777, p. 58, pl. 34, fig. 75 (North Sea).—Echinocardium cordatum (PENNANT) A. AGASSIZ, 1872-74, pp. 109, 349, pl. 19, figs. 10-17, pl. 20, figs. 5-7. [Type validated by Opinion 209 of the International Commission on Zoological Nomenclature].
- Amphidetus Agassiz, 1836, p. 184 (17).—Agassiz, 1840-a, p. 16.—Forbes, 1841, p. 190.— Agassiz and Desor, 1847, p. 11.—Forbes, 1852-a, p. 16.—Schlüter, 1899, pp. 111-114.— Checchia-Rispoli, 1923, p. 26.
- Type-species.—Spatangus arcuarius LAMARCK, 1816, p. 13 (l'Océan atlantique austral, les côtes de Guinés).=Echinus cordatus PENNANT, 1777, p. 58.
- Echinospatangus [BREYNIUS] POMEL, 1883, p. 28 (Echinospatangus BREYNIUS, 1732, p. 61. pre-Linnean.—non Echinospatangus POMEL, 1854, p. 18).—POMEL, 1888, p. 444.
- Type-species.—Echinospatangus cordiformis BREYNIUS, 1732, p. 61, pl. 5.=Echinus cordatus PENNANT, 1777, p. 58.
- Amphidetus (AGASSIZ) POMEL, 1883, p. 28.—LAMBERT, 1951-b, p. 206.—LAMBERT and THIÉRY, 1924, p. 469.
 - Type-species.—Amphidetus mediterraneus FORBES, 1844, p. 183 (Mediterranean Sea, Recent).— Echinocardium mediterraneum (FORBES) GRAY, 1855-a, p. 44.
- Non Echinocardium GRAY: LAMBERT, 1907-C, p. 113.—LAMBERT, 1915-b, p. 206.
- Logotype.—Spatangus atropos LAMARCK, 1816, p. 32 (l'Océan europén, la Manche).—Moira atropos (LAMARCK) A. AGASSIZ, 1872-74, pp. 146, 356, pl. 23, figs. 1-6. [LAMBERT, 1907-c, p. 113].

Small to medium-sized of oval outline, distinctly heart-shaped with a more or less distinct frontal depression. Test delicate and fragile, generally high, more or less gibbous. Posterior end vertically truncated; oral side flattened. Frontal ambulacrum (III) varying from flush with test (e.g., *pennatifidum* NORMAN, 1867) to markedly sunken (e.g., *cordatum*); the pores varying from forming regular single series to being crowded to a varying degree so as to form irregular double series, pore-pairs without a peduncular granule or bead. Paired ambulacra form conspicuous petals adapically; petals more or less sunken, with rather small number of pore-pairs; triangular in outline and apparently abutting at their proximal end against the internal fasciole; outside the fasciole double pored and within small, simple pored. Apical system subcentral, ethmolytic, with four genital pores; madreporite widening behind posterior genitals and oculars. Peristome not very eccentric in anterior; periproct at upper edge of truncate posterior end. Well developed internal fasciole from which issues an anal branch passing upwards along each side of periproct; fasciole placed verti-

cally and forms a more or less sharp point orally where it meets sternum. Sternum fully tuberculated, rather broad posteriorly, narrowing anteriorly towards more or less prominent labrum. Radiole-covering rather dense and uniform; a few, not very conspicuous, primary radioles (tubercles) found scattered in antero-lateral interambulacra (2 and 3), rarely in postero-lateral interambulacra (1 and 4), and especially along frontal ambulacrum (III) inside the fasciole; radioles of plastron curved, spatulate. All the usual five types of pedicellariae present (mainly after MORTENSEN, 1951). From the Oligocene (Tongrian) to Recent.

The use of this generic name and its type-species is fully discussed by MORTEN-SEN (1932-e, p. 356; 1951, p. 150), and is validated by Opinion 209 of the International Commission on Zoological Nomenclature, there is no need of repetition of it here.

The generic distinction between Echinocardium and Amphidetus was attempted by some echinologists being based on the misconception of the type-species on one hand and on the differences of features in the frontal ambulacrum (III) on the other hand. POMEL (1883, p. 28) is the first author who distributed the species of the genus Echinocardium, which is now generally considered as a single genus, into the three genera, viz., Echinospatangus BREYNIUS, 1732 (Type-species.-Ech. cordatus (PENNANT, 1777), Echinocardium (Type-species.—Ech. flavescens (O. F. Müller, 1776), and Amphidetus AGASSIZ, 1836 (Type-species .- Amph. mediterraneus FORBES, 1844), and it causes much confusion in the echinological nomenclature and taxonomy. In their work LAM-BERT and THIÉRY distinguished the two genera, Echinocardium restricted to the species cordatum being characterized by the pores of the frontal ambulacrum are in irregular double series, and the rest of the species are referred to a separate genus Amphidetus being characterized by the pores of the frontal ambulacrum are in single regular series. A. AGASSIZ (1863, p. 26) kept separating the Echinocardium from Amphidetus, but in the latter work (1872-74, p. 351) he recognized that the generic distinction between Amphidetus and Echinocardium is untenable. H.L. CLARK (1917, p. 261; 1925, p. 232) and MORTENSEN (1932-e, p. 356; 1951, pp. 150-151) do not separate the Echinocardium from Amphidetus in due to the large irregularities in the pores of the frontal ambulacrum in Ech. cordatum. A great variation occurs in Ech. cordatum is respect to the arrangement of the pores in the frontal ambulacrum, the one with frontal ambulacral pores (without a peduncular granule) arranged in a single series and the other with the pores in rather irregular double series (probably owing to plate-complexity to compressure of plate-growth). It seems to be a quite extraordinary case among the Spatangoina and cannot be applied for the frontal pores of the other Spatangoina with a peduncular granule between pores of a pair. The species with the frontal ambulacral pores of same regular shape, obliquely placed to the suture of plates, and separated by a peduncular granule, cannot be congeneric with the species with the frontal ambulacral pores of irregular double series, horizontally placed to the suture of plates and not separated by a peduncular granule, as being separated Diploporaster from Paraster. But it is not a case between Echinocardium and Amphidetus (in the sense of LAMBERT), as the both having the frontal ambulacral pores are not separated by a peduncular granule and rather horizontally placed to the suture of plates. The type-species of Amphidetus, moreover, is the same the type-species of Echinocardium and the former must become the absolute synonym (typonym) of the

latter.

The genus *Echinocardium* dates back to the Oligocene (Tongrian) and the fossil species are not very numerous and less than nineteen species are enumerated by LAM-BERT and THIÉRY in their work (1924, pp. 468-469). The genus seems to have its greatest development in Recent seas, where at least ten living species are known. The species of this genus are widely distributed in temperate, subtropical and tropical seas, but appear to be lacking along the West American coasts, whereas they occur in the West Indian region and are also known as fossil in North America (*Ech. orthonotum* (CONRAD, 1843), *Ech. gothicum* (RAVENEL, 1848), etc.)

Echinocardium cordatum (PENNANT, 1777)

(Pl. 22, figs. 7-10, pl. 23, figs. 1-6, the living)

- Echinocardium cordatum (PENNANT) GRAY, 1848, p. 6.—GRAY, 1851, p. 131.—GRAY, 1855-a, p. 43.—DESOR, 1855-58 (58), p. 407, pl. 43, figs. 4-5.—A. AGASSIZ, 1863, p. 27.—A. AGASSIZ, 1872-74, pp. 109, 349, 580, pl. 19, figs. 10-17, pl. 20, figs. 5-7.—LOVÉN, 1874, pl. 1, figs. 2-7, pl. 3, fig. 38, pl. 12, fig. 107, pl. 39.—LOVÉN, 1883, pl. 11, figs. 120–126, pl. 12, fig. 148.— CARUS, 1884, p. 102.—GREGORY, 1891, p. 42.—BELL, 1892, p. 169, pl. 16, figs. 1-4.—SCHLÜTER, 1889, p. 106.—HESSE, 1899, p. 256, pl. 13, figs. 8a-b.—CHECCHIA-RISPOLI, 1907, p. 221, pl. 19, figs. 8-9.—MORTENSEN, 1907, p. 145, pl. 16, fig. 21, pl. 17, figs. 15, 21–25, 30, 34, 37–38, 43, 48–49.—HAWKINS, 1913-a, p. 169, pl. 26.—H. L. CLARK, 1917, p. 262,—HAWKINS, 1920, pl. 69, fig. 4.—LAMBERT and THIÉRY, 1924, p. 468.—H. L. CLARK, 1925, p. 232.—GORDON, 1926, pp. 255–313.—MORTENSEN, 1929, p. 478.—CHANG, 1932, p. 18, pl. 3, figs. 5-6.—NISIYAMA, 1937, p. 59.—IKEDA, 1940, p. 5.—MORTENSEN, 1951, p. 152, pl. 18, figs. 6-7 (complete synonymy; figs. 1-3, 8.—australe GRAY), text-fig. 78.—UTINOMI, 1954, p. 355.—COOKE, 1959, p. 78.
- Amphidetus cordatus (PENNANT) FORBES, 1841, p. 190.—AGASSIZ and DESOR, 1846, pl. 15, fig. 8.—AGASSIZ and DESOR, 1847, p. 11.—FORBES, 1852-a, p. 16, pl. 2 (11), figs. 1a-b.—Sch-LÜTER, 1899, p. 112[.]—LAMBERT, 1915-b, p. 206.—CHECCHIA-RISPOLI, 1923, p. 26, pl. 5, figs. 4-4a.

Echinocardium australe GRAY, 1851, p. 131.—GRAY, 1855-a, p. 44, pl. 4, fig. 1,—A. AGASSIZ, 1872-74, pp. 109, 580, pl. 37, fig. 15.—TENISON-WOOD, 1878, p. 174.—Döderlein, 1885, p. 107.—Yoshiwara, 1900, p. 402 (in Japanese).—A. AGASSIZ and H. L. Clark, 1907-b, p. 137.—H. L. Clark, 1914-a, p. 169.—Mortensen, 1921, p. 192.—Lambert and Thiéry, 1924, p. 469.

Echinocardium zealandicum GRAY, 1851, p. 131.—GRAY, 1855-a, p. 44, pl. 4, fig. 4. Echinocardium stimpsoni A. AGASSIZ, 1863-a, p. 360.

Locality and geological horizon.—IGPS loc. no.—Ak.-1.—Road-side cutting at Tayazawa, Wakimoto-mura, Minami-Akita-gun, Akita Prefecture (tm Funakawa, Lat. 39° 55'N., Long. 139°53'10"E.). Shibikawa formation, Pliocene. Hypotype.—IGPS coll. cat. no. 73769.

Locality and geological horizon.—Wanga, Goryû-shô, Chikunan-gun, Shinchiku-shû (Wanwa, Chunanchiu, Hsinchuhsien), Formosa (Taiwan). Byôritsu formation, Pliocene. Hypotype.—IGPS coll. cat. no. 73770.

There are several specimens referred to this species of rather delicate test at the writer's disposal, they are usually not well preserved and some are badly distorted.

Large one measured about 37 mm in longitudinal diameter, 36 mm in transverse one, and about 24 mm in height. Test irregularly heart-shaped, widest at a little anterior to centre, higher posteriorly than anteriorly. Frontal ambulacrum (III) in a rather deep groove and the groove begins at the apical system and becoming deep at the ambitus; ambulacral pores in close double series, as usual, on each side and the pores being not departed by a peduncular granule. Antero-lateral petals (II and IV) in rather shallow grooves, the number of well-marked pairs of pores 8 in anterior poriferous series and 12 in the posterior series; postero-lateral petals (I and V) somewhat shorter and narrower than the antero-laterals, and in rather shallow grooves, the number of well-marked pairs of pores 9 in outer poriferous series and about 8 or 9 in the inner series. Internal fasciole well-marked, symmetrical on either side of midline. Subanal fasciole distinct and broad, rounded in outline, lower end coincides with a prominent truncation point; within the fasciole 3 large penicillate pores (tube-feet) on each side. Peristome rather small, situated at 12 mm from the anterior margin; about 5 mm wide and 2 mm high. Periproct large, oval in outline and placed vertically. Posterior end of test straight, vertically truncated. Tuberculation on aboral surface uniform, but large primary tubercles in antero-lateral interambulacra (2 and 3).

The writer has found a small specimen, in the large collection of the United States National Museum, from the Naha limestone (Pliocene) at USGS 17590 (Kamimotobu-mura office, by between Johana and Urasaki, Okinawa). Although this specimen is not mentioned by COOKE, it measures about 22 mm in longitudinal diameter of test and is safely assigned to *Ech. cordatum*.

This species is reported as fossil from the Pliocene of England, Sicily, and Barcelone, and the occurrence as fossil from the Pliocene of Formosa, Okinawa, and northern Japan is very interesting. In the study of the large amount of materials which have now been gathered from the four quarters of the globe, H. L. CLARK (1917, p. 262; 1925, p. 233) and MORTENSEN (1907, p. 145; 1951, p. 157) say, shows that this species is a very variable and remarkably wide-spread form, and further large series of specimens does not reveal any satisfactory way of separating the Pacific *Ech. australe* (loc. cit.) from the Atlantic *Ech. cordatum*, for there is no constant difference between specimens of the same size from England, Japan, South Africa, and Australia (H. L. CLARK, 1925, p. 233).

MORTENSEN (1907, p. 147; 1951, p. 157) speaks it as cosmopolitan, but *Ech. cordatum* is not known to occur as the western side and the northeastern shores of Africa, the southern and western part of South America, the western coast of the United States and British North America, the southwestern coast of Asia, and the islands of the tropical Paciffc.

The world-wide distribution of this species may be due to one or combination of the factors of the long period and stoutness of larval stage, very adaptative character to the environments, the long period of ovulation, and or the old appearrance in the geological age; but the true state is not certain in the present state of our knowledge.

The bathymetrical range of *Ech. cordatum* is quite limited, in contrasting to the geographical range which is remarkably for so wide and so far as hitherto recorded then, it is bathymetrically from the littoral zones down to about 230 metres (85 fathoms).

S. Nisiyama

Family Schizasteridae Lambert, 1905

Schizasterinae LAMBERT, 1905-a, p. 154 (tribus).—LAMBERT and THIÉRY, 1925, p. 517 (tribus).— Schizasteridae LAMBERT: MORTENSEN, 1950-a, p. 181.—MORTENSEN, 1951, p. 204. Type-genus.—Schizaster Agassiz, 1836.

Peristome transverse, labrum well developed. Apical system usually ethmolytic, or rarely ethmophract, with four, three, or two genital pores. Ambulacra more or less distinctly petaloid adapically and more or less usually deeply sunken, or markedly deepen to slit-like. Both a peripetalous and a latero-anal fasciole (except the genus *Amphipneusles* KOEHLER, 1900) usually complete and distinct, but no subanal fasciole. From the Cretaceous to Recent.

The origin of the Schizasteridae is not clearly known. LAMBERT (1931, p. 147) stated, without any restriction, that the genus *Periaster* D'ORBIGNY, 1854, a primitive form of the Schizasteridae, is a descendant of the genus *Hemiaster* of the Hemiasteridae, and the genus *Linthia* DESOR, 1853, in turn, a descendant from *Periaster*. MORTENSEN (1951, p. 209) offered an idea that it seems to be more natural to seek the source of the Schizasteridae in forms with fascioles not yet defined, viz., the Toxasteridae, by the reason of remarkable difference of the fasciole between the Hemiasteridae and the Schizasteridae, and it strongly againsts the direct derivation of the Schizasteridae from the Hemiasteridae, as suggested by LAMBERT.

The Schizasteridae, whether they are derived directly from the Hemiasteridae providing with a peripetalous fasciole or from the Toxasteridae with fascioles not yet clearly defined, are characterized by, as diagnosed above, having both a peripetalous and a latero-anal fasciole, by which they are distinguished from other Spatangoina.

In the classification adopted by LAMBERT and THIÉRY their tribus Schizaterinae (1925, p. 517-533), which is characterized by having a peripetalous and a latero-anal (lateral) fasciole, comprising the Recent genera, viz., *Faorina* GRAY, 1851, *Prymnaster* KOEHLER, 1914, *Schizaster* GRAY, 1855, *Spatangus* KLEIN, 1734 (=*Ova* GRAY, 1825), *Tripylus* PHILIPPI, 1845, *Protenaster* POMEL, 1883, *Moiropsis* A. AGASSIZ, 1881, *Moira* A. AGASSIZ, 1872 and *Paraster* POMEL, 1869, and the fossil genera *Periaster* D'ORBIGNY, 1854, *Hemigymnia* ARNAUD, 1898, *Linthia* DESOR, 1853, *Schizopneustes* THIÉRY, 1907, *Lutetiaster* LAMBERT, 1920 and *Isopetalum* LAMBERT, 1911. LAMBERT and THIÉRY (1925, p. 514) also separated the tribus Prenasterinae (LAMBERT, 1905-a, p. 25.—LAMBERT and THIÉRY, 1925, p. 514) from the tribus Schizasterinae, owing to the peculiar arrangement of the peripetalous fasciole that going down to the oral side anteriorly: to their tribus Prenasteridae LAMBERT and THIÉRY referred the following genera, *Parabrissus* BITTNER, 1880, *Cestobrissus* LAMBERT, 1912, *Pseudobrissus* LAMBERT, 1905, *Prenaster* DESOR, 1858, *Peribrissus* POMEL, 1869, *Anisaster* POMEL, 1886 and *Agassizia* VALENCIENNES, 1846.

MORTENSEN (1951) united the Prenasterinae with the Schizasteridae in considering the peculiar arrangement of the peripetalous fasciole of the former being as a normal fasciole as in the Schizasteridae, and to the family Schizasteridae MORTENSEN then referred the following Recent genera, viz., Schizaster, Paraster, Diploporaster, Hyfselaster, Brisaster, Prymnaster, Protenaster, Tripylaster, Tripylus, Abatus, Amphipneustes, Moira, Moiropsis, Faorina, and the fossil genera Periaster, Proraster, Prenaster, Linthia, Lutetiaster, Peribrissus, Schizopneustes, Parabrissus, Anisaster, and the following genera are placed in the family as incertae sedies, viz., Cestobrissus, Hemifaorina, Hemigymnia, Saviniaster and Pseudobrissus.

The important genera and subgenera of the family Schizasteridae are discriminated from one another as shown by the following key.

Key to the important genera and subgenera of the family Schizasteridae.

1.	At least the peripetalous fasciole developed. Anterior plate-series of antero-lateral
	petals (II and IV) quite rudimentary. Test high, globose Agassizia
	At least the peripetalous fasciole developed. Anterior plate-series of antero-lateral
	petals (II and IV) fairly well developed 2
2.	Genital pores 4 3
	Genital pores 3
3.	Pores of frontal ambulacrum (III) in irregular double series Diploporaster
	Pores of frontal ambulacrum (III) in regular single series 4
4.	No frontal notch. Apical system distinctly anterior. Paired ambulacra distinctly
	petaloid adapically. Test not globose Prenaster
	Frontal notch more or less conspicuous 5
5.	Frontal ambulacrum (III) scarcely sunken, notch faint, not well marked. Apical
	system ethmophract Periaster
	Frontal ambulacrum (III) distinctly sunken, well marked. Apical system ethmolytic
6.	Antero-lateral petals (II and IV) not reaching the peripetalous fasciole. Latero-
	anal fasciole distinct Peribrissus
	Antero-lateral petals (II and IV) reaching the peripetalous fasciole. Antero-lateral
	fasciole distinct
7.	Antero-lateral petals (II and IV) curving distally Paraster
	Antero-lateral petals (II and IV) straight
8.	Periproct elongate Linthia
	Periproct transverse
9.	Valves of globiferous pedicellariae terminating in a single tooth. Test low, apex
	posterior Brisaster
	Valves of globiferous pedicellariae, if present, terminating in two or more teeth
10.	Globiferous pedicellariae lacking (?). Test high, subglobular. Peripetalous fasciole
	double anteriorly Faorina
	Globiferous pedicellariae conspicuous. Test low. Peripetalous fasciole single an-
	teriorly. Latero-anal fasciole rudimentary or lacking Abatus
11.	Genital pores 2. Petals very deeply sunken, almost closed 12
	Genital pores 2. Petals not deeply sunken, not at all closed 13
12.	Anterior petals longer than the sunken part of the frontal ambulacrum (III)
	Moiropsis
	Anterior petals not longer than the sunken part of the frontal ambulacrum (III)

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- 13. Pores of frontal ambulacrum (III) in irregular double series Ova Pores of frontal ambulacrum (III) in regular single series 14

There are fossil representatives of the genera Paraster, Prenaster, Linthia, Brisaster, Schizaster, Aplospatangus, Moira (with subgenus Moiropsis), and a new genus Cagaster, in our collection.

Genus Paraster POMEL, 1869

- Paraster POMEL, 1869, p. 54 (Le Schizaster gibberulus de la Mer Rouge peut en être le type).—
 POMEL, 1883, p. 36.—DUNCAN, 1889-a, p. 235.—TORNQUIST, 1903, p. 391.—FOURTAU, 1904-a,
 p. 435.—MORTENSEN, 1907, pp. 121, 123.—LAMBERT, 1907-c, p. 112.—KOEHLER, 1914, pp. 172-180.—H.L. CLARK, 1917, p. 170.—JACKSON, 1922, p. 74.—H.L. CLARK, 1925, p. 202.—
 MORTENSEN, 1951, p. 215.—KIER, 1957, p. 882 (subgenus ad Schiaster Agassiz, 1836).—
 COOKE, 1959, p. 71.
 - Orthotype.—Schizaster gibberulus AGASSIZ in AGASSIZ and DESOR, 1847, p. 22 (Red Sea).— Paraster gibberulus (AGASSIZ): FOURTAU, 1908, p. 109, text-figs. 1-6 (Red Sea).—KOEH-LER, 1914, p. 172, pl. 8, figs. 10-11 (pl. 9, figs. 1-2, 16).—MORTENSEN, 1951, p. 218, pl. 22, fig. 7, pl. 52, fig. 4, text-figs. 104b, 105a (Red Sea, fully reliable, and Indian Ocean, in shallow depths).

Forms of moderate to medium size. Test fairly high, rather stout, subglobular, not much sloping anteriorly; posterior end vertically or obliquely truncated; oral side somewhat convex. Frontal ambulacrum (III) moderately excavated, forming a distinct but generally not deep notch in anterior margin of test, not continuing to peristome. Tube-feet (pores) in frontal ambulacrum in single regular series with a peduncular granule between pores of a pair. Postero-lateral petals (I and V) about half the length of antero-laterals (II and IV). Apical system subcentral or slightly posterior, ethmolytic, with four genital pores, the anterior usually smaller than the posterior ones. Peristome not very close to anterior end, not sunken. Latero-anal and peripetalous fascioles usually distinct; antero-lateral petals (II and IV) reaching the peripetalous fasciole. Frontal tube-feet with more or less developed sucking disc; subanal tubefeet well developed. Globiferous pedicellariae with two or several short teeth surrounding terminal opening of valves (mainly after MORTENSEN, 1951). From the Eocene to Recent.

FOURTAU (1904-a, pp. 434-436; 1908, pp. 190-193), KOEHLER (1914, pp. 172-180), BRIGHTON (1931, pp. 328-332), and MORTENSEN (1951, pp. 215-223, and pp. 241-243) have thrown much light on the feature of the type-species, *Par. gibberulus*, of the genus, the species is hitherto imperfectly known to science. *Par. gibberulus* much resembles *Schizaster lacunosus* (LINNAEUS, 1758) in the general features of test, but differs from the latter species on the characters in the test, by the shallower and narrower frontal ambulacrum (III), the form of the peripetalous fasciole and by the position of the peristome. These differences, however, are not to be regarded as criteria of the generic distinction. The position of the peristome in *Paraster* is somewhat posterior than in *Sch. lacunosus*; pores in the frontal ambulacrum (III) of *Par. gibberulus* in a single series on each side and placed at about 45° to the transverse suture of the plates, thus very similar to those of *Sch. lacunosus*, but the plates much higher than those of *Sch. lacunosus*. *Diploporaster* (?) *savignyi* (*Schizaster savignyi* FOURTAU, 1904-a, p. 436, pl. 1, figs. 4-5, text-figs. 2a-b.—*Paraster savignyi* (FOURTAU) KOEHLER, 1914, p. 172, pl. 8, figs. 12-15, pl. 9, figs. 3, 11, 15) also much resembles *Sch. lacunosus* and *Par. gibberulus* in the characters of the test. The difference, however, is found in the frontal ambulacrum, especially in the arrangement of pore-pairs, as, in *Dip.* (?) *savignyi* the pore-pairs sometimes irregularly in two series on each side and nearly parallel to the transverse suture of plates (Text-fig. 68 [43]e), while in



Fig. 68 [43]. Diagrammatical figures of Paraster and Diploporaster (?).

- a-b. Paraster gibberulus (AGASSIZ, 1847); a. Aboral view of the young individual, ×0.8; b. Side view of the same (after BRIGHTON, 1931).
- c-e. Diploporaster (?) sávignyi (FOURTAU, 1904);
 c. Aboral view of an adult individual, ×0.8;
 d. Side view of the same, ×0.8;
 e. View of frontal ambulacrum (III), ×1.2 (after BRIGHTON, 1931).

Sch. lacunosus and Par. gibberulus the pore-pairs in a single regular series on each side and placed obliquely to the transverse suture of plates and furthermore the pores of a pair in the latter two species are separated by a high, prominent, peduncular granule excepting for the proximal six or seven. *Dip.* (?) savignyi and Par. gibberulus have four genital pores, while Sch. lacunosus only two. Thus the generic distinction between Paraster and Schizaster mainly depends upon the number of genital pores.

As for the systematic value of the number of genital pores in this group many disputations are repeated. DUNCAN and SLADEN (1885-a, p. 330), CURRIE (1925, p. 73), LAMBERT and THIÉRY (1925, pp. 517, 524), and KIER (1957, pp. 886-887) have regarded the distinction in due to the number of genital pores as a specific rather than a generic character, whereas POMEL (1869, 1883), H. L. CLARK (1917, 1925), MORTENSEN

(1951), and COOKE (1959, p. 71), regarded it as a generic character. KIER (1957), in the research of the Tertiary Echinoidea from Somaliland, has found a variation in the number of genital pores in specimens of the same species (*Linthia somaliensis*) and he claimed that the systematic value of the number of genital pores may be considered as a subgeneric character. It seems that this species (*Lin. somaliensis*) is rather variable species in a variable genus *Linthia*, in which some variations are observed by authors in the apical system and petals. It must be, however, generally regarded that *Lin. somaliensis* having a ethmolytic apical system with, in general, four genital pores and rarely three in lacking in the genital (2). That the variation in the number of genital pores found in *Lin. somaliensis* and other Linthias cannot be steadily applied to the generic distinction between *Paraster* and *Schizaster* as is made by MORTENSEN and the writer.

There are also other characters to be taken into consideration as to the generic or subgeneric distinction of *Paraster* from others, namely, the arrangement of the pores (tube-feet) in the frontal ambulacrum (III), this character will help materially to a natural classification of the numerous fossil forms; in *Paraster*, as described above, those pores are arranged in a single regular series to each side as in *Schizaster*. MORTENSEN (1951, p. 216) took the structure of the globiferous pedicellariae as a distinctive character, although it is unfortunately not to be used fossil forms, it is, actually, regarded by MORTENSEN as the main systematic value of specific distinction of three living species in *Paraster*. Also the character of the apical system, it is whether ethmolytic or ethmophractic, is of considerable classificatory importance, and we have herein the important distinction between *Paraster*, with ethmolytic apical system, and *Periaster* (Type-species.—*Per. elatus* (DESMOULINS, 1837) D'ORBIGNY, 1853– 55 (54), p. 270, pl. 897—Cenomanian of France), with ethmophractic apical system.

It seems highly probable that some of fossil species amongest once assigned to the genus *Schizaster* should be transferred to the genus *Paraster*, and it is an interesting case that this genus appears to be now extinct in the West Indian seas, while it was well represented there in the Eocene and Oligocene epochs. The genus *Paraster* dates back to the Eocene and flourished in the Oligocene and Miocene, and then gradually declined to the present seas, and comprising only three living species, which are almost limited in the geographical distribution to west of the Indian Ocean, viz., *Par. gibberulus* (Red Sea and Indian Ocean), *Par. compactus* (KOEHLER, 1914, p. 180, pl. 9, figs. 4-10, 12 (Gulf of Bengal), and *Par. rotundatus* (*Linthia rotundata* DÖDERLEIN, 1906, p. 249) (Chatham Islands).

Paraster nummuliticus (TOKUNAGA, 1903)

(Pl. 23, fig. 7)

Schizaster nummuliticus Tokunaga, 1903, p. 21, pl. 4, figs. 4-6.—Schizaster (Brisaster) nummuliticus Tokunaga: Lambert and Thiéry, 1925, p. 528.—Paraster nummuliticus (Tokunaga) Nisiyama, 1965, p. 80.

Locality and geological horizon.-Nishi-ura in Haha-jima, Bonin Islands.

Nummulites-zone (Eocene, Lutetian). Hypotype.—IGPS coll. cat. no. 73791 (topo-type).

There are several specimens referred to this species at the writer's disposal, range from 34 mm to about 60 mm in longitudinal diameter of test. The small specimen, 34 mm in longitudinal diameter, 34 mm in transverse one, and 24 mm in height, shows a good characters on the aboral surface. Apical system much eccentric posteriorly, situated at about 19 mm from anterior margin, ethmolytic, with four genital pores (Pl. 23, fig. 7), posterior pair (genitals 1 and 4) larger than the anterior pair (genitals 2 and 3). Frontal ambulacrum (III) lies in rather shallow groove, the pores in a single regular series on each side; ambulacral plates rather high, nearly as twice as high those of *Dipl.* (?) savignyi and *Sch. lacunosus*, and nearly as high as those of *Par*. gibberulus; pore-pairs placed about 45° to the transverse suture of plates and separated by a peduncular granule. Course of peripetalous fasciole as in Par. gibberulus, curved at nearly right angle in antero-lateral interambulacra (2 and 3), and runs close to petals; latero-anal fasciole (lateral fasciole of TOKUNAGA 1903, p. 22), joins the peripetalous fasciole at some distance behind the extremity of antero-lateral petals and proceeds thence in a direct backwards and downwards towards posterior truncation of test and below the periproct. Position of peristome somewhat more posteriorly than that of Ech. lacunosus and nearly coincides with that of Dip. (?) savignyi and Par. gibberulus. In the small specimen, an angle between median lines of the posterolateral petals (I and V) is more acute, about 65°, than that of the type-specimen, and the petals with about 15 or 16 pore-pairs on each poriferous zone, less in number than in the type-specimen of larger form.

This species seems to be confined in its distribution to the Eocene of Bonin Islands, and may be referred to the genus *Paraster* on the characters as mentioned above.

Paraster saipanicus COOKE, 1957

(Pl. 23, figs. 9-11)

Paraster saipanicus Cooke, 1957, p. 363, pl. 119, figs. 18-21.—NISIYAMA, 1965, p. 80.

Locality and geological horizon.—In doline, on the Denshin-yama, Saipan Island, Mariana (Ladrone) Islands, Micronesia, South Sea Islands. Donney formation (Tagpochau limestone) (*Spiroclypeus*-horizon), Miocene. Hypotype.—IGPS coll. cat. no. 73734.

Locality and geological horizon (after COOKE, 1957).—S144, northwest-central Saipan. Tagpochau limestone, Miocene. Holotype.—USNM 561585.

There are only two specimens referred to this species at the writer's disposal. Following the description of specimen at hand. Dimensions of specimen.—26 mm in longitudinal diameter, 24 mm in transverse one, and over 13 mm in height; it is somewhat smaller than the holotype.

Test small, oval in ambital outline, deeply and broadly notched anteriorly by a frontal depression, rather more contracted towards posterior extremity. Aboral surface not very high, more than half test-length, in longitudinal profile, it forms a well-marked curve, sloping gently from the highest point, which is much eccentric posteriorly and situated at near distal end of postero-lateral petals (I and V) in posterior interambulacrum (5), to anterior extremity, which is thick and tumid. Immediately behind the highest point, outline slightly curved and then abruptly truncate obliquely

at a steep angle of inclination, which inclined inwardly and periproctal region somewhat concave. Sides of test somewhat tumid and aboral surface more or less convex. Posterior interambulacrum (5) aborally rising into a more or less distinct keel, and more or less overhanging the periproct. Every antero-lateral interambulacrum (2 or 3) form a sharp keel-like ridge proximal to the apical system.

Ambulacra form well-marked petals adapically; petals more or less deeply sunken and broad. Frontal petal (III) lies in a rather wide and deeply excavated anterior groove, long and broad, 13 mm long from apical system to peripetalous fasciole and 3.5 mm wide at halfway of petal to peripetalous fasciole, where the broadest, and showing a tendency to be narrowed towards anterior margin; ambulacral plates rather low and broad, there are over 30 plates on each side; poriferous zones very narrow and close to both sides of the petal; pores small and somewhat elongate, pores of a pair very close and alike those of proximal 7 or 8 of adult *Sch. lacunosus*, and arranged in a single series on each side; interporiferous zone broad, ornamented with miliary tubercles amongest which a few larger ones occasionally found especially near poriferous zones on both sides.

Antero-lateral petals (II and IV) large, wide and situated in deep well-defined grooves; they at first diverge, then little converge and the tips curved outwardly; 9 mm long and 2.5 mm wide; there are over 20 plates on each side; pores wide apart and slit-like, indistinctly conjugate, adjacent pairs separated by a very low and scarce-ly definite costa; interporiferous zones narrower than the poriferous, and seem to be devoid of tubercles. Postero-lateral petals (I and V) small, elliptical in outline, with their tips rounded, and proximally rapidly contracting to a point; 5.5 mm long and 2.5 mm wide, a little over half of antero-laterals; there are over 15 plates in the petals; poriferous zones similar in character to those of antero-laterals, but less curved than those of antero-laterals.

Apical system eccentric posteriorly, situated about 10 mm from posterior extremity, genital pores and madreporite not well observable (in the holotype, 4 genital pores arranged in a rectangle, the anterior pair smaller than the posterior and close to them, COOKE, 1957, p. 353). Peristome very eccentric in front, about 4 mm from anterior extremity; semilunular in outline, 4 mm wide and 2 mm high; labrum broad but not much produced anteriorly. Phyllodes rather poorly developed, large pores for penicillate tube-feet rather scattered on the adoralmost 3 or 4 plates and few in number. Sternum large and broad, closely covered with large tubercles. Periproct comparatively small, vertically elliptical, and placed a short below at summit of concave region of posterior truncation.

Peripetalous fasciole very sinuous, broad, closely embraces petals, and crosses a groove of frontal ambulacrum (III) a short distance above ambitus, transverses anterolateral interambulacra (2 and 3) with a very concave curve, bends sharply round distal tips of antero-lateral petals, and after proceeding for a short distance beyond their extremity, bends at a great angle to run close and parallel with the groove nearly up to inner corner of postero-lateral interambulacra (1 and 4), and then again bends sharp angle nearly parallel with postero-lateral petals, and passes into posterior interambulacrum (5) with a slightly curve to cross a median keel. Latero-anal fasciole joins with peripetalous fasciole at its sharp angular bend behind extremity of anterolateral petals, and proceeds thence in a direct course backwards and downwards towards posterior truncation, and passes beneath the periproct with a deep curve.

Tuberculation on aboral surface uniformly small, excepting along inner flanks bounding the frontal ambulacrum, where more or less larger tubercles present; all tubercles increase in size and in distance apart as approach the ambitus. On oral surface, sternum with a more or less definite arrangement of tubercles of lines radiating from culminating point, and size of tubercles increasing as they approach the peristome.

This species is related to *Schizaster jeanneti* MARTIN, 1937 (JEANNET and MARTIN, 1937, p. 293, text-figs. 63a-c), from the Pliocene (?) of Soembawa and Java, but it differs from, as stated by COOKE (1957, p. 363), that species in the not so steeper posterior truncation, the more eccentric position of apical system, and in the form of peripetalous fasciole. This species also resembles *Par. nummuliticus* in the form of petals and the course of a peripetalous fasciole, but is distinguished from that species in the position of peristome, which is much nearer the anterior end of test, and in the less developed phyllodes.

Genus Prenaster DESOR, 1853

- Prenaster DESOR, 1853, p. 279 (396).—DESOR, 1855-58 (58), p. 401.—COTTEAU, 1863-a, p. 296.— WRIGHT, 1864, p. 487.—COTTEAU, 1875, p. 34.—ZITTEL, 1879, p. 543.—DUNCAN and SLADEN, 1882-a, p. 90.—POMEL, 1883, p. 35.—COTTEAU, 1885-89 (87), p. 382.—DUNCAN, 1889-a, p. 235.—LAMBERT and THIÉRY, 1925, p. 514.—H. L. CLARK, 1946, p. 363.—MORTENSEN, 1951, p. 229 (complete synonymy), text-figs. 11a-c, 113.
 - Logotype.—Prenaster alpinus DESOR, 1853, p. 279 (396).—DESOR, 1855-58 (58), p. 401, pl. 43, figs. 6-8.—COTTEAU, 1885-89 (87), p. 383, pl. 109, figs. 1-9 (Eocene of Alpes). [LAMBERT and THIÉRY, 1925, p. 514].

Usually small forms of ovoid outline. Apical system very eccentric anteriorly; petals accordingly also mainly confined to anterior end or part of test. Apical system ethmolytic, with four genital pores. Frontal ambulacrum (III) with pores distant, arranged in regular series; it flush with surface and not sunken, and there is no frontal depression of test. Antero-lateral petals (II and IV) short, outwards directed, postero-lateral petals (I and V) distinctly longer, more longitudinally directed. Peripetalous fasciole going down to oral side anteriorly, looks like a marginal fasciole; latero-anal fasciole well developed. Peristome anterior; periproct on truncate posterior end of test (mainly after MORTENSEN, 1951). The Eocene of rather world-wide distribution.

In the genera of the Schizasteridae without the frontal depression and with distinctly anterior position of the apical system and four genital pores the genus *Prenaster* is distinguished from *Saviniaster* (LAMBERT, 1911, p. 33.—LAMBERT and THIÉRY, 1924, p. 431.—Type-species.—*Sav. miqueli* LAMBERT, 1911, p. 35, pl. 16, figs. 25-27.— Eocene of l'Alarie), by the feature of the paired ambulacra and the form of the peripetalous fasciole.

In the genus *Prenaster* the peculiar arrangement of the fasciole, which is considered or designated by LAMBERT as a marginal or a "semiperipetalous", as stated by MORTENSEN (1951, p. 230), would be regarded as an unusual position of a normal

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peripetalous fasciole. The writer agrees with MORTENSEN's idea that the moving of the apical system to front and the lengthening of petals may force the peripetalous fasciole shift to the margin of the test and the peripetalous fasciole becomes large and looks like a marginal fasciole. We have no positive data for the origin of this peculiar genus, which has a very anterior position of the apical system and the anterior part of the peripetalous fasciole that going down to the oral side. The genus would become thence such a form by the result of the moving of the apical system to frontal which has necessitated the shifting to the anterior part of the peripetalous fasciole and the anterior petals.

This genus seems to be almost confined to the Eocene in the geological distribution and about 24 species are hitherto known besides the type-species from Europe, India, North Africa, and the Bonin Islands.

Prenaster boninensis LORIOL, 1902

Prenaster boninensis LORIOL, 1902-a, p. 35, pl. 3, figs. 6-6c.—TOKUNAGA, 1903, p. 23.—LAMBERT and THIÉRY, 1925, p. 514.—NISIYAMA, 1965, p. 80.

Locality and geological horizon.—Nishi-ura, in Haha-jima, Bonin Islands. Nummulites-horizon (Eocene, Lutetian). Hypotype.—IGPS coll. cat. no. 73745 (topotype).

There are three specimens of this species at the writer's disposal, but the twoof them are badly broken and the one is not good state in preservation.

The original description is very good, and the specimens at the writer's disposal are not good state in the preservation that the supplementary description is not necessary and cannot be given herein. A notice in LORIOL's description must be recommonded as that his "le fasciole marginal" is a peripetalous fasciole of unusual position as stated above. In comparison of this species with *Pren. alpinus, Pren. desori* (COTTEAU, 1885-89 (87), p. 392, pl. 111, pl. 112, figs. 1-5), and *Pren. arabicus* (GAUTHIER, in FOURTAU, 1900-a, p. 46, pl. 2, figs. 13-15) LORIOL noticed the differences of the position of apical system and other characters of specific distinction.

The genus as a whole is quite limited in its geological distribution and leaves no descendants to later ages. Its very short life-range may be due to the peculiar mode of life that hastened the extinction, because it could not be adapted to exchanging: environment, as assumed from the peculiar features of test.

Genus Linthia DESOR, 1853

Linthia Desor, 1853, p. 278 (395).—Desor, 1855-58 (58), p. 395.—A. Agassiz, 1872-74, p. 604.—Loriol, 1875, p. 99.—Cotteau in Locard, 1877, p. 286.—Zittel, 1879, p. 542.—Duncan and Sladen, 1882, p. 17.—Pomel, 1883, p. 36.—Cotteau, 1883-b, p. 176.—Cotteau, 1885-89 (86), p. 206.—Duncan, 1889-a, p. 233.—Cotteau, 1889-c, p. 26.—Tornquist, 1903, p. 392.—Bather, 1904, p. 298.—Lambert, 1905-a, p. 154.—Gregory, 1906, p. 249.—Pritchard, 1908, p. 392.—Hoffmann, 1914, p. 258.—Lambert and Thifry, 1925, p. 518.—Jeannet, 1935, p. 52.—Grant and Hertlein, 1938, p. 124.—H. L. Clark, 1946, p. 365.—Mortensen, 1951, p. 233.—Termier and Termier, 1953, p. 944.—Kier, 1957, p. 886.—Cooke, 1959, p. 69. .
Escheria Mérian in Desor, 1853, p. 143 (278) (non Escheria Heer, 1847).

Logotype.-Escheria insignis MÉRIAN in DESOR, 1853, p. 143.-Linthia insignis (MÉRIAN) DESOR, 1855-58 (58), p. 395, pl. 43, fig. 9 (Terrain nummulitique de Blangg près d'Yberg; (environs d'Einsiedein).—LORIOL, 1875, p. 101, pl. 16, figs. 1-1a, pl. 17, figs. 1a-b (Canton de Schwytz). [DESOR, 1855-58 (58), p. 395].

Forms of varying sizes, rarely up to quite large, of ovoid outline; test not very high, more gently arched aborally, posterior end not very high. Petals long, usually straight, well sunken; postero-lateral petals (I and V) somewhat shorter than the antero-laterals (II and IV). Frontal ambulacrum (III) deep in the typical forms, forming a conspicuous notch in frontal edge of test; pores small, in regular single series and the pores of a pair being separated by a peduncular granule of small form. Apical system subcentral or more anterior, with four genital pores in generally ethmolytic; the madreporite separating the posterior oculars (I and V). Peripetalous fasciole either following the edges of petals or, at least, bending more or less deeply inwards between antero- and postero-lateral petals, not going in a straight line between the end of petals, as in the case of *Periaster*. Latero-anal fasciole passes deep below the periproct, as in *Periaster*. Peristome near anterior end of test; periproct elongate, on upper part of posterior end of test. No large primary tubercles within or without the peripetalous fasciole aborally (mainly after MORTENSEN, 1951). From the Cretaceous (Senonian) to Pliocene (or Recent).

In the family Schizasteridae some genera with four genital pores, more or less conspicuous frontal notch, ethmolytic apical system, and with a distinct latero-anal fasciole, the genus *Linthia* is distinguished from *Lutetiaster* (LAMBERT, 1920-a, p. 27.— Type-species.—*Lut. subglobosus* (LAMARCK): COTTEAU, 1885-89 (86), p. 209, pl. 59) chiefly by the form of periproct, i. e., in this genus it is longitudinally elongate while in that genus it is transversely elongate. From the genus *Paraster* it differs in the more or less straight antero-lateral petals, while in *Paraster* the petals curving distally.

As for the type-species, *Lin. insignis*, some confusions occur on the characters of test chiefly owing to the not fair condition of the type-specimen. The apical system of the type-species has never been figured, although it is generally considered as an ethmolytic type and having four genital pores. It seems highly probable, however, the apical system of *Lin. insignis* being ethmolytic character as is suggested by LAMBERT (1926, p. 212) and admitted by MORTENSEN (1951, p. 235). The apical system of the genus *Linthia* seems to vary to some extent in the character of individuals, as is shown by KIER (1957, p. 886) in *Lin. somaliensis*. LAMBERT and THIÉRY (1925, p. 517 note) also offered an idea of individual variation from the ethmophractic to the ethmolytic character of the system; but, this idea is not supported by MORTENSEN (1951, p. 235) in his studies of the Recent species. It seems to the writer that the nature of the apical system may be generally used for generic or specific distinction of the Spatangoina.

Linthia and Protenaster (POMEL, 1883, p. 36.—Type-species.—Prot. australis (GRAY): A. AGASSIZ, 1872-74, p. 605, pl. 19a, figs. 7-9) agree with each other in the apical system which is ethmolytic and has four genital pores, in the latero-anal fasciole which is more or less distinct throughout, and in the apex which is subcentral or somewhat eccentric in front in position; but differ in the frontal notch, which in Linthia is more or less conspicuous and the frontal ambulacrum (III) is rather broad, distinctly sunken and well-marked, while in Protenaster the frontal notch is almost faint and the frontal ambulacrum is narrow, scarcely sunken and not well marked. A considerable number of fossil species have been referred to the genus *Linthia*. In their work (1925, pp. 518-520) LAMBERT and THIERY enumerated over 40 species, and since then some 30 more species have been described. The genus *Linthia* ranges from the Senonian to the Pliocene and has been recorded from widely separated localities. The genus comprising many varied forms and hence is an ill-defined and perplexing one among the Schizasteridae. The Japanese Miocene and Pliocene species seem to be much different from the typical Eocene species from Europe in the features of the petals and the fascioles. No living species actually referred to this genus has been known till 1951. MORTENSEN (1951, p. 236, pl. 19, fig. 3, text-fig. 118) reported a species that seems actually belonging to the genus *Linthia* existing in the Japanese seas.

There are more than four species referable to this genus from the Japanese. Tertiary formations.

Linthia nipponica YOSHIWARA, 1899

(Text-fig. 69 [44])

Linthia nipponica Yoshiwara, 1899, p. 2 (in English article).—Tokunaga, 1903, p. 18, pl. 1,. fig. 5 (tantum).—Lambert and Thiéry, 1925, p. 250.—Kuroda, 1931, p. 90.—Morishita, 1950, p. 258.—Mortensen, 1951, p. 237, foot-note.—Morishita, 1953-a, p. 222, pl. 1, figs. 5-7.—Morishita, 1954-a, p. 227, pl. 7, figs. 4-8(?).—Morishita, 1960, p. 62 (pro parte).— Nisiyama, 1965, p. 80.

Type-locality and geological horizon.—" Hidaka-mura in Kamimizura-gôri, Province of Shinano" of Токимада (1903, p. 20 and explanation to pl. 1, fig. 5)—probably " A point on bank of the Dojiri River, north of Hidaka, and south of Ichinose, Sakai-mura, Kami-Minochi-gun, Nagano Prefecture (tm Nagano, ca. Lat. 36°36′30″N., Long. 138° 03′E.). Upper part (Takafu sandstone) of Ogawa formation, Pliocene. MORISHITA, 1953-a, pp. 223-224, text-fig. 4 on page 225.

Locality and geological horizon (after MORISHITA, 1953-a).—Stream-side of a small tributary (Sakai-no-sawa) northwest of Ichinose, Sakai-mura, Kami-Minochi-gun, Nagano Prefecture (tm Nagano, Lat. 36°36′48″N., Long. 138°03′15″E.). Upper part of Ogawa formation, Pliocene.

Locality and geological horizon (after MORISHITA, 1953-a).—Road-side cutting south of Shio, Naniai-mura, Kami-Minochi-gun, Nagano Prefecture (tm Nagano, Lat. 36°36′ 53″N., Long. 138°04′47″E.). Upper part of Ogawa formation, Pliocene.

Locality and geological horizon.—IGPS loc. no.—Ch-78.—Probably sea-cliff of Byôbugaura, west of Na-arai, south of Misaki, Chôshi City, Chiba Prefecture (tm Chôshi, ca. Lat. 35°42′30″N., Long. 140°48′50″E.). Iioka formation, Pliocene. MARU-HASHI, 1947, p. 1.—OZAKI, 1954, p. 47.

This species seems to be rather rare fossil in Japan. The writer, however, had an opportunity of studying the specimens referable to this species and described herein.

Test of rather large-size, rather thick, somewhat rounded cordiform in marginal outline, slightly longer than wide or almost as wide as long, the greatest breadth being in the middle, just posterior to apical system in postero-lateral interambulacra (1 and 4), of test; anterior portion with deep and broad frontal depression, posterior



Fig. 69 [44]. Structure of aboral surface of *Linthia nipponica* YOSHIWARA, 1899, × ca 1.

portion also rounded with rather narrow posterior truncation. Test not very high, less than half of longitudinal diameter of test, rather abruptly elevated aborally from thin margin to the highest point, which is situated just posterior to apical system in posterior interambulacrum (5); adoral surface nearly flat or slightly concave orally, especially the peristomial region depressed orally; posterior extremity vertically truncated. Largest specimen measures 87 mm in longitudinal diameter, 86 mm in transverse one, and 38 mm in height (the holotype, TOKUNAGA, 1903, pl. 1, fig. 5).

Frontal ambulacrum (III) in a rather deep groove, rather short and narrow, about 33 mm long from apical system to peripetalous fasciole and about 7 mm wide in the broadest point; straight and subparallel but more or less convergently curved proximally; pores small and round, pores of a pair separated by an indistinct peduncular granule, excepting three or four near peripetalous fasciole; pore-pairs slightly oblique to transverse suture and placed middle to adradial suture of the plates, and the pores in rather regular series on each side; ambulacral plates rather low, about 1.2 mm high and 3.5 mm wide at halfway from apical system to peripetalous fasciole; about 32 pore-pairs (ambulacral plates) in a column on aboral side; interporiferous zone rather wide, about 2.5 mm in the broadest point, and tuberculated with small tubercles and miliaries.

Apical system eccentric in front, about 35 mm from anterior margin, more or less sunken, ethmolytic, the madreporite separating postero-lateral oculars (I and V), rather small, about 5.5 mm wide and 4.5 mm long; postero-lateral genitals (1 and 4) slightly larger and wider apart than the antero-lateral ones (2 and 3).

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Antero-lateral petals (II and IV) long and straight, subparallel and open at distal ends, about 35 mm long from apical system to peripetalous fasciole and about 7 mm wide in the broadest point, in a rather deep groove, angle between median line of petal (II) and that of petal (IV) being about 110°; poriferous zone broad; pores of a pair rather large, wide apart, and in a shallow groove, about 39 pore-pairs on each series in the petals; ambulacral plates low and wide, about 1 mm high and 5.5 mm wide at middle of the petals; interporiferous zone narrow, about 1.5 mm wide at middle of the petals and seems to be free from tubercles. Postero-lateral petals (I and V) also long and narrow, nearly straight and subparallel, and not closed at distal ends; about 34 mm long from apical system to peripetalous fasciole, and about 7 mm wide at the broadest point, in a rather deep groove, angle between median line of petal (I) and that of petal (V) being about 65°; poriferous zone broad; pores of a pair rather large, wide apart, and also in a shallow groove, about 29 pore-pairs on each series in the petals; ambulacral plates rather low and broad, about 1.2 mm high and 3.5 mm wide at middle of the petals: interporterous zone narrow, about 1.5 mm wide at middle of the petals and seems to be free from tubercles. Ratio of length of antero-lateral petals (II and IV) to postero-laterals (I and V) being about 1.0:0.9.

Peripetalous fasciole narrow and rather sinous, it crosses the groove of frontal ambulacrum (III) slightly above ambitus, transverses antero-lateral interambulacra (2 and 3) with convex curve parallel to and slightly above ambitus, passes distal ends of antero-lateral petals (II and IV), then bends nearly at right angle with a little downward curve runs parallel to course of the petals to middle of them, and then again bends nearly right angle on the sixth plate of anterior column in postero-lateral interambulacra (1 and 4) and runs posteriorly to distal ends of postero-lateral petals (I and V) with a slight curve and crosses with a sharp curve there, and lastly it passes into posterior interambulacrum (5) with almost nearly straight or slightly posteriorly convex curve. Latero-anal fasciole joins with peripetalous fasciole at its extremity a short distance behind (at about one-third anterior column of interambulacral areas in postero-laterals (1 and 4)) the antero-lateral petals (II and IV) nearly parallel and slightly above ambitus, and runs anterior column of postero-lateral ambulacra (I and V), and lastly it crosses ambitus at about middle portion of posterior column of the area, and passing posteriorly below the periproct.

Interambulacral plates on aboral side broad and low, and there are 10 or 11 plates in a column of antero-lateral areas (2 and 3) and in posterior interambulacrum (5), and 8 or 9 in a column in postero-lateral areas (1 and 4).

Plate arrangement and feature on adoral surface, which are observed from smaller specimen other than the type-specimen, are as follows. Peristome rather large, semi-lunular in outline, more than 18 mm wide and 3 mm high. Labrum rather small, and short, its posterior end not reaching the second plate of adjoining ambulacral plates; sternum rather narrow and long, nearly flat or slightly rising toward posterior end; second plate on both sides long and narrow, and nearly equal in size, about 36 mm long and 10 mm wide at the broadest point, respectively; third plate on each side rather low and broad, about 12 mm wide and 8 mm long, respectively, rectangular in outline; anterior portion of fourth plate on both sides joins the adoral posterior extremity. Postero-lateral ambulacra (I and V) on oral surface consist of 7 plates in

each column, plates long and narrow excepting 1 or 2 near posterior extremity, and tuberculated with tubercles. On peristomial region, 6 large pores (for penicillate tube-feet) on each column of antero-lateral ambulacra (II and IV), 2 or 3 large pores on each column of postero-lateral ambulacra (I and V), and 2 large pores of frontal ambulacrum (III) join phyllodes, and the phyllodes well developed. Periproct elliptical, situated on upper portion of posterior extremity. Tubercles of interambulacra on adoral surface larger than those on aboral surface and arranged in more or less regular lines; tubercles on sternum continuing onto the labrum.

The large size and the rounded-cordiform of the test, the distinct and deep frontal notch, the position of the apical system, which is eccentric in front, narrow and deep paired petals, and the long postero-lateral petals (I and V) of this species make a notable combination of characters, and in these characters this species recalls *Lin. insignis*, the type-species of the genus, and can be safely referred it to this genus. But this species is distinguished from that species by the course of the peripetalous and latero-anal fascioles, which is more sinuous in that species than in this species.

The two Japanese species, Lin. nipponica and Lin. tokunagai LAMBERT, 1925 (see below), are often confounded with each other, and regarded as one species of rather long geological range from the Miocene to Pliocene. Lin. nipponica, however, differs from Lin. tokunagai in the deeper frontal notch, the narrower and deeper paired petals, and in the longer postero-lateral petals (I and V); the ratio of length of the anterolateral petals (II and IV) to that of the postero-lateral petals (I and V) in Lin. nipponica being 1,0:0.9 or more, while in Lin. tokunagai it is 1,0:0.7 or a little more. This species seems to distribute as fossil in central and northern Japan and occupies younger geological age than Lin. tokunagai. This species seems to range probably from the Pliocene to perhaps as young as the Recent, in there MORTENSEN (1951, p. 236) reported an occurrence of this or very related species from western Japan. The living species of Linthia, according to the inference of MORTENSEN, seems to be a descendant of the Pliocene Lin. nipponica or has survived to the Recent sea from the Pliocene. It is very noticeable fact that this large and widely distributed genus of *Linthia*, which is generally regarded as having been already extinct in the Pliocene, has a single living representative in Japan.

Specimens reported under this specific name from the Miocene of Japan, e.g., MORISHITA (1954-a, p. 228), need re-examination; it seems to the writer that they are not certainly typical *nipponica* in the emended sense. The wider and shorter paired petals in some specimens do not enable us to refer them to *Lin. nipponica*, and a case that the trace of fasciole, or even of genital pores, is not discernible in due to bad state of preservation of specimens, makes the systematic position of them uncertain. However, as in a specimen figured by MORISHITA (1954-a, pl. 7, fig. 8) the plate-arrangement on the oral surface and feature of labrum and phyllodes recall the Japanese fossil Linthias, if it were prove the existence of a peripetalous and a lateroanal fasciole and having four genital pores, it should be referred to the genus *Linthia* but represents a distinct species differing from the Pliocene *Lin. nipponica*.

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Linthia tokunagai LAMBERT, 1925

(Pl. 24, figs. 3, 6, Pl. 25, figs. 1-3, Pl. 26, figs. 1-3)

(Text-fig. 70 [45])

Linthia nipponica YOSHIWARA: TOKUNAGA, 1903, p. 18, pl. 1, figs. 6-7, pl. 3, fig. 1 (non pl. 1, fig. 5).—AOKI (now NISIYAMA), 1933, p. 51, text-fig. 66 (not typical nipponica).

Linthia tokunagai LAMBERT in LAMBERT and THIÉRY, 1925, p. 520.—MORTENSEN, 1951, p. 237, foot-note.—NISIYAMA, 1965, p. 80.

Type-locality and geological horizon (TOKUNAGA, 1903, p. 20, explanation to figures 6 and 7 on plate 1, and to figure 1 on plate 3).—Probably, A point on left bank of the Dojiri River, near Ichinose, Sakai-mura, Kami-Minochi-gun, Nagano Prefecture (tm Nagano, ca. 36°36′30″N., Long. 138°03′10″E.). Upper part (Takafu mudstone) of Ogawa formation, Pliocene.

Locality and geological horizon.—IGPS loc. no.—Na-26.—A point of the Dojiri River, about 250 metres southwest of the primary school at Ikari, Sakai-mura, Kami-Minochi-gun, Nagano Prefecture (tm Nagano, Lat. 36°36′29″N., Long. 138°03′35″E.). Upper part (Takafu mudstone) of Ogawa formation, Pliocene. Hypotype.—IGPS coll. cat. no. 7918.

Locality and geological horizon.—IGPS loc. no.—Yt-32.—Stream side of the Geppu River, about 250 metres southwest of the village office at Kuzusawa, Hongô-mura, Nishi-Murayama-gun, Yamagata Prefecture (tm Aterazawa, Lat. 38°22'26"N., Long. 140°09'42"E.). Kuzusawa formation, Pliocene. Hypotype.—IGPS coll. cat. no. 78632.

Locality and geological horizon.—IGPS loc. no.—Ak-38.—Road-side cutting along the Fujikoto River, north of Niageba, Niageba-mura, Yamamoto-gun, Akita Prefecture, (tm Noshiro, Lat. 40°13′14″N., Lat. 140°15′E.). Sasaoka (Wakimoto) formation, Pliocene. Hypotype.—The Nat. Sci. Mus., foss. coll. cat. no. 277.

There are several specimens referred to this species at the writer's disposal. The following is the description of this species, which is not yet fully described hitherto.

Test stout, of large-size, attains 70 mm in longitudinal diameter, rounded-cordiform in marginal outline, slightly longer than wide or almost as wide as long; the greatest breadth being in just front of middle of test; anterior portion of test broadly rounded and frontal margin broadly and shallowly notched by a frontal groove; posterior portion more or less narrowed from posterior half of postero-lateral interambulacra (1 and 4) to posterior truncation; test not very high, as nearly as half the longitudinal diameter of test, gently elevated aborally with convex curve from margin to the highest point, and penultimate part of proximal interambulacra raised; oral surface nearly flat or slightly concave orally; peristomial region suddenly deepen, and the sternum slightly rising to posterior margin; posterior extremity nearly vertically truncated or slightly concave.

		Longitudinal diameter	Transverse diameter	Height
Туре-specimen (Pl. 1, figs. 6, 7 of Токимада, 1903)	!	64 mm	 60 mm	 25 mm
Specimen from Nagano		67 mm	66 mm	33 mm
Specimen from Yamagata	+	70 m m	68 mm	25 m m
Specimen from Akita		63 mm	61 mm	26 mm

Measurements of specimens-

Frontal ambulacrum (III) in a shallow groove, long and rather broad, about 28 mm long from apical system to peripetalous fasciole and 8 mm wide at the broadest point, both sides nearly straight and subparallel, rather suddenly converge proximally and slightly diverge distally; pores very small and round, pores of a pair, excepting distal 3 or 4, separated by an indistinct peduncular granule; pore-pairs slightly or more or less oblique to transverse suture and placed near adradial suture of plates; there are about 30 pore-pairs in each series and the pores in rather regular series on each side; ambulacral plates rather low, about 1.2 mm high and 4 mm wide at two-thirds of ambulacrum from apical system; interporiferous zone wide, about 5 mm wide at halfway from apical system to peripetalous fasciole, and tuberculated with small tubercles and miliaries.

Apical system subcentral or slightly eccentric in front, about 32 mm from anterior margin in a specimen of 67 mm in longitudinal diameter, depressed below a level of raised penultimate part in proximal interambulacra, ethmolytic, the madreporite separating postero-lateral oculars (I and V), rather small, about 4 mm high and 4 mm wide, with four genital pores.

Antero-lateral petals (II and IV) long and straight and open at distal ends, about 32 mm long from apical system to peripetalous fasciole in a specimen of 70 mm in longitudinal diameter of test, and 31 mm long in a specimen of 64 mm in longitudinal diameter, and 7 mm or 6.5 mm wide in the broadest point respectively, slightly depressed excepting proximal part, angle between median line of petal (II) and that of petal (IV) being about 110°; poriferous zone broad, about 3 mm wide on each series, the pores diverge at first and a little converge at middle of petals and again slightly diverge distally; the pores rather large and wide apart and pores of a pair in a shallow groove, about 36 pore-pairs on each series in petals; interporiferous zone narrow, about 2 mm wide at middle of petals, and seems to be free from tubercles; ambulacral plates low and broad.

Postero-lateral petals (I and V) short, also nearly straight, and open at distal ends, about 22 mm long from apical system to peripetalous fasciole and about 6.5 mm wide at the broadest point, slightly depressed excepting proximal part, angle between median line of petal (I) and that of petal (V) being about 80°; ambulacral petals low and wide; poriferous zone broad, each series of pores diverge at first and a little converge at middle of petals and then slightly diverge distally; pores rather large and wide apart and pores of a pair in a shallow groove; there are about 28 pore-pairs in each series of petals; interporiferous zone narrow, about 2 mm wide at middle of petals, and seems to be free from tubercles. Ratio of length of antero-lateral petals.



Fig. 70 [45]. Structure of Linthia tokunagai LAMBERT, 1925, (somewhat diagrammatically drawn from IGPS coll. cat. no. 7918), ×ca 1.
a. Aboral surface; b. Oral surface; c. Posterior surface.

to that of the postero-laterals being about 1,0:0.7.

Peristome large, depressed adorally, semilunular in outline, about 13 mm wide and 2 mm high, and situated at about 14 mm from anterior margin. Labrum well developed and well labiated, small and short, well arched anteriorly and pointed posteriorly, about 8.5 mm high and 10 mm wide, the posterior end beyond second plate of adjoining ambulacra. Sternum long and narrow; second interambulacral plate on each side very long and narrow, about 40 mm long and 12 mm wide at the broadest point; third interambulacral plate on each side rather low and broad, rectangular in outline, about 8 mm high and 14 mm wide; anterior part of fourth interambulacral plate on each side joins the posterior broder of test on oral surface. Sternum tuberculated with primaries of relatively small-size, they have a more or less definite arrangement of oblique and diagonal lines and the size of tubercles more or less increasing as they approach anterior part, and the tubercles continuing onto labrum but smaller in size. Each of paired interambulacra on oral surface terminated by a single plate of large-size; there are 3 in 4b and 3b, 2 in 1b, 2b and 3a, and 1 in 3b, of low and broad interambulacral plates; paired interambulacra on oral surface also tuberculated with

primaries, which more or less larger than those on posterior interambulacrum (5), and the size of tubercles more or less decreasing from middle part towards margin. Postero-lateral ambulacra (I and V) on oral surface composed of 7 plates in each column, the plates long and narrow excepting 1 or 2 near posterior margin; the area not naked, the anterior part tuberculated with small tubercles and the posterior part with primary and small tubercles; antero-lateral ambulacra (II and IV) on oral side composed of 8 plates in each column, the plates long and narrow, and tuberculated with small tubercles and primaries near margin; frontal ambulacrum (III) on oral surface composed of 5 plates in IIIa and 4 in IIIb, the plates small, comparatively high but narrow, and tuberculated with small tubercles. On peristomial region, 6 large pores (for penicillate tube-feet) on each series of antero-lateral ambulacra, 3 pores in outer and 2 in inner series of postero-lateral ambulacra, and 2 pores in IIIa and 3 in IIIb of frontal ambulacrum join phyllodes, and the phyllodes rather well developed. Periproct elliptical or rather pear-shaped, pointed upward and rounded downward, about 6 mm high and 5 mm wide, situated on upper portion of posterior extremity, and 2 or 3 posterior interambulacral plates near periproctal region curved convergently to join the periproct.

Interambulacral plates on aboral side broad and low, and there are 10 or 11 plates in a column of postero-lateral interambulacra (1 and 4) and of posterior interambulacrum (5), and 11 or 12 plates in a column of antero-lateral interambulacra (2 and 3).

Peripetalous fasciole narrow, being not suddenly widened at any point, and rather sinuous. It crosses the groove of frontal ambulacrum (III) slightly above ambitus or frontal margin, transverses antero-lateral interambulacra (2 and 3) with convex curve almost parallel to and slightly above ambitus, passes distal ends of antero-lateral petals (II and IV) on the extension of the same curve, then bends at nearly right angle with a little downward curve running almost parallel to the course of petals to nearly middle of them, then again bends at nearly right angle at about the center on 6th plate of anterior column of postero-lateral interambulacra (1 and 4) and runs posteriorly, crossing 6th and 7th plates of the posterior column of the area with a slight curve to distal ends of postero-lateral petals (I and V) and passes there with a rounded curve, and lastly it passes 7th plates in posterior interambulacrum (5) with almost straight or slightly convex curve. Latero-anal fasciole joins with peripetalous fasciole at its extremity a short distance behind (at about one-third of anterior column of postero-lateral interambulacra and on 9th plate from apical system) distal ends of antero-lateral petals, crosses 9th plate in postero-lateral interambulacra with convex curve nearly parallel to and slightly above ambitus, continues with a slight curve to a short distance exterior to middle part of each column of posterior interambulacrum (5), crossing postero-lateral ambulacra, and lastly passing posteriorly under periproct, where the fasciole is rather abruptly curved and passes a short distance under the periproct with a nearly straight line.

This species resembles at great length the other Japanese Pliocene Linthia, Lin. nipponica (the preceding species), the two species are often confounded with each other, particularly in the course of a peripetalous and a latero-anal fasciole, but is distinguished from that species in the shallower and wider frontal notch, distinctly shallower and wider paired petals, and in the much shorter postero-lateral petals (I and V). That the difference of the paired petals in the two forms would not due to the sexual diamorphism, since such difference in petals as this case is not be observed in any other echinoids, but it would imply a distinction of species. This species seems to occupy the older geological age than *nipponica*, as old as the lower Pliocene or perhaps the upper Miocene, and has been reported by many authors from the Neogene deposits of central and northern Japan, and Hokkaido, under the name *Lin. nipponica* in large part. But some of these specimens are need of re-examination. *Lin. tokunagai* also closely resembles *Lin. praenipponica* NAGAO, 1928, from the Oligocene deposits of Kyushu, but differs from that species by having the narrower test, the broader posterior portion, the shallower and wider frontal notch, and by the shallower paired petals.

The shallow frontal ambulacrum (III), the shallow and wide frontal notch, and not well-sunken paired petals of this species are more or less against the general characters of the genus *Linthia*, and the reference of this species to the genus, according to MORTENSEN (1951, p. 237, foot-note), is not certain, as he regarded it may rather be a *Paraster* or *Periaster*. However, by the features of the frontal ambulacrum (III) and paired petals, and the ethmolytic character of the apical system, this species cannot be safely referred to one of these genera, i. e., *Paraster, Periaster*, or even *Protenaster*. The general characters on the adoral surface in this species recall the Japanese fossil Linthias, particularly the typical *Lin, nipponica*, and the writer leaves it in the genus *Linthia* as being originally placed.

Linthia praenipponica NAGAO, 1928

(Text-fig, 72 [47]d)

Linthia praenipponica NAGAO, 1928, p. 18, pl. 1, figs. 1-4.—MINATO, 1949, p. 14.—MINATO, 1950, p. 158.—MORISHITA, 1956, p. 196, pl. 2, figs. 2a-d.—MORISHITA, 1960, p. 63.—NISIYAMA, 1965, p. 80.

Locality and geological horizon.—IGPS loc. no.—FK-28.—Sea cliff facing the mouth of the Onga River, about 400 metres northeast of Yamaga, Ashiya-machi, Onga-gun, Fukuoka Prefecture (tm Orio, Lat. 33°53′56″N., Long. 130°39′54″E.). Yamaga formation of Ashiya group, Oligocene. Holotype.—IGPS coll. cat. no. 36421.

Locality and geological horizon (after MORISHITA, 1956).—Sakihario-mura, Higashi-Sonogi-gun, Nagasaki Prefecture (ca. Lat. 33°5'N., Long. 129°45'E.). Kijima group, Oligocene. Hypotype.—No. JC750006, deposited in Geol. Inst., Kyoto Univ.

Locality and geological horizon (after MORISHITA, 1956).—Kamihasami-machi, Higashi-Sonogi-gun, Nagasaki Prefecture (ca. Lat. 33°10'N., Long. 129°55'E.). Kijima group, Oligocene. Hypotype.—No. Gk-14731, deposited in Geol. Inst., Kyoto Univ.

This species is, as described by the original author, closely related to *Lin. toku-nagai* (the shorter broad-cordiform form of NAGAO, 1928), not to *Lin. nipponica* (the long and somewhat elliptical form of NAGAO, 1928). The broad-cordiform of the test, the rather deep depression of the frontal margin, the deep depression of the frontal ambulacrum (III), the deep and rather narrow paired petals, the short length of the postero-lateral petals (I and V), and the course of the peripetalous fasciole make

remarkable combination of characters of this species.

MORISHITA described (1956, p. 196) and figured (pl. 2, figs. 2a-d) other specimens of this species from the Oligocene of Kyushu. The differences between the typespecimen and the specimens of MORISHITA are found in the angle between the median line of petal (II) and that of petal (IV); i.e., in the type-specimen it is about 110° and the value approaches that of Lin. tokunagai, while in the specimens of MORISHITA it is about 130° and larger than that of Lin. tokunagai; and in the profile of the test, as in the type-specimen it is semiglobular and the height is over half of the longitudinal diameter of test, while in the specimen of MORISHITA it is pyramidal and the height is decidedly smaller than half of the longitudinal diameter. The two forms agree with each other in the angle between the median line of petal (I) and that of petal (V), which measures about 70°. The ratio of length of the antero-lateral petals (II and IV) to that of the postero-lateral ones (I and V) being about 1.0:0.7 or a little more, and the ratio nearly of the same value as that of Lin. tokunagai and evidently less than that of Lin. nipponica. The structure of the labrum, sternum, and the phyllodes are of not discernible from any specimen; however, presumably they are normal Linthian type in general appearance. The course of the peripetalous fasciole of this species is also similar to that of *Lin. tokunagai*, although a slight difference may be found in the posterior interambulacrum (5), where the fasciole is more or less curved posteriorly.

This Oligocene species, as stated by the both authors, closely resembles *Lin. toku-nagai*, but is distinguished from that species in several respects being noticed by authors; e.g., the deeper frontal notch, the deeper petaloid grooves, and the narrower posterior portion.

It could be assumed that this Oligocene species might represent an ancestor of the Pliocene (or the upper Miocene) species, *Lin. tokunagai* (*Lin. nipponica* pro parte), as the names indicate. Should this be the case, the shallowing in the frontal notch and the paired petals of *Lin. tokunagai* from the deep frontal notch and the paired petals of *Lin. praenipponica* would be in regarding the deepening of the ambulacra only, contrary to the general tendency of the spatangoid specialization, and if it were really occurred, the intermediate forms between *praenipponica* and *tokunagai* would be found in the Miocene deposits of Japan; but this is a mere suggestion.

Linthia yessoensis MINATO, 1950

(Text-fig. 72 [47]e)

Linthia yessoensis MINATO, 1949, p. 14 (without description).—MINATO, 1950, p. 158, text-figs. 1-2 (on page 158).—MINATO, 1954, p. 392 (3).—MORISHITA, 1960, p. 63.—NISIYAMA, 1965, p. 80.

Locality and geological horizon (after MINATO, 1950).—A point at a small tributary (Shimizusawa) of the River Penke, Kami-Ashibetsu-mura, Sorachi-gun, in the northeastern Ishikari coal-field, Hokkaido. Upper *Corbicula* bed, Oligocene.

There is no authentic specimen of this species at the writer's disposal.

This species resembles, as stated by the original author, *Lin. praenipponica* in outline of the test, but is distinguished from that species in the course of the peri-

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petalous fasciole in the posterior interambulacrum (5), i. e., in this species it evenly curves posteriorly, as is shown by MINATO in his figure, while in *praenipponica* it only slightly curves posteriorly. The angles between the median line of the petal (II) and that of the petal (IV) and between the median line of the petal (I) and that of the petal (V) of this species seem to be larger than those of *Lin. praenipponica*. The ratio of length of the antero-lateral petals (II and IV) to that of the postero-lateral petals (I and V) in this species, as judged from the figure of MINATO, seems to indicate nearly as 1.0:0.7 or a little more, and the ratio is nearly of the same value as that of *Lin. praenipponica*; however, the breadth of the postero-lateral petals is much wider than that of *Lin. praenipponica*. The frontal ambulacral plates of this species in each column from the apical system to the peripetalous fasciole. The features of the peristome, labrum, and the sternum are not discernible, although they sometimes guide good specific characters.

Lin. yessoensis was collected, according to MINATO (1950, p. 157; 1954, p. 392 (3)), together with Corbicula sunagawaensis NAGAO and OTATUME, 1943, of non-marine or brackish-water mollusc. As for this respect, MINATO offered his opinion that this echinoid would lived in shallow tidal bottom near the strand line and easily transported by waves to the line after death, and then mingled with shells of brackish-water form.

Linthia boreasteria NISIYAMA, n. sp.

(Text-figs. 71 [46]a-b)

Holotype.—IGPS coll. cat. no. 45018.

Locality and geological horizon.—A point at the middle course of the River Minami-Nayoshi, Notoro Peninsula, South Sakhlain. Nissakutan formation, Oligocene. ISHIZAKI and SAKAKURA, 1937, p. 1132.

Test stout, of moderate-size, angular rounded-cordiform in marginal outline, more or less polygonal, slightly broader than long, the greatest breadth being in just front of middle of the test; anterior part broadly rounded and indented in frontal margin, posterior part rather sharply narrowed from the posterior column of postero-lateral interambulacra (1 and 4) with more or less concaved margin to posterior truncation; test is not very high, less than half of longitudinal diameter of test, gently elevated aborally from thick margin to the highest point; adoral surface nearly flat and more or less abruptly depressed adorally near peristomial region; vertically truncated in posterior interambulacrum (5).

Dimensions of holotype.—46 mm in longitudinal diameter of test, 51 mm in transverse one, and 22 mm in height.

Frontal ambulacrum (III) in a more or less deep groove, rather short and narrow, about 18 mm long from apical system to peripetalous fasciole and 5.5 mm wide in the broadest point; the pores small and round, pores of a pair separated by an indistinct peduncular granule excepting 3 or 4 near peripetalous fasciole; pore-pairs slightly oblique to transverse suture and placed near adradial suture of plates and the pores in regular series on each side; ambulacral plates rather high, about 1 mm high and



Fig. 71 [46]. Structure of *Linthia boreasteria* NISIYAMA, n. sp., ×ca 1. a. Aboral surface; b. Oral surface.

2.5 mm wide at halfway from apical system to peripetalous fasciole, and there are about 23 plates in each column of the petal; interporiferous zone wide and tuber-culated with small tubercles and miliaries.

Apical system eccentric in front, about 20 mm from frontal margin, more or less sunken, ethmolytic, the madreporite separating postero-lateral oculars (I and V), rather small, 3 mm wide and 2.5 mm long with four genital pores.

Antero-lateral petals (II and IV) in more or less deep groove, long and straight, about 20 mm long from apical system to peripetalous fasciole, 4 mm wide in the broadest point, angle between median line of petal (II) and that of petal (IV) large, being about 130°; poriferous zone broad, both series of pores a little converge at middle of the petals and a little diverge distally, not closed at distal ends; the pores rather small, about 28 pore-pairs on each series in the petals; interporiferous zone narrow and seem to be free from tubercles. Postero-lateral petals (I and V) short and also nearly straight, in more or less deep groove, about 14 mm long from apical system to peripetalous fasciole and about 4 mm wide at the broadest point, angle between median line of petal (I) and that of petal (V) being about 80°; poriferous zone broad and not closed at distal end; pores rather small and there are about 20 pore-pairs on each series in the petals; ratio of length of antero-lateral petals (II and IV) to that of postero-lateral petals (I and V) being about 1.0:0.7.

Peristome large, suddenly depressed adorally, semilunular in outline, about 12.5 mm wide and 2 mm high, situated at about 8 mm from anterior margin. Labrum well developed, broad and short, well arched anteriorly and less prolonged posteriorly, about 10 mm wide and 6.5 mm long, its posterior end not reaching second plate of adjoining ambulacral plates. Sternum large and rather narrow; second interambul-acral plate on each side very long, about 25 mm long and 9 mm wide at the broadest point; third plate on each side short and comparatively wide, rectangular in outline, about 5 mm long and 6.5 mm wide; anterior half of fourth plate on each side terminates posterior extremity on adoral surface. Sternum and posterior part of labrum usually tuberculated with small primary tubercles, which have a more or less definite arrangement of lines and the size of tubercles more or less increasing as they ap-

proach peristomial region. Interambulacral plates on adoral surface large and first interambulacral plate on paired areas (1 and 4) not touch the peristome; there are 2 post-primordial interambulacral plates in the area 1a, 2 in 1b, 2a, 2b, 3a and 4a, 3 in 4b, and 1 in 3b; interambulacral plates of paired areas also tuberculated with small primary tubercles and the size of tubercles as nearly as those on posterior interambulacrum (5). On peristomial region, 5 large pores (for penicillate tube-feet) on each series in antero-lateral ambulacra, 2 on each series in frontal ambulacrum, 2 on each series in postero-lateral ambulacra join phyllodes, and hence the phyllodes rather well developed. Postero-lateral ambulacra on oral surface not naked but with small tubercles and they become prominent posteriorly.

Interambulacral plates on aboral surface broad and low, and there are 9 or 10 plates in a column in each area.

Peripetalous fasciole narrow and rather sinuous. It crosses the groove of frontal ambulacrum slightly above ambitus, transverses antero-lateral interambulacra (2 and 3) with convex curve nearly at parallel to ambitus and passes distal ends of anterolateral petals, then bends nearly right angle with a little rising convex curve running approximately up to the middle of petals. Then it again bends posteriorly with concave curve proceeds to middle part of postero-lateral interambulacra (1 and 4), turns to approach distal ends of postero-lateral petals, passing with rounded curve there, and lastly runs into posterior interambulacrum (5) with posteriorly concave curve. Latero-anal fasciole joins with peripetalous fasciole at its extremity a short distance behind antero-lateral petals, sloping posteriorly a short distance above ambitus towards posterior ambitus and abruptly curved near its posterior end, and then passing under the periproct. Periproct elliptical, situated on upper portion of the extremity, only visible in a posterior view.

The angular rounded-cordiform of the test, the large angle between the median lines of the antero-lateral petals (II and IV), the course of the peripetalous fasciole (e.g., posteriorly concave curve in the posterior interambulacrum (5) and a little rising convex curve behind the antero-lateral petals) make a notable combination of characters of this species. This species resembles *Lin. praenipponica* in the outline of test and in the more or less sunken petals, but differs from that species in the course of the peripetalous fasciole of the posterior interambulacrum (5), i.e., in this species it curves anteriorly with convex line as in some species of *Pericosmus*, while in that species it runs nearly straight or slightly curves posteriorly with convex line, and with a larger angle between the median lines of the antero-lateral petals (II and IV). The three Palaeogene species of *Linthia* in Japan agree with one another in having the broad test, which contrasts to the long test of the Pliocene species. MINATO claimed the well-marked specific differences of the Japanese Linthias (MINATO, 1949, pp. 14-17) (e.g., Lin. nipponica (he did not separate tokunagai from nipponica), Lin. praenipponica, and Lin. yessoensis), that is the course or the bending degree of a peripetalous fasciole in the posterior interambulacrum (5). This difference is also applied for the distinction between this species and Lin. yessoensis, that is the peripetalous fasciole of this species passes the posterior interambulacrum with anteriorly convex curve, while that of Lin. yessoensis passes the area with posteriorly convex curve of rather great degree; this species also differs from that species in having



Fig. 72 [47]. Diagrammatic outline of aboral surface of the five species of *Linthia* from Japan.

a.	Linthia	boreasteriá	Nisiyama.

- b. L. nipponica YOSHIWARA, 1899.
- c. L. tokunagai LAMBERT, 1925.
- d. L. praenipponica NAGAO, 1928.
- e. L. yessoensis MINATO, 1950.

the much narrower postero-lateral petals (I and V), although the ratio of length of the antero-lateral petals to that of the postero-lateral petals in the two species is not different.

The five species of the genus *Linthia* from Japan and the adjacent regions are discriminated mainly from one another by the diagramatic figures given by the writer in the text (Text-figs. 72[47]a-e).

There is an another species, which is formerly referred by HAYASAKA (1948-a, p. 90) to the genus *Linthia*, from the Miocene of Formosa. The systematic position of this species, however, is not certain, and it necessitates some notes herein.

Linthia? taiwanensis HAYASAKA, 1948

Linthia taiwanensis HAYASAKA, 1948-a, p. 90, pl. 1, figs. 1a-b (pl. 2, figs. 1a-b?).

No specimens of this species have been available for study.

Locality and geological horizon (after HAYASAKA, 1948-a).—Neighbourhood of Kuantzuling Hot Spring, Taininhsien (exact place of origin is not clear), Formosa. Kansirei formation (upper division of Kaizan group), Miocene.

There are two specimens of this species. The large one is compressed anteroposteriorly and the smaller one laterally. Although HAYASAKA identified them as one and same species and found together at the same locality, there is no sound evidence of the identification. They differ in the course of peripetalous fasciole and in the features of the postero-lateral ambulacra (I and V) on the oral surface and of the subperiproctal region or the posterior extremity. Therefore the writer hesitates to identification of them as the same species.

If a fossil specimen, which is not definitely show the nature and kinds of fasciole

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and of apical system but has subcentral position of apical system, long and nearly straight paired petals, broad poriferorus and narrow interporiferus zones in paired petals, and deep frontal notch, it is very diffcult to refer it to the proper genus. In these respects the two specimens under consideration, if they would not be a single species, are more or less akin to certain species of following genera of different families, viz., *Linthia*, *Lutetiaster*, and *Paraster* (with long and straight petals) of the Schizaster-idae, *Pericosmus* of the Pericosmidae, and *Brissopsis* and *Metalia* of the Brissidae.

In discussion of affinities HAYASAKA states that this species looks very much like *Lin. orientalis* DUNCAN and SLADEN, 1884 (DUNCAN and SLADEN, 1884, p. 217, pl. 37, figs. 7-14), an Eocene species of western Sind, in the distinct frontal notch, and the antero-lateral petals and the postero-laterals are almost of the same length. *Lin. orientalis*, however, is removed from the genus *Linthia* and transferred by LAMBERT and THIÉRY (1925, p. 521) to *Lutetiaster*, by the form of periproct, which is in that genus transversely elongated. The form of periproct of *Lin. taiwanensis* is not definitely known and it is situated, according to HAYASAKA (1848-a, pp. 91-92), near the upper margin of a shallow but quite distinct posterior or anal depression.

The large specimen, which is compressed more or less antero-posteriorly, resembles the typical *Lin. nipponica* in the outline of test and the form of petals. The peripetalous fasciole in the large specimen, as judged from the original description and illustration, seems to form a roughly pentagonal outline and more or less angular with a rather deep re-entering angle in the postero-lateral interambulacra (1 and 4),. as in many species of *Linthia*, but almost nearly straight or slightly re-entering curve in the posterior interambulacrum (5). If the latero-anal fasciole is branching off from the peripetalous fasciole at the distal ends of the antero-lateral petals, it brings a very close resemblance with that of *Linthia*. The genera *Pericosmus*, *Brissopsis* and *Metalia* have a peripetalous fasciole besides a marginal in *Pericosmus* and in the latter two a subanal fasciole but without a latero-anal fasciole. The peripetalous fasciole in the genera *Brissopsis* and *Metalia* crosses the posterior interambulacrum with usually a more or less pointed curve posteriorly, while in *Pericosmus* it bends more or less inwards in that area, and thus the fasciole of the large specimen of this species differs at length from that of the three genera.

The details of the labrum and phyllodes and the structure of the sternum or plastron and the postero-lateral ambulacra (I and V) on the oral surface in the large specimen are not fully described nor well illustrated. It seems, however, to the writer that the sternum with long second interambulacral plate on each side of *Linthia*-type and the postero-lateral ambulacra on the oral surface are narrow as in *Lin. cavernosa* LORIOL, 1888 (LORIOL, 1880, p. 111, pl. 8, figs. 8-10.—KIER, 1957, p. 888, text-fig. 17c.— Eocene of Egpyt).

In all these respects, the large specimen of *Lin. taiwanensis* seems to be most probably referred to the genus *Linthia* as originally referred than to other genera, but may represent a distinct species from the typical *Lin. nipponica*.

The small specimen of this species has a close affinity with species of the genus *Pericosmus*. In this respect the writer agrees therewith HAYASAKA (1948-a, p. 92), who regarded that this species (particularly the small specimen) is apparently very much like a species of that genus (e.g., *Per. timorensis* LAMBERT, 1908-a, p. 687, pl.

4.—Pliocene of Timor). As for the peripetalous fasciole of the small specimen HAYA-SAKA (1948-a, p. 91) described it as—" In the smaller specimen we can recognize the re-entrant curves of the peripetalous fasciole on both sides and in the rear", and in the figure 1a on plate 2 of HAYASAKA it is recognized that the fasciole bending inwards between the petals, particularly between the antero-lateral petal and the postero-lateral one and more or less between the frontal petal and the antero-lateral one but slightly between the postero-lateral petals, as in many species of *Pericosmus* (e. g., the living *Per. macronesius* KOEHLER, 1914, p. 133, pl. 12, figs. 1–5). The presence of a latero-anal and a marginal fasciole in this specimen is not ascertained. But in the figure 1a on plate 2 of HAYASAKA, if some traces of line which are observable slightly above the ambitus in the ambulacra I, III and IV represent a part of fasciole, it would be a marginal fasciole as that of *Pericosmus*, and there seems no trace of a latero-anal fasciole. The course of peripetalous fasciole and the presence of a marginal fasciole, if they were really existing in this small specimen, agree with the most characteristic feature of *Pericosmus*.

Although the frontal ambulacral pores are not ascertained, in the paired petals of the small specimen the poriferous zones are broad, the interporiferous zones are narrow, and the pores seem to not conjugate, and also there may happen a peculiar feature that the distalmost pores seem to not arranged parallel to the other porepairs but obliquely placed to the other, it may suggest that the distalmost pores seem to be occluded as in the species of *Pericosmus*, which is one of the characteristics of that genus.

So far as the description and illustration concern, the structure of peristome and phyllodes of the small specimen are unknown to the writer. The labrum seems to be short and wide, as in that of *Linthia* and *Pericosmus*, not long and narrow as in that of *Metalia* and *Brissopsis*, and its posterior end should not reach the second adjoining ambulacral plates. The sternum rather broad, the second interambulacral plate on each side seems to be rather short, plainly shorter than that of *Lin. tokunagai* and *Lin. cavernosa*, and the postero-lateral ambulacra (I and V) on the oral surface rather narrow but their tuberculation is not ascertained.

The course of the peripetalous fasciole, the feature of the paired petals, and the structure of the labrum of this small specimen, nevertheless the presence of a marginal fasciole and the structure of apical system are not certainly ascertained, would seem to be referable to the genus *Pericosmus*. The living species of this genus are confined to the Indo-West Pacific, as north as the Japanese seas, and also the fossil species are in mainly confined to that region.

Genus Brisaster GRAY, 1855

Brisaster GRAY, 1855-a, p. 61.—LAMBERT, 1907-c, p. 112.—MORTENSEN, 1907, p. 123.—H. L. CLARK, 1917, p. 178.—H. L. CLARK, 1925, p. 206.—LAMBERT and THIÉRY, 1925, p. 528 (pro parte).—H. L. CLARK, 1937-c, p. 369.—GRANT and HERTLEIN, 1938, p. 122.—MORTENSEN, 1951, p. 280 (complete synonymy).

Logotype.—Brissus fragilis DÜBEN and KOREN, 1844 (46), p. 280, pl. 10, figs. 47-49.—Schizaster fragilis (DÜBEN and KOREN) A. AGASSIZ, 1872-74, pp. 157, 363, pl. 21, fig. 3, pl. 26, fig. 42. [LAMBERT, 1907-c, p. 123].

Lymanaster LAMBERT, 1920-b, p. 52, note.

Orthotype.—Schizaster townsendi A. AGASSIZ, 1898, p. 82.—A. AGASSIZ, 1904, p. 207, pl. 100,, figs. 1-5, pl. 101, figs. 1-10, text-figs. 301-302.

Forms of moderate size, of more or less elongate ovoid outline; test generally rather low. Frontal ambulacrum (III) deep, forming a deep notch in anterior edge of test; the pores in single, regular series on each side. Vertex generally posterior or rarely subcentral. Postero-lateral petals (I and V) considerably shorter than anterolaterals (II and IV). Apical system posterior, ethmolytic with three genital pores. Periproct on truncate posterior end of test; peristome close to anterior end of test, rather deeply sunken, sunken peristomial region continuing directly into frontal notch; labrum fairly prominent, its posterior prolongation only quite exceptionally reaching beyond middle of first adjoining ambulacral plates. Subanal tube-feet well developed; frontal tube-feet terminating in a crown, supported by radiating calcareous lamellae. Latero-anal fasciole usually well developed or may be totally reduced. Pedicellariae of globiferous, tridentate, ophicephalous, and triphyllous types; globiferous pedicellariae characteristic, the valves forming in a single tooth, with the opening of the poison-gland on one side (mainly after MORTENSEN, 1951). From the Eocene to Recent.

Since the publication of GRAY (1855-a, p. 61) this genus has called little attention among the echinologists, particularly the specialists on the fossil forms, being usually united with the genus *Schizaster*. H. L. CLARK (1917, p. 178) is the first author who clearly separated it from *Schizaster* as a generic rank and the specialists on the living forms, such as KOEHLER and MORTENSEN, agree with him in this procedure.

This genus is characterized, as diagnosed above, by the low test with the posterior vertex, the ethmolytic apical system with three genital pores, and by the peculiar character of the globiferous pedicellariae, which are unfortunately not steadily applied for the fossil forms, and these characters make a marked distinction of it from the other Schizasteridae. Among the related Schizasteridae providing with three genital pores the genus Tripylaster is so close to this genus that H.L. CLARK (1917, p. 177) has doubted its taxonomic validity as a genus, but that genus is characterized by the subcentral position of the apical system and the globiferous pedicellariae with four teeth around the terminal opening. A Japanese living species of Brisaster, Br. owstoni, in the high posterior end of the test and the course of peripetalous fasciole, closely resembles a Japanese Schizaster, Sch. lacunosus, as the twoforms are frequently confounded with each other; but the number of genital pores, two in the latter and three in the former, and the feature of globiferous pedicellariae, as in the former the valves terminating in a single tooth and while in the latter a number of short teeth surrounding the terminal opening of the valves, distinguish the former from the latter, and owstoni can safely referable to the genus Brisaster by its characters.

The genus Lymanaster proposed by LAMBERT (loc. cit.) for a schizasterid with three genital pores, with *Br. townsendi* as the type-species, may be identical with *Brisaster*. This species is readily identified by its test being flattened aborally and the postero-lateral petals (I and V) are not markedly short. But, these characters would be regarded as a specific level rather than generic one, and according to H. L. CLARK (1923-d, p. 160) the specific characters are usually well shown but there is a tendency to intergrade with Br. latiforns (A. AGASSIZ, 1898).

This genus is rather ill-defined and rather widely spread one among the family Schizasteridae and some seven living species are known, viz., Br. fragilis, Br. capensis (STUDER, 1880) (South Africa), Br. townsendi (West Coast of North America), Br. latifrons (A. AGASSIZ, 1898) (American West Coast, from Alasaka to southern California), Br. owstoni MORTENSEN, 1950 (central Japan), Br. moseleyi (A. AGASSIZ, 1881) (Strait of Magellan), and Br. kergulenensis H. L. CLARK, 1917 (Kergulen). The genus Brisaster comprises two somewhat different groups; the typical one has usually a complete latero-anal fasciole and the other it reduced to only a slender piece below the periproct or entirely wanting, but this differences seem to be no value for the generic distinction. The genus dates back to the Eocene (LAMBERT and THIÉRY, 1925, pp. 528-530) and ranges to the Recent, showing a relatively wide distribution.

There is a fossil representative of this genus in our collection.

Brisaster owstoni MORTENSEN, 1950

(Pl. 24, fig. 1)

Schizaster ventricosus: A. Agassiz, 1881-a, p. 204, pl. 36, figs. 1-3 (non GRAY, 1851).—Yoshiwara (Tokunaga), 1906, pl. 17, figs. 7-9.—A. Agassiz and H. L. Clark, 1907-b, p. 137.

Brisaster latifrons A. AGASSIZ: H.L. CLARK, 1917, p. 180 (pro parte).—H.L. CLARK, 1925, p. 207 (pro parte).

Brisaster owstoni Mortensen, 1950, p. 160.—Mortensen, 1951, p. 291, pl. 23, figs. 7-8, 11-15, pl. 53, figs. 11, 14, 17-19.—Ozaki, 1958, p. 177, pl. 18, figs. 15-16.

Locality and geological horizon.—IGPS loc. no.—Ch-68.—A point about 200 metres north of cutting on main road, north of Sanuki-machi, Kimitsu-gun, Chiba Prefecture (tm Futtsu, Lat. 35°15′44″N., Long. 139°43′40″E.). Sanuki formation, Pleistocene. Hypotype.—IGPS coll. cat. no. 73779.

Locality and geological horizon (after OZAKI, 1958).—Omate, Unakami-machi, Unakami-gun, Chiba Prefecture. Iioka formation, Pliocene. Hypotype.—Nat. Sci. Mus., coll. cat. no. 4494.

There is a single specimen of internal mould referred to this species at the writer's disposal, which is somewhat deformed and lacking the posterior part of test.

Specimen measures about 48 mm in longitudinal diameter of test and about 22 mm in height, and the highest point lies on the just posterior of the apical system. In the marginal outline of the test this specimen somewhat recalls *Schizaster lacunosus* (LINNAEUS, 1758) (*Echinus lacunosus* LINNAEUS, 1758, p. 665.—*Schizaster japonicus* A. AGASSIZ, 1881-a, p. 202, pl. 36, figs. 8-13, pl. 43, fig. 26, pl, 65, figs. 7-10) on account of deformation of test; but aside from the number of genital pores, which is not discernible in this specimen, in the broader and shallower frontal ambulacrum (III), the longer and more flexuous antero-lateral petals (I and IV), much greater degree of divergence of the postero-lateral petals (I and V), and the peristome nearer to the anterior margin, and larger eccentricity of the apical system to posterior, it can be referred to *Brisaster owstoni* rather than to *Schizaster lacunosus*.

Frontal ambulacrum (III) lies in a broad and deep groove, and anterior sulcus deep and broad; frontal petal long and broad, about 30 mm long and 10 mm wide; ambulacral plates rather low, about 42 plates in the petal on each side. Antero-lateral petal (II) long, 17 mm long and 6 mm wide at the widest point, in a rather deep groove, diverges at first a little and then slightly converge some distance from distal part and finally diverge outwardly near the middle of the petal, and hence the antero-lateral interambulacrum (2) becomes very narrow from the proximal to middle part of the area; pore-pairs numerous, over 40 on each side. Postero-lateral petal (I) very short, about 12 mm long and 5 mm wide, greatly diverge, angle between median line of petal (I) and that of petal (V) no less than 130°; pore-pairs few, about 18 on each side in the petal. Test rather high posteriorly, vertical diameter probably more than half of longitudinal diameter of test.

This species closely resembles *Br. latifrons* (A. AGASSIZ, 1898) (*Schizaster latifrons* A. AGASSIZ, 1898, p. 81.—A. AGASSIZ, 1904, p. 205, pl. 102, figs. 1–4, text-figs. 297, 297b.— *Brisaster latifrons* (A. AGASSIZ): MORTENSEN, 1951, p. 289, pl. 23, figs. 1–2, 3, 9, pl. 53, fig. 16.—American West Coast, from Alaska to southern California, and probably Bering and Ochotsk seas) in the very short and broad postero-lateral petals, and is regarded by H. L. CLARK (1917, p. 180; 1925, p. 207) and others (GRANT and HERTLEIN, 1938, p. 122) as being unseparable from that species. MORTENSEN (1950, p. 160) clearly distinguished this species from *Br. latifrons* by its test is distinctly higher and more abruptly truncated and the well developed rostrate pedicellariae, while in that species the pedicellariae are very scarce or lacking.

This species is known with certainty only from the central Japan, and probably from the western Japan, and it ranges from 10 to 530 metres in depth.

Genus Cagaster NISIYAMA, n. gen.

Type-species.—Schizaster recticanalis YOSHIWARA, 1899, p. 2 (in English article).—TOKUNAGA, 1903, p. 20, pl. 4, figs. 1-3 (Miocene of Environs of Kanazawa City).

Test high, angular rounded-cordiform; apical system subcentral, ethmolytic, with three genital pores; frontal ambulacrum (III) in a shallow but broad groove, and the frontal notch at the ambitus rather broad; frontal ambulacral plates rather high; the pores small, pores of a pair separated by an indistinct peduncular granule; pore-pairs placed almost parallel to transverse suture of the plates, and the pores in regular series on each side. Antero-lateral petals (II and IV), not so depressed or in rather shallow groove, long and almost straight, and not closed at distal ends; postero-lateral petals (I and V) short, slightly depressed, curved and closed at distal ends; pores of the paired petals elongate and sli-tlike, distinctly conjugate, and pore-pair in a shallow groove. A peripetalous fasciole strongly recurved in postero-lateral interambulacra (1 and 4), and retreating far from the center of posterior interambulacrum (5); lateroanal fasciole large as in a marginal fasciole, joins with the peripetalous fasciole at beyond the extremity of antero-lateral petals. Antero-lateral ambulacra on oral surface strongly developed, forming a conspicuous phyllode; postero-lateral ambulacra adorally not very narrow, and naked. Peristome rather large, not closed the anterior edge of test; periproct not discernible. No large primary tubercles within or without the peripetalous fasciole aborally. Miocene of the Far East countries.

This genus differs from Brachybrissus (POMEL, 1883, p. 37.-Type-species.-Brachy-
brissus ambulacrum (DESHAYES): COTTEAU, 1885-89 (87), p. 320, pls. 95-96-Eocene of France), to which Sch. recticanalis was once referred by LAMBERT and THIÉRY (1925, p. 527), in the shallower frontal ambulacrum (III), arrangement of the frontal ambulacral pores, less depressed paired petals, the position of apical system, and in the number of genital pores. This genus is also closely related to Brisaster in the number of genital pores, long antero-lateral petals, and in the course of peripetalous fasciole; particularly Cag. recticanalis closely resembles Br. moselevi (A. AGASSIZ, 1881) (Schizaster moseleyi A. AGASSIZ, 1881-a, p. 203, pl. 36, figs. 14-16.-Br. moseleyi (A. AGASSIZ) H. L. CLARK, 1917, p. 184, pl. 155, fig. 5, pl. 156, fig. 4.—Strait of Magellan) in outline of the test; but, this genus is distinguished from that genus by the shallower frontal ambulacrum, higher and fewer ambulacral plates in the frontal ambulacrum, arrangement of the frontal ambulacral pores, the distinct latero-anal fasciole, the well developed phyllodes adorally, the position and structure of peristome, and by the position of apical system. This genus seems to be suppressed to subgeneric rank of Brisaster, but the writer would give it a full generic rank with some hesitation. The genus Cagaster also resembles Lutetiaster (loc. cit.) in the form of petals, the position of apical system, and in the course of latero-anal fasciole, but differs from that genus in the number of genital pores, and in the narrower and shallower frontal ambulacrum (III), but the periproct, which is characteristic in that genus, is not discernible in the type-species.

Two fossil species are referable to this genus, the one is the type-species, and the other seems to be closely akin to the type but differs in the anterior part of a peripetalous fasciole.

Cagaster recticanalis (YOSHIWARA, 1899)

(Pl. 24, figs. 2, 4, 5)

Schizaster recticanalis YOSHIWARA, 1899, p. 2 (in English article).—TOKUNAGA, 1903, p. 20, pl. 4, figs. 1-3.—Schizaster (Brachybrissus) recticanalis YOSHIWARA: LAMBERT and THIÉRY, 1925, p. 527.—Schizaster recticanalis YOSHIWARA: MORISHITA, 1950, p. 258.—MORISHITA, 1960, p. 64.

Holotype.--IGPS coll. cat. no. 5235.

Locality and geological horizon.—IGPS loc. no.—Is-25.—River side of the Saikawa, at Saikawa and north of Nozoki, Kanazawa City, Ishikawa Prefecture (tm Kanazawa, Lat. 36°30′10″N., Long. 136°42′10″E.). Yokawa (Nozoki) formation, Miocene.

There is a single specimen at the writer's disposal, which is probably the holotype, and well described and illustrated by TOKUNAGA (1903).

The supplementary description of this species is as follows.—Frontal ambulacrum (III) in a shallow groove and long, about 30 mm from apical system to peripetalous fasciole; the pores small and round, pores of a pair separated by a very indistinct peduncular granule; pore-pairs placed almost parallel to transverse suture and nearer to adradial suture of the plates and in regular series on each side; ambulacral plates rather high, about 1.2 mm high and 3.5 mm wide at halfway from apical system to peripetalous fasciole; interporiferous zone not very wide and closely tuberculated with small tubercles and miliaries.

Apical system subcentral, or somewhat eccentric to posterior, ethmolytic, the posterior half of madreporite lacking, vacant area prolonged posteriorly; three genital pores, genital (2) without the pore.

Antero-lateral petals (II and IV) long, about 30 mm long and 3 mm wide, not so depressed or in rather shallow groove, angle between median line of petal (II) and that of petal (IV) being about 120°, almost straight, but at length of one-third from distal ends the inner series of poriferous zone somewhat concave or slightly divergent; not closed at distal ends; ridge between pore-pairs with a series of small tubercles about from 10 to 12; pores subequal, or the outer pore slightly more elongate, they are more or less distinctly conjugate; interporiferous zones narrow and seem to be free from tubercles. Postero-lateral petals (I and V) short, 12 mm long from apical system to peripetalous fasciole and 5 mm wide at the broadest point, not so depressed, they at first diverge then curved convergently at middle of the petals and lastly again slightly diverge near distal ends, thus form a characteristic feature of the species; ridge between pore-pairs with a small tubercles numbering about 10; pore-pairs similar to those of the antero-lateral petals.

Peristome large, semilunular in outline, about 12 mm wide and 4 mm high, situated at about 12 mm from the anterior margin; anterior part of labrum broken away; posterior part of labrum and sternum or plastron equally tuberculated with small primary tubercles; sternum narrow and rather high, about 25 mm high and 12 mm wide, and with a more or less definite arrangement of lines of tubercles radiating from culminating point, size of tubercles more or less increasing as they approach the peristome. On peristomial region, antero-lateral ambulacra (II and IV) with a prominent phyllode, of more than 6 large pores (for penicillate tube-feet) on each side, and the pores form a roughly triangular shape pointed outwardly.

Peripetalous fasciole very sinuous, it crosses the groove of frontal ambulacrum (III) only slightly above the ambitus, transverses antero-lateral interambulacra with slightly concave curve, and passes distal ends of antero-lateral petals to a short distance beyond their extremities, bends at almost right angle to run parallel with the petals nearly up to the inner third of the petals; it then again bends nearly at right angle, and proceeds to middle part of postero-lateral interambulacra, then turns to approach distal ends of postero-lateral petals, and lastly passes into posterior interambulacrum with a point posteriorly. Latero-anal fasciole joins with the peripetalous fasciole at its extremity behind antero-lateral petals as alike a elongation of peripetalous fasciole, it transverses postero-laterals slightly above the ambitus and looks like a marginal fasciole, and proceeds thence in a direct course backwards and slightly downwards towards the posterior truncation, where it runs deeply downwards to the ambitus below periproctal region.

Large part of postero-lateral ambulacra (I and V) on oral surface almost naked, excepting the posterior part, where some small primary tubercles are developed; paired interambulacra on oral surface also tuberculated with primaries; the primaries coarser than those on posterior interambulacrum and becoming smaller and denser as they approaching the periphery.

The subcentral position of apical system, shallow and long frontal ambulacrum, arrangement of the frontal ambulacral pores, short and curved petals of the postero-

lateral ambulacra (I and V), nearly straight but slightly concave inner third of the antero-lateral petals (II and IV), course of the peripetalous fasciole, and a well developed phyllodes make a combination of characters of this species, and it is very characteristic species amongst the Japanese fossil echini.

Cagaster species

Sinaechinus kawaguchii: HAYASAKA, 1948-a, p. 96, pl. 4, figs. 1a-c (non pl. 3, figs. 1-5). Faorina chinensis GRAY: HAYASAKA, 1953, p. 218, pl. 14, figs. 4-6 (non GRAY, 1851).

Locality and geological horizon (after HAYASAKA, 1948-a).—Along the bank of the Tachuchi, a tributary of the Tsenhuenchi, Tapuchuang, Chaichu, Tainanhsien, Taiwan (Formosa). Unsui formation, corresponds to the lower part of the Byôritsu group; earlier Pliocene.

There is no authentic specimen referred to this species at the writer's disposal, and HAYASAKA first described this fossil species under the name *Sinaechinus kawaguchii*.

The Recent specimen from the bay of Tonkin, that being named and well illustrated by HAYASAKA (1948-a, p. 94, pl. 3, figs. 1-5) as Sinaechinus kawaguchii, is a very peculiar and interesting echinoid. It is a large form of roundly heart-shaped, attains 72 mm in longitudinal diameter, high and nearly spherical shape, and the oral side slightly rounded and not quite flattened. The apical system nearly central with three genital pores; the madreporite somewhat prolonged posteriorly. The frontal ambulacrum (III) rather deeply sunken, but not petaloid; the pores are small and in a regular series on each side; the interporiferous zone broad and closely tuberculated with small tubercles excepting the naked median space anteriorly. Paired petals rather narrow, straight, and abutting rather sharply against the peripetalous fasciole; the pore-zones of each petal are also straight; the distalmost plates (or pores) are occluded; the interporiferous zone are of the same width and broad and seems to be free from tubercles of large-size; beyond the petals, particularly the anterolateral ones (II and IV), there is a slightly sunken, naked median space or smooth groove continuing to the oral side almost up to the peristome. A similar sunken, naked median space, in the posterior interambulacrum (5), continuing to the periproct. The peristome situated very close to the anterior margin. The sternum or plastron broad and is densely tuberculated with small primary tubercles, the tubercles continuing over the labrum, which forms a prominent lip. The naked space of the postero-lateral ambulacra (I and V) is narrow and inconspicuous, the plates of the series Ia and Vb being naked, but the plates of the series Ib and Va (excepting the three adoralmost) being usually covered with tubercles. The phyllodes inconspicuous, the penicillate tube-feet of the lateral ambulacra are confined to the three or four proximal plates. The periproct is at the top of the posterior truncation, which is slightly concave. There is a conspicuous, broad and well-marked peripetalous fasciole; it is double anteriorly and enclosing a somewhat large elongated space.

All features, as described above, of this specimen of *Sin. kawaguchii* closely recall *Faorina chinensis* GRAY, 1851 (1851, p. 132.—GRAY, 1855-a, p. 57, pl. 6, figs. 1-1a.— A. AGASSIZ, 1872-74, pp. 129, 607, pl. 19a, figs. 4-6.—KOEHLER, 1914, p. 129, pl. 13, figs.

14-15, pl. 19, figs. 14-24.—MORTENSEN, 1951, p. 245, pl. 20, figs. 1-8, pl. 52, figs. 8, 10-11, 14, 16-17, 20, 23-27, text-figs. 123-125.—Coast of China (Hongkong) and Indo-China to the Sulu Sea, in 50-180 metres depth) (MCZ nos. 7042, 2813 and 2866), when in comparison the figures of naked test of Fao. chinensis given by MORTENSEN (1951, pl. 20) (and specimens in MCZ collection) and those of naked test of Sin. kawaguchii given by HAYASAKA (1948-a, pl. 3) side by side the two are almost quite coincide with each other even in the details and not separable as two distinct species. The only difference between the two is found in a latero-anal fasciole, which is distinctly present, though narrow, inconspicuous and in part, in Fao. chinensis, but is not mentioned the presence of it in Sin. kawaguchii. MORTENSEN (1950-a, p. 378) referred Sin. kawaguchii, probably after the original description, to the family Hemiasteridae, which are characterized by having only a peripetalous fasciole but no other fasciole. The presence of a latero-anal fasciole in Fao. chinensis is not discernible by the original author, who (GRAY, 1855-a, p. 56) described the fasciole of Fao. chinensis as follows .-- "surrounded by a broad, rather sinuous peripetalous fasciole, which is double on the front sides, without any lateral or subanal fasciole". The latero-anal fasciole of Fao. chinensis, in reality, is narrow and inconspicuous, transverses the periproctal plates in the posterior interambulacrum (5), bends upwards, again at a nearly right angle, and then disappears before reaching the median line of the postero-lateral ambulacra (I and V). KOEHLER (1914, p. 130) described the fasciole as follows.—" Le fasciole latéral est tout à fait rudimentaire; je n'en observe qu'une simple indication sans forme d'une branche qui traverse les plaques 4-4 de l'interradius postérieur, au point de réunion de la face ventrale et de la face postérieure, et qui se continue sur les plaques .5-5 au delà desquelles elle disparait." This description of latero-anal fasciole in Fao. chinensis seems to be applicable to that of Sin. kawaguchii. The course of a lateroanal fasciole in Sin. kawaguchii is traceable, though it is very inconspicuous, by close observation on the posterior view of a bare test in the figure 5 on plate 3 of HAYA-SAKA, as it seems transverse the periproctal plates in the posterior interambulacrum below the periproct, bends upwards at a nearly right angle and to the posterior column of the postero-lateral ambulacra. In all respects the Recent specimen of Sin. kawaguchii may be the most probably identical with the Chinese Fao, chinensis, and HAYASAKA (1953, p. 218) has an identify of the two species basing on a suggestion offered by the writer. If the more or less obliteration of the latero-anal fasciole in .Sin. kawaguchii were definitely ascertained, it would have been the best way to identify the Recent specimen of Sin. kawaguchii from the bay of Tonkin with Fao. chinensis from Hongkong, although the pedicellariae and radioles are not ascertained whether they are identical or not with those of Fao. chinensis.

As for the fossil specimen from Formosa, which HAYASAKA (1948) formerly referred to *Sin. kawaguchii*, after he identified it with *Fao. chinensis* in accord with the abandoning the name *Sin. kawaguchii*, he (1953, pp. 218-219) described as follows.—

"The fossil from Taiwan (Formosa) is an incomplete specimen having the posterior portion of the test broken off, and the test as a whole is more or less markedly compressed antero-posteriorly, and deformed. The width is measured to be about 58 mm, and the height about 43 mm, but evidently these do not seem to represent true values. But for these dimensional disproportions the fossil also is an example of *Faorina chinensis* GRAY: otherwise, it might be a subspecies or possibly another species."

Judging from HAYASAKA's illustrations (1948-a, pl. 4, figs. 1a-c.-1953, pl. 14, figs. 4-6) and descriptions (1948-a, p. 96.-1953, pp. 218-219), the fossil specimen from Formosa referring to Fao. chinensis (or Sin. kawaguchii) recalls Cagaster recticanalis in the form of paired petals and in the position and feature of peristome, although even into consideration of the specimen is subsequently antero-posteriorly compressed. The existence of the peripetalous fasciole double anteriorly alone does not prove it belongs to Fao. chinensis, as such fasciole is known to occur in other spatangoins other than Fao. chinensis, viz., in the living Pericosmus akabanus MORTENSEN, 1939 (1939-a, p. 38, pl. 3, figs. 1-6, pl. 4, figs. 1-16.—the Arabian Red coast) (MCZ 7400) and Plethotaenia spatangoides (A. AGASSIZ, 1883) (Macropneustes spatangoides A. AGASSIZ, 1883-a, p. 64, pl. 27.-Pl. spatangoides (A. AGASSIZ): MORTENSEN, 1951, p. 485, pl. 39, figs. 6, 10-11, pl. 64, fig. 24, text-figs. 253-254—from Bermuda to Barbados), and in fossil species, Pericosmus latus (AGASSIZ) (AGASSIZ and DESOR, 1847, p. 19, pl. 16, fig. 1.—COTTREAU, 1913, p. 121, text-fig. 36.—Langhian of central Europe). The discrimination, therefore, among them must be dealt with other important characters disregarding the peripetalous fasciole, e. i., the characters of petals (providing the distalmost plates occluded or not), structure of peristome, particularly the character of the other fascioles than the peripetalous one, and here is made a clear separation among them that *Pericosmus* having a marginal fasciole besides a peripetalous one, in Faorina both a latero-anal and a peripetalous fasciole, and in Plethotaenia both a subanal and a peripetalous fasciole present, and these genera in the characters of their fascioles are steadily and safely referred to their proper families, viz., Pericosmus to its own family Pericosmidae, Faorina to the family Schizasteridae, and Plethotaenia to the family Brissidae.

As to the fascioles of the fossil specimen from Formosa, only the anteriorly doubled peripetalous fasciole is mentioned by the original author but the nature of other fasciole is not ascertained, and hence the true taxonomic determination of this peculiar form has caused a much trouble to the writer. The form of test, which is high and angular rounded-cordiform, subcentral position of the apical system, shallow and broad frontal ambulacrum (III) and the arrangement of the ambulacral pores, long and straight antero-lateral petals (II and IV) and the inner series of the poriferous zones slightly concaved, particularly the form of the postero-lateral petals (I and V) as in they at first diverge then curved convergently at the middle of the petals and lastly again slightly diverge near distal end, and the position of peristome, in the fossil specimen from Formosa, recall Cagaster recticanalis. The long and straight antero-lateral petals, which are comparatively longer than those of Fao. chinensis but shorter than Cag. recticanalis, indicate that the peripetalous fasciole of this specimen runs nearer the ambitus than that of Fao. chinensis and higher than Cag. recticanalis. The differences between this fossil specimen and Cag. recticanalis from the Miocene of Japan are found in the antero-lateral petals, which are deeper and shorter in the specimen while shallower and longer in Cag. recticanalis, the posterolateral petals, though much alike in shape, are longer in the specimen (about 18 mm) than in Cag. recticanalis (about 12 mm), the phyllodes are less developed in the specimen, and the naked portion of the postero-lateral ambulacra on the oral surface is narrower in the specimen, as only 2 or 3 adoralmost plates are naked. The peripetalous fasciole of the specimen seems to, in close observation on figure 1a on plate 4 of HAYASAKA, more strongly recurved than that of *Fao. chinensis* in the posterolateral interambulacra and there is an indication of existence of a latero-anal fasciole.

By those respects as described in the foregoing paragraphs the writer has come to a conclusion that the fossil specimen from Formosa might be congeneric with the Japanese Miocene Cag. recticanalis not with the living Fao. chinensis. It seems to the writer that the inter-relationships of the two fossil species, Cag. recticanalis and Cag. sp., can be correlated with those of the two living species of the genus Pericosmus, viz., Per. cordatus MORTENSEN, 1950 (MORTENSEN, 1950, p. 158; 1951, p. 182, pl. 16, figs. 1-7, pl. 50, figs. 15, 18, 23-27, 31, text-figs. 84b, 86c, 88a, 91b—Near Goto Islands, Japan) and Per. akabanus (loc. cit.) :—the former species is characterized by an heart-shaped test with a very deep frontal depression and anterior simple peripetalous fasciole, while the latter by a high or subconical test with a rather shallow frontal depression and an anteriorly doubled peripetalous fasciole. The fossil specimen from Formosa appears to be a species distinguishable from the type-species, but the writer leaves it unnamed till the more authentic material is available.

The assignment of the Formosan fossil species to the genus *Cagaster* offers an interesting problem that this genus may stand an intermediate position between the genera *Brisaster* and *Faorina* in the Schizasteridae.

Genus Schizaster AGASSIZ, 1836

- Schizaster Agassiz, 1836, p. 185 (18).—Agassiz, 1840-a, pp. 2, 15.—Agassiz and Desor, 1847, p. 20 (pro parte).—Forbes, 1852-a, p. 27.—Gray, 1855-a, p. 59 (pro parte).—Desor, 1855-58 (58), p. 389.—A. Agassiz, 1872-74, pp. 157, 363, 609 (pro parte).—Loriol, 1875, p. 106.—Cotteau, 1875, p. 28.—Zittel, 1879, p. 543.—A. Agassiz, 1881-a, p. 199 (pro parte).—Pomel, 1883, p. 37.—Duncan, 1889-a, p. 234 (pro parte).—Tornquist, 1903, p. 391.—Lambert, 1907-c, p. 110.—Mortensen, 1907, pp. 116-123.—Fourtau, 1908, p. 193.—Hoffmann, 1914, p. 259.—H.L. Clark, 1917, p. 192.—H.L. Clark, 1925, p. 210.—Lambert and Thiéry, 1925, p. 522.—Grant and Hertlein, 1938, p. 119.—Cooke, 1942, p. 39.—Hayasaka, 1948-a, p. 96 (pro parte).—Mortensen, 1951, p. 295 (complete synonymy).—Kier, 1957, pp. 880-881.—Cooke, 1959, p. 72.
 - Logotype.—Schizaster studeri AGASSIZ, 1836, p. 185 (18).—COTTEAU, 1885-89 (87), p. 344, pl. 104, figs. 4-5 (S. 6, type de l'espèce), pl. 105, figs. 3-6 (Priabonian of southern France). [LAMBERT, 1907-c, p. 112.—Designation validated by Opinion 209 of the International Commission on Zoological Nomenclature.—Bull. Zool. Nomencl., vol. 4, 1950, p. 527].

Forms of moderate size; vertex posterior; test high, sloping anteriorly; posterior end high, vertically truncate; oral side slightly convex. Frontal ambulacrum (III) deeply excavate, the adjoining interambulacra rising as vertical walls, usually covering the frontal pore-pairs, which are, in the typical subgenus, regular series on each side and pores of a pair being separated by a peduncular granule; while in the subgenus *Ova* the pore-series are double and pores of a pair without a peduncular granule. Apical system posterior, ethmolytic, with only two genital pores. Paired petals fairly deeply sunken, with the antero-lateral petals (II and IV) long and flexuous, the posterolateral ones (I and V) about half or only one-third the length of the antero-laterals and usually straight. Usually 6-7 penicillate subanal tube-feet. Posterior interambulacrum (5) rising into a more or less conspicuous keel, more or less distinctly overhanging the periproct. Peripetalous fasciole broad and sinuous, well circumscribing the paired petals; latero-anal fasciole usually distinct, making a deep bend below the periproct. Peristome near the anterior end of test, somewhat sunken; labrum fairly prominent, its posterior prolongation not continuing beyond the first adjoining ambulacral plates; periproct situated high on the vertical posterior end of test. Of the pedicellariae, globiferous ones with a number of short teeth surrounding the terminal opening of valves; ophicephalous pedicellariae unknown in the typical subgenus (mainly after MORTENSEN, 1951). From the Eocene to Recent.

AGASSIZ (1836, p. 185 (18)) included in his proposed genus only two species, viz., atropos LAMARCK, 1816 and studeri (loc. cit.). The former was removed by MICHLEIN (1855, p. 245) to form genus Moera (the name was unfortunately pre-occupied and emended by A. AGASSIZ, 1872-74, p. 146, to Moira), leaving studeri in Schizaster, and this species was definitely designated as the type-species by LAMBERT (1907-c, p. 112) and the Thirteenth International Congress of Zoology in Paris, 1948. AGASSIZ recorded Sch. studeri from the Italian Tertiary (Nice, Italy in 1836), following a generic diagnosis (AGASSIZ's original diagnosis read "two genital pores") and stated that there was one fossil species. The number of genital pores of this species has been much disputed whether it is two or four. It is unfortunate that the insufficiently defined fossil species studeri has to be accept as the type-species of the important genus Schizaster, but there seems to be no legitimate way by which one of the Recent species can serve in that capacity. The form of the test, deeply sunken petals, and a peripetalous and a latero-anal fasciole of this type-species, are evidently similar to those of the living Sch. lacunosus (loc. cit.), but whether the two species have the same the number of genital pores and ambulacral pores in the frontal ambulacrum (III) or not is not definitely ascertained. The discussions offered by many authors, such as POMEL, COTTEAU, LAMBERT, MORTENSEN, and KIER, on the number of genital pores and ambulacral pores in the frontal ambulacral of the type-species seem to be endless owing to the unfavourable condition of the type-specimen, and the writer in the present condition agrees MORTENSEN's idea that Sch. studeri must be accepted as



Fig. 73 [48]. Diagrammatic figures of *Schizaster studeri* AGASSIZ, 1836. a. Aboral view, ×0.75; b. Side view, ×0.75 (from COTTEAU, 1887).

the type of the genus *Schizaster*, characterized by having only two genital pores and the frontal pores arranged in a single series. The plaster cast of the type as figured by COTTEAU (1885-89 (87), p. 344, pl. 104, figs. 4-5—Text-figs. 73 [48]a-b) seems to be its apical system at the posterior third, apparently with only two, widely separated genital pores.

The genus *Schizaster* resembles *Paraster* in the form of petals and with a distinct latero-anal fasciole, but differs in the number of genital pores, i. e., *Schizaster* with two, while *Paraster* with four genital pores. This genus also closely resembles *Hypselaster* (H. L. CLARK, 1917, p. 185.—Type-species.—*Schizaster limicola* A. AGASSIZ, 1878, p. 193—Gulf of Mexico) in the number of genital pores, the pores of the frontal ambulacrum (III) and in the form of petals, but differs from that genus in having a distinct latero-anal fasciole, while in that genus a latero-anal fasciole is rudimentary.



Fig. 74 [49]. Diagrammatic figures of Schizaster and Ova.

- a. Aboral view of *Schizaster lacunosus* (LINNAEUS, 1758), ×0.75 (Recent specimen from Hiroshima Bay, Hiroshima Prefecture).
- b. Aboral view of Schizaster (Ova) canaliferus (LAMARCK, 1816),
 - ×0.75 (after CHECCHIA-RISPOLI, 1916).

The living species of this genus are very unsatisfactory known. At least three species of the typical schizasterids are recognized and they are comparatively wide-spread. Of the species, *Sch. lacunosus* (loc. cit.) has been assigned to *Schizaster*, and even LAMBERT and THIÉRY (1925, p. 530) allowed to keep *Sch. edwardsi* COTTEAU, 1889 (COTTEAU, 1889-b, p. 286, pl. 3, figs. 7-12, pl. 4, figs. 1-2.—MORTENSEN, 1951, p. 304, pl. 21, figs. 1-4, 11-13, pl. 54, figs. 4, 6, 10-11, 13, 18, text-figs. 140c, 141c—the Coast of Guinea) and *Sch. orbignyanus* A. AGASSIZ, 1880 (A. AGASSIZ, 1880-b, p. 84.—A. AGASSIZ, 1883-a, p. 76, pl. 28, figs. 1-7—off Barbados) in the genus (though erroneously referred them to the subgenus *Brisaster*).

The fossil forms described under the name *Schizaster* are very numerous, in all no less than about 200 species, and actually comprise a number of different forms. The inter-relationships of the extinct and living species are in need of further elucidation, e.g., *Sch. howa* (TORNQUIST, 1904) (TORNQUIST, 1904, p. 329, pl. 46, figs. 1-2) and *Sch. lacunosus* represent two obviously divergent types.

LAMBERT and THIÉRY (1925, pp. 522-530) took the genus *Schizaster* in very broad sense and they divided it into five sections, whose type-species are as follows, re-

spectively.

1re	section	n:	Schizaster (Sch. studeri)
2e	,,	:	Rotundaster (Sch. foveatus)
3e	,,	:	Brachybrissus (Sch. ambulacrum)
4e	,,	:	Aplospatangus (Sch. eurynotus)
5e	,,	:	Brisaster (Sch. fragilis)

Of these sections, *Brisaster* and *Aplospatangus* should be raised as generic rank in the modern echinological taxonomy.

Of the Japanese fossil species formerly referred to the genus *Schizaster*, viz., *Sch. nummuliticus* and *Sch. recticanalis*, were removed by the writer from this genus, as the former is referred to *Paraster* and the latter forms genus *Cagaster*. There are fossil representatives of the typical schizasterids in our collection, of which *Sch. lacunosus* from the Neogene or Quaternary of Japan is postponed for description until the authentic material becomes available to the writer.

Schizaster kinasaensis MORISHITA, 1953

Schizaster kinasaensis Morishita, 1953-a, p. 224, pl. 1, fig. 8.—Morishita, 1960, p. 63.—Nisiyama, 1965, p. 80.

Locality and geological horizon (after MORISHITA, 1953).—A place of construction, southwest of Ichinosaka, Kinasa-mura, Kami-Minochi-gun, Nagano Prefecture. Middle part of Ogawa formation, Miocene. Holotype.—No. JC750004, in Geol. Inst., Kyoto Univ.

No specimens of this species have been available for study. This species is said to differs from *Cagaster recticanalis* (YOSHIWARA, 1899) in the anteriorly eccentric peristome, the frontal ambulacrum (III) in the deep furrow, the short and straight postero-lateral petals (I and V), and the apical system at much posteriorly on aboral surface.

This small species appears to be referred to the genus *Schizaster* in the position of apical system, the frontal ambulacrum in the deep groove, the short and straight postero-lateral petals, and in the anteriorly eccentric peristome. It is very regrettablethat the number of genital pores, the course of a peripetalous and a latero-anal fasciole, and the structure of frontal ambulacral pores are not discernible, and the specific characters distinguishing this from other species of *Schizaster* are not well established.

Schizaster miyazakiensis MORISHITA, 1956

Schizaster miyazakiensis Morishita, 1956, p. 197, pl. 3, figs. 1a-d, 2a-d, pl. 4, figs. 1a-d.— Morishita, 1960, p. 63.—Nisiyama, 1965, p. 80.

Locality and geological horizon (after MORISHITA, 1956).—Tano-machi, Miyazaki gun, Miyazaki Prefecture (ca. Lat. 31°50'N., Long. 131°15'E.). Miyazaki group, Miocene. Holotype.—GK-14710, paratype GK-14711, in Geol. Inst., Kyushu Univ.

There is no authentic specimen of this species at the writer's disposal.

The important features of this species being recognized by the original author,

that all the ambulacra are in the deep grooves and the antero-lateral petals are curved outwards, can be rather regarded as general characters of the genus than the specific characters of this species.

The phyllodes seem to be rather well developed, as is observed in figure 1b on plate 3 of MORISHITA (1956), although the original author did not mention about them; the five or six adoral plates of the antero-lateral ambulacra (II and IV) on each side seem to have large pores (for penicillate tube-feet). Sternum of this species seems to be moderately broad and narrowing anteriorly; labrum seems to form a more or less prominent lip with reversed edge; the postero-lateral ambulacra (I and V) on the oral surface very narrow.

The paratype-2 of MORISHITA (1956, pl. 4, figs. 1a-1d) seems to be more or less different from the typical one in the postero-lateral petals (I and V), which are longer and more or less confluent proximally; it is not ascertained whether the difference is due to a deformation of the test or to a specific distinction.

It is regrettable that the course of a latero-anal fasciole of this species is not discernible in any specimen, and excepting the feature of fascioles, this species closely resembles, in the several features, the living Hypselaster affinis MORTENSEN, 1948 (MORTENSEN, 1948-b, p. 121.—MORTENSEN, 1951, p. 321, pl. 22, figs. 8-13, pl. 52, figs. 12-13, 15, 18-19, text-figs. 146a-b, 147-148a-b-the Philippines) or Hyp. fragilis (A. AGASSIZ and H. L. CLARK, 1907) (Periaster fragilis A. AGASSIZ and H. L. CLARK, 1907-b, p. 138.—Hypselaster fragilis (A. AGASSIZ and H. L. CLARK) H. L. CLARK, 1917, p. 189, pl. 148, figs. 5-8-southwest of Koshiki Island, Japan). In the two living species of Hypselaster, the test is distinctly higher at the posterior than the anterior, the posterior end of the test is truncate subvertically, the posterior interambulacrum (5) forms a sharp keel and the antero-lateral interambulacra (2 and 3) also form rather sharp keels, the apical system is distinctly posterior (in affinis) with two genital pores; the petals are small and rather much sunken, the postero-lateral petals (I and V) are somewhat less than half the length of the antero-lateral ones, which are slightly curved, not strongly as in Sch. lacunosus, outwards; the peristome is not so closed to the anterior margin: all these features of the two living species of Hypselaster fairly coincide with those of Sch. miyazakiensis and more or less differ from those of the living Sch. lacunosus. Schizaster is discriminated from Hypselaster, in the main, by having a complete and distinct latero-anal fasciole, and in the two living species of *Hypselaster* the fasciole is distinct only as a straight line below the periproct. The assignment of Sch. miyazakiensis to the proper genus is not established until the course of latero-anal fasciole of it is definitely ascertained. Sch. miyakiensis also more or less resembles species of the genus Aplospatangus, but the narrower and deeper frontal ambulacrum (III) and the higher test of this species may prevent to refer it to that genus.

Schizaster excavatus MARTIN, 1937

Schizaster cf. canaliferus (LAMARCK): STAFF and RECK, 1911, p. 44.
Schizaster cf. japonicus A. AGASSIZ: GERTH, 1927, p. 183, pl. 218 (1), figs. 3a-b.
Schizaster excavatus MARTIN in JEANNET and MARTIN, 1937, p. 292, text-figs. 62a-b.—COOKE, 1954, p. 49, pl. 12, figs. 1-4.

Locality and geological horizon (after COOKE, 1954).—USGS 17576.—Limestone exposed in small cliff on the west end of the beach at Imatomari, Okinawa, Ryukyu Islands. Naha limestone, Pliocene. Hypotype.—USNM 561568.

A single specimen measures about 47 mm in longitudinal diameter of test, about 43 mm in transverse one, and about 31 mm in height, and it is more or less compressed antero-posteriorly. Although the number of genital pores and the course of the fascioles are not discernible in this specimen, in its general features it may be referred to *Sch. excavatus*, from the Pliocene of Java and Timor; but, it is somewhat wider than MARTIN's figures, and its petals are consequently more diverging. COOKE (1954, p. 49) regarded that the differences between this specimen and the original specimen are presumably individual variations. In general appearance it is more similar to the living *Sch. lacunosus* than to the living *Brisaster owstoni*.

Schizaster sp. indet.

Schizaster sp. indet., Morishita, 1953-b, p. 63, pl. 6, fig. 6.—Morishita, 1954-a, p. 229.—Morishita, 1960, p. 64.

Locality and geological horizon (after MORISHITA, 1953-b).—Dan, Mizunami-Tokimachi, Toki-gun, Gifu Prefecture. Oidawara tuffaceous mudstone, Miocene.

The position of the apical system, which is eccentric posteriorly, the straight petals and the short postero-lateral petals (I and V) being about half the length of the antero-lateral petals (II and IV), and the shallow frontal ambulacrum (III) in this specimen may not manifest a specific character that distinguishing from other species, and according to the original description and illustration in poor condition of this specimen its referring to proper genus is also hard to settle.

Of the living species of the genus *Schizaster* in Japan enumerated by MORISHITA (1953-b, p. 63), *Sch. ventricosus* (A. AGASSIZ, 1881-a, p. 204, pl. 36, figs. 1-3, non GRAY, 1851) is not a *Schizaster* but a species of *Brisaster*, which was identical with *Br. latifrons* by H. L. CLARK (1917, p. 180; 1925, p. 207), but is separated from that species by MORTENSEN and named as *Br. owstoni*, as its test is distinctly higher posteriorly and abruptly truncated, so that it recalls *Sch. lacunosus*. *Sch. japonicus* (A. AGASSIZ, 1879, p. 212.—A. AGASSIZ, 1881-a, p. 202, pl. 36, figs. 8-13, pl. 43, fig. 26, pl. 65, figs. 7-10) is regarded, according to LOVÉN's decision (1887, p. 168), as being identical with LINNAEUS' *Ech. lacunosus*, and after the adoption of H. L. CLARK (1947, p. 193) it is now universally used by echinologists. This specifically indeterminable form seems to differ, as stated by MORISHITA (1953-b, p. 63), from these species and cannot be referred to any of them in various characters.

Genus Aplospatangus LAMBERT, 1907

Aplospatangus LAMBERT, 1907-c, p. 113.—LAMBERT and THIÉRY, 1925, p. 527 (subgenus of Schizaster Agassiz, 1836).

The generic diagnosis given by LAMBERT and THIÉRY (1925, p. 527) is as follows.-

Orthotype.—Schizaster eurynotus AGASSIZ, 1840-a, p. 2.—LAMBERT, 1907-b, p. 67, pl. 5. figs. 6-7 (Langhian and Helvetian of southern Europe).

S. NISIYAMA

"Test subcordiforme, acuminé en arrière, à large et très profond sillon; apex ex-centrique, à quatre pores génitaux, les antérieurs souvent plus petits; pétales pairsinégaux."

The type-species and its allies, e.g., Apl. parkinsoni (DEFRANCE) (LAMBERT, 1907-b, p. 66, pl. 4, fig. 4, pl. 5, figs. 3-4) and Apl. scillae (DESMOULINS) (LAMBERT, 1907-b, p. 63, pl. 4, fig. 3), reported from the Miocene of Sardinia, southern France, and Italy and further from Sicily and Malta in the Mediterranean countries, closely resembles some species of Paraster. Apl. eurynotus resembles Par. gibberulus in the course of peripetalous fasciole, and it also resembles Diploporaster (?) savignyi in the broad and deep frontal ambulacrum (III) and in the shape of petals, but differs from latter species in the arrangement of the frontal ambulacral pores. Apl. parkinsoni resembles Dip. (?) savignyi in the course of peripetalous fasciole and in the from of petals, and also to Par. gibberulus in the narrow and shallow frontal ambulacrum. The species of *Aplos patangus* are stated to have four genital pores, thus the both genera. (Aplospatangus and Paraster) agree with each other in the number of genital pores. MORTENSEN (1951, p. 300) regarded Aplospatangus as only a synonym of Schizaster, but the latter having only two genital pores. The genus Aplospatangus is distinguished from the genus Paraster by the lower test and much concaved periproctal region.

This genus is very ill-defined and may be extinct one, dating back to the Eocene and ranges to the Miocene. The species seem to be distributed from southern Europe to as east as East Indies, where *Schizaster subrhomboidalis* HERKLOTS, 1854 (HERKLOTS, 1854, p. 20, pl. 5, fig. 4.—GERTH, 1922, p. 509, pl. 66, fig. 3) and *Sch. progoensis* GERTH, 1922 (GERTH, 1922, p. 510, pl. 62, fig. 2) from the Miocene of Java, are assigned by LAMBERT and THIÉRY (1925, p. 528) to *Aplospatangus*, are known. The specimens of unfavourable condition of preservation from the 'Slate formation' of Formosa may be referred to this ill-defined genus, and this procedure may be for convenience sake in echinological taxonomy.

Aplospatangus taiwanicus (HAYASAKA, 1948)

Schizaster (? Paraster) taiwanicus HAYASAKA, 1948-a, p. 98, pl. 2, fig. 4, pl. 5, figs. 2-5.

Locality and geological horizon.—South of Rôdô, Kiirun-gun, Taihoku-shû, Formosa. (Taiwan). Karisan formation (Slate formation), Palaeogene (Eocene). Hypotype.— Only one comparatively well-preserved specimen, IGPS coll. cat. no. 73788.

There are several specimens referable to this species at the writer's disposal, but they are mostly crushed and deformed, and the detailed characters are not discernible. HAYASAKA described this species from the Slate formation in many localities in the northern half of the island of Formosa (Taiwan), and almost all the specimens occur in association with *Cyclammina complanata* YABE and HANZAWA, a characteristic higher foraminifer from the Slate formation of Formosa. This species is certainly identified with TOKUNAGA's manuscript name *Schizaster taiwanicus*. These specimens derived from the Slate formation are so badly preserved that it is not ascertained whether they comprise one or more species and whether they are referable to *Schizaster*, *Paraster*, or *Aplospatangus*. The writer quite provisionally refer them to *Aplo*- *spatangus* on account of the resemblance in general features to the species of that genus.

The specimen at the writer's disposal, in comparison with HAYASAKA'S specimens, is smaller and somewhat higher, and petals are somewhat shorter and the periproctal region evidently concave. The specimen resembles *Apl. howa* (TORNQUIST, 1904), from the Eocene of Madagascar, but is distinguished from that species by the narrower and more elongate test and by the shorter postero-lateral petals (I and V). Of the three allied species in enumerating of HAYASAKA, the two, *Sch. acuminatus* (GOLDFUSS, 1829), from the Oligocene of Germany and *Sch. scillae* (DESMOULINS), from the Miocene of southern France, are referred to *Aplospatangus*; the rest *Sch. armiger* W. B. CLARK, 1915 (not *armigera* in feminine gender), from the upper Eocene of Alabama, is referred to *Paraster* (their *Schizaster* typicus) by LAMBERT and THIERY (1925, p. 524) and COOKE (1959, p. 71). At any rate, *Schizaster taiwanicus* much allied to some species of the genus *Aplospatangus*.

Genus Moira A. AGASSIZ, 1872

Moira A. Agassiz, 1872-74, pp. 146, 365 (pro Moera Michelin, 1855).—Zittel, 1879, p. 543.— Pomel, 1883, p. 37.—Duncan and Sladen, 1883, p. 64.—Duncan and Sladen, 1884, p. 225.—Pomel, 1887-a, pp. 68, 69.—Duncan, 1889-a, p. 238.—Meissner, 1904, p. 1392.— Fourtau, 1904-a, p. 440.—H. L. Clark, 1917, p. 195.—H. L. Clark, 1925, p. 211.—Lambert and Thiéry, 1925, p. 532.—Nisiyama, 1935, p. 155.—Grant and Hertlein, 1938, p. 125.— Cooke, 1942, p. 43.—H. L. Clark, 1946, p. 369.—Hayasaka, 1948-a, p. 102.—Mortensen, 1951, p. 325 (complete synonymy).—Cooke, 1959, p. 73.

Type-species.—Spatangus atropos LAMARCK, 1816, p. 32.—Moira atropos (LAMARCK) A. AGASSIZ, 1872-74, pp. 365, 615, pl. 23, figs. 1-6 (East Coast of North America).

Moera Michelin, 1855, p. 246 (non Leach, 1814, nec Hübner, 1819).—Desor, 1855-58 (58), p. 394.—Dujardin and Hupé, 1862, p. 603.—Bolau, 1873, p. 21.

Type-species.—Spatangus atropos LAMARCK, 1816, p. 32.

Schizaster: GRAY, 1855-a, p. 61 (ex Schizaster Agassiz, 1836).

Type-species.—Spatangus atropos LAMARCK, 1816, p. 32.

Echinocardium: LAMBERT, 1907-c, p. 113 (ex Echinocardium GRAY, 1825).

Type-species.—Spatangus atropos LAMARCK, 1816, p. 32.

Moderately sized form of ovoid outline; aboral side high vaulted, oral side flattened; posterior end vertically truncated or more or less deeply concave. Petals usually deeply sunken, but the entrance to them very narrow, the interambulacra nearly above them, especially adapically; the postero-lateral petals much shorter than the anterior ones. Frontal ambulacrum (III) likewise deeply sunken, but the entrance not so narrow as that of the paired petals, sometimes scarcely narrowed; deeply sunken part ends rather abruptly near front end, where the peripetalous fasciole crosses it; frontal notch in general quite conspicuous, though not nearly as deep as aboral part of the frontal ambulacrum; pores of frontal ambulacrum in regular single series on each side. Posterior interambulacrum (5) may form a fairly distinct keel and then overhangs the periproct to some degree; sternum forms a projection, posterior end of test thus becoming concave in some forms but not in other forms. Apical system subcentral, more or less sunken, with only two genital pores, ethmolytic; the madreporite covers greater part of the plate adjoining the posterior interambu-

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lacrum. Peripetalous fasciole follows edge of petals, forming there a smooth band. on denuded test; latero-anal fasciole well developed, issuing from middle of anterolateral petals, as a consequence of the peripetalous fasciole going in a straight line up on the very edge of the petals; on posterior end of test this fasciole forms a deep bend below the periproct. Peristome close to anterior end, not much sunken; labrum usually little prominent, reaching posteriorly not beyond middle of first adjoining ambulacral plates; sternum long, with almost parallel sides, only in one species (Moi. *clotho*) conspicuously widened posteriorly; phyllodes not strongly developed, the pores situated rather far from peristomial edge and the region rather usually naked. Postero-lateral ambulacra on oral surface narrow, especially posteriorly, and tuberclesof the lateral interambulacra encroaching upon them, so that they disappear at end of test; presence of penicillate subanal tube-feet therefore hard to ascertain. Tubefeet of frontal ambulacrum (III) with a beautiful entire disc supported by usual radiating laminae. Pedicellariae, the globiferous and tridentate types; globiferous pedicellariae have terminal opening surrounded by a number of short teeth (mainly after MORTENSEN, 1951). From the Oligocene to Recent.

All discussions about the use of the generic name (cf. MORTENSEN, 1932-e, pp. 356-360.—NISIYAMA, 1935, pp. 156-158) are fortunately now has come an end, the name *Moira* A. AGASSIZ, 1872, with the species *atropos* LAMARCK, 1816, as the type-species, having been out on the official list of generic names by Opinion 209 of the International Commission on Zoological Nomenclature, and the name thus being a nomen conservandum.

The genus *Moira* is generally regarded by many echinologists as being closely related to *Schizaster*, but is distinguished from that genus by much more sunken petals. POMEL (1887, p. 69) directly regarded *Moira* as a subgenus of *Schizaster*. As to the depression of petals of the higher spatangoins, in *Schizaster* in addition to the specialized frontal ambulacrum (III), the lateral paired ambulacra become sunken, in *Moira* there is the greatest development in the sunken ambulacra, not only of the paired petals but also of the frontal ambulacral pouch, which is more sunken than that of the lateral pairs. There may be afforded a view that *Moira* shows a further stage in the development of sunken ambulacra than *Schizaster*. *Moira* should be separated from *Schizaster* as a distinct genus.

The Recent species of this genus have comparatively wide geographical distribution, viz., *Moi. atropos* (West Indian region), *Moi. stygia* LUTKEN in A. AGASSIZ, 1872 (A. AGASSIZ, 1872, p. 58.—MORTENSEN, 1930-a, p. 392, pl. 2, figs. 8-11, text-fig. 1b) (Zanzibar, Gulf of Suez and Timor), *Moi. clotho* (MICHELIN, 1855) (A. AGASSIZ, 1904, p. 214, pl. 109, text-fig. 312) (American West coast), *Moi. lachesinella* MORTENSEN, 1930 (*Moi. lachesis* MORTENSEN, 1930-a, p. 389, pl. 2, figs. 1-7, pl. 3, figs. 5-8, pl. 4, figs. 1-14 (non GIRARD)) (western and central Japan), and *Moi. lethe* MORTENSEN, 1930 (MORTENSEN, 1930-a, p. 392, pl. 3, figs. 1-4) (Queensland and N. S. Wales); and this separate geographical distribution of them has not been explained by any author. In his paper of 1930 MORTENSEN has suggested that the two American species, *Moi. atropos* and *clotho*, in those species the posterior end of the test is vertically truncated and the sternum not projecting as a beak, ought perhaps rather be united with the genus (or subgenus) *Moiropsis* A. AGASSIZ, 1881. The much open petals of *Moiropsis* form a so conspicuous distinction from the species of *Moira* that it would hardly justifiable to unite them into one strict genus.

In our collection of fossils there is a fossil species of this genus and it can be safely brought into the genus *Moira*, on account of the petals being very deeply sunken and resemble narrow slits and the antero-lateral petals are not longer or wider than the frontal petal and of the course of the fascioles.

Moira obesa Nisiyama, 1935

Moira obesa Nisiyama, 1935, p. 164, pl. 8, figs. 6-16, text-figs. 9а-с.—Науазака, 1948-а, p. 103, pl. 1, figs. 2а-с.—Могізніта, 1960, p. 64.—Nisiyama, 1965, p. 80.

Holotype.-Saito Ho-on Kai Mus., coll. cat. no. 6164.

Locality and geological horizon.—IGPS loc. no.—Ao-28.—Rock beach in front of the Tanosawa railway station, Ôdose-mura, Nishi-Tsugaru-gun, Aomori Prefecture (tm Ajigasawa, Lat. 40°45′07″N., Long. 140°02′03″E.). Tanosawa formation (*Miogyp-sina-Op erculina* horizon), Miocene. Holotype and paratype.—IGPS coll. cat. no. 57238.

Locality and geological horizon.—GISM loc. nc.—Tt-3.—Cliff by a pond, north of Araya, Tari-mura, Hino-gun, Tottori Prefecture (tm Tari, Lat. 35°16'10"N., Long. 133° 10'E.). Tari formation, Miocene. Hypotype.—GISM coll. cat. no. 3120.

Locality and geological horizon (after HAYASAKA, 1948-2).—Along the beach of Shuinantung, at the foot of the Chinkusashin mines, east of Chilung harbour, Formosa (Taiwan). Nanko formation, Miocene.

This species is first described from the Miocene of Aomori Prefecture in Northeast Japan, and Dr. HAYASAKA reported its occurrence in the Miocene of Chilung, Formosa. The third locality is found by the writer in the Miocene of Tottori Prefecture, San'in district, western Japan, and there is an expect to find of this or allied species in the Miocene formations among relatively separated these three localities.

The specimen from the Tari formation, on the southwestern corner of Tottori Prefecture, is an internal mould of small size and compressed antero-posteriorly. It measures about 15 mm in longitudinal diameter of the test and about 11 mm in height. The deepening of the periproctal area, very forwardly inclined profile of the test, the eccentricity of apical system, the position of the peristome, and the shape of the paired petals of this specimen may be safely assigned to this species.

The very forwardly inclined profile of the test, the eccentricity of ethmolytic apical system, the position of peristome, deepening of periproctal area, and the feature of sternum form a notable combination of characters of this species. In the shape of the paired petals, this species is most closely allied to *Moi. antiqua* DUNCAN and SLADEN, 1883 (DUNCAN and SLADEN, 1883, p. 64, pl. 8, figs. 1-6—from the Miocene of Kachh, India), however, the position and form of the peristome are quite different, and the eccentricity of the apical system is much lesser than in that species. It is clear that this species is also closely related to *Moi. stygia* (MORTENSEN, 1951, p. 335, pl. 19, figs. 16, 19, 21, pl. 55, figs. 9, 17, 25–26, text-fig. 150c) in outline of the test, and in the eccentricity of the apical system; but the latter species shows no trace of the deepening just above the subanal part of the latero-anal fasciole, further the position of the maximum breadth is situated more anteriorly and the profile form of the test

is prominently different. It is very interesting to find that the deepening immediately above the subanal part of the latero-anal fasciole is well represented in the Japanese Recent species, *Moi. lachesinella*. This is a characteristic and constant feature, even in the young specimens, and it seems to indicate that the Recent *Moi. lachesinella* a descendant of the Miocene fossil species (*Moi. obesa*). Furthermore the sloping posterior end of forwardly inclined test and the posterior end of sternum of *Moi. obesa* are very characteristic features, and in these respects this species very closely resembles *Moiropsis claudicans* (A. AGASSIZ, 1879), although the two are specificially distinct.

The Japanese Recent species, *Moi. lachesinella*, was first described by MORTENSEN (loc. cit.) on the specimens from the beach of Hakata Bay, Fukuoka Prefecture, and it is now known to be distributed on the Pacific side as east as Tateyama Bay, Chiba Prefecture, central Japan. The writer possesses two specimens (Pl. 28, figs. 3-6.—IGPS coll. cat. no. 56984) from that locality. On the Japan Sea side it is found on the beach of Yomigahama, Tottori Prefecture. Therefore, there is this species is expected to be found in shallow water of these localities. The Japanese fossil species, *Moi. obesa*, occurs in the northeastern Japan together with other fossil echinoids of the Miocene age, such as *Astriclypeus mannii ambigenus* NISIYAMA, 1935 and *Echinolampas yoshiwarai* LORIOL, 1902, and with the higher foraminifers *Miogypsina kotoi* HANZAWA, 1931, and *Operculina complanata japonica* HANZAWA; in the western Japan, Tottori Prefecture, it occurs together with *Ech. yoshiwarai* and other fossil molluscus of the Miocene age, and in Formosa with *Astriclypeus integer* YOSHIWARA, 1899 (atypical form), *Echinolmapas jacquemonti* D'ARCHIAC and HAIME, 1853, and *Breynia carinata* HAIME, 1853, of the Miocene age.

Subgenus Moiropsis A. AGASSIZ, 1881

- Moiropsis A. Agassiz, 1881-a, p. 205.—Duncan, 1889-a, p. 238.—Meissner, 1904, p. 1393.—
 Lambert, 1907-c, p. 113.— H. L. Clark, 1917, p. 195.—H. L. Clark, 1925, p. 210.—Lambert and Thiéry, 1925, p. 532.—Nisiyama, 1935, p. 162.—Hayasaka, 1948-a, p. 102.—
 Mortensen, 1951, p. 337 (complete synonymy).
 - Haplotype.—Schizaster claudicans A. AGASSIZ, 1879, p. 211.—Moiropsis claudicans (A. AGASSIZ) A. AGASSIZ, 1881-a, p. 205, pl. 36, figs. 4-7, pl. 40, figs. 51-53 (Challenger Station 192, at Kei Islands, in 220 metres depth).

Test high, of small or moderate size, with a conspicuous posterior keel; frontal notch well marked, marginal outline of test being otherwise rounded, test seen from below distinctly heart-shaped. Sternum forms a distinct posterior prominence, posterior end of the test thus being concave as in the Indo-West Pacific species of *Moira*. Petals conspicuously sunken, though remaining more open than in *Moira*. Frontal ambulacrum (III) sunken like the paired petals, but the sunken part not as long as the antero-lateral petals (II and IV). Apical system ethmolytic, with two genital pores as in *Moira*. Peripetalous fasciole follows the edge of petals, as in *Moira*; latero-anal fasciole well developed and runs exactly as in *Moira*. Peristome close to anterior end; periproct high up on the posterior surface. Tuberculation fine and dense (mainly after MORTENSEN, 1951). From the Miocene to Recent.

DUNCAN (1889-a, p. 238) makes *Moiropsis* merely a subgenus of *Moira*, and the writer (NISIYAMA, 1945, p. 162) and MORTENSEN (1951, p. 338) join him. Although

the globiferous pedicellariae of *Moiropsis* are unknown whether they are another type than that of *Moira* or not, this is the best way to settle the classifactory position of *Moiropsis*.

LAMBERT (1911-b, p. 9, text-figs. 3-5) reported the occurrence of a species of Moiropsis from the Eocene of the Paris Basin, based on Schizaster velaini COTTEAU, 1887 (COTTEAU, 1885-89 (87), p. 309, pl. 93, figs. 1-3). It is true that the aboral surface and pore of the petals of this species closely resemble those of the Recent Moi. (Moiropsis) claudicans, as the antero-lateral petals are somewhat longer and wider than the frontal petal as in *Moiropsis*; but, it is hardly possible and not safely to bring this species into Moiropsis. The differences between this species and Moi. claudicans lay in the number of the genital pores and the course of the fascioles as shown in the description and figures given by COTTEAU (op. cit.). On the apical system of Sch. velaini COTTEAU gave the following statement—" Appareil apical peu développé, muni de quatre pores génitaux; plaque madréporiferme étroite, traversant l'appareil", and on the fasciole--" Le péristome, le périprocte et les fasciole ne sont pas consérvés dans notre exemplaire." By judging from COTTEAU's and LAMBERT's description and figures, although Sch. velaini is apparently an allied form of Moi. claudicans. It may belong to a quite distinct genus which was apparently derived from the associated schizasterids in the sea at that time or the earlier age.

The writer now confirmed in his belief that the resemblance between the sunken petals of the Eocene *Sch. velaini* and those of the Recent *Moi. claudicans* is not an indication of generic or genetical connection but of probably 'parallelism' or 'convergence' in development. That the depression of petals in the higher spatangoins (here, the writer disregards for the structure of ambulacral plates) may occur independently in unrelated genera seems not only possible, but also probable, as in the case of the rostrate pedicellariae between the Diadematoida and the Spatangoida and the peripetalous fasciole between the families Hemiasteridae and Schizasteridae.

The discovery of a fossil species of this subgenus from the Miocene of Formosa made by HAYASAKA is very noteworthy, as this is the second species of the subgenus and the date goes backwards as old as the Miocene.

Moira (Moiropsis) depressa (HAYASAKA, 1948)

Moiropsis depressa HAYASAKA, 1948-a, p. 106, pl. 1, figs. 4a-c.—Moira (Moiropsis) depressa (HAYASAKA) NISIYAMA, 1965, p. 80.

Locality and geological horizon (after HAYASAKA, 1948-a).—Shantzuchiao, west of Taipei, Formosa. Upper Kaizan formation, Miocene.

Locality and geological horizon (after HAYASAKA, 1948-a).—Shihting, about 25 kilometres southeast of Taipei, Formosa. Upper Kaizan formation, Miocene.

Locality and geological horizon (after HAYASAKA, 1948-a).—Neighbourhood of Patu, near Chilung harbour, Formosa. Kaizan formation, Miocene.

There is no available specimen referred to this species at the writer's disposal. This species occurs together with *Operculina multiseptata* YABE and HANZAWA, which is regarded as one of the important fossils for the determination of the geological age of the formation.

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This species is characterized by having the almost straight and comparatively broad antero-lateral petals (II and IV), which measure about 16 mm in length and about over 2 mm in width, eccentric posterior position of the apical system, which is situated about 19 mm from the anterior margin, the frontal petal (III) in groove seems to be shorter, about 13 mm in length, but wider than the antero-lateral ones. Thus it has characters between *Moira* and *Moiropsis*, in the feature of the frontal petal (III), much depressed anterior part of the test, and by the posterior truncation, which is not vertical but curved back downwards to form an overhanging and slightly concave wall, as in *Moi. primaeva* DUNCAN and SLADEN, 1884 (DUNCAN and SLADEN, 1884, p. 225, pl. 35, figs. 1-3—the Oligocene of Sind, India).

The characters of this species seem to be related to *Moiropsis* than to *Moira*, but the posterior end is overhanging, and also below the periproctal region is a shallow spoon-like depression, not conspicuously sloping as in *Moi. claudicans* and the Indo-West Pacific species of *Moira*. It seems highly probable that this species may be a combined form between *Moiropsis* and *Moira*, therefore the systematic position of *Moiropsis* treats as a subgenus of *Moira* seems to be justify in its procedure.

Family PERICOSMIDAE LAMBERT, 1905

Pericosmidae LAMBERT, 1905, p. 153.—LAMBERT and THIÉRY, 1925, p. 512 (tribus).—MORTEN-SEN, 1950-a, p. 181.—MORTENSEN, 1951, p. 166. Type-genus.—Pericosmus AGASSIZ, 1847.

Paired ambulacra form adapically very distinct, more or less sunken petals, which are generally straight, the distalmost plates being occluded. Pores of paired petals not conjugate; interporiferous zone usually narrow. Frontal ambulacrum (III) more or less deeply sunken; the pores small, distant, and forming regular series on each side. Interambulacra aborally remarkably naked, there being no large primary radioles (tubercles). Apical system ethmolytic, genital pores usually three, or rarely four. Labrum forms a more or less prominent lip. Both a peripetalous and a marginal fasciole present, but no subanal fasciole. Pedicellariae usually of five types. From the Eocene to Recent.

The family Pericosmidae are characterized by having both peripetalous and marginal fascioles, the distalmost plates of the paired petals being occluded, and by the reduction of primary radioles (tubercles) on the aboral surface. The first character, the presence of both peripetalous and marginal fascioles, is an unique feature among the spatangoins, and it makes a distinct demarcation of this family from other spatangoins. By the peculiar character of the paired petals, i. e., the distalmost plates being occluded, and also the the reduction of primary tubercles on the aboral surface, *Pericosmus* of the Pericosmidae has a habitual resemblance to *Plesiozonus* of the Palaeopneustidae and to *Faorina* of the Schizasteridae. *Plesiozonus* has no fasciole but has three genital pores, as in *Pericosmus*, and by the absence of fasciole is sharply distinguished from *Pericosmus*, but the fasciole certainly distinguishes it sharply from *Pericosmus*. The superficial resemblance between *Per. cordatus* MORTENSEN, 1950, and *Plethotaenia spatangoides* (A. AGASSIZ, 1883) of the Brissidae cannot mean any

relationship between them, the absence of a subanal fasciole in *Pericosmus* making a sharp distinction between that genus and all the forms providing with this fasciole.

The classification of the Pericosmidae is very simple in that only the one genus *Pericosmus* can with certainty be referred to this family. LAMBERT and THIÊRY (1925, p. 521) refer to the family also the genus *Victoriaster* LAMBERT, 1920, but MORTENSEN (1951, pp. 169, 170, 171) regarded *Victoriaster* as simply synonymous with *Pericosmus*. MORTENSEN also referred to this family the fossil genera *Polydesmaster* LAMBERT, 1920 (LAMBERT, 1920, p. 22.—Type-species.—*Poly. fourtaui* LOMBERT, 1920, pl. 2, figs. 7-8, 11—Cenomanian of France) and *Washitaster* (loc. cit.) as incertae sedis. By the general features *Washitaster* has a close resemblance with *Heteraster* of the Toxasteridae and should be removed from the Pericosmidae and referred to the Toxasteridae.

There are fossil representatives of the genus Pericosmus in our collection.

Genus Pericosmus AGASSIZ, 1847

- Pericosmus Agassiz in Agassiz and Desor, 1847, p. 19.—Desor, 1855-58 (58), p. 396.—Loriol, 1875, p. 111.—ZITTEL, 1879, p. 543.—MacCoy, 1882, p. 15.—Pomel, 1883, p. 41.—Cotteau, 1885-89 (87), p. 430.—Duncan, 1889-a, p. 232.—H. L. Clark, 1917, pp. 161, 164.—Lambert and Thiéry, 1925, p. 512.—H. L. Clark, 1925, p. 199.—Sanchez Roig, 1926, p. 217.—Jeannet and Martin, 1937, p. 283.—H. L. Clark, 1946, p. 363.—Mortensen, 1951, p. 169 (complete synonymy).
 - Logotype.—Pericosmus latus (AGASSIZ) AGASSIZ and DESOR, 1847, p. 19, pl. 16, fig. 1.—DESOR, 1855-58 (58), p. 396 (Langhian of France). [LORIOL, 1875, p. 114].
- Megalaster DUNCAN, 1877, p. 61.—DUNCAN, 1887, p. 422.—DUNCAN, 1889-a, p. 221. (Based on a specimen in which the fascioles were not observable).
- Victoriaster Lambert, 1920-b, p. 27.—Lambert and Thiéry, 1925, p. 513.—Sanchez Roig, 1926, pp. 129, 217.—Sanchez Roig, 1949, p. 248.

Orthotype.-Pericosmus gigas MACCOY, 1882, p. 15, pls. 53-54 (Miocene of Australia).

Moderately sized to large forms of rather varying shape, from heart-shaped or broader than long to almost cylindrical, more or less high, or subconical, or eggshaped; oral side flattened or convex, the edge rounded. Frontal ambulacrum (III) usually somewhat sunken, usually forming a conspicuous frontal depression; the pores very inconspicuous, placed vertically one above the other. Paired petals well developed, usually distinctly sunken; the distalmost plates occluded. Apical system ethmolytic, with three or (some fossils) four genital pores. Phyllodes moderately developed; postero-lateral ambulacra (I and V) on oral side naked, or sometimes densely covered with ophicephalous pedicellariae; 2 or 3 penicillate tube-feet (large pores) along the periproctal region; labrum short, not continuing posteriorly beyond the second adjoining ambulacral plates; sternum broad, tuberculated throughout, the tubercles even continuing onto the labrum. No large tubercles (radioles) aborally, test being densely and uniformly covered with small radioles (tubercles). A peripetalous and a marginal fasciole present, the peripetalous fasciole mostly bending inwards between the petals, sometimes double anteriorly (as in fossil Per. latus and in the living Per. akabanus): the marginal fasciole passes all round test, near ambitus, passing below the periproct; no subanal fasciole. Pedicellariae of the globiferous, tridentate, rostrate, ophicephalous, and triphyllous types in the living (mainly after MORTENSEN, 1951). From the Eocene to Recent.

As for the type-species of the genus *Pericosmus*, the opinions are diverse. On establishing the subgenus *Pericosmus* AGASSIZ (and DESOR) mentioned three genosyn-types under it, viz., *latus* (AGASSIZ), *brevisulcatus* (AGASSIZ), and *edwardsii* AGASSIZ; the first species being well figured on the plate 16, figure 1. The name *Pericosmus* was used in a nearly same ground of AGASSIZ by DESOR (1855-58 (58), p. 396) and he enumerated *Per. latus* as the first and *edwardsii* only as the second species of the genus. LORIOL (1875, p. 114) is the first author who definitely designate the type-species of the genus *Pericosmus*, he stated that *Per. latus* (the first species of AGASSIZ) is the type-species of the genus. However, H. L. CLARK (1917, p. 164) subsequently designated *Per. edwardsii* AGASSIZ as the type-species of the genus, and also again (1925, p. 199) cited the same species as the type. LAMBERT and THIÉRY (1925, p. 512) gave correctly *Per. latus* as the type-species as already designated by LORIOL: MORTENSEN (1951, p. 170) and the writer agree them in this respect. That LORIOL's designation (1875) has a clear priority over H. L. CLARK'S (1917) is quite evident.

Megalaster is regarded by LAMBERT and THIÉRY (1925, p. 512) as only a junior synonym of *Pericosmus*, based on the fact that the fascioles are recognized by MACCOY (1882) in other specimens to contrary the view of DUNCAN that the fascioles were not observable in a specimen, that caused the discrimination from *Pericosmus*. *Victoriaster* was erected on MACCOY'S *Per. gigas*, from the Miocene of Australia, as the type-species. *Victoriaster* is stated to differ from *Pericosmus* by its larger size, its longer petals, and by the marginal fasciole obliterating anteriorly. But, these differences cannot be regarded, as stated by MORTENSEN (1951, pp. 170-171), as generic characters that distinguishing the *Victoriaster* from *Pericosmus*. As for the identification of the genera *Pericosmus* and *Victoriaster* the writer agrees MORTENSEN's view at least at present, until new material may manifest the distinction of the two.

The characteristic features of the genus Pericosmus are the presence of both a peripetalous and a marginal fasciole, and the occluded distalmost plates of the paired petals. The delicate fascioles, particularly the marginal, of *Pericosmus* are often not well preserved in the fossils and it causes a difficulty, as in the case of DUNCAN (1977, p. 61), in tracing them. The referring of fossil specimens without preserved fascioles to the proper genus is a matter of considerable difficulty. If the marginal fasciole of Pericosmus, the subanal of Brissopsis, and the latero-anal of Linthia were not well discernible in the fossil specimens, and the shape of petals and the peripetalous fasciole only were preserved on the aboral side, the distinction of the three genera would be difficult. The subcentral position of the apical system, the long and rather straight paired petals and the sinuous and well circumscribing peripetalous fasciole of them at glance are very alike one another and cannot be referred them at once to their proper genera respectively. In this case, however, the structure of the ambulacra assists the identification of them, i.e., in Pericosmus the distalmost plates of the paired petals are occluded and the interporiferous zone is very narrow, if this were not an absolutely distinctive character, and it distinguishes the species of *Pericosmus* from those of the genera Brissopsis and Linthia.

The living species of the genus *Pericosmus*, which is up till 1914 known only as extinct, about ten are known by enthusiastic research of MORTENSEN, are in main

confined to the Indo-West Pacific. They and their geographical distribution are as follows.--

Pericosmus macronesius KOEHLER, 1914 (the Andamans and Mauritius, 100-230metres in depth).

Pericosmus akabanus Mortensen, 1939 (Gulf of Akaba).

Pericosmus cordatus MORTENSEN, 1950 (Near Goto Island, 200 metres in depth).

Pericosmus bidens MORTENSEN, 1950 (Mauritius; probably off Port Louis).

Pericosmus tenuis MORTENSEN, 1950 (Mauritius, 230 metres in depth).

Pericosmus keiensis MORTENSEN, 1950 (the Great Kei Islands, 90 metres in depth). Pericosmus melanostomus MORTENSEN, 1948 (Near Hongkong, Java Sea, and the

Sunda Strait, 18-80 metres in depth).

Pericosmus mauritianus MORTENSEN, 1950 (Mauritius).

Pericosmus oblongus MORTENSEN, 1950 (Bali Sea, 240 metres in depth).

Pericosmus sp. MORTENSEN, 1948 (off Cape Gardafui, 27 metres in depth).

This genus dating back to the Eocene and some 50 fossil species are known. LAMBERT and THIERY (1925, pp. 512-513) enumerated 42 fossil species in *Pericosmus* and 2 in *Victoriaster*, and some species are added thereafter. The fossil species are also in the main confined to the Tertiary System of the Indo-West Pacific regions and with the formations of the circum-Mediterranean countries; however, a few species are known from the West Indian region.

The peripetalous fasciole in the fossil *Per. latus* is, according to the precise observation of COTTREAU (1913, p. 121, text-fig. 36), double anteriorly and also in the living *Per. akabanus* it is the same case. The presence of the anteriorly doubled peripetalous fasciole is not a sole character of this genus, but is found also in the living *Faorina chinensis* of the Schizasteridae and *Plethotaenia' spatangoides* of the Brissidae, and in the fossil *Cagaster* species from Formosa. The peripetalous fasciole of *Pericosmus* is mostly bending inwards between the petals, but in the living *Per. melanostomus* it is not. The labrum in the Recent species of *Pericosmus* generally short, it reaches to the middle of the second adjoining ambulacral plates, while in *Per. mauritianus* it is very short and not extending posteriorly beyond the first adjoining ambulacral plates. The species of the genus *Pericosmus* seem to differ in the main from one another in the shape and height of test, the length and depth of petals, and in the course of fascioles.

There are fossil representatives of the genus Pericosmus in our collection.

Pericosmus magnificus NISIYAMA, n. sp.

(Pl. 28, figs. 1-2)

Holotype.—IGPS coll. cat. no. 73868.

Locality and geological horizon.—IGPS loc. no.—Mi-76.—Near the Myôjin shrine at Magaki-jima, 700 metres east of Higashi-Shiogama station of the Senseki electric railway line, Shiogama City, Miyagi Prefecture (tm Shiogama, Lat. 38°19'12"N., Long. 141°02"25"E.). Ajiri (Hatatate) formation, Miocene.

In the specimen at the writer's disposal the features of the aboral surface are only observable. It is very regrettable that the features of the oral side, namely the peristome, labrum, sternum, phyllodes and the postero-lateral ambulacra (I and V) on the surface, are not discernible. The aboral features, however, which are derived from a cast that clearly manifesting the course of fascioles and the tuberculation, and from a mould that showing plates arrangement of the aboral side, give an important information about the characters of this species.

Test of rather large size, probably attains 90 mm or more in longitudinal diameter of test and 80 mm in transverse one; ovoid in marginal outline, the greatest breadth may lie in middle of test; frontal notch not very deep, though distinct; height unknown.

Frontal ambulacrum (III) in a rather shallow groove and forming a rather conspicuous frontal depression, about 36 mm long from apical system to peripetalous fasciole, nearly 10 mm wide at the broadest point, from where the ambulacrum slightly narrowing towards anterior margin; the pores inconspicuous, round and small, pores of a pair without a peduncular granule; pore-pairs more or less oblique to transverse suture and nearer to adradial suture of plates; pore-pairs placed almost vertically one above the other and in regular series on each side; ambulacral plates rather low, about 2 mm high and 4.8 mm wide at halfway from apical system to peripetalous fasciole; interporiferous zone not very wide and closely tuberculated with small tubercles and miliaries.

Apical system subcentral, about 45 mm from the anterior margin, small, about 2 mm wide and 3 mm long, ethmolytic, the madreporite prolonged posteriorly, with three genital pores; the pores rather large, genital (2) without the pore.

Antero-lateral petals (II and IV) slightly sunken, long and broad, about 36 mm long and 11 mm wide at the broadest point, almost straight; they at first diverge to middle part of the petals and slightly converge from distal part, but not quite closed at the extremity; angle between median line of petal (II) and that of petal (IV) being about 105°; the distalmost plates being occluded; poriferous zones broad, about 4 mm wide at the broadest point; the pores subequal, large and more or less elongate, ridge between pore-pairs seems to be with a rather distinct tubercle on the middle; interporiferous zones narrow, about 3 mm wide at the broadest point and seem to be free from distinct tubercles. Postero-lateral petals (I and V) also slightly sunken, long and broad, about 34 mm long and 10.5 mm wide at the broadest point, almost straight and resemble the antero-lateral ones in shape; inner series of poriferous zones at first diverge to middle of the petals and distal part slightly converge, the outer series run almost straight and only slightly converge distally, not closed at the extremity; angle between median line of petal (I) and that of petal (V), very small, being about 55°; the pores subequal and more or less elongate, not conjugate as in the antero-lateral petals; the distalmost plates being occluded; ridge between pore-pairs seems to have a rather distinct tubercle on the middle; poriferous zones broad, about 4 mm wide at the broadest point; there are about 30 pore-pairs in postero-lateral petals and about 31 in antero-lateral ones on each side; interporiferous zones narrow, less than 3 mm wide at the broadest point and seem to be free from distinct tubercles.

Peripetalous fasciole very sinuous and distinct, which crosses the groove of frontal ambulacrum (III) a short distance above ambitus with an anteriorly convex curve, transverses the inner column of antero-lateral interambulacra (2 and 3) with slightly convex curve parallel to ambital margin, bends at almost right angle in the outer column of the area to run close to the distal ends of antero-lateral petals (II and IV), passes there with rounded curve, runs nearly parallel or slightly downwards the petals nearly up to middle of the petals, then bends at a large angle in the anterior column of postero-lateral interambulacra (1 and 4) and runs a short distance as nearly as straight line, again bends at a large angle in the posterior column of postero-lateral petals (I and V), approaching the distal ends of the petals, and turns there with a rounded curve; the course of the fasciole, unfortunately, in the posterior interambulacrum (5) is not discernible owing to missing of the area; there is no latero-anal fasciole; the course of the peripetalous fasciole is very alike that of *Per. macronesius* KOEHLER (KOEHLER, 1914, pl. 11, fig. 1). A trace of a marginal fasciole partly observable in the preserved part of antero-lateral interambulacrum (3).

Tuberculation on aboral surface small and rather dense, no large tubercles; tubercles on antero-lateral interambulacra (2 and 3) along frontal ambulacrum (III) more or less larger than the others, and tubercles become more or less larger as they approaching the ambital margin. Several radioles are preserved on the right posterolateral interambulacrum (1), they are slender and slightly curved, measure from 4 mm to 6 mm in length.

The subcentral position of apical system with three genital pores, the long and broad paired petals with the distalmost plates being occluded and the narrow interpoirferous zones, the long postero-lateral petals (I and V) being as long as the anterolateral ones (II and IV) with small angle between them, and the course of the distinct peripetalous fasciole, make a combination of characters of this species, and can be safely referred it to the genus *Pericosmus* by the characters.

In the course of peripetalous fasciole this species resembles *Per. macronesius* KOEHLER, 1914 (MORTENSEN, 1951, p. 176, pl. 17, figs. 5-7, 12-14, 17), the first known living species, but is easily distinguised from that species by having shallower and decidedly broader paired petals. The broad and not distinctly sunken paired petals of this species resemble the petals of *Per. tenuis* MORTENSEN, 1950 (MORTENSEN, 1950, p. 159.—MORTENSEN, 1951, p. 188, pl. 14, figs. 8-9, pl. 51, figs. 1-2, 6-7, 9, 17-18, 22, 31, text-figs. 82a-c, 93b) and *Per. melanostomus* MORTENSEN, 1948 (MORTENSEN, 1948-b, p. 119.—MORTENSEN, 1951, p. 194, pl. 13, figs. 5-8, 13-25, 35, pl. 51, figs. 10, 13-14, 16, 19, 23, 29-30, text-figs. 95c, 96a-c, 97a), but this species is distinguished from those species by having the longer postero-lateral petals (I and V).

The geographical distribution of the living species of this rather common genus of the Indo-West Pacific regions is known to range as north as about Latitude 32° north. The fossil species of the genus from Java are known since the time of HER-KLOTS, 1854, and at least four species occur there as fossil, viz., *Per. parvus* HERKLOTS, 1854 (HERKLOTS, 1854, p. 19, pl. 5, fig. 3.—JEANNET and MARTIN, 1937, p. 284, text-fig. 58—Miocene and Pliocene of Java), *Per. altus* HERKLOTS, 1854 (HERKLOTS, 1854, p. 19, pl. 4, fig. 2.—JEANNET and MARTIN, 1937, p. 285—Miocene and Pliocene of Java), *Per. altus* HERKLOTS, 16, pl. 3, fig. 3.—JEANNET and MARTIN, 1937, p. 285—Miocene and Pliocene of Java, 1937, p. 285, pl. 218, fig. 2—Pliocene of Timor and Java). The writer suggested, in the preceding pages under the genus

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Linthia, that the occurrence of a fossil species of *Pericosmus* from the Miocene Series of Formosa based on the smaller specimen of *Linthia taiwanensis* HAYASAKA, 1948 (HAYASAKA, 1948-a, p. 90, pl. 2, figs. 1a-b). The feature of paired petals, the course of peripetalous fasciole, and the short and narrow labrum of the smaller specimen from Formosa might be referred it to the genus *Pericosmus*. *Pericosmus magnificus* resembles the smaller specimen from Formosa in the outline of test, the shape of paired petals, and in the course of peripetalous fasciole, but is distinguished from that species by having the much broader and shallower paired petals. It seems highly probable that the presence of Miocene species of this rather common genus of the Indo-West Pacific, in both northern Japan and East Indies, indicates the occurrence of as well as the Miocene species in the intermediate region, i. e., Formosa, is expected.

Pericosmus cf. spatangoides (DESOR, 1858)

Pericosmus cf. spatangoides LORIOL: MORISHITA, 1956, p. 195, pl. 1, figs. 2-5.—MORISHITA, 1960, p. 62.—NISIYAMA, 1965, p. 80.

Locality and geological horizon (after MORISHITA, 1956).—Yarikawa, Nii-mura and Saraura, Mitsushima-machi, Shimoagata-gun, Tsushima, Nagasaki Prefecture (ca. Lat. 34°15′-25′N., Long. 129°20′E.). Taisyu group, Oligocene? Hypotype.—GK L4732-4738, in Geol. Inst., Kyushu Univ.

There is no authentic specimen referable to this species at the writer's disposal. The feature of the paired petals (e.g., the distalmost plates (pores) being occluded as is detected by close observation on the distal part of the antero-lateral petals of MORISHITA's figure 3 on plate 1, and the narrow interportiferous zones), and the course of a peripetalous fasciole (i.e., re-entrant between the antero-lateral petals and posterolateral ones) of these specimens can be referred with slight doubt them to the genus Pericosmus. Unfortunately, the presence of a marginal fasciole, one of the characteristic features of this genus, is not ascertained by MORISHITA. As for another fasciole MORISHITA (1956, p. 196) gave a curious description that—" the subanal fasciole is above the periproct "-this means an extraordinary case in echinological terminology, as the term "subanal" is named for the position that below the periproct; and if this peculiar fasciole (or a subanal fasciole) were really exist the specimens in question would not be referred to the genus Pericosmus, but he gives no its form. If this peculiar fasciole were represent a part of a marginal, it would be against the normal course of the fasciole that generally runs below the periproct, and if it were really passes "below" the periproct with a curve line it would be represent a part of marginal fasciole as in the character of *Pericosmus*.

MORISHITA conferred these specimens with the European *Per. spatangoides* (LORIOL, 1875, p. 112, pl. 19, fig. 1, pl. 20, fig. 1), of the Eocene form, probably owing to the poor condition of preservation and a precise identification must be postponed till new material comes to available for study. In discussion of affinity of this conferred species MORISHITA (1959, p. 196) enumerated two fossil species as being closely allied forms, viz., *Per. petasatus* LAMBERT, 1907 (LAMBERT, 1907-c, p. 87, pl. 6, fig. 3, pl. 8, figs. 3-4—Miocene) and *Per. granulosus* HERKLOTS, 1854 (loc. cit.); the two species are referred steadily by LAMBERT and THIÉRY (1925, p. 513) to the genus *Pericosmus*.

1.	Petals crossed by the peripetalous fasciole, the pores continuing outside the fasciole
⁻ 2.	Petals not crossed by the peripetalous fasciole
	Petals well formed. Oral side with prominences in the peristomial region; fossil
:3.	Peripetalous fasciole double anteriorly. Test with a wide and deep frontal notch
	Peripetalous fasciole not double anteriorly
.4.	Only two genital pores, on the left side
	Genital pores three or four
5.	Genital pores three only
	Genital pores four
·6.	The madreporite (2) lacking a genital pore Cyclaster
	Left genital (3) lacking a genital pore Anabrissus
7.	Apical system ethmophract. Frontal ambulacrum (III) petaloid, the pores round; fossil
	Apical system ethmolytic
.8.	Plastron extending posteriorly so as to form a more or less conspicuous "anal
	snout", surrounded by the subanal fasciole
	Plastron not extending posteriorly to form a "anal snout" 10
9.	Frontal ambulacrum (III) forming a deep furrow on the oral side Cionobrissus
	Frontal ambulacrum (III) not forming a deep furrow on the oral side
	Anametalia
10.	Antero-lateral interambulacra (2 and 3) sunken adapically Brissopatagus
11	Antero-lateral interambulacra (2 and 3) not sunken adapically 11
11.	Frontal notch deep and conspicuous, at least at the ambitus; Recent
	Frontal notch faint or none 12
12	Large primary tubercles on the aboral side
	No large primary tubercles on the aboral side
13.	Primary aboral tubercles confined within the peripetalous fasciole
	Primary aboral tubercles not confined within the peripetalous fasciole
14.	Anal fasciole present; mainly large forms Plagiobrissus
	No anal fasciole; mainly smaller forms Eupatagus
15.	Subanal plastron reniform 16
	Subanal plastron cordiform, shield-shaped 19
16.	A faint frontal depression
1/7	No trontal depression
11.	America)
	Subanal fasciole not tending to disappear in the adult (excepting Br. evanescens)

	(World-wide) Brissopsis
18.	Apical system anterior. Subanal fasciole complete, surrounding a distinct subanal
	plastron Brissus
	Apical system subcentral; fossil Trachypatagus
19.	Anal fasciole present. Plastron not narrow. Periproct not visible from above
	No anal fasciole Spatangobrissus
20.	Subanal plastron more or less distinctly projecting downwards or backwards
	Rhinobrissus
	Subanal plastron not projecting Metalia.
	There are fossil representatives of the genera Brissopsis, Eupatagus, Brissus and
Me	talia in our collection, and a species of the genus Plesiaster is reported from Japan.

Genus Plesiaster POMEL, 1883

Plesiaster POMEL, 1883, p. 42.—DUNCAN, 1889-a, p. 246.—LAMBERT, 1907-b, p. 94.—LAMBERT and THIÉRY, 1924, p. 483.—MORTENSEN, 1951, p. 368. Haplotype.—Micraster peini Coquand, 1862, p. 245, pl. 27, figs. 1-3 (Santonian of Algeria and Tunisia, north Africa).

Forms of moderate size, of oval outline, with broad and shallow frontal notch; test in general rather low, truncate posteriorly, oral side nearly flat. Frontal ambulacrum (III) in broad and shallow groove, more or less petaloid adapically, the pores resemble in shape those of the paired petals. Paired ambulacra petaloid adapically, more or less sunken; the petals nearly straight and not closed distally, not crossed by the peripetalous fasciole; the pores more or less elongate and more or less conjugate; postero-lateral petals (I and V) in general shorter than the antero-laterals (II and IV). Apical system subcentral, ethmophract, with four genital pores. Peristome anterior, semilunular in shape, with a short lip of the labrum; periproct on the truncate posterior end. Peripetalous fasciole circumscribes the petals and not crossing the petals, not as in *Neopneustes* and *Gaultieria*, and subanal fasciole rather broad and distinct. Tubercles in general uniform and small, there are no large primary tubercles within the fasciole. Upper Cretaceous (Santonian—Campanian) of North. Africa and Europe.

The genus *Plesiaster* has an ethmophractic character of the apical system that with having four genital pores is in common with the brissid genera *Diplodetus* SCHLUTER, 1900 (SCHLUTER, 1900, p. 364.—Type-species.—*Dip. brevistella* SCHLUTER, 1900, p. 364, pl. 15, figs. 3-5—Campanian of Baltic) and *Protobrissus* LAMBERT, 1907 (1907-a, p. 719.—Type-species.—*Prot. mortenseni* LAMBERT, 1907-a, p. 719, pl. 25, figs. 17-20— Danian (Garumnian) of Algeria). By this character of apical system and the older geological occurrence (at least from the Santonian to Danian) these three genera are regarded as primitive forms among the Brissidae. So the genus *Plesiaster* appears to be closely related in its general feature to the genus *Micraster* of the Micrasteridae that LAMBERT and THIÉRY (1924, p. 483) readily regarded it as a subgenus of *Micraster*. This resemblance between the two genera suggests that primitive brissids, such as the genera *Plesiaster* and *Diplodetus*, which have both a distinct subanal and a. MORISHITA distinguished this conferred species from these two species in its shorter ambulacral petals and in the shallower grooves. This species also resembles to some extent *Per. magnificus* and *Per.*? species (the smaller specimen of *Linthia taiwanensis*, from the Miocene of Formosa) in the form of shallow paired petals, and it is noteworthy that a Palaeogene *Pericosmus*, which resembles the Japanese Miocene form, has already existed in Japan.

Family BRISSIDAE LAMBERT, 1901

(Emend. by MORTENSEN, 1950)

- Brissina GRAY, 1855-a, p. 49 (pro parte).—A. AGASSIZ, 1872-74, p. 585 (pro parte).—A. AGASSIZ, 1881-a, p. 177 (pro parte).
- Les Brissidés POMEL, 1883, p. 31 (pro parte).—Brissidées COTTEAU, 1885-89 (85), p. 127 (pro parte).
- Brissidae LAMBERT, 1901, p. 969 (pro parte).—LAMBERT, 1905-a, p. 153 (pro parte).—LAMBERT and THIÉRY, 1924, p. 472 (pro parte).—SMISER, 1933, p. 157 (pro parte).—MORTENSEN, 1950-a, p. 181 (emend.).—MORTENSEN, 1951, p. 353.
 Type-genus.—Brissus [KLEIN] GRAY, 1825.

Peristome transverse, labrum more or less well developed. Ambulacra more or less distinctly petaloid adapically. Apical system ethmolytic or rarely ethmophract, with four or three, or rarely only two, genital pores. Both a peripetalous and a subanal fasciole present; anal branches from the subanal fasciole may be present, but no other fascioles. Peripetalous fasciole rarely double anteriorly and subanal fasciole rarely tending to disappear in the adult. Plastron sometimes extending posteriorly so as to form a more or less conspicuous "anal snout". From the upper Cretaceous to Recent.

The main character of this family, as diagnosed above, is the presence of both a peripetalous and a subanal fasciole. In the presence of a subanal fasciole this family is in common with the families Micrasteridae, Spatangidae, Maretiidae, and Loveniidae, and a part of the Palaeopneustidae, and the presence of a peripetalous fasciole has to do with the families Hemiasteridae, Schizasteridae, and a part of the Loveniidae and others. These families, however, are characterized, well limited, and are separated from one another by the presence and characters of various fascioles. that specialized each family. In these families the Micrasteridae providing with only a subanal and the Hemiasteridae having a peripetalous fasciole only. The subanal fasciole has occurred in the upper Cretaceous (Cenomanian) with the Micrasteridae while the peripetalous one in the lower Cretaceous (Aptian) with the Hemiasteridae, and a primitive brissid that provide with both a subanal and a peripetalous fasciole has occurred during the upper Cretaceous (Santonian). It is naturally estimated that the Brissidae would have been originated from a form that provide with one of the two fascioles, a peripetalous or a subanal fasciole. As for the origin of the Brissidae MORTENSEN (1951, p. 358) offered his view that the Brissidae must have originated from the Micrasteridae, not from the Hemiasteridae, the peripetalous fasciole having originated from as a new formation in the more primitive brissids, not derived from the fully formed and very prominent peripetalous fasciole of the Hemiasteridae. To this point of view of MORTENSEN on the origin of the Brissidae, the genus Plesiaster POMEL, 1883, would be given as an instance of the derivation. The genus Plesiaster is regarded as the primitive brissid and of the oldest geological occurrence, the Santonian, and it appears, according to LAMBERT and THIÉRY (1924, p. 483) and MORTEN-SEN (1951, p. 368) to be alike the Micrasteridae in the general feature and in the ethmophract apical system with four genital pores, but differs from the latter in the presence of a peripetalous fasciole and in the frontal ambulacral pores are similar to those of the paired petals. On the contrary, the genus Neopneustes DUNCAN, 1889, is regarded by MORTENSEN (1951, p. 359) as a primitive brissid and its peripetalous fasciole is in a rudimentary condition. Although the genus resembles to some extent the Micrasteridae, but is a quite Recent origin and seems to have nothing to do with the Cretaceous Micrasteridae. The question then arises as for the origin of the Brissidae, that all the genera, which are referred to the family Brissidae on account of the presence of both a subanal and a peripetalous fasciole, are actually have originated from single source such as the Micrasteridae or from diverse sources and they are really related one another or not related actually. MORTENSEN (1951, p. 358) stated also a possibility of derivation of the Brissidae from the Palaeopneustidae than from the Micrasteridae.

The classification of the Brissidae is not simple, as they comprising various forms, as stated in the preceding pages, of probably have descended from various sources, i.e., a polyphyletic group, and it may be necessary to group them in a single family by main character or subdivide them into several groups (or subfamilies) by smaller characters with recongnizing certain exceptions. MORTENSEN (1948-b, p. 123) at first followed H. L. CLARK (1917, 1925) in the classification of the Brissidae and all the brissids refer to the family Spatangidae; but subsequently (1950-a, 1951) to the family Brissidae he refers only the genera providing with both a peripetalous and a subanal fasciole. In this way, however, MORTENSEN has some doubts on the limit and relation of the family; he stated (1951, p. 360) that-" When I am placing also these two genera (Gymnopatagus and Plethotaenia) among the Brissids it is mainly for practical reasons, not because I feel sure that they belong to this family. So far then I have to agree that the family of the Brissidae as here limited may not be a quite natural family. But I do not see any other families to which they could with certainty be referred." A large number of genera provided with both a subanal and a peripetalous fasciole is referred by MORTENSEN (1951) to the family Brissidae; the following genera, viz., Anabrissus MORTENSEN, 1950, Neopneustes, Gaultieria, Blaviaster, Granobrissoides, Plesiaster, Protobrissus, Diplodetus, Brissopsis, Cionobrissus, Anametalia MORTENSEN, 1950, Cyclaster, Gymnopatagus, Macropneustes (with subgenus Deakia), Brissopatagus, Schizobrissus, Migliorinia CHECCHIA-RISPOLI, 1942, Eupatagus, Hikelaster, Plesiopatagus, Trachypatagus, Lissopatagus MORTENSEN, 1950, Plethotaenia, Rhinobrissus, Spatangobrissus, Plagiobrissus (with subgenus Rhabdobrissus), Lajanaster, Brissus, (with subgenus Allobrissus MORTENSEN, 1950), Meoma, Metalia, Idiobryssus H.L. CLARK, 1939 and Radiobrissus. The important genera of the family Brissidae are discriminated from one another as shown by the following key.

AGASSIZ, 1840, as the type-species. Fortunately, all discussions on this matter have come to conclusion that the description of the genus (AGASSIZ, 1840-a, p. 16) validates Br. elegans as of 1840 by the Opinion 46 of the International Commission on Zoological Nomenclature.

Not only this is one of the most wide-spread of spatangoin genera, but it is also one of the most perplexing from a taxonomic point of view. The subdivision or separation of *Brissopsis* to subgenera or distinct genera is attended by some previous authors, such as GRAY (1851, 1855-a), DESOR (1858), LAMBERT (1907-c), and LAMBERT and THIÉRY (1924), and several generic or subgeneric taxa are proposed for various forms. On the establishing of the genus *Kleinia*, GRAY did not refer it to an ally of AGASSIZ's genus, but to the genera *Brissus* and *Plagiobrissus* (his *Plagionotus* AGAS-SIZ, 1847, non MULSANT, 1842), and in this case the Indo-West Pacific *luzonica* seems to be clearly separated from the Atlantic *lyrifera* in generic characters. LAMBERT (1907-c, pp. 106-107) subdivided the genus *Brissopsis* into two subgenera, namely, *Brissopsis* (with two sections) and *Kleinia*; his classificatory scheme is summarized as follows.—

- III. Sous-genre Brissopsis AGASSIZ, 1840.
 - Ire Section, Brissopsis AGASSIZ, 1840.—Synonyme Toxobrissus DESOR. Type: B. elegans AGASSIZ.
 - 2e Section, Zeugaster (nom. nov.)
 - Type: Z. Lamberti GAUTHIER (Brissopsis).
- IV. Sous-genre Kleinia GRAY, 1855.
 - Type: K. luzonica GRAY.

LAMBERT and THIÉRY (1924, pp. 487-490) also proposed a more or less modified classification of *Brissopsis*; their classificatory scheme is summarized as follows.—

Genre: Brissoma POMEL, 1888.—Type: B. duclei WRIGHT (Brissopsis).

Genre: Brissopsis AGASSIZ, 1840.—Type: B. elegans AGASSIZ.
Sous-genre: Kleinia GRAY, 1855.—Type: K. luzonica GRAY.
Sous-genre: Verbeekia FRITSCH, 1879.—Type: V. dubia FRITSCH.

As for these genera (or subgenera) *Kleinia, Toxobrissus, Brissoma, and Zeugaster,* MORTENSEN (1951, pp. 372, 380) claimed that it seems hopeless to try to separate them from *Brissopsis*, and at present the earlier name *Brissopsis* is only accepted. To this idea the writer quite agrees.

The species are exceedingly difficult to separate from one another with satisfactory and there has been much confusion, as in the case of *Br. lyrifera* of A. AGASSIZ, as a consequence, as in the living species. H. L. CLARK reported common occurrence of a single species, *Br. luzonica* (GRAY, 1851), from the western and eastern Pacific (H. L. CLARK, 1917, pp. 204-206; 1925, p. 213), but MORTENSEN (1948-b, pp. 123-129; 1951, pp. 397-429), on a careful revision, discriminated no less than six different species among them occur there, viz., *Br. similis* MORTENSEN, 1948, *Br. micropetala* MORTEN-SEN, 1948, *Br. obliqua* MORTENSEN, 1948, *Br. oldhami* ALCOCK, 1898, *Br. bengalensis* KOEHLER, 1914, and *Br. luzonica* (GRAY, 1851).

This large genus dates back to the Eocene and comprising a large number of

species. LAMBERT and THIÉRY (1924, pp. 487-490) enumerated 85 species from wide spread areas.

There are fossil representatives of this genus in our collection.

Brissopsis luzonica cosibensis NISIYAMA, n. subsp.

(Pl. 25, figs. 5-6)

Compared with:

Kleinia luzonica GRAY, 1851, p. 133.—GRAY, 1855-a, p. 49, pl. 4, figs. 5-5a.—Brissopsis luzonica (GRAY) A. AGASSIZ, 1872-74, pp. 95, 593.—YOSHIWARA, 1900, p. 400 (in Japanese).—MEI-JERE, 1904, p. 188, pl. 5, figs. 44-45, pl. 23, figs. 469-476.—YOSHIWARA (TOKUNAGA), 1907, pl. 19, figs. 7-10.—KOEHLER, 1914, p. 207, pl. 13, fig. 15, pl. 14, figs. 4-5, 7, 12-13, pl. 20, figs. 51-54.—H.L. CLARK, 1917, p. 204, pl. 152, figs. 5-8, pl. 155, figs. 2-3.—H.L. CLARK, 1925, p. 213.—MORTENSEN, 1948-b, p. 128.—MORTENSEN, 1951, p. 398, pl. 32, figs. 2-4, 12-14, 19, 21, pl. 39, fig. 12, pl. 56, figs. 2, 4-5, 8-11, 13-15, 18-29, text-figs. 190b, 192, 194a, 195, 196a, 199c.

Brissopsis circosemita A. AGASSIZ and H.L. CLARK, 1907-a, p. 257.—A. AGASSIZ and H.L. CLARK, 1907-b, p. 148.

Brissopsis duplex KOEHLER, 1914, p. 212.

Holotype.—IGPS coll. cat. no. 73747.

Locality and geological horizon.—IGPS loc. no.—Kn-1.—Sea-cliff of Shiba, Minato Ward, Yokohama City, Kanagawa Prefecture (tm Yokohama, Lat. 35°20'N., Long. 139°38'E.). Koshiba formation, Pliocene. Holotype.—IGPS coll. cat. no. 73747.

Locality and geological horizon.—IGPS loc. no.—Kn-48.—Well wall at 118 metres high hill in Koshigoe-mura, Kamakura-gun, Kanagawa Prefecture (tm Yokosuka, Lat. 35°18′48″N., Long. 139°31′35″E.). Koshiba formation, Pliocene. Paratype.—IGPS coll. cat. no. 73748.

There are two specimens referred to this new subspecies at the writer's disposal, the one broken posterior half, the other is an internal mould and somewhat deformed.

Test small, thin, elongate and narrow; the greatest breadth at anterior middle of test, from which test is narrowing gently towards both the anterior and posterior ends; the greatest height behind posterior to line of postero-lateral petals in posterior interambulacrum (5); posterior end of test truncate, so the periproct scarcely visible from above.

Dimensions of holotype; about 30 mm in longitudinal diameter of test, 21 mm in transverse one, and about 15 mm in height.

Aboral surface not so raised; frontal notch of test moderate; frontal ambulacrum (III) rather deeply sunken and short, and rather narrow, about 1.5 mm wide near middle of ambulacrum from apical system to peripetalous fasciole; ambulacral plates rather low and carry small tubercles, plates outside the peripetalous fasciole carry from 4 to 6 tubercles on each plate; the pores in frontal ambulacrum small and in a single series on each side as in *luzonica*.

Antero-lateral petals (II and IV) small, short and rather sunken, 5 mm long and 2 mm wide, shorter than half of test-radius of same ambulacrum, rising and slightly outcurved near middle of the petals; outer poriferous zones slightly broader than the inner poriferous ones, and having about 12 pore-pairs; plates outside the peripetalous

rather rudimentary peripetalous fasciole, as stated by MORTENSEN (1951, p. 358), were directly derived from the Micrasteridae during the upper Cretaceous in new formation of a peripetalous fasciole.

The genus *Plesiaster*, however, is clearly distinguished from the genus *Micraster* in the main in the presence of a peripetalous fasciole and also in that the frontal ambulacrum (III) is petaloid adapically and the pores are alike those of the paired petals. The genus *Diplodetus*, which is also referred by LAMBERT and THIÉRY (1924, p. 484) to a subgenus of *Micraster*, closely resembles this genus in having an ethmophractic apical system, both a peripetalous and a subanal fasciole, and in the postero-lateral petals are shorter than the antero-lateral ones, but differs from this genus in the frontal ambulacrum (III) that flush with the test and not petaloid being contradistinction it is in wide and shallow groove and petaloid in this genus.

There is a report of occurrence of this genus from the Cretaceous of Japan.

Plesiaster peini (COQUAND, 1862)

Plesiaster peini (COQUAND): BITTNER, 1893, p. 258.—LAMBERT, 1907-b, p. 94.—MORTENSEN, 1951, p. 368, text-fig. 174.—MORISHITA, 1956, p. 199, pl. 1, fig. 1, pl. 4, fig. 3.—NISIYAMA, 1965, p. 81.

Locality and geological horizon (after MORISHITA, 1956).—Coast of Kamakuraura, Nakakoshiki-jima, Satsuma-gun, Kagoshima Prefecture (ca. Lat. 31°45'N., Long. 129° .50'E.). Cretaceous.

Locality and geological horizon (after MORISHITA, 1956).—Fukami-machi, Ushifuka City, Kumamoto Prefecture (ca. Lat. 32°N., Long. 130°E.). Cretaceous.

There are no specimens of this species have been available for study.

It is very regrettable that the two specimens referred by MORISHITA to this species are in so deficient condition of preservation that the presence of a subanal (his latero-anal) and a peripetalous fasciole is not discernible and that the detailed observation on the frontal ambulacrum (III) and the apical system not be permitted to make notation; and herewith in uncertainty of these respects the two specimens from the Cretaceous of Japan would not be safely referred to the named species. That the genera provide with petaloid frontal ambulacrum (III), i.e., the pores are not different from those of the paired petals, and the ethmophractic apical system with four genital pores, is found in the Hemiasteridae, *Heterolampas* COTTEAU, 1862, providing with a peripetalous fasciole, and if the kind of fascioles were not definitely known, it would be very difficult to make generic distinction among them. In the general features, however, the two specimens from Japan appear to be resembling *.Ples. peini* of North African Cretaceous.

Genus Brissopsis AGASSIZ, 1840

Brissopsis Agassiz, 1840-a, pp. 3, 16.—Agassiz and Desor, 1847, p. 14.—Gray, 1855-a, p. 55.—
Desor, 1855-58 (58), p. 378.—A. Agassiz, 1872-74, pp. 95, 354.—Loriol, 1875, p. 94.—
ZITTEL, 1879, p. 541.—Pomel, 1883, p. 34.—Claus, 1884, p. 103.—Duncan and Sladen, 1884, p. 202.—Cotteau, 1885-89 (86), p. 182.—Duncan, 1889-a, p. 248.—Schlüter, 1900, p.

360.—MEISSNER, 1904, p. 1395.—LAMBERT, 1907-c, p. 107.—MORTENSEN, 1907, p. 174.— LAMBERT, 1915-b, p. 171.—H. L. CLARK, 1917, p. 199.—LAMBERT and THIÉRY, 1924, p. 489.— H. L. CLARK, 1925, p. 212.—SANCHEZ ROIG, 1926, p. 116.—GRANT and HERTLEIN, 1938, p. 126.—COOKE, 1942, p. 48.—H. L. CLARK, 1946, p. 371.—MORTENSEN, 1951, p. 371 (complete synonymy).—KIER, 1957, p. 898.—COOKE, 1959, p. 84.

Haplotype.—Brissopsis elegans AGASSIZ, 1840-a, pp. 3, 16.—COTTEAU, 1885-89 (86), p. 184, pls.
 52-53 (Médoc, France; Priabonian). [Type-species is validated by Opinion 46 of the International Commission on Zoological Nomenclature].

Logotype.—Brissus lyrifer FORBES, 1841, p. 187.—Brissopsis lyrifera (FORBES) AGASSIZ and DESOR, 1847, p. 14. [AGASSIZ and DESOR, 1847, p. 14].

Kleinia GRAY, 1851, p. 133.—GRAY, 1855-a, p. 48.—DESOR, 1855-58 (58), p. 423.—POMEL, 1883, p. 33.—LAMBERT, 1907-c, p. 107.—LAMBERT and THIÉRY, 1924, p. 490.

Haplotype.—Kleinia luzonica GRAY, 1851, p. 133 (Luzon, Philippines).—GRAY, 1855-a, p. 49, pl. 4, figs. 5-5a.

Toxobrissus Desor, 1855-58 (58), p. 399.—Pomel, 1883, p. 34.—Bittner, 1891, p. 137.—A. Agassiz, 1904, p. 193.

Logotype.—Brissopsis crescenticus WRIGHT, 1855, p. 186, pl. 6, fig. 2 (Miocene of Malta). [POMEL, 1883, p. 34].

Logotype.—Brissopsis elegans AGASSIZ, 1840-a, pp. 3, 16. [LAMBERT, 1907-c, p. 107].

Brissoma POMEL, 1887-a, p. 41.—LAMBERT and THIÉRY, 1924, p. 487.

Logotype.—Brissopsis duclei WRIGHT, 1855, p. 185, pl. 6, fig. 1 (Miocene of Malta), [LAM-BERT and THIÉRY, 1924, p. 487].

Zeugaster LAMBERT, 1907-c, p. 106.

Orthotype.—Brissopsis lambert GAUTHIER in FOURTAU, 1900-a, p. 42, pl. 3, figs. 7-8 (Eocene of Egypt).

Forms of moderate to fairly large size; test often very delicate and fragile, of elongate ovoid outline; frontal notch deep, though distinct. Paired ambulacra petaloid adapically, more or less sunken; the petals of about equal size; postero-lateral petals. divergent or to a varying extent parallel (confluent) and the pores of proximal plates to a varying degree rudimentary. Frontal ambulacrum (III) not petaloid, but deepened,. forming a distinct frontal notch; frontal tube-feet (usually) with a well developed disc, lobed or entire, supported by radiating calcareous laminae; a pair of pores separated by a peduncular granule; pore-pairs generally placed more or less oblique to transverse suture of plates and in a regular series on each side. Three or four penicillate tube-feet to each side within the subanal fasciole. Apical system subcentral, generally small in size, ethmolytic, with four genital pores. Peristome not very closed to anterior margin; sternum rather broad, densely tuberculated throughout; labrum with only a short posterior prolongation. Peripetalous and subanal fasciole well developed; the peripetalous fasciole sinuous and distinct, generally bending inwards. on paired interambulacra; in most species a branch, the anal fasciole, proceeds from the subanal fasciole to each side of the periproct, joining the peripetalous fasciole; exceptionally (Br. evanescens) the subanal fasciole disappear in the adult; in Br. persica it is heart-shaped, in the other species it is usually reniform. Radioles uniform, short, curved, usually spoon-shaped widened distally. Pedicellariae of the globiferous, tridentate, rostrate, ophicephalous, and tiphyllous types. Sphaeridia placed singly at oral tube-feet, not in grooves or pits (mainly after MORTENSEN, 1951). From the Eocene to Recent, of the world-wide distribution.

As to the type-species of this genus, opinions are diverse. Most authors preferthe living *Brissus lyrifer* FORBES, 1841, while some claim the fossil *Brissopsis elegans*: 1951, p. 412, pl. 30, fig. 6, pl. 31, figs. 1-2, 4, pl. 33, figs. 1-3, pl. 59, figs. 8-9, 14-15), a Recent species from southwestern Japan, Bay of Bengal, near Borneo, and Celebes, but is distinguishable from that species by the position of the apical system, which is in that species decidedly eccentric in front and by the smaller and coarser tuberculation on both the aboral and oral surfaces. This species also differs from Br. *luzonica* (with subspecies *cosibensis*) by the outline of test, form of petals, particularly the postero-lateral petals (I and V) being less confluent, and by the higher ambulacral plates outside the antero-lateral petals (II and IV). It is very interesting fact that this species is more related to southern species, viz., Br. oldhami and Br. bengalensis, rather than to the Japanese species, Br. luzonica, but this resemblance seems to be superficial, as judged from the associated fauna in this formation that indicating rather cooler climate than now in that region. Further it is suspected that there will be the report of this or allied species from northern Japan.

The associated fauna (NOMURA, 1949) identified by Dr. HATAI is as follows: Limopsis tokaiensis YOKOYAMA, Portlandia scapha (YOKOYAMA), Nucula palula SMITH, Ancistrolepis trochoideus (DALL), Japelion adelphicus DALL, Cavolina trispinosa LESSON, and Coronula diadema (LINNAEUS).

Brissopsis makiyamai MORISHITA, 1957

(Pl. 26, figs. 4-5)

Brissopsis makiyamai Morishita, 1957, p. 161, pl. 1, figs. 1-5.—Morishita, 1960, p. 65.—Nisiyama, 1965, p. 81.

Brissopsis luzonica: TOKUNAGA, 1903, p. 23 (non GRAY, 1851)?

Locality and geological horizon.—IGPS loc. no.—Mi-76.—Road-side cutting near a pond, about 300 metres south of Kami-Nobiru, Ono-mura, Monô-gun, Miyagi Prefecture (tm Matsushima, Lat. 38°22′48″N., Long. 141°09′28″E.). Ajiri (Nobiru) formation, Miocene. Hypotype.—IGPS coll. cat. no. 73801.

Locality and geological horizon.—IGPS loc. no.—Mi-78.—Road-side cutting about 500 metres west of Kagitori electric railroad station, Akiu-mura, Natori-gun, Miyagi Prefecture (tm Sendai, Lat. 38°13′02″N., Long. 140°50′06″E.). Hatatate formation, Miocene. Hypotype.—IGPS coll. cat. no. 73802.

Locality and geological horizon.—IGPS loc. no.—Iw-36.—Cliff of the River Mabechi at Yuda, Kintaichi-mura, Ninohe-gun, Iwate Prefecture (tm Ichinohe, Lat. 40°19'N., Long. 141°19'05"E.). Shiratori (Yuda) formation, Miocene. Hypotype.—National Science Museum, foss. coll. cat. no. 4241.

Locality and geological horizon.—IGPS loc. no.—Sm-12.—Lake cliff below Jyakusan, north of Fujina, Tamayu-machi, Yatsuka-gun, Shimane Prefecture (tm Matsue, Lat. 35°26'N., Long. 133°02'02"E.). Fujina formation, Miocene. Hypotype.—GIMS coll. cat. no. 3218.

MORISHITA (1957) reported this species from the following localities and geological horizons.—

 Ôdose-mura, Nishi-Tsugaru-gun, Aomori Prefecture. Miogypsina-Operculina Zone-Holotype.—No. JC750008.

- 2. Kuraha, Minami-Kanda-mura, Nishi-Tonami-gun, Toyama Prefecture. Asagaya mudstone, Miocene. Paratype.—No. JC750009.
- Koyama, Susa-machi, Abu-gun, Yamaguchi Prefecture. Susa formation, Miocene. Paratype.—No. JC750010.
- 4. Inari-machi, Tanabe City, Wakayama Prefecture. Tanabe group, Miocene. Paratype.—No. JC750011.

There are several specimens referred to this species at the writer's disposal. The supplementary description is as follows.

Test attains rather large size as nearly as 60 mm in longitudinal diameter of test, elongate ovoid in marginal outline, but broader than *Br. luzonica*, frontal notch moderate, not so deep but distinct; slightly notched in margin of antero-lateral ambulacra (II and IV); posterior end truncate, concave in the periproctal region, and the periproct not visible from above; the greatest breadth at middle of test, from which the test narrows gently towards both anterior and posterior ends; test low and the highest point near posterior margin in posterior interambulacrum (5). Oral side nearly flat; peristomial region rather suddenly depressed orally, and sternum not forming a prominent keel.

Frontal ambulacrum (III) rather broad (about 6 mm wide in the specimen of 60 mm test-length and about 5 mm wide in the smaller specimen of 48 mm test-length) and in shallow groove; ambulacral plates rather high, about 1.5 mm high and 3 mm wide at middle part of the ambulacrum, and numbering 24 on each column in the larger specimens; pores small and round; a pair of pores separated by an indistinct peduncular granule, and the pores placed obliquely to transverse suture and a short distance (about 1 mm in the larger specimen) from adradial suture; pore-pairs in regular series on each side; in middle part of the ambulacrum each plate carries 2 secondary tubercles inside the peduncular granule closing and parallel to it, and a few (2 to 4) miliaries inside the secondaries; this feature more or less resembles that of *Br. bengalensis*.

Antero-lateral petals (II and IV) rather short, reaching about halfway or a little more radius of the ambulacra, 17.5 mm long and 5.5 mm wide in the larger specimen; posterior poriferous zones slightly broader than the anterior ones and having about 22 pore-pairs; anterior poriferous zones having about 18 pore-pairs, the pores of 4 or 5 proximal plates rudimentary; the petals rising and curve outwards near middle part; plate outside the peripetalous fasciole having from 4 to 6 small tubercles. Postero-lateral petals (I and V) rather long, about 16 mm long and 5 mm wide, almost straight or slightly curving outwards distally, angle between median line of petal (I) and that of petal (V) being about 20° or a little more; outer poriferous zones rather well developed and having about 20 pore-pairs, while the inner poriferous ones slightly narrower than the outer ones and having about 21 pore-pairs, the pores of 5 or 6 proximal plates rudimentary.

Apical system subcentral in position or slightly eccentric anteriorly, small as usual in the genus; distance between the right postero-lateral genital (1) and left one (4) being about 1.5 mm in the larger specimen, but the madreporite prolonged posteriorly in 3 mm length.

Peripetalous fasciole distinct and very sinuous, it crosses the groove of frontal ambulacrum (III) at some distance, on 18th plate from apical system in the larger

fasciole having from 5 or 6 small tubercles (apart from minute miliary tubercles observable only on a high magnification) as in *Br. oldhami* ALCOCK, 1893 (ALCOCK, 1893, p. 174, pl. 8, figs. 7-8.—KOEHLER, 1914, p. 218, pl. 14, figs. 1-3, 8-9, 15, pl. 15, fig. 12, pl. 20, figs. 28-43) and *Br. micropetala* MORTENSEN, 1948 (MORTENSEN, 1948-b, p. 124), and the antero-lateral ambulacra (II and IV) outside the petals very narrow and alike those of *Br. luzonica* and *Br. similis* MORTENSEN, 1948 (MORTENSEN, 1948-b, p. 123), but differ from those species by the number of tubercles on each plate. Postero-lateral petals (I and V) near together proximally but curving outwards distally, short and sunken, about 5 mm long and 1.8 mm wide; anterior poriferous zones broader than the posterior ones and having 12 pore-pairs, the posterior poriferous zones narrow and having 7 pore-pairs.

Apical system as in *Br. luzonica*, but the madreporite relatively large, 1.5 mm long and 0.6 mm wide. Peristome situated at 7 mm from anterior margin of frontal ambulacrum, small, about 3 mm wide and 2 mm long. Labrum small, reaches posteriorly beyond first adjoining ambulacral plates. Peripetalous fasciole in preserved part as in *luzonica*; that is distinct and more or less bending inwards between the petals. Tuberculation on both surfaces rather large and numerous, e.g., second plate in 3b having about 30 primary tubercles.

This subspecies closely resembles *Br. luzonica lunozica*, a Recent subspecies from Luzon, the Philippines, and extending as north as Latitude 35 degrees North in Japan, in outline of test, form of petals, and in the form of peripetalous fasciole, but is distinguished from that subspecies by the narrower and deeper frontal ambulacrum (III), smaller petaloid area, and by the tuberculation on the plates outside the petals of the antero-lateral ambulacra and on interambulacral areas of both oral and aboral surfaces. Tuberculation on the plates outside the antero-lateral petals of this subspecies resembles *Br. oldhami*, a Recent species from the Malay region, and *Br. micropetala*, a Recent species from the Philippines, but is distinguished from those two species by the form of test and in the deeper and shorter frontal ambulacrum (III). The differences between this subspecies and the typical *luzonica* seem to fall into a limit of specific rank. *Br. luzonica* may be regarded as not so variable species as hitherto considered, and is distincly discriminated from allied species, viz., *Br. oldhami, bengalensis*, and *similis*, in the specific characters.

Associated fauna.—A large number of fossils is reported from the Koshiba formation, however, the writer only enumerates the names of some important species herein: Mollusca (ОТИКА, 1937, pp. 1020-1022)—Brachytoma cosibense (YOKOYAMA), Clavatula nivalioides (YOKOYAMA), Mitra cosibensis OTUKA, Turritella nipponica YOKO-YAMA, Epitonium densicostatum YOKOYAMA, Lima quantoensis YOKOYAMA, Chlamys cosibensis (YOKOYAMA), Pecten tokunagai YOKOYAMA; Brachiopoda (HATAI, 1954, pp. 102-131)—Kurakithyris quantoensis HATAI, Kurakithyris nipponensis (YOKOYAMA), and Terebratulina peculiaris HATAI.

Brissopsis japonica NISIYAMA, n. sp.

(Pl. 25, fig. 7, Pl. 26, figs. 8-9)

Holotype.--IGPS coll. cat. no. 73774.

S. NISIYAMA

Locality and geological horizon.—IGPS loc. no.—Ch-72.—Rail-road cutting near north entrance of tunnel about 1 kilometres north of Ôkubo railway station, Shiratorimura, Ichihara-gun, Chiba Prefecture (tm Ôtaki, Lat. 35°17′18″N., Long. 140°08′36″E.). Kokumoto formation, Pliocene. Holotype.—IGPS coll. cat. no. 73774.

Locality and geological horizon.—IGPS loc. no.—Ch-73.—Road-side cutting at Takura, Tamaki-mura, Kimitsu-gun, Chiba Prefecture (tm Futtsu, Lat. 35°14′06″N., Long. 139°57′28″E.). Kokumoto formation, Pliocene. Paratype.—IGPS coll. cat. no. 73775.

There are two specimens referred to this new species at the writer's disposal, each of the two is an internal mould and the paratype is deformed in posterior half of the aboral surface.

Test small, oval, posterior end truncated, frontal notch moderate; the greatest breadth at just anterior to apical system, from which the test narrow gently towards both anterior and posterior ends; test low, the highest point probably some distance from the posterior end and behind the line of postero-lateral petals (I and V), from which the test slopes very gradually towards the posterior end, but posterior end truncate vertically so the periproct is not visible from above. Dimensions of holotype: about 40 mm in longitudinal diameter of test, about 35 mm in transverse one, and about 13 mm in height.

Petaloid area small, smaller than that of *Br. luzonica*. Frontal ambulacrum (III) in a shallow groove, 19 mm long from apical system to anterior margin of test and 2.5 mm wide; ambulacral plates rather high, composed of about 20 plates on each side on aboral surface; pores small, pores of a pair separated by a very indistinct peduncular granule, arranged in regular series on each side.

Antero-lateral petals (II and IV) short and wide, about 10 mm long and 4 mm wide, both petals rising and slightly outcurved near distal ends; outer poriferous zones narrow, about 1 mm wide near middle of the petals, with 12 pore-pairs, while the inner poriferous zones broader than the outer ones, about 1.5 mm wide near middle of the petals, with 19 pore-pairs; outside from the petal to ambitus there are 4 plates in each column and each plate carries 2 or 3 small tubercles. Postero-lateral petals (I and V) not so near together proximally but somewhat diverge and more or less curving outwards distally, short and sunken, about 9 mm long and 3.5 mm wide; outer poriferous zones broader than the inner poriferous ones, about 1.5 mm wide near middle of the petals and having 16 pore-pairs; inner poriferous zones narrow, about 1 mm wide near distal ends, with 9 pore-pairs.

Apical system situated central, as in that of *Br. luzonica*, but the madreporite relatively large, 2 mm long and 1 mm wide. Peristome (in paratype) rather large and relatively eccentric in front than that of *Br. luzonica*. Labrum very small, reaches posteriorly not beyond first adjoining ambulacral plates. From apical system to ambitus, there are 5 or 6 plates in each column on the postero-lateral interambulacra (1 and 4). Tuberculation rather close, on fourth plate from apical system in 4a there are over 135 small primary tubercles. Fascioles are not preserved on the specimens.

This new species resembles *Br. oldhami* (MORTENSEN, 1951, p. 409, pl. 31, fig. 10, pl. 58, figs. 1-3, 5-20, text-fig. 198a) in the outline of test and the form of petals, but is distinguished from that species by the lower test and by the shorter and narrower frontal ambulacrum (III). *Br. japonica* also related to *Br. bengalensis* (MORTENSEN,
Brissopsis species

(Pl. 26, figs. 6-7)

Locality and geological horizon.—South of Rôdô, Kirun-gun, Taihoku-shû, Formosa. Karisan formation (Slate formation), Eocene. Hypotype.—IGPS coll. cat. no. 73878.

This unnamed species is represented in our collection by two distorted specimens of rather large size; one is comparatively well preserved but compressed more or less antero-posteriorly, and the other badly deformed. Owing to the deformation the real form of the test is not exactly recognizable, but as in the illustrations (Pl. 26, figs. 6-7) given in natural size, it may not be difficult to judge from them what the specimen is like, both in size and shape. The estimated measurements of the specimens are as follows: about 54 mm in longitudinal diameter of test, about 48 mm in transverse one, and about 25 mm in height.

Test of rather large-size, oval in marginal outline, posterior end more or less truncated, frontal notch rather wide; the greatest breadth seems to be on the line at just anterior to apical system, and the highest point on median line of posterior interambulacrum (5), posterior end truncate nearly vertically so the periproct not visible from above.

Frontal ambulacrum (III) broad, about 7 mm wide at the broadest point, to which the ambulacrum is gradually broadening from proximal part and from there the ambulacrum more or less narrowing towards frontal margin, and about 24 mm long from apical system to anterior margin, in a more or less deep groove; ambulacral plates rather high, about 2 mm high and 3 mm wide at middle part of the ambulacrum; there are about 20 or 21 plates on each side on aboral surface; pores seem more apart from adradial suture than in Br. luzonica. Antero-lateral petals (II and IV) narrow and rather long, about 17 mm long and 4 mm wide at the broadest point, nearly half of test-radius, in rather deep grooves, distal ends rounded; they first diverge from each other at a nearly right angle and then curve outwardly at about middle part, and distal parts of them thus become great divergence with convex side anteriorly; posterior pore-series with having about 24 pore-pairs and seem to remain complete the whole length, but the anterior pore-series, more or less narrower than the posterior ones, with having about 18 or 19 pore-pairs and the proximal 5 or 6 rudimentary; the pores comparatively small and closer set than in the living species; there are 4 plates to each column outside the petals, but number of tubercles not discernible. Postero-lateral petals (I and V) narrow and rather short, shorter than the antero-laterals, about 14 mm long and 3.5 mm wide at the broadest point, less than half of test-radius, in rather deep grooves; they more or less merged proximally and the only one-third the distal part diverging as in the living Br. luzonica; outer series of poriferous zones, which have about 20 pore-pairs, seem to remain almost complete for the whole length, but the inner pore-series have about 13 or 14 pore-pairs of which the proximal 6 or 7 are rudimentary probably owing to confluency of the petals; the pores are small and rather closely set with each other.

Apical system is subcentral or slightly eccentric in front, about 27 mm from anterior margin, small, the madreporite prolonged posteriorly for about 3 mm long. Peristome large, more or less compressed laterally, semilunular in outline, about 12 mm wide and 3 mm high in the compressed part, situated at about 15 mm or a little more from anterior margin; its position is more eccentric posteriorly than that of Br. makiyamai and as nearly as the position of Br. luzonica. Labrum short, but broad, about 6 mm wide and 5 mm long, and not reach beyond first adjoining ambulacral plates; it is distinctly broader than that of Br. japonica and much alike in form that of Br. makiyamai. Sternum narrow, nearly flat; second interambulacral plate on each side narrow and long, broadening posteriorly and narrowing anteriorly, about 25 mm long and 8 mm wide at the broadest point; third interambulacral plate on each side more or less narrowing towards posterior extremity on oral surface, but not suddenly narrowed as in the living luzonica. Antero-lateral ambulacra (II and IV) on oral surface narrow and the phyllode rather poorly developed with 2 large pores to each column. Postero-lateral ambulacra (I and V) on oral surface also narrow as in Br. japonica and Br. makiyamai, distinctly narrower than those of the living species; there are 7 plates in a column, each plate usually longer than wide. Periproct situated at summit of posterior truncated surface, more or less distorted, probably subcircular in shape.

Tuberculation is partly preserved on only the antero-lateral interambulacra (2 and 3) on oral surface; the tubercles are very small and sparsely distributed. Peripetalous and subanal fascioles, unfortunately, are not preserved on the specimen.

The specimen at the writer's disposal, in its general features, more or less resembles Verbeekia dubia FRITSCH, 1877 (FRITSCH, 1877, p. 140, pl. 11, figs. 4a-b), from the Eocene of Borneo, but is distinguished from that species by having a distinct frontal notch and by great divergency of the antero-lateral petals (II and IV). Ver. dubia is somewhat problematical one in the echinological taxonomy, as LAMBERT and THIÉRY (1924, p. 490) suppressed the genus Verbeekia as a subgenus of Brissopsis in differing of the lacking of a frontal notch, the narrower plastron and of the difference of tubercles. In the form of paired petals Ver. dubia is similar to some species of Brissopsis in the appearance of X-type that is made by combination of the petals. MORTENSEN (1951, p. 148, text-figs. 77a-b) referred Ver. dubia to a loveniid as incertae sedis. The proximal part of anterior pore-series of the antero-lateral petals is so degenerated that it offers a possibility of existence of an internal fasciole, which characterizes the Loveniidae, but a similar degeneration of pore-series also occurs in the species of Brissopsis. The primary tubercles of aboral side in Ver. dubia are not so conspicuous and areoles of them not so deeply sunken as to form internal ampullae. This feature contradictory to the Loveniidae. However, the paired petals of Ver. dubia are not broadening proximally and not pointed distally as in the genera of the Loveniidae. It is doubtful whether Verbeekia really belongs to the Loveniidae or to the Brissidae, although the frontal ambulacrum (III) flushes with the test that more or less resembles the member of the Loveniidae.

That the specimen at the writer's disposal, in spite of unrecognizability of a peripetalous and a subanal fasciole, from the features of the frontal ambulacrum (III), the apical system, the form of the paired petals, the peristome, the labrum, and the postero-lateral ambulacra (I and V) on the oral surface, can be safely referred to the genus *Brissopsis*, not to *Verbeekia*. In the form of the postero-lateral petals, which more or less proximally merged and only one-third the distal part diverging, the

specimen, above ambitus with a nearly straight line of some length, from end of this line it bends at nearly right angle and runs nearly parallel to the side of frontal ambulacrum to middle part of the ambulacrum, again turns with convex curve and crosses posterior column of antero-lateral interambulacra (2 and 3) to distal ends of antero-lateral petals (II and IV), passes there with convex curve to some distance, then bends at large angle and runs nearly parallel to the petals (II and IV) on each side to middle of them, crosses postero-lateral interambulacra (1 and 4) with slightly concave curve and turns to approach distal ends of postero-lateral petals (I and V), passes there with rounded curve and lastly passes into posterior interambulacrum (5) with nearly straight line; this character of the fasciole in posterior interambulacrum (5) more or less differs from that of Br. luzonica (in this species it curves slightly inwards or forwards), and Br. oldhami and Br. bengalensis (in both species it curves outwards or backwards). It is regrettable that the nature of subanal fasciole is not definitely discernible and that the presence or absence of anal branches is not ascertained, but the presence of three large pores (for penicillate tube-feet) to each side within the subanal fasciole, as in Br. oldhami, is observable.

Peristome rather large, semilunular in outline, about 10 mm wide and 2.5 mm high in the specimen of 48 mm test-length, situated at about 8 mm from anterior margin and more eccentric anteriorly than that of Br. luzonica and Br. japonica. Labrum short, but broad, distinctly broader than that of Br. luzonica, Br. japonica and Br. bengalensis, more or less well labiated, 6 mm wide and 5 mm high in the specimen of 48 mm test-length, but reaches not beyond first adjoining ambulacral plates. Sternum rather narrow, nearly flat, but the central part more or less convex and the median line more or less raised; second interambulacral plate on each side narrow and very high, about 25 mm high and 8 mm wide at the broadest point in the specimen of 48 mm test-length; third interambulacral plate on each side broad and low, about 8 mm wide and 5.5 mm high; fourth interambulacral plate on each side more or less narrowing towards posterior extremity on oral surface. Antero-lateral ambulacra (II and IV) on oral surface narrow and the phyllode rather poorly developed. Postero-lateral ambulacra (I and V) on oral surface also narrow as in Br. japonica, distinctly narrower than those of Br. oldhami, Br. luzonica and bengalensis; there are 7 plates in each column, each plate longer than wide, the longest (4th plate of Ia and Vb) measures about 9 mm long and 3.5 mm wide at the broadest point in the specimen of 48 mm test-length.

Tuberculation of aboral surface seems to be rather coarse, on 4th plate from apical system in 4a there are about 100 or slightly less small primary tubercles; tubercles on interambulacra within the peripetalous fasciole comparatively conspicuous, particularly along the edge of frontal ambulacrum and paired petals.

The identification of all the specimens derived from the Miocene series of Japan and the specimens at the writer's disposal to this species meets some difficulty. Because of the fact that the specific characters of this species are not sufficiently deduceable, particularly the feature of a subanal and a peripetalous fasciole and the tuberculation on the plate outside the antero-lateral petals (II and IV), from the typespecimen in due to not good state of its preservation, and it is hardly possible to reach full certainty in the identification of the specimens at the writer's disposal. So far as, however, can be judged from the form of petals and outline of test, and other characters of test, from the description and illustrations of original author, the writer has identified the specimens with *Br. makiyamai*.

Br. makiyamai is distinguished from the living Br. luzonica by the broader test, the tuberculation on the frontal ambulacrum (III), i.e., in this species 2 secondary tubercles placed inside an indistinct peduncular granule closing and parallel to it and a few (2 to 4) miliaries also inside the secondaries, while in that species the miliary tubercles are so very minute and numerous that they are only visible by high magnification, the form of the postero-lateral petals, which are almost straight and not confluent proximally, the position of peristome that is much nearer to the anterior margin, the number of tubercles (2-4) on plate outside the antero-lateral petals, it contrasts a single tubercle of *luzonica*, the course of peripetalous fasciole in the posterior interambulacrum, and by the number (3) of large pores to each side within the subanal fasciole. In the tuberculation on the frontal ambulacrum and in the form of the postero-lateral petals this species more or less resembles the living Br. bengalensis, but is distinguished from that species in the smaller petaloid area, more or less smaller number of tubercles on a plate outside the antero-lateral petals, the more eccentricity of the peristome, the course of the peripetalous fasciole in the posterior interambulacrum, the narrower postero-lateral ambulacra on the oral surface, and in the number of large pores to each side within the subanal fasciole. In the number (2-4) of tubercles on a plate outside the antero-lateral petals and in the number (3) of large pores to each side within the subanal fasciole this species coincides with the living Br. oldhami, but differs from that species in the larger and smaller number of miliary tubercles on the frontal ambulacrum, the course of the peripetalous fasciole in the posterior interambulacrum, and the narrower postero-lateral ambulacra on the oral surface.

In the characters of the paired petals and the postero-lateral ambulacra on the oral surface this species closely resembles *Br. japonica*. But, it is very regrettable that, in *Br. japonica*, the feature of a peripetalous and a subanal fasciole, the number of tubercles on a plate outside the antero-lateral petals, and the number of large pores to each side within the subanal fasciole are not discernible. This species, however, differs from that species in the higher test, the more eccentricity of the peristome, the shorter and broader labrum, the longer sternum (plastron), the narrower and longer ambulacral plates in the postero-lateral areas (I and V) on the oral surface. It seems evident that this species in its specific characters nearly related to the Japanese Pliocene *Br. japonica* than to the Indo-West Pacific living species of the genus *Brissopsis*, viz., *Br. luzonica*, oldhami, micropetala, and obliqua.

Until a new adequate material is available for study, this Miocene species may be conveniently termed as *Br. makiyamai* at present, and it seems to guide a certain horizon, as stated by MORISHITA (1957, p. 162), from the *Miogypsina* to *Desmostylus* the middle Miocene, in the Japanese Islands. specimen is similar to the living *Br. luzonica*, but is readily distinguished from that species in the broader frontal ambulacrum, the arrangement of the frontal ambulacral pores, the narrower and more deeply sunken paired petals, the less rising and more divergent antero-lateral petals, the shorter and broader labrum, and the narrower postero-lateral ambulacra on the oral surface. In the narrower postero-lateral ambulacra on the oral surface the specimen resembles *Br. makiyamai* and *Br. japonica*, but differs from those species in the narrower and more deeply sunken paired petals, the form of the postero-lateral petals that more or less merged proximally and the more divergent antero-lateral petals.

In conclusion the specimen is characterized by having a broad frontal ambulacrum (III), the narrow and deeply sunken paired petals, the great divergency of the anterolateral petals (II and IV), the proximally merged postero-lateral petals, the broad and short labrum, and the narrow postero-lateral ambulacra on the oral surface. It is quite probable that we have here a new species of the genus *Brissopsis* from the Eocene of Formosa, but in view of the deficient condition of the specimen at hand the writer prefers not to name it.

This unnamed species occurs, though comparatively rare, in association with *Aplospatangus taiwanicus* (HAYASAKA, 1948) from the Slate formation of northern Formosa.

Genus Eupatagus AGASSIZ, 1847

- Eupatagus Agassiz in Agassiz and Desor, 1847, p. 9.—Forbes, 1852-a, p. 26.—D'Archiac and Haime, 1853-54 (53), p. 217.—Gray, 1855-a, p. 49.—Desor, 1855-58 (58), p. 413.—A. Agassiz, 1872-74, pp. 128, 572.—Zittel, 1879, p. 545.—Pomel, 1883, p. 28.—Duncan, 1889-a, p. 253.—Meissner, 1904, p. 1397.—H. L. Clark, 1917, pp. 199, 226.—Jackson, 1922, p. 88.—H. L. Clark, 1925, p. 223.—Grant and Hertlein, 1938, p. 134.—Cooke, 1942, p. 53.—H. L. Clark, 1946, p. 376.—Mortensen, 1951, p. 456 (complete synonymy).—Kier, 1957, p. 896.—Cooke, 1959, p. 88.
 - Logotype.—Eupatagus valenciennesii AGASSIZ in AGASSIZ and DESOR, 1847, p. 9.—A. AGASSIZ, 1872-74, pp. 128, 572, pl. 15a, figs. 3-4 (southeastern Australia).—MORTENSEN, 1951, p. 466, pl. 27, figs. 1-3, 6-7, pl. 60, figs. 20-22, 24, 27, text-figs. 236-237, 239, 241-242a (southeastern Australia, in 10-65 metres depth). [POMEL, 1883, p. 28].
- Euspatangus Agassiz: Cotteau, 1869-b, p. 257.—Loriol, 1875, p. 127.—Duncan and Sladen, 1884, p. 235.—Cotteau, 1885-89 (85), pp. 17, 44.

Type-species.—Eupatagus valenciennesii AGASSIZ in AGASSIZ and DESOR, 1847, p. 9. Pseudopatagus POMEL, 1887, p. 18.

Haplotype.—Spatangus (Pseudopatagus) cruciatus POMEL, 1887, p. 18.—COTTEAU, 1889-94(93), p. 642, pl. 355, figs. 2-7, pl. 356, fig. 1 (Oligocene of Algeria).

Heterospatangus Fourtau, 1905-a, p. 606.—LAMBERT and THIÉRY, 1924, p. 454.

Haplotype.—Macropneustes lefebveri LORIOL, 1880, p. 131, pl. 9, figs. 7-9 (Eocene of Egypt). Melitia FOURTAU, 1913-a, p. 68.

Haplotype.—Melitia meltiensis GREGORY, 1892-c, p. 621, pl. 2, figs. 5a-c (Eocene of Malta).
Brissoides [KLEIN]: LAMBERT, 1902, p. 48 (CUVIER, 1817, p. 19; non Brissoides KLEIN, 1734, p. 36—pre-Linnean).—LAMBERT and THIÉRY, 1924, p. 450.—SANCHEZ ROIG, 1926, p. 101.— CHECCHIA-RISPOLI, 1944, p. 103.

Tautotype.—Spatangus brissoides LESKE, 1778, p. 251 (LAMBERT identified this species with Brissoides cranium KLEIN, 1734, p. 36, pl. 27, fig. B).—Spatangus veronensis AGASSIZ, 1840-a, p. 2.—Peripneustes veronensis (AGASSIZ) DAMES, 1877, p. 77, pl. 10, fig. 4a (non 4b), pl. 11, fig. 1 (moule M21) (Eocene of Verona) (non Spatangus brissoides DESMOULINS, 1835-37 (37), p. 392.—*Macropneustes brissoides* ([LESKE]) COTTEAU, 1885-89 (86), p. 148, pls. 36-38).

Forms of small to moderate size; test of ovoid outline, usually low arched; sides rounded; oral side usually flat, not sunken towards the peristome. Frontal ambulacrum (III) narrow, not depressed, there being merely a faint notch at anterior edge of test or none. Paired ambulacra petaloid adapically, petals short and well formed, not sunken, closed distally, terminated by the peripetalous fasciole, postero-lateral petals (I and V) generally wide near their rounded tips at the middle. Apical system anterior, ethmolytic, with four genital pores; peristome rather large, lip not prominent; periproct on vertical posterior end. A well developed peripetalous fasciole circumscribes the petals, not bending between the petals; subanal fasciole more or less distinctly shield-shaped; no anal fasciole. Large aboral tubercles only within the peripetalous fasciole; primary tubercles of oral side elegantly shaped, with large, simple scrobicules. Adorally tube-feet do not form conspicuous phyllodes; labrum posteriorly prolonged; sternum well tuberculated. Pedicellariae of the rostrate, tridentate, ophicephalous types; globiferous pedicellariae questionable, ophicephalous ones may be present. Sphaeridia in open grooves (mainly after MORTENSEN, 1951). From the Eocene to Recent.

The troublesome confusions have arisen regarding this genus and the genus Macropneustes AGASSIZ, 1847 (AGASSIZ in AGASSIZ and DESOR, 1847, p. 8) and the name Brissoides. The type-species (logotype) of Macropneustes is Micraster deshayesi AGASSIZ, 1840 (AGASSIZ, 1840-a, p. 2.—COTTEAU, 1885-89 (86), p. 141, pls. 31-33—Lutetian of France), by the subsequent designation of DUNCAN (1889-a, p. 254). But it becomes now evident that the specimen for Mic. deshayesi used by AGASSIZ was worn and useless; for good one showed a subanal besides the peripetalous fasciole. In the meantime COTTEAU (1875, p. 88 (38)) had established *Peripneustes*, which is very alike Macropneustes, with a subanal fasciole. LAMBERT and THIERY (1924, p. 494) united Peripneustes with Schizobrissus POMEL, 1869. The genera Macropneustes and Schizopneustes (with Peripeneustes) are characterized by having both a peripetalous and a subanal fasciole and are evidently the member of the Brissidae. The two genera have a deep and conspicuous frontal notch on the test and anal branches of the subanal fasciole, and in these characters the two genera are easily distinguished from the genus Eupatagus. The peripetalous fasciole of Macropheustes is not bending inwards between the petals, while that of Schizobrissus is bending inwards between the petals.

LAMBERT (1902, p. 48, and later) rejected the name *Eupatagus* hitherto universally used, introducing alternatively the name *Brissoides* KLEIN (1735, p. 36—pre-Linnean), of which *Eupatagus* is declared a synonym, and it is followed by some paleontologists. But, as MORTENSEN (1951, p. 464) has pointed out, KLEIN's type of *Brissoides cranium* was so poorly preserved as to prohibit generic identification. By seeing of all discussions on the use of the name *Brissoides* it seems to the writer that there is no sound proof that the generic name *Brissoides* antecedates the name *Eupatagus*, and the writer prefers the name *Eupatagus* for this group of the echinoids as diagnosed above. KIER (1957, p. 896) stated on this respect, as—" the substitution of an almost unknown name for an old and well known name, whether systematically correct or not, is a very questionable procedure. Apparently no official action has been taken on this question as it was not discussed at the International Congress of Zoology in Paris in 1948."

The genus Gymnopatagus DÖDERLEIN, 1901 (1901, p. 22. — Type-species.—Gym. valdiviae DÖDERLEIN, 1901, p. 23; 1906, p. 266, pl. 19, fig. 7) relates to this genus, but is distinguished by having a deep and conspicuous frontal notch on the test. This genus is very similar to the genus Migliorinia CHECCHIA-RISPOLI, 1942 (1942, p. 305.—Typespecies.—Mig. migiurtina CHECCHIA-RISPOLI, 1942, p. 305, pl. 1, figs. 1-10, text-figs. 1-3), but is distinguished from that genus by having the broader interporiferous zones in the petals and large primary tubercles within the area circumscribed by the peripetalous fasciole.

The genus *Eupatagus* dates back to the Eocene and once supposed to be single species is still living in the Australian region. A considerable number of the living species are recently recorded from the Indo-Pacific Oceans, besides the type-species, viz., *Eu. lymani* (LRMBERT snd THIÉRY, 1924)—Hawaiian Islands, *Eu. micropetalus* (H. L. CLARK, 1917)—Sagami Sea, Japan, *Eu. obscurus* (A. AGASSIZ and H. L. CLARK, 1907)—Hawaiian Islands, and *Eu. rubellus* MORTENSEN, 1948—the Philippines, but *Eu. dyscritus* H. L. CLARK, 1938, recorded from Victoria, Australia may not belong to this genus. The West Indian fossil species of *Eupatagus* (JACKSON, 1922, p. 96) are very different from the typical ones of the Australian region, and may refer to another genus. The number of fossil species of this genus is fairly numerous, about over 50 and seem to be confined to the Indo-Pacific regions as in the living species and the circum-Mediterranean countries.

There are fossil representatives of this genus in our collection.

Eupatagus marianensis NISIYAMA, n. sp.

(Pl. 27, figs. 7-8, 10-11)

Holotype.—IGPS coll. cat. no. 73739.

Locality and geological horizon.—Hill behind Forestry Industry, Saipan Island, Mariana (Ladrone) Islands, Micronesia, South Sea Islands. *Nephrolepidina*-horizon, Miocene. Holotype and paratype.

There are two specimens referred to this new species at the writer's disposal, range from 30 mm to 33 mm in longitudinal diameter of test.

Test elongate, rather egg-shaped in marginal outline, not flattened on oral surface; the highest point lies on median line of carinated posterior interambulacrum (5); not raised before the apical system; mere indication of a frontal depression anteriorly and somewhat truncated posteriorly; lower anteriorly than posteriorly. Dimensions of holotype: 33 mm in longitudinal diameter of test, 25 mm in transverse one, which is slightly contracted by lateral pressure, and 15 mm in height.

Petals, excepting for the frontal ambulacrum (III), tend to close at their tips, moderately broad, rather long, and terminated by the peripetalous fasciole. Posterolateral petals (I and V) longer than the antero-lateral petals (II and IV). Frontal ambulacrum (III) very narrow, almost flush with the test, with only mere indication of a depression at the margin; ambulacral plates rather high and closely tuberculated with small miliaries, and the pores very minute, there are about 14 or 15 pores on each side from apical system to peripetalous fasciole; series of minute pores gradually broadened toward the ambitus.

Antero-lateral petals (II and IV) rather broad, 11 mm long and 3 mm wide at middle; anterior series of poriferous zones with 15 pore-pairs, proximal 4-5 quite rudimentary; posterior series of poriferous zones with 18 pore-pairs and proximal 2-3 rudimentary; pores of a pair round or ovoidal-shape, far apart each other, and in a groove; interporiferous zones rather broad and closely tuberculated with miliary tubercles. Postero-lateral petals (I and V) long and broad, 13 mm long and 4 mm wide at middle of the petals; anterior series of poriferous zones with 20 or 21 pore-pairs; posterior series of poriferous zones with 18 pore-pairs, proximal 2-3 rudimentary; pores of a pair as in those of the antero-lateral petals, ridge between pore-pairs with 2 or 3 small tubercles; interporiferous zones rather broad and closely tuberculated with miliary tuberculated with miliary tubercles.

Apical system eccentric in front, situated at about 14 mm from anterior margin, small and much longer than wide, with four genital pores, ethmolytic, and the mad-reporte prolonged posteriorly.

Peristome small, somewhat depressed orally and situated at 8 mm from anterior margin, nearly circular in shape, about 3 mm in diameter; labrum not form a prominent lip anteriorly and much prolonged posteriorly, to end of second adjoining ambulacral plates, 6.5 mm long and 2.2 mm wide. Phyllodes rudimentary, but with first and second adperistomial ambulacral plates with large pores (for penicillate tube-feet). Postero-lateral ambulacra (I and V) on oral surface free from large tubercles, but the postero-lateral interambulacra (1 and 4) on oral surface closely tuberculated with large primary tubercles, which are elegantly shaped with large scrobicules. Sternum small and densely covered with small tubercles.

Peripetalous fasciole distinct, elliptical in outline, and well circumscribing the petals and large aboral primary tubercles, not bending inwards between the petals. Subanal fasciole large, distinct and broad, near 1 mm in the widest point, measures 11 mm in width and 8mm in height, with somewhat anterior angle and straight posterior band, suboval in outline and angular above, higher than broad; no anal branches.

There are about 12 large aboral primary tubercles in each postero-lateral interambulacrum (1) or (4), and about 9 on each antero-lateral interambulacrum (2) or (3), inclosed by the peripetalous fasciole, but no large tubercles on posterior interambulacrum (5); the large tubercles placed rather regularly in 2 or 3 rows.

Distinction.—This new species resembles Eu. pulchellus (HERKLOTS, 1854) (Spatangus pulchellus HERKLOTS, 1854, p. 12, pl. 4, fig. 7.—Maretia? pulchella (HERKLOTS) GERTH, 1922, p. 512, pl. 62, fig. 9.—Eu. (Brissoides) pulchellus (HERKLOTS): JEANNET and MARTIN, 1937, p. 273, text-figs. 50a-b), a Miocene species from Java, but is distinguished from that species by the narrower test and smaller sternum. This species is also similar to Eu. affinis (HERKLOTS, 1854) (Spatangus affinis HERKLOTS, 1854, p. 12, pl. 2, fig. 5 (pars).—Eu. martini GERTH, 1922, p. 511, pl. 62, figs. 1-1a.—Eu. affinis (HERKLOTS) JEANNET and MARTIN, 1937, p. 274, text-fig. 51 (non Eu. affinis DUNCAN and SLADEN, 1883, p. 46, pl. 12, fig. 2), a Miocene species from Java, but differs from that species in the larger subanal fasciole and in the form of the peripetalous fasciole. Eu. marianensis also resembles Eu. (Spatangomorpha) rostratus D'ARCHIAC, 1853. (D'ARCHIAC in D'ARCHIAC and HAIME, 1853-54 (53), p. 218, pl. 15, figs. 3.—DUNCAN and :SLADEN, 1884, p. 240, pl. 38, figs. 15-18), from the Khirthar series (Nummulitic strata) of western Sind, India, but is distinguished from that species by the higher test, slight indication of the anterior depression and by the form of the subanal fasciole.

Eupatagus nipponicus MORISHITA, 1957

Eupatagus nipponicus Morishita, 1957, p. 163, pl. 1, figs. 7-8.—Morishita, 1960, p. 65.—Nisiyama, 1965, p. 81.

Locality and geological horizon (after MORISHITA, 1957).—Yamamoto, Hirose-mura, Nishi-Tonami-gun, Toyama Prefecture. Sunagozaka tuffaceous member, Miocene. Holotype.—JC750012.

Locality and geological horizon (after MORISHITA, 1960).—Ôdose, Fukaura-machi, Nishi-Tsugaru-gun, Aomori Prefecture. Tanosawa formation, Miocene.

Locality and geological horizon (after MORISHITA, 1960).—Fumisato, Tanabe City, Wakayama Prefecture. Tanabe group, Miocene.

It is regrettable that the features of a peripetalous and a subanal fasciole and large aboral primary tubercles of this species are not definitely discernible owing to not good condition of preservation of the type-specimen. In its general features this species, however, as pointed out by the original author, recalls *Eu. carolinensis* W. B. CLARK, 1915 (W. B. CLARK in CLARK and TWITCHELL, 1915, p. 153, pl. 71, figs. 3a-d, 4.—*Eu. (Gymnopatagus) carolinensis* CLARK : COOKE, 1959, pl. 42, figs. 4-7.—from the Eocene of North Carolina), which is referred by LAMBERT and THIERY (1924, p. 450) to their genus *Brissoides (Eupatagus* of authors), and is also identical with *Eupatagus (Brissoides)* sp. of JEANNET and MARTIN (1937, p. 275, text-fig. 52.—from the Miocene of Ngembak, Java), and seems to be referred to the genus *Eupatagus*. A feature that the test somewhat raised before the apical system is also found in the type-species (*Eu. valenciennesii*) and other species of the genus. This species is characterized by the form of paired petals, which are very narrow, long and more or less open distally, are contrasting to the generally short and well formed petals in the many species of the genus.

Genus Brissus [KLEIN] GRAY, 1825

- Brissus Klein: Gray, 1825, p. 431 (Brissus Klein, 1734, p. 29—pre-Linnean.—Leske, 1778, pp. 55, 29).—Agassiz, 1836, p. 185 (18).—Agassiz and Desor, 1847, p. 12.—Forbes, 1852-a, p. 15.—Gray, 1855-a, pp. 51, 52 (pro parte).—Desor, 1855-58 (58), p. 403.—Wright, 1864, p. 485.—A. Agassiz, 1872-74, p. 356.—Zittel, 1879, p. 541.—Carus, 1883, p. 103.—Pomel, 1883, p. 34.—Duncan, 1889-a, p. 241.—Meissner, 1904, p. 1394.—Lambert, 1907-c, p. 105.—Hoffmann, 1914, p. 262.—Lambert, 1915-b, p. 184.—H. L. Clark, 1917, p. 217.—Lambert and Thiéry, 1924, p. 496 (pro parte).—H. L. Clark, 1925, p. 218.—Mortensen, 1932-e, p. 359.—Grant and Hertlein, 1938, p. 128.—Cooke, 1942, p. 47.—Hayasaka, 1948-a, p. 109.—Mortensen, 1951, p. 505 (complete synonymy).—Cooke, 1959, p. 81.
- Tautotype.—Spatangus brissus unicolor LESKE, 1778, pp. 55, 185, pl. 26, figs. B, C.—Brissus unicolor (LESKE): A. AGASSIZ, 1872-74, pp. 357, 598, pl. 22, figs. 1-2.—Brissus brissus (LESKE): H.L. CLARK, 1917, p. 218. [Type designation validated by Opinion 209 of the International Commission on Zoological Nomenclature].

Large forms of elongate ovoid outline, without frontal depression; aboral side more or less high arched, often with posterior interambulacrum (5) raised as a keel; posterior end truncate, vertically or obliquely; oral side flattened or slightly convex; sides tumids. Frontal ambulacrum (III) flush with test, narrow; pore-pairs usually united into a narrow vertical slit, but with a more or less distinct peripodium; frontal tube-feet quite simple, not disc-like expanded. Paired ambulacra distinctly petaloid adapically, somewhat sunken; antero-lateral petals (II and IV) outwards directed, postero-lateral petals (I and V) only slightly divergent; pore-series equally developed; pores subequal, or outer poses slightly elongate, and they distinctly conjugate: ridge between consecutive pore-pairs low, with a series of small tubercles (radioles); interporiferous zones very narrow, entirely smooth or with a few small tubercles. Apical system anterior, ethmolytic, with four genital pores, posterior pair somewhat larger than the anterior; the madreporite extends posteriorly beyond the posterior oculars, widening there more or less conspicuously. Periproct on upper part of truncate posterior end of test broadly oval or more elliptical, with both ends pointed. Peristome near anterior edge of test, usually semilunular; labrum broad, but short, not very prominent, its posterior prolongation exceedingly short, not reaching middle of first adjoining ambulacral plates, and a number of small tubercles along its anterior edge; sternum large and broad, densely covered by tubercles, a fan-shaped arrangement of tubercles more or less distinct. Antero-lateral ambulacra (II and IV) strongly developed adorally, forming a conspicuous phyllode; postero-lateral ambulacra (I and V) on oral side very narrow, naked, and the 6th plate enters the subanal fasciole. Usually 4 large pores (for penicillate tube-feet) to each side within the subanal fasciole, often only 3, rarely 5. Subanal fasciole broad, with a more or less conspicuous lobe on each side towards the periproctal region, but without anal branches. Peripetalous fasciole bends inwards between the petals; in antero-lateral interambulacra (2 and 3) it usually forms two sharp angles on each side, sometimes only one. Radiole-covering, or the tuberculation, is very dense and uniform, only in antero-lateral interambulacra tubercles somewhat larger; radioles here somewhat stronger and erect, not appressed as on the rest of aboral side. Radioles of plastron somewhat spade-shaped, but not longer than the others of oral side. A series of small radioles along edge of labrum, like a mustache covering the mouth-opening. Pedicellariae of the usual five types, globiferous, tridentate, rostrate, ophicephalous, and triphyllous; tridentate and globiferous pedicellariae occur in two or three forms (mainly after MORTENSEN, 1951). From the Eocene to Recent.

LAMBERT (1907-c, p. 105) maintained *Echinospatangus ovalis* BREYNIUS, 1732 (p. 62—pre-Linnean) to be the type-species of the genus *Brissus* KLEIN, 1734. LAMBERT and THIÉRY (1924, p. 496) also designated *Spatangus columbaris* LAMARCK, 1816 (p. 30) as the type-species of this genus. This species is identical with, as stated by LAMBERT and THIÉRY, LESKE'S *Spatangus brissus unicolor* (loc. cit.), and there is no question that the older of these two names, *unicolor* (H. L. CLARK'S specific name *brissus*) is the one to be used for the species.

This genus is distinguished from the genus *Metalia* GRAY, 1855 (GRAY, 1855-a, p. 41.—Type-species.—*Spatangus sternalis* LAMARCK, 1816, p. 31), in the feature of subanal fasciole. In *Brissus* it forms two posterior lobes but having no anal fasciole, while in *Metalia* it accompanies anal fasciole. From the related genus *Trachypatagus* POMEL 1868 (POMEL, 1868, p. 302,—Type-species—*Brissus tuberculatus* WRIGHT, 1864, p. 486, pl. 22, fig. 1—Tortonian of Malta) it is distinguished by the position of apical system. Namely, in *Brissus* the apical system is anterior while in *Trachypatagus* it is subcentral.

The living species of the genus *Brissus* are common and widely spread in shallow waters, throughout the tropical and subtropical regions, and at least six species are recognized by MORTENSEN (1951, pp. 505-523), viz., *Br. unicolor* (LESKE, 1778)—western and eastern Atlantic, *Br. latecarinatus* (LESKE, 1778)—widely distributed Indo-West Pacific, *Br. gigas* BELL—North Auckland, *Br. obesus* VERRILL, 1867—West American coast, *Br. (Allobrissus) agassizii* DÖDERLEIN, 1885—Japan, and *Br. (Allobrissus) meridio-nalis* MORTENSEN, 1950—New Zealand and N. S. Wales. But MAYR (1954, p. 6) regarded that these species are all apparently allopatric, and the subgenus *Allobrissus* (MORTENSEN, 1950, p. 162; 1951, pp. 509, 520) founding on the difference in the teeth of the globiferous pedicellariae should not be recognizable.

As fossil it appears to date back to the Eocene, but it is rather richly developed in the Miocene and Pliocene epochs and including about 16 species.

There are fossil representatives of this genus in our collection.

Brissus latecarinatus (LESKE, 1778)

(Pl. 27, fig. 9, Pl. 29, figs. 1-3, Pl. 30, fig. 4)

- Spatangus brissus latecarinatus LESKE, 1778, pp. 249, pl. 48, figs. 4-5.—Brissus latecarinatus (LESKE) H. L. CLARK, 1917, p. 219, pl. 146, fig. 15.—H. L. CLARK, 1921, p. 153.—LAMBERT and THIÉRY, 1924, p. 497.—H. L. CLARK, 1925, p. 219.—BRIGHTON, 1931, p. 332.—JEANNET and MARTIN, 1937, p. 280.—GRANT and HERTLEIN, 1938, p. 129, pl. 12, figs. 3-4, pl. 13, fig. 5 (pro parte).—NISIYAMA, 1942, p. 24, text-fig. 12 (in Japanese).—H. L. CLARK, 1945, p. 324, pl. 43, figs. B-E.—H. L. CLARK, 1946, p. 375.—MORTENSEN, 1948-b, p. 139.—H. L. CLARK (MORTENSEN), 1948, p. 343, pl. 67, fig. 74, pl. 68, fig. 75.—MORTENSEN, 1951 (complete synonymy), p. 514, pl. 33, fig. 8, pl. 34, figs. 3-5, pl. 63, figs. 8-10, 22, 25-26, text-fig. 264.—MORISHITA, 1954, p. 131, pl. 15, figs. 1-6.
- Spatangus carinatus LAMARCK, 1816, p. 30.—Brissus carinatus (LAMARK) GRAY, 1825, p. 431.— AGASSIZ, 1836, p. 185 (18).—AGASSIZ and DESOR, 1847, p. 13.—GRAY, 1855-a, p. 53.—A. AGASSIZ, 1872-74, pp. 96, 596, pl. 21a, figs. 1-3, pl. 25, figs. 36-37, pl. 26, fig. 38.—LORIOL, 1883, p. 46.—HESSE, 1899, p. 259, text-fig. 5.—BEDFORD, 1900, p. 287.—MEIJERE, 1904, p. 184.—DÖDERLEIN, 1906, p. 256.—A. AGASSIZ and H. L. CLARK, 1907-a, p. 258.

Locality and geological horizon.—Kita-Daitô-jima (North Borodino Island) in the Ryukyu Islands. Ryukyu Limestone, Pleistocene. Hypotype.—IGPS coll. cat. no. 73778.

Locality and geological horizon.—A point on Angaur Island, Palao Islands, Micronesia, South Sea Islands. Older Angaur Limestone, Pleistocene. Hypotype.—IGPS coll. cat. no. 73826.

Locality and geological horizon (after HAYASAKA, 1948-a).—Takangshans, Kaohsiunghsien, Formosa (Taiwan). Ryukyu Limestone, Pleistocene.

Locality and geological horizon (after MORISHITA, 1954).—Ishigaki-jima, Ryukyu Islands. Ryukyu Limestone, Pleistocene.

There are five specimens referred to this common species at the writer's disposal, range from 52 mm to 120 mm in longitudinal diameter of test. They are not in good

state of preservation, particularly in the aboral surface, yet manifest some important features that make identify them with the named species.

A large specimen measures 84 mm in longitudinal diameter of test, 62 mm in transverse one, and over 45 mm in height; elongate oval in marginal outline, the greatest breadth lies posterior to middle of test, the highest point lies on carinate median line in posterior interambulacrum (5); oral surface more or less convex to posterior; posterior end obliquely downward truncate, and posterior interambulacrum protruding somewhat beak-like above the periproct.

Apical system eccentric in front, situated at about 25 mm from anterior margin, rather small, and the madreporite not so strongly widened posteriorly so as to remove the postero-lateral petals (I and V) from the apical system.

Aboral surface not well preserved, but frontal ambulacrum (III) seems to almost flush with test without indication of a frontal depression. Paired petals in narrow and rather deep grooves; antero-lateral petals (II and IV) long and widely divergent, about 26 mm long and 5 mm wide, angle between median line of petal (II) and that of petal (IV) being about more than 160°; postero-lateral petals (I and V) long, about 31 mm long and over 5 mm wide, almost straight but they curve slightly outwards at about one-third the distance from distal ends of the petals, angle between median line of petal (I) and that of petal (V) being less than 50°. Peristome rather large, 14 mm wide and 6 mm high, rather reniform in outline, and very eccentric anteriorly, situated at about 15 mm from anterior margin, depressed orally below level of labrum and sternum; frontal ambulacrum (III) on adperistomial region with 4 large pores on each side, and antero-lateral ambulacra (II and IV) with a series of 7 large pores on each side.

Periproct large, 13 mm high and 9 mm wide, broadly oval in outline, situated below the overhanging posterior interambulacrum (5). Sternum large and broad, about 36 mm long from the posterior margin of labrum to the subanal fasciole, closely tuberculated in the posterior part of its center it somewhat culminates in a single point and also at the subanal fasciole again culminates in a point; tubercles being largest near the margin and smallest at culminating points.

Subanal fasciole distinct and complete, the posterior band deeply pointed anteriorly below the periproct, without anal fasciole; subanal plastron distinct and obliquely downwards truncate, 5 ambulacral pores enter into its composition on each side within the subanal fasciole.

The specimens at the writer's disposal are safely referred to the living Br. *latecarinatus* (LESKE, 1778), to which the abbreviated name *carinatus* (LAMARCK, 1816) has been in constant use for a century, on the characters as described above. The aboral surface without a peripetalous fasciole in the fossil specimens of this species closely resembles superficially that of *Metalia spatangus* (LINNAEUS, 1758), but it is distinguished, fortunately, from that species by the features of the subanal fasciole and sternum. This is a common Indo-West Pacific species of the genus and its wide range extends as far as the Hawaiian Islands, from the littoral zone down to about 45 metres in bathymetrical distribution. This species dates back to the Miocene (Java) and has been known to occur as fossil in Farsan Island of Red Sea (Pliocene), Ryukyu Islands (Pleistocene), and Hawaiian Islands (Pliocene). This species shows

the diversity to a certain extent in form, appearance of petals and shape of subanal plastron that the species is well known to exhibit.

HAYASAKA'S Brissus sp. indet, α (1948-a, p. 110, pl. 2, fig. 2) may be referred to this species, as pointed out by MORISHITA (1954, p. 132), so far as judged from his description and figure. HAYASAKA (1948-a, p. 111) remarked on his specimen from Formosa that—" Perhaps Brissus latecarinatus LESKE may have to be taken into consideration in the study of this Pleistocene Brissus of Taiwan. NISIYAMA briefly describes it in his preliminary report (NISIYAMA, 1942, p. 23, text-fig. 12) on the Recent echinoids of the Micronesian waters. In not having anterior sulcus and having a raised posterior interambulacrum the two forms coincide, but the lateral sides in Brissus latecarinatus are not parallel as in the present specimen : moreover, the posterior petals appear rather converging in the former instead of diverging in the latter." The differences in the form and in the postero-lateral petals (I and V) of his specimen between NISIYAMA'S Recent specimen may have to be regarded, as stated above, as the specific variation of Br. latecarinatus.

MORISHITA (1954, p. 132, pl. 15, figs. 5-6) reported an occurrence of this species from the Ryukyu Limestone (Pleistocene) of Ishigaki-jima, Ryukyu Islands. Although he did not separate *Br. agassizii* DÖDERLEIN, 1885, from *Br. latecarinatus*, his specimen, which is not deformed but the peripetalous and subanal fasciole are obscure, can be referred to *Br. latecarinatus* in the characters of high test, well carinate and protruding posteriorly the posterior interambulacrum (5), and of broadly oval periproct.

The Japanese species, which is united into a single species by H. L. CLARK (1917, p. 218; 1925, p. 218) under the name *latecarinatus*, but is separated by DÖDERLEIN (1885, p. 108.—YOSHIWARA (TOKUNAGA), 1906, pl. 18, figs. 1-6) and by MORTENSEN (1951, p. 520, pl. 33, fig. 7, pl. 34, fig. 2, pl. 35, figs. 1, 6-8, pl. 62, figs. 9-10, 12, 16-21, 23-28) as *Br. agassizii*, must be regarded as a distinct species or even a distinct subgenus *Allobrissus*, because the features of the globiferous pedicellariae are distinct, the posterior interambulacrum (5) is not at all overhanging, unlike obliquely downwards truncate end of *latecarinatus*, and the periproct is not visible from below.

Genus Metalia GRAY, 1855

- Metalia GRAY, 1855-a, p. 51.—VERRILL, 1867-71 (67), p. 318.—A. AGASSIZ, 1872-74, pp. 144, 597.—Bell, 1879, p. 254.—Pomel, 1883, p. 33.—Duncan and Sladen, 1884, p. 206.—Duncan, 1889-a, p. 206.—Meissner, 1904, p. 1397.—Lambert, 1907-c, p. 106.—H. L. Clark, 1917, p. 209.—Lambert and Thiéry, 1924, p. 495 (partim).—H. L. Clark, 1925, p. 214.—Grant and Hertlein, 1938, p. 127.—Mortensen, 1951, p. 532 (complete synonymy).
- Haplotype.—Spatangus sternalis LAMARCK, 1816, p. 31 (Habite l'Ocean austral).—Metalia sternalis (LAMARCK): A. AGASSIZ, 1872-74, pp. 145, 600, pl. 21a, figs. 4-5, pl. 21c, figs. 5-9, pl. 32, figs. 11-12, pl. 37, fig. 20 (Tropical and warm temperate Pacific Ocean).

- Haplotype.—Xanthobrissus garreti A. AGASS1Z, 1863, p. 28 (Kingsmills Islands).=Spatangus sternalis LAMARCK, 1816, p. 31.
- Prometalia POMEL, 1883, p. 34.—LAMBERT and THIÉRY, 1924, p. 496.

Haplotype.—Brissus robillardi LORIOL, 1876-a, p. 665, pl. 2, fig. 1 (Mauritius).—Metalia robillardi (LORIOL) MORTENSEN, 1951, p. 538, pl. 31, fig. 13, pl. 38, figs. 1-2, 4-6, pl. 64, figs. 7, 15 (Mauritius and Madagascar).

Xanthobrissus A. AGASSIZ, 1863, p. 28.

Eobrissus BELL, 1904, p. 236.

Haplotype.—Eobrissus townsendi BELL, 1904, p. 236.—Metalia townsendi (BELL) MORTENSEN, 1951, p. 545, pl. 38, figs. 3, 11 (Gulf of Oman and the Persian Gulf).

Metaliopsis FOURTAU, 1913-a, p. 68.

Haplotype.—Metalia maculosa (GMELIN) A. AGASSIZ, 1872-74, pp. 144, 598, pl. 21b, figs. 8-9, pl. 38, fig. 29 (Pacific Ocean).—Echinus maculosus GMELIN, 1788-93 (91), p. 3199.—Echinus spatangus LINNAEUS, 1758, p. 665.

Large forms of ovid or heart-shaped, with or without frontal depression; frontal ambulacrum (III) rather conspicuously depressed or almost flush with test. Apical system more or less anterior or subcentral, ethmolytic, with four genital pores; anterior end of test fall almost vertically downwards or simply rounded anteriorly. Paired ambulacra distinctly petaloid adapically, somewhat sunken; postero-lateral petals (I and V) generally not coalescing adapically, rarely coalescing adapically. Phyllodes conspicuous as in the genus *Brissus*; labrum broad and very short as in *Brissus*; no large tubercles within the peripetalous fasciole. Subanal fasciole very narrow, with an adoral median point and no posterior lobes, the subanal plastron thus being shield-shaped; from adproctal side of the fasciole proceeds a branch upwards on each side of the periproctal area, the anal fasciole; many pores (tube-feet) enclosed by the fasciole, up to 11, and conspicuous radiating lines separate the included ambulacral plates. All the five usual types of pedicellariae, however, the globiferous known with certainty only in one species (mainly after MORTENSEN, 1951). From the Eocene to Recent.

As for the genera Prometalia, in which Metaliopsis is exactly included by LAM-BERT and THIERY (1924, p. 496), and Eobrissus, it seems almost hopeless to try to separate them from *Metalia*. Prometalia was erected on the basis of the difference in form of the postero-lateral petals (I and V), which are not coalescing adapically, while in the type-species, Met. sternalis, they are coalescing adapically, and Eobrissus on the subcentral position of the apical system. From these differences, however, it seems better to put them as distinct species in the genus Metalia. But difficulty lies between this genus and the perplexing and ill-defined genus Macropneustes (loc. cit.); both genera agree in the form of peripetalous fasciole, in the form of petals in some species, and in the tuberculation within the peripetalous fasciole, but differ from each other in the frontal depression of the test and in the anal fasciole, which is in Metalia distinctly present on each side of the periproctal area, but in Macropneustes it is doubtful whether it is present or not, and in the type-species, Mac. deshayesi, of that genus it is said to lacking. Metalia is also distinguished from the genus Rhinobrissus A. AGASSIZ, 1872 (A. AGASSIL, 1872, p. 58 (Rhynobrissus).—Type-species.—Rh. pyramidalis A. AGASsiz, 1872, p. 58; 1872-74, pp. 154, 590, pl. 23a, figs. 4-6-China Sea), in the subanal plastron, which in Metalia is not projecting, while in Rhinobrissus the plastron is more or less distinctly projecting downwards or backwards.

The living species of the genus Metalia are common and widely spread in shallow water, from littoral zone down to ca. 130 metres, throughout the tropical and subtropical regions, and at least seven species are recognized by MORTENSEN, viz., Met. sternalis (LAMARCK, 1816)—Indo-West Pacific, Met. robillardi (LORIOL, 1876)—Mauritius and Madagascar, Met. spatangus (LINNAEUS, 1758)—Indo-West Pacific, Met. nobilis VERRILL, 1867—Lower California, Met. townsendi (BELL, 1904)—Gulf of Oman and the Persian Gulf, Met. dicrana H. L. CLARK, 1917—South Sea, and Met. latissima H. L. CLARK, 1925—India. As fossil it appears to date back as far as the Eocene, but it is rather richly developed in the Miocene and Pliocene epochs, and including about 18 species.

There are fossil representatives of this genus in our collection.

Metalia pelagica NISIYAMA, n. sp.

(Pl. 27, figs. 1-5, Pl. 29, fig. 4)

Holotype.—IGPS coll. cat. no. 73735.

Locatity and geological horizon.—In a doliné on Denshin-yama, Saipan Island, Mariana (Ladrone) Islands, Micronesia, South Sea Islands. Donney formation (*Spiroclypeus*-horizon), Miocene. Holotype and paratype.

There are only two specimens referred to this new species at the writer's disposal, range from 22 mm to 24.5 mm in longitudinal diameter of test.

Test small, elongate oval in ambital outline, rounded anteriorly, the greatest breadth slightly anterior to center, aboral surface raised, the highest point lies somewhat eccentric in front just behind apical system, median area in posterior interambulacrum (5) more or less carinate; anterior slope of test down to ambital margin more sharply than the posterior slope, posterior slope gradually down to the posterior end, which has a slightly outwardly inclined posterior truncation; adoral surface more or less convex to the axis of III-5 line of test, especially the sternum, with a distinct median carina.

Dimensions of holotype: 24.5 mm in longitudinal diameter of test, 18 mm in transverse one, and 13 mm in height; test narrow, breadth about three-fourths of test-length, and rather high, the height over half of test-length.

Petals, excepting the frontal ambulacrum (III), tend to close their tips and terminated by the peripetalous fasciole, slightly depressed, moderately broad, and rather long; postero-lateral petals (I and V) longer than the antero-lateral ones (II and IV). Frontal ambulacrum (III) very narrow, about 1.5 mm wide at a midway between apical system and anterior margin, and almost flush with the test, no indication of a frontal depression at the margin; ambulacral plates rather high and closely tuberculated with miliary tubercles on median area, 2 or 3 tubercles in a row; the pores small, arranged as in the Recent *Met. spatangus* in a single series on each side; there are 20 or 21 pores in each side from apical system to peripetalous fasciole; series of small pores, excepting for the proximal 4 or 5, run subparallel to each other.

Antero-lateral petals (II and IV) rather broad and rather long, 8 mm long and 3 mm wide at the middle; anterior series of poriferous zones with 15 pore-pairs, the proximal 3 or 4 quite rudimentary; posterior series of poriferous zones with 16 porepairs, the proximal 2 or 3 rudimentary; the petals greatly divergent each other, angle between median line of petal (II) and that of petal (IV) being about 140°; pores of a pair round or ovoid-shape, far apart from each other and in a shallow groove; on each consecutive ridge between pore-pairs there is a series of 5-6 small tubercles; interporiferous zones rather broad, about 1 mm at the middle, ornamented with secondary and miliary tubercles. Postero-lateral petals (I and V) long and broad, 9 mm long and 3.5 mm wide at the middle; anterior series of poriferous zones with 17 or 18 porepairs, the proximal 2 or 3 rudimentary; posterior series of poriferous zones with 16 or 17 pore-pairs, the proximal 3 or 4 quite rudimentary; a pair of pores slightly more elongate and wider apart than those of the antero-lateral ones; there is a series of 5-6 small tubercles on each consecutive ridge between pore-pairs; interporiferous zones rather broad, about 1 mm wide at the middle, provided with secondary and miliary tubercles; the petals divergent a little, angle between median line of petal (I) and that of petal (V) being about 50°.

Apical system eccentric in front, situated at about 8 mm from anterior margin, small, with four large genital pores, and the madreporite prolonged posteriorly.

Peristome small, slightly depressed orally and situated at 8 mm from anterior margin, just as in the apical system, semilunular in outline, 2.5 mm wide and 2 mm high; labrum broad but short, not forming a short lip anteriorly. Phyllodes rather rudimentary, with 3 or 4 large pores (for penicillate tube-feet) on each series. Posterolateral ambulacra (I and V) on oral surface narrow and seem to be free from large primary tubercles, but other areas, except around the peristomial region, on oral surface provided with large tubercles. Sternum long and rather matrow, closely covered with tubercles posteriorly, and with a single median point where it meets with the subanal fasciole.

Peripetalous fasciole well-marked, oval in outline, well circumscribing the paired petals, and going down in antero-lateral interambulacra (2 and 3) to the level a short distance above ambitus, and at least in the frontal ambulacrum (III) down to almost the ambitus, not bending inwards between the petal (I) and petal (V). Subanal fasciole small, but distinct and broad, wide heart-shaped in outline, 1 mm wide at the broadest point of the fasciole, measures 8 mm in breadth and 6.5 mm in length, and with an anterior angle which meets with a median point of sternum; anal fasciole branches rising from the subanal fasciole, and one on each side of periproctal area, runs up nearly the level with top of periproct. Interambulacral areas on aboral surface covered sparsely with small primary tubercles, which are not sunken scrobicules, within and without the peripetalous fasciole, and the posterior interambulacrum (5) carrying small primary tubercles the whole way up to apical system as in *Met. spatangus*.

Periproct rather large, close to upper edge of nearly vertical posterior end of the test, suboval in outline, angular above, higher than wide, 2 mm wide and 3 mm high.

Distinction.—In this species the frontal ambulacrum (III) flush with the test as in the living *Met. spatangus* and *Met. townsendi*, and a marked distinction from *Met. sternalis*, in which it is conspicuously deepened. The postero-lateral petals (I and V) of this species are not coalescing adapically as in *Met. spatangus*, but the proximal posterior series of the petals are rudimentary as in *Met. sternalis*, in contradistinction to remain complete the whole length of the petals as in *Met. spatangus*. This new species, in its general features, resembles *Met. spatangus*, a Recent species of the Indo-West Pacific Oceans, but is distinguished from that species by the smaller, narrower and lower test, the form of peripetalous fasciole and by the form of sternum. *Met. pelagica* is also related to *Met. dicrana* H. L. CLARK, 1917 (H. L. CLARK, 1917, p. 211, pl. 146, fig. 16, pl. 160, figs. 1-4.—MORTENSEN, 1951, p. 546, pl. 37, figs. 1-3, pl. 64, figs. 6, 12), a Recent species of the tropical Pacific Ocean, but differs in the smaller and narrower test, and in the position of the apical system.

Metalia spatangus (LINNAEUS, 1758)

(Pl. 27, fig. 6, Pl. 28, figs. 7-8)

- Metalia spatangus (LINNAEUS) LOVÉN, 1887, p. 162.—MEIJERE, 1904, p. 184.—H.L. CLARK, 1917, p. 210.—, Prometalia spatangus (LINNAEUS): LAMBERT and THIÉRY, 1924, p. 496.— Metalia spatangus (LINNAEUS): H.L. CLARK, 1923, p. 402.—H.L. CLARK, 1925, p. 216.— H.L. CLARK, 1932, p. 219.—GRANT and HERTLEIN, 1938, p. 127, pl. 8, figs. 4–5.—NISIYAMA, 1942, p. 23, text-fig, 11 (in Japanese).—H.L. CLARK, 1946, p. 372.—MORTENSEN, 1948-b, p. 139.—MORTENSEN, 1951, p. 540 (complete synonymy), pl. 38, figs. 7–9, pl. 39, figs. 1–2, 4, pl. 64, figs. 1, 5, 9–10, 25, text-fig. 271a.—UTINOMI, 1954, p. 357.
- Metalia maculosa (GMELIN) A. AGASSIZ, 1872-74, pp. 144, 598, pl. 21b, figs. 8-9, pl. 38, fig. 29.
 —A. AGASSIZ, 1881-a, p. 199 (pro parte; one specimen from Arafura Sea is Anametalia regularis (H.L. CLARK, 1925)).—DöDERLEIN, 1885, p. 37.—FOURTAU, 1904-a, p. 431.—YOSHIWARA (TOKUNAGA), 1907, pl. 20, figs. 1-6.—A. AGASSIZ and H.L. CLARK, 1907-a, p. 258.—KOEHLER, 1914, p. 127, pl. 19, figs. 61-70.

Spotangus compressus LAMARCK, 1816, p. 30.—Brissus compressus (LAMARCK) AGASSIZ and DESOR, 1847, p. 13.—GRAY, 1855-a, p. 53.

Prometalia ventricosa (KLEIN): LAMBERT and THIÉRY, 1924, p. 496.

Locality and geological horizon.—A point on Angaur Island, Palao Islands, Micronesia, South Sea Islands. Older Angaur Limestone, Pleistocene. Hypotype.—IGPS coll. cat. no. 73788.

There is a single specimen of internal mould referred to this species at the writer's disposal. It measures about 70 mm in longitudinal diameter of the test, 60 mm in transverse one, and about 33 mm in height. Test elongate ovoid in outline; aboral side more or less highly arched; oral side nearly flat, but the sternum more or less concave adorally.

Frontal ambulacrum (III) almost flush with test, narrow, without indication of a frontal depression, about 5 mm wide at ambitus; ambulacral plates rather high, broadly hexagonal, 2 mm wide and 1.5 mm high midway between apical system and frontal margin; pores placed subcentral of the plate; there are 21 or 22 plates on each side from apical system to frontal margin. Antero-lateral petals (II and IV) rather long and broad, about 19 mm long and 5 mm wide at the middle and in shallow depressions; the petals divergent greatly, angle between median line of petal (II) and that of petal (IV) being about 140°; poriferous zones with about 23 pore-pairs on each series. Postero-lateral petals (I and V) a little longer than the antero-lateral ones, and not at all confluent adapically, nearly straight, about 21 mm long and 5 mm wide at the middle part and in shallow grooves, angle between median line of petal (I) and that of petal (V) being about 60°; poriferous zones with about 25 pore-pairs on each series; pore-series of the petals remain complete in whole length, not become rudimentary adapically.

Peristome rather large, about 9 mm wide and 6 mm high, semilunular in outline, situated at 16 mm from anterior margin. Labrum broad, but short, not make a prominent lip anteriorly. Phyllodes on the frontal ambulacrum (III) with 3 or 4 large pores on each side and those on the antero-lateral ambulacra (II and IV) with 5 large pores on each side, the pores forming a narrow triangle that point outwardly. Periproct large, 12 mm high and 10 mm wide, situated near upper margin of vertically truncate posterior end of test. Fascioles and tubercles are not discernible.

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This specimen can be safely referable to the living *Met. spatangus* (LINNAEUS, 1758) on the characters as described above; but in comparison with the living specimens from Palao Islands slight differences are found in the position of apical system and in the size of petals. These differences, however, seem to fall into the limits of variation within the species. The geographical distribution of this species is remarkable for its width, it occurs Red Sea, East Africa to Japan, and Hawaii and the Society Islands, in littoral zone down to about 130 metres depth.

Metalia spatangus (LINNAEUS, 1758) is distinguished from Met. sternatis (LAMARCK, 1816), the type-species of the genus and it has a nearly same geographical distribution, in the postero-lateral petals, which do not coalesce adapically in this species, while in *Met. sternalis* they are coalescing adapically. The pore-series of the posterolateral petals (I and V) of this species remain complete the whole way up, while in sternalis the posterior pore-series become rudimentary proximally. The frontal ambulacrum (III) in this species is flush with the test and there is no indication of frontal depression, a marked distinction from sternalis, in which it is conspicuously deepened. In this species there are never more than 4 tube-feet (pores) to each side within the subanal fasciole, but their number rising to 11 in sternalis. This species differs from the allied species, Met. dicrana H. L. CLARK, 1917 (loc. cit.), in the smaller height of test, smaller eccentricity of the apical system, and particularly in the form of sternum, which in this species is ending posteriorly in a single median point, while in that species it is ending posteriorly in two distinct points. Met. spatangus closely resembles Met. nobilis VERRILL, 1867 (VERRILL, 1867-71 (67), p. 319.-MORTENSEN, 1951, p. 542, pl. 37, figs. 4–8, pl. 39, fig. 5, pl. 64, figs. 2–8, 8, 11, 16, 18, 20–21, text-figs. 269b, 270, 271b) in the frontal ambulacrum (III) and vertex of test, but differs from that species in the form of sternum, which in this species is concave adorally, particularly in the adult specimens, while in that species it is convex.

V. SYNOPSIS OF THE RECENT ECHINOIDEA OF JAPAN AND THE ADJACENT REGIONS

In the preceding chapters the writer describes and revises the fossil echinoids, although not completely cover the whole species but nearly the almost ones, from Japan and the adjacent regions. In studying of the fossil forms, it was soon discovered that a review of nomenclature of the generic and specific taxa of the fossil forms was necessary in order to make effective comparison with the Recent Indo-Pacific echinoids and with fossil forms in other parts of the world, and to trace the former and present distribution of the genera and species. The Recent fauna of a region is a descendant of the former that comprises various forms whether they are directly derived from ancestors in the same region or modified from past migrants from the other regions. In comparison of the Recent echinoids with fossil echinoids it is more or less traceable that the change of composition of fauna in the sequence of geological ages, and, although there lies a difficulty and poverty of data, the origin of Recent fauna so far as the available data are concerned. The comparison, moreover, of fossil echinoid assemblage with the present-day assemblage is of particularly aid for the determination of the environment of deposition in the geological age.

Before the consideration of these problems, the writer gives at first a synopsis, not of full description but of characters that distinguish from one another of the species and genera or higher ranks, of the Recent Echinoidea of Japan and the adjacent regions, together with geographical and bathymetrical distribution of each species.

The Recent echinoids from Japan and the adjacent regions, (—the large part of the northwestern Pacific Ocean comprising the marine waters of Japan Proper, both sides of Sakhalin, Coasts of the Kurile Islands, Asiatic Coast of Sea of Japan, Yellow Sea, East China Sea, Coasts of the Ryukyu Islands, Coasts of the Formosa Island and the south, a part of South China Sea, and the Bonin Islands)—the area in bounding from the Longitude about 115° East to 160° and from the Latitude about 20° North to 60°—, is called attention by many echinologists.

Since the publication of BRANDT (1835) on the Recent echinoids of the Bonin Islands, many authors dealt with the Recent fauna from said area on the materials collected and brought by surveying-ship and collectors. Descriptive works are rather numerous, and of the important authors the following are to be mentioned : A. AGASSIZ (1863-a, 1872-74, 1881-a, 1098), A. AGASSIZ and H. L. CLARK (1907-b, 1908, 1909), BELL (1888, 1894), CHANG (1932, 1948), H. L. CLARK (1907, 1908, 1912-b, 1914, 1917, 1923-c, 1925), DJAKONOV (1930, 1938), DÖDERLEIN (1885, 1887, 1888, 1903, 1906-a), DURHAM (1955), HAYASAKA (1948), IVES (1891), VON MARTENS (1865, 1865-a, 1866, 1867), MORI-SHITA (1954, 1955, 1963), MORTENSEN (1903-b, 1904, 1904-a, 1907, 1927, 1927-a, 1928, 1927-b, 1929, 1930-a, 1932-b, 1934-b, 1935, 1940, 1943, 1943-a, 1948-a, 1948-b, 1948-c, 1950-a, 1951), NISIYAMA (formerly AOKI) (1933, 1937, 1939, 1940, 1942, 1942-a, 1961), OHSHIMA (1933, 1934), ROXAS (1928), SLADEN (1879), TOKIOKA (1953), UTINOMI (1949, 1952, 1954, 1960, 1962), and YOSHIWARA (lately TOKUNAGA) (1897, 1898, 1898-a, 1900, 1904, 1905, 1906-a, 1907, 1908). Other records on the Recent echinoids from the said area are scattered in various works in the main dealing with the embryological, physiological or ecologial subjects, and are, naturally, not all of them quite reliable taxonomically.

Available literature and materials in the collections of the Institute of Geology and Paleontology, Tohoku University, Sendai, the National Science Museum, Tokyo, the Seto Marine Biological Laboratory, Kyoto University, Wakayama Prefecture, the Museum of Comparative Zoology at Harvard University, Cambridge, and of other Institutes show a large number of species and genera have been known and reported from Japan and the adjacent regions, as many over as some 170 species. The number of species is nearly equal or a little larger than that of the West Coasts of North, Central and South Americas (GRANT and HERTLEIN, 1938; H. L. CLARK, 1948, and others), the East Pacific Ocean, in ranging from the Latitude 60° North through the equator to the Latitude 60° South, nevertheless the area of Japan and the adjacent region is about one-third the West Coasts of North, Central and South Americas in size and the fauna seems to be less surveyed than that of the latter area.

As for the systematic arrangement of the Recent Echinoidea of Japan and the adjacent regions, during the preparation of this article the writer received important papers on major classification of the echinological systematics (DURHAM and MELVILLE, 1957; PHILIP, 1965), the writer herewith adopts in part of their classificatory scheme in the following.

Order LEPIDOCENTROIDA MORTENSEN, 1934

Lepidocentroida Mortensen, 1934, p. 162.—Mortensen, 1935, pp. 26, 42.—Philip, 1965, p. 56.—Nisiyama, 1966, p. 30.

Type-family.-Lepidocentridae Lovén, 1874.

Echinocystitoida JACKSON, 1912, pp. 203, 282 (pro parte).—Durham and Melville, 1957, p. 249 (partim).—Kier, 1965, p. 446.—Nisiyama, 1966, p. 30.

Type-family.-Echinocystitidae GREGORY, 1897.

Test of various shape; 20 or more columns of plates; coronal plates always imbricate, ambulacral plates adorally, interambulacral plates adapically and over the ambulacrals along the adradial suture; pore-pairs uniserial or pluriserial; ambulacra continuing over the peristome; peristome with only the ambulacral series of plates, no series of interradial plates; primordial ambulacral and interambulacral plates in basicoronal row; perignathic girdle absent, or of simple auricles; primary radioles usually not very large, without a cortex layer; tubercles perforate, generally noncrenulate; lantern of masticatory apparatus inclined; teeth grooved; foramen magnum large, epiphyses very narrow; sphaeridia present; peristomial gills present or absent.

Suborder ECHINOTHURIOINA CLAUS, 1880

Echinothurideae CLAUS, 1880, p. 355.—Echinothurioida CLAUS: DURHAM and MELVILLE, 1957, p. 253, (order).—Echinothuriina CLAUS: PHILIP, 1965, p. 56.—Echinothurioina CLAUS:

NISIYAMA, 1966, p. 31. Type-family.—Echinothuriidae Thomson, 1872.

Two columns of plates in interambulacra; auricles usually well developed, forming a closed arch over each ambulacrum, but no apophyses; gill-slits usually present; lantern usually more or less erect; teeth grooved; foramen magnum large, open, epiphyses very narrow; pits in pyramids under epiphyses; axis of primary radioles hollow; Stewart's organs present.

Family ECHINOTHURIIDAE THOMSON, 1872

Echinothuridae THOMSON, 1872, p. 492.—THOMSON, 1874, p. 730.—DUNCAN, 1889-a, p. 42.— Echinothuriidae THOMSON: A. AGASSIZ and H.L. CLARK, 1909, p. 135.—MORTENSEN, 1935, pp. 42, 80.

Type-genus.—Echinothuria WOODWARD, 1863.

Test low, flattened, flexible; generally large forms; ambulacral plates compound; pore-pairs uniserial to pluriserial; apical system in adult more or less dissolved; gills usually present, but small, in some forms absent; pedicellariae richly developed, in several sorts; Stewart's organs present, sausage-shaped; no C-form (bihamate) spicules. From the Jurassic Period to Recent.

Subfamily Phormosomatinae Mortensen, 1934

Phormosominae Mortensen, 1934, p. 162.—Mortensen, 1935, p. 123. Type-genus.—Phormosoma Thomson, 1872.

Echinothuriids with ambulacra trigeminate, not polyporous, and the primary radioles of the oral side club-shaped, clad in a thick bag of skin, not capped with a hoof; all tubercles non-crenulate; teeth sharp and pointed; stalk of pedicellariae simple.

Genus Phormosoma THOMSON, 1872

Phormosoma THOMSON, 1872, p. 492.—MORTENSEN, 1935, p. 123. Haplotype.—Phormosoma placenta THOMSON, 1872, p. 494.—MORTENSEN, 1935, p. 125, pl. 1, figs. 1-5, pl. 2, figs. 1-19, pl. 74, figs. 1-6, 19, text-figs. 80-82.

Primary radioles on adoral surface straight, club-shaped; adoral tube-feet in a single more or less irregular series, each primary ambulacral plate normally accompanied by two secondary components; each aboral and adoral surface strikingly and abruptly unlike, usually a distinct marginal fringe; areoles on adoral surface very large and deep, giving the test a honey-comb appearance; usually no hoofs on adoral radioles; only tridentate and triphyllous pedicellariae present.

Phormosoma bursarium A. AGASSIZ, 1881 (C-P)

Phormosoma bursarium A. Agassiz, 1881-a, p. 99, pl. 10b.—Yoshiwara (Tokunaga), 1905, pl. 4, figs. 4-5.—Mortensen, 1935, p. 135, pl. 2, fig. 20, pl. 3, figs. 1-2, pl. 74, figs. 11-15, text-figs. 83-85.

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Primary tubercles of ambulacra, aborally, not conspicuously smaller than those of interambulacra; primary radioles of aboral side curved; usually smooth, or at least never verticillate; arcs of pores oblique aborally; aboral primary tubercles large, and not confined to peripheral half of test.

From the Japanese Seas (central and southwestern Japan) to the Philippines and the Indian Ocean.

170-2340 metres in depth.

Subfamily ECHINOTHURIINAE THOMSON, 1872

Asthenosominae Mortensen, 1934, p. 162.-Mortensen, 1935, pp. 122, 163.

Echinothuriids with ambulacra trigeminate and the primary radioles of the oral side terminating a hoof, not skin-clad; all tubercles non-crenulate; teeth rather broad, not sharp and pointed; stalk of pedicellariae simple.

Genus Tromikosoma MORTENSEN, 1903

Tromikosoma Mortensen, 1903-b, pp. 62, 64.—Mortensen, 1935, p. 164.

Haplotype.—Tromikosoma koehleri Mortensen, 1903-b, p. 78, pl. 11, figs. 2, 13, pl. 12, figs. 22, 31, 41, pl. 14, figs. 12, 16, 19, 21, 23, 25, 28, 30.—Mortensen, 1935, p. 167, pl. 5, text-fig. 100.

Aboral primary radioles curved, with a large hoofs; aboral and adoral surfaces not abruptly and markedly different; areoles moderate in size; pores on oral side arranged, in each side of the area, in a single, more or less regular series close to the border; on the aboral side the outer secondary ambulacral plate is very broad, reaching to the edge of the area, only the inner secondary plate included; three kinds of pedicellariae, ophicephalous, tridentate, and triphyllous ones present; tridentate pedicellariae with valves non-involute; gills absent or very rudimentary; spicules irregularly lattice-form, scattered.

Tromikosoma tenue (A. AGASSIZ, 1879)

Phormosoma tenue A. AGASSIZ, 1879, p. 202.—A. AGASSIZ, 1881-a, p. 91, pls. 13-14.—YOSHIWARA (TOKUNAGA), 1905, pl. 3, figs. 3-3 (reproduced from A. AGASSIZ, 1881).—*Tromikosoma tenue* (A. AGASSIZ): MORTENSEN, 1935, p. 171, pl. 6, fig. 1, pl. 7, figs. 1-5, pl. 75, figs. 8-17, text-figs. 102-105.

Size large, attains 200 mm or more in test-length; tube-feet aborally in one or two series; inner secondary ambulacral plate on a great part of the aboral side very broad, reaching the median line of the area; aboral surface sparsely covered with radioles (tubercles); aboral coronal plates rather numerous; valves of tridentate pedicellariae not involute at all.

Known only from off central Japan.

1530-3375 metres in depth.

Genus Sperosoma KOEHLER, 1897

Sperosoma Koehler, 1897, p. 304 (306).—A. Agassiz and H.L. Clark, 1909, p. 195.—Mortensen, 1935, p. 182.

Haplotype.-Sperosoma grimaldii KOEHLER, 1897, p. 304 (306).-KOEHLER, 1898, p. 16, pl. 2, fig. 2, pl. 13, figs. 3-4, pl. 4, fig. 8, pl. 9, fig. 48.

Adoral primary radioles curved with a large white hoofs; areoles very large; both adoral and aboral surfaces strikingly and abruptly different; pores on oral side arranged in three series in each side of the area; secondary ambulacral plates of oral side large, the primary ambulacral plate divided into an outer, poriferous and inner, non-poriferous plate; the ambulacra of the oral side thus consist of eight distinct series of plates, the two median non-poriferous; spicules large, lattice-shaped; only tridentate and triphyllous pedicellariae present.

Sperosoma quincunciale MEIJERE, 1904

Sperosoma quincunciale MEIJERE, 1904, p. 40, pl. 13, figs. 166-167.—MORTENSEN, 1935, p. 189, pl. 76, figs. 7-12, text-figs. 111-112.

Aboral tube-feet numerous in three unequal series, a more or less distinct quincuncial arrangement being evident; poriferous zones often quite broad; adoral primary radioles rather more than 150; aboral ambulacral plates not twice as numerous as the adorals.

From the Japanese Seas (central and western Japan) to the Malay region. 715-919 metres in depth.

Sperosoma giganteum A. AGASSIZ and H. L. CLARK, 1907

Sperosoma giganteum A. AGASSIZ and H. L. CLARK, 1907-b, p. 120.-A. AGASSIZ and H. L. CLARK, 1909, p. 197, pl. 64, figs. 9-12, pl. 65, figs. 1-3, pls. 83-86.-MORTENSEN, 1935, p. 199.

Size very large; colours of test and radioles deep-purple; aboral primary tubercles very small or wanting; ambulacra much wider than interambulacra.

Known only from the Japanese Seas (central Japan).

In 1204 metres depth.

Genus Hygrosoma MORTENSEN, 1903

Hygrosoma MORTENSEN, 1903-b, pp. 59, 64.—MORTENSEN, 1935, p. 200.

Orthotype.—Phormosoma petersii A. AGASSIZ, 1880-b, p. 76.—Hygrosoma petersii (A. AGASSIZ): MORTENSEN, 1935, p. 202, pls. 13-17, pl. 18, fig. 2, pl. 19, fig. 2, pl. 78, figs. 1, 24, 25, text-figs. 118-119.

Adoral primary radioles curved with a large white hoofs and sparsely towards the ambitus; areoles large; each aboral and adoral surface strikingly and abruptly different; adoral tube-feet rather regular in a series; on the aboral side both secondary ambulacral plates small, included, none of them reaching the edge of the area; only tridentate and triphyllous pedicellariae present; tridentate pedicellariae with valves strongly involute; gills well developed; spicules large, lattice-shaped.

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Hygrosoma hoplacantha (THOMSON, 1877)

Phormosoma hoplacantha THOMSON, 1877-78 (77), p. 148, text-fig. 35.—A. AGASSIZ, 1881-a, pls..
11-12, 12a, figs. 10-13, pl. 39, fig. 37, pl. 40, figs. 37-38, pl. 44, figs. 28-31.—Hygrosoma hoplacantha (THOMSON) MORTENSEN, 1903-b, pp. 59, 64.—Phormosoma hoplacantha THOMSON: YOSHIWARA (TOKUNAGA), 1905, pl. 4, fig. 6 (reproduced from A. AGASSIZ, 1881).—
Hygrosoma hoplacantha (THOMSON): MORTENSEN, 1935, p. 208, pl. 18, fig. 1, pl. 19, fig. 1, pl. 20, figs. 1-2, pl. 78, fig. 2, text-figs. 120-121.

Aboral tube-feet in three series; aboral ambulacral plates only two or three times as numerous as the adorals; aboral radioles small and numerous; valves of large tridentate pedicellariae strongly involute at the middle.

From the Japanese Seas (central Japan) to the Philippines and South Pacific. 306-2068 metres in depth.

Genus Calveriosoma MORTENSEN, 1934

- Calveria THOMSON, 1872, p. 617 (non Calveria CARPENTER, JEFFREYS, and THOMSON, 1870,. an asterid).
- Calveriosoma Mortensen, 1934, p. 163 (pro Calveria Thomson, 1872).— Mortensen, 1935, p. 220.

Logotype.—Calveria hystrix THOMSON, 1872, p. 617.—Calveriosoma hystrix (THOMSON) MOR-TENSEN, 1935, p. 222, pl. 23, figs. 1-5, pl. 24, fig. 1, pl. 78, fig. 12, text-figs. 126-128. [MOR-TENSEN, 1903-b, p. 50].

Radioles of oral side not invested in thick skin-bags, only the secondaries with the point invested by a small poison-gland; each aboral and adoral surface slightly unlike; areoles small, primary radioles (tubercles) make very distinctly rows along the outer margin of interambulacral area on adoral surface, especially near to the ambitus; adoral tube-feet in a close three series; only tridentate and triphyllous pedicellariae present; stalk irregularly perforated; dactylous pedicellariae absent; the wide and terminal part of the strongly involute tridentate pedicellariae irregularly serrate; membrane interstices between the coronal plates small and inconspicuous, mainly confined to the oral side of test; spicules in the outer part of tube-feet large, in lower part small, longitudinally arranged, lattice-shaped.

Calveriosoma gracile (A. AGASSIZ, 1881)

Asthenosoma gracile A. AGASSIZ, 1881-a, p. 89, pl. 17a, figs. 1-4.—Calveria gracilis (A. AGAS-SIZ) MORTENSEN, 1903-b, p. 51.—Araeosoma gracile (A. AGASSIZ) A. AGASSIZ and H.L. CLARK, 1909, p. 191, pl. 81, figs. 3-4, pl. 82, figs. 5-8.—Calveriosoma gracile (A. AGASSIZ) MORTENSEN, 1935, p. 227, pls. 25-28, pl. 78, figs. 13-14, text-fig. 129.

Asthenosoma longispinum Yoshiwara, 1897, p. 5, pl. 2, figs. 1-7.—Yoshiwara (Tokunaga),. 1905, pl. 3, figs. 8-9.

Asthenosoma pyrochloa A. AGASSIZ and H.L. CLARK, 1907-b, p. 118.—A. AGASSIZ and H.L. CLARK, 1909, p. 186, pl. 66, figs. 1-4, pls. 78-80.

Test rather small to moderate; colour dull to bright vermilion; membranous interstices (leathery interspace) between coronal plates small; aboral ambulacral plates much more numerous than the adoral ambulacrals; peristome less than one-fifth of test-diameter; the most adoral interambulacral plates with two or more primaries; ambulacra moderately broad; valves of large tridentate pedicellariae curved, with blades strongly involute except where they meet at tip.

From the Japanese Seas (central and western Japan) to Halmahera. 160-800 metres in depth.

Genus Haplosoma MORTENSEN, 1903

Haplosoma MORTENSEN, 1903-b, p. 56.—MORTENSEN, 1935, p. 270. Haplotype.—Asthenosoma pellucidum A. Agassiz, 1879, p. 200.—A. Agassiz, 1881-a, p. 85,

pl. 18, figs. 1-6, pl. 18a, figs. 14-17, pl. 19, figs. 1-6, pl. 38, fig. 6, pl. 40, figs. 39-42.

Radioles of oral side not invested in thick skin-bags and regularly arranged in a row along the outer margin of interambulacral area; areoles not very large; no marked difference between oral and aboral side of test; pores on oral side arranged in three series close to the border; secondary ambulacral plate not divided into an outer and an inner parts; the area consisting only of the two usual series of plates (not counting the small demi-plates); three kinds of pedicellariae, globiferous, tridentate, and triphyllous ones; dactylous pedicellariae with valves rudimentary; tridentate pedicellariae with simple, leaf-shaped, not indented valves; stalk irregularly perforate; feet-disc well developed; spicules staff-like.

Haplosoma gemmiferum MORTENSEN, 1934

Haplosoma gemmiferum MORTENSEN, 1934, p. 165.—MORTENSEN, 1935, p. 276, pl. 54, figs. 3-6, pl. 83, figs. 3, 11-13.

Some large tubercles outside the oblique series of the aboral side of interambulacra, generally forming a series parallel to the primary series; globiferous pedicellariae very large and numerous; colour of test light brownish.

Known only from the Japanese Seas (from Sagami Sea to Kagoshima Gulf). 185-400 metres in depth.

Genus Araeosoma MORTENSEN, 1903

Araeosoma Mortensen, 1903-b, pp. 53, 63.—A. Agassiz and H.L. Clark, 1909, p. 174.—Mortensen, 1935, p. 230.

Logotype.—Calveria fenestrata THOMSON, 1872, p. 494.—Araeosoma fenestratum (THOMSON): MORTENSEN, 1935, p. 233, pls. 29-30, pl. 78, fig. 11, text-figs. 130-132. [A. AGASSIZ and H. L. CLARK, 1909, p. 174].

Radioles of oral side not invested in thick skin-bags; no marked differences between oral and aboral side of test; areoles very small; pores on oral side arranged in three series in each side of the area; each half of an ambulacrum, adorally, consists of a column of wide low primary plates, each accompanied by two small secondaries; aboral surface with at least 30 primary tubercles; aboral primary radioles not encased in loose skin-sheaths; usually four kinds of pedicellariae, tridentate, triphyllous, globiferous, and tetradactylous ones present; dactylous pedicellariae with valves well developed; large tridentate pedicellariae with valves usually strongly involute, or at least coarsely indented; spicules large, lattice-shaped.

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Araeosoma owstoni Mortensen, 1904

Araeosoma owstoni MORTENSEN, 1904-a, p. 82, pl. 2, figs. 1-2, pl. 5, figs. 4-9, 11, 18-20.—A.
AGASSIZ and H. L. CLARK, 1909, p. 192, pl. 81, figs. 1-2, 5-6, pl. 82, figs. 1-4.—MORTENSEN, 1935, p. 261, pls. 46-48, pl. 49, fig. 1, pl. 50, fig. 1, pl. 80, fig. 11, text-figs. 142-146.

Test rather stout; colours of test and radioles dull; ambulacra only moderately wide; coronal plates with small interspaces; valves of large tridentate pedicellariae straight or nearly so, the blades not involute but in contact with for most of their length.

Known only from the Japanese Seas (from Sagami Sea to Korean Strait). 109-209 metres in depth.

Araeosoma owstoni bicolor (A. AGASSIZ and H. L. CLARK, 1907)

Asthenosoma bicolor A. AGASSIZ and H. L. CLARK, 1907-b, p. 118.—Araeosoma bicolor (A. AGASSIZ and H. L. CLARK) A. AGASSIZ and H. L. CLARK, 1909, p. 179, pl. 64, figs. 1-8, pls. 71-72.—Araeosoma owstoni var. bicolor (A. AGASSIZ and H. L. CLARK): MORTENSEN, 1935, p. 265, no figure.

Aboral primary tubercles more than 200, much smaller than those of adoral side; adoral primary tubercles not forming an uninterrupted marginal series at ambulacral edge of each half-interambulacrum; size moderate; colour yellowish and purple.

Known only from the Japanese Seas (southwestern Japan).

In 135 metres depth.

Genus Asthenosoma GRUBE, 1867

Asthenosoma GRUBE, 1867, p. 42.-MORTENSEN, 1935, p. 278.

Haplotype.—Asthenosoma varium GRUBE, 1867, p. 42.—MORTENSEN, 1935, p. 280, pls. 55-58, pl. 61, figs. 1-6, pl. 62, figs. 1-2, pl. 82, figs. 1-3, 5-6, 8-14, text-figs. 152-154.

Radioles of aboral side wholly invested in thick skin-bag; each aboral and adoral surface strikingly unlike; aboral surface covered by numerous small primary tubercles; areoles subequal in size on both surfaces; adoral tube-feet in three close series; secondary ambulacral plates of oral side small, wholly included; the primary ambulacral plate not divided into an outer and an inner parts; the area consisting only of the two usual series of plates (not counting the small demi-plates); only tridentate and triphyllous pedicellariae present; stalk irregularly perforate; spicules small, stellate-form, longitudinally arranged.

Asthenosoma ijimai YOSHIWARA, 1897

Asthenosoma ijimai Yoshiwara, 1897, p. 8, pl. 2, figs. 8-12.—Mortensen, 1904-a, p. 87, pl. 3, figs. 1-2, pl. 5, figs. 1-3, 10, 12-14.—Yoshiwara (Tokunaga), 1905, pl. 4, figs. 1-2.—Mortensen, 1935, p. 288, pls. 63-64, pl. 65, figs. 1-2, text-fig. 155.

Size moderate; columns of primary tubercles of aboral side not reach beyond the ambitus; madreporic pores extent over the adjoining periproctal plates, so that it has the appearance that the madreporite is divided into several separate plates; adoral primary radioles white and unbanded.

From the Japanese Seas (Sagami Sea, Tanabe Bay, and Amakusa) to the Malay region (Kei Islands).

20-120 metres in depth.

Order CIDAROIDA CLAUS, 1880

Cidaroida Claus, 1880, p. 355.—Philip, 1965, p. 56.—Nisiyama, 1966, pp. 30, 153. Type-family.—Cidaridae Gray, 1825.

Test regular; corona rigid or imbricating; 20 or, rarely, more columns of plates; ambulacral plates simple; peristome with both ambulacral and interradial series of plates; base of corona resorbed; primary radioles large, with a cortex layer; lantern erect; teeth grooved; foramen magnum very shallow; no pits in the top of pyramids; perignathic girdle consisting of apophyses only, or none; no speaeridia and no peristomial gills, but Stewart's organ present; pedicellariae of two main sorts only, globiferous, which occur in a large and a small form, and tridentate. From the Devonian to Recent.

Family CIDARIDAE GRAY, 1825

Cidaridae Gray, 1825, p. 426.—Mortensen, 1928-b, p. 61.—Nisiyama, 1966, p. 156. Type-genus-—Cidaris Leske, 1778.

Coronal plates with rigid sutures; pores non-conjugate or conjugate, arranged in single series; primary radioles very varied, though in the main cylindrical or club-shaped, sometimes (*Goniocidaris*) the upper ones shield-shaped; primary tubercles crenulate or non-crenulate; pedicellariae typically in three forms, large and small globiferous and tridentate, but sometimes one or the other of these forms may be lacking. From the Jurassic Period to Recent.

Subfamily HISTOCIDARINAE MORTENSEN, 1928

Histocidarina MORTENSEN, 1928-b, pp. 68, 69.

Tubercles perforate and rather strongly crenulate; pores not conjugate; areoles not very deep; primary radioles long and slender, cylindrical, smooth or thorny; oral primaries strongly serrate, curved; secondary radioles rather long, more or less flattened, erect, not scale-like; no globiferous pedicellariae, tridentate pedicellariae strongly developed; ambulacral plates of peristome each with a conspicuous distally directed prolongation on the inner side; spicules of intestinal walls very scarce and small, often wanting.

Genus Histocidaris MORTENSEN, 1903

Histocidaris Mortensen, 1903-b, p. 30.—H. L. Clark, 1925, pp. 6, 9, 37.—Mortensen, 1928-b, p. 70.

Haplotype.-Porocidaris elegans A. AGASSIZ, 1879, p. 198.

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Size large; ambulacral pores near together, more or less oblique; primary radioles long, straight, usually cylindrical, white and often shining, unless stained, with usually a short, simple collar; adoral primary radioles flat, somewhat curved, coarsely and sharply serrate; secondaries flat and not peculiar; tridentate pedicellariae very variable in size and form, three stout and wide valves.

Histocidaris elegans (A. AGASSIZ, 1879) (C- P-T)

Porocidaris elegans A. AGASSIZ, 1879, p. 198.—A. AGASSIZ, 1881-a, p. 40, pl. 3, figs. 1-2, pl. 38, figs. 12-16, pl. 44, figs. 6-14.—Histocidaris elegans (A. AGASSIZ) MORTENSEN, 1903-b, pp. 21, 30, 173.—Cidaris elegans (A. AGASSIZ) YOSHIWARA (TOKUNAGA), 1905, pl. 3, fig. 7.—Histocidaris elegans (A. AGASSIZ): MORTENSEN, 1927, p. 250, pl. 52, fig. 1, pl. 77, figs. 1-3.—MORTENSEN, 1928-b, p. 72, pl. 1, figs. 1-5, pl. 2, figs. 1-3, pl. 68, fig. 6, pl. 75, fig. 16, pl. 76, figs. 9-13.

Apical system about half of test-diameter; primary radioles rather slender, perfectly smooth, at most with some longitudinal ridges without serrations; ambital primaries downwards curved; no special depression on inner surface of valves of large pedicellariae above hypophyses; test, secondaries, and collar of primaries light reddish- or yellowish-brown.

From the Japanese Seas (southern Japan) to the Philippines and to Australia. 200-1440 metres in depth.

Histocidaris misakiensis (YOSHIWARA, 1898)

Cidaris (Porocidaris) misakiensis YOSHIWARA, 1898, p. 58.—YOSHIWARA (TOKUNAGA), 1904, pl. 2, figs. 9-10.—Histocidaris misakiensis (YOSHIWARA) MORTENSEN, 1928-b, p. 79, pl. 10, fig. 3, pl. 69, fig. 2, pl. 75, figs. 3-4, pl. 77, fig. 24.

Primary radioles rather stout, fusiform, thickest not far from the base and then taper steadily to a blunt point, longitudianly striated with about 28 series of minute sharp prickles, and white in colour; apical system less than half of test-diameter; interporiferous zone without a well-marked, deeply sunken midline; valves of large tridentate pedicellariae spoon-shaped; the whole inside concave; small radioles (tubercles) numerous on aboral half of test; secondaries white with a tinge of yellow.

Known only from the Japanese Seas (Sagami Sea).

In moderate depths.

Histocidaris carinata MORTENSEN, 1928

Histocidaris carinata MORTENSEN, 1928, p. 66.—MORTENSEN, 1928-b, p. 89, pls. 6-7, pl. 79, fig. 1, pl. 75, figs. 11-13, pl. 77, figs. 25-26.

Ambital primary radioles with scattered larger thorns in the basal part, not curved; scrobicular radioles with a median keel; valves of pedicellariae very broad, triangular, the blade concave, not filled up by coarse meshwork.

Known only from the Japanese Seas (southwestern Japan, Kyushu).

In 360 metres depth.

Subfamily CTENOCIDARINAE MORTENSEN, 1928

Ctenocidarina MORTENSEN, 1928-b, pp. 69, 108.

Oblique ambulacral pores close together, very often narrow wall is perforated so that the pores become confluent; ocular pore usually surrounded by a elevated wall; milled ring usually rather prominent, sometimes very much so; secondary radioles cylindrical or club-shaped, or scrobicular radioles more or less distinctly flattened; globiferous pedicellariae without an end-tooth; tridentate pedicellariae wanting.

Genus Aporocidaris A. AGASSIZ and H. L. CLARK, 1907

Aporocidaris A. Agassiz and H.L. Clark, 1907, p. 35.—H.L. Clark, 1925, pp. 6, 9, 36.— Mortensen, 1928-b, p. 109.

Orthotype.—Porocidaris milleri A. AGASSIZ, 1898, p. 74.—Aporocidaris milleri (A. AGASSIZ): MORTENSEN, 1928-b, p. 110, pl. 11, fig. 11, pl. 68, fig. 12, pl. 77, figs. 1-4.

Apical system about three-fourths of test-diameter; primary radioles very long and slender, oral primaries rather strongly serrate, but not much widened; pores bipartite; no sunken furrows in the ambulacra, at most an indistinctly limited, naked slightly sunken median space in the interambulacra; ambulacral plates few, seldom more than 30 in each column.

Aporocidaris fragilis A. AGASSIZ and H. L. CLARK, 1907

Aporocidaris fragilis A. Agassiz and H. L. Clark, 1907, p. 37, pl. 10, figs. 10-21, pl. 23, figs. 5-8.—Mortensen, 1928-b, p. 114, pl. 11, fig. 12, pl. 68, fig. 13, pl. 77, fig. 7.

Periproctal plates almost in a single circle; primary radioles with a fairly close coat of low simple hairs.

Known from the North Pacific; Shumagin Island, Alaska and southwest of Kamtchatka.

2800-3550 metres in depth.

Subfamily GONIOCIDARINAE MORTENSEN, 1928

Goniocidarina MORTENSEN, 1928-b, pp, 69, 144.

More or less distinct grooves or pits in the horizontal sutures between the coronal plates; tubercles non-crenulate; primary radioles with the surface covered with a close, often extremely developed, coat of fine hairs; pores non-conjugate; large globiferous pedicellariae usually globular without an end-tooth, the valves usually very short and broad; small globiferous form often develops into a large, coarse form resembling the tridentate type.

Genus Goniocidaris AGASSIZ and DESOR, 1846

Goniocidaris Agassiz and Desor, 1846, p. 337.—H. L. Clark, 1925, pp. 5, 8, 30.—Mortensen, 1928-b, pp, 149, 153.

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Orthotype.—Cidarites tubaria LAMARCK, 1816, p. 57.—Goniocidaris tubaria (LAMARCK): MACCOY, 1885, p. 33, pl. 100 (coloured).—MORTENSEN, 1928-b, p. 156, pl. 12, figs. 1-7, pl. 13, figs. 10-11, pl. 69, fig. 4, pl. 78, figs. 1-6.

Stephanocidaris A. AGASSIZ, 1863, p. 18.

Haplotype.—Goniocidaris geranioides A. AGASSIZ, 1872-74 (72), p. 131, pl. 1g, figs. 3-4 (non: LAMARCK, 1816).=Cidarites tubaria LAMARCK, 1816, p. 57.

Ambulacra wide; median interambulacral areas more or less bare and sunken, especially at angles of coronal plates; primary radioles very diverse, with either or one of basal and terminal discs usually developed; in the typical subgenus, no basal discs, terminal disc usually not much developed; size relatively large; primary radioles coarse, or at least coarsely thorny, not curved; hair coat not very strongly developed; secondaries somewhat thickened.

Subgenus Petalocidaris MORTENSEN, 1903

Petalocidaris MORTENSEN, 1903-b, pp. 25, 28.—MORTENSEN, 1928-b, pp. 149, 153. Haplotype.—Goniocidaris florigera A. AGASSIZ, 1881-a, p. 46, pl. 1, figs. 7-20.

Basal and terminal discs more or less well developed; primary radioles coarsely thorny, banded with white and pink or darker colour; hairy coat more or less well developed; secondary radioles flattened, more or less thorny at base; miliary radioles slender.

Goniocidaris (Petalocidaris) biserialis (DÖDERLEIN, 1885)

Stephanocidaris biserialis Döderlein, 1885, p. 80 (8).—Goniocidaris biserialis (Döderlein) Döderlein, 1887, pp. 10, 49, pl. 5, figs. 1-27, pl. 8, figs. 8a-h.—Cidaris (Goniocidaris) biserialis (Döderlein): Yoshiwara (Tokunaga), 1905, pl. 3, figs. 3-5.—Goniocidaris (Petalocidaris) biserialis (Döderlein): Mortensen, 1928-b, p. 173, pl. 14, figs. 12-20, pl. 69, fig. 17, pl. 78, figs. 29-30, text-fig. 56.

Test low; apical system nearly or quite equals vertical diameter; primary radioles with relatively few, long and stout, coarsely thorny, but otherwise smooth; secondary radioles not excavate, generally smooth, more rarely thorny at base; colours variable, ranging from dull brownish-yellow to yellowish, olive-green, or brownish-red.

Known only from the Japanese Seas (from Sagami Sea to Kagoshima Gulf, on the Pacific side, and Miyazu Bay, on the Japan Sea side).

80-360-rarely-500 metres in depth.

Subgenus Discocidaris DÖDERLEIN, 1885

Discocidaris Döderlein, 1885, p. 80 (genus).—H. L. CLARK, 1925, pp. 5, 8, 32 (genus).—Mor-TENSEN, 1928-b, pp. 149, 153.

Haplotype.-Discocidaris mikado Döderlein, 1885, p. 80.

Size small; test rather delicate; median ambulacral and interambulacral areas usually not bare and sunken; basal disc very strongly developed and usually repeated several times along the shaft of ambital primaries; terminal disc more or less well developed; hairy coat not anastomosing; secondary radioles flattened, sometimes thorny at base, miliary radioles in the shape of granules or slender, or conical.

Goniocidaris (Discocidaris) mikado (DÖDERLEIN, 1885)

Discocidaris mikado Döderlein, 1885, p. 80.—Goniocidaris mikado (Döderlein) Döderlein, 1887, p. 15, pl. 7, figs. 1-6, pl. 8, figs. 6a-f.—Cidaris (Goniocidaris) mikado (Döderlein) Yoshiwara (Tokunaga), 1905, pl. 3, figs. 1-2.—Goniocidaris (Discocidaris) mikado (Döderlein): Mortensen, 1928-b, p. 178, pl. 14, figs. 1-11, pl. 69, fig. 16, pl. 79, figs. 7-8, text-fig. 57.

Test rather small and high; apical system much less than vertical diameter of test; secondary radioles very small, spherical or elliptical; miliary radioles in the shape of rather thick, rounded grains; primary radioles diverse, but usually with a conspicuous, flat, horizontal disc just above collar; colours almost cream-white, with a purplish tint aborally and on the peristome.

Known only from the Japanese Seas (from Tokyo Bay, Sagami Sea to Goto-Islands).

50-700 metres in depth.

Subgenus Aspidocidaris MORTENSEN, 1928

Aspidocidaris MORTENSEN, 1928, p. 67.—MORTENSEN, 1928-b, pp. 149, 153. Orthotype.—Goniocidaris clypeata Döderlein, 1885, p. 82.

Basal disc more or less developed; terminal disc usually well developed, often forming large round discs, which cover the whole the apical side; primary radioles fairly stout, not curved, with a fairly well developed coat of slightly anastomosing hairs; secondaries flattened, with straight cut end, not very long; miliaries slender.

Goniocidaris (Aspidocidaris) clypeata DÖDERLEIN, 1885

Goniocidaris clypeata Döderlein, 1885, p. 82.—Döderlein, 1887, p. 16, pl. 4, figs. 8-20, pl. 6, figs. 1-19, pl. 8, figs. 7a-f.—Yoshiwara (Tokunaga), 1904, pl. 2, figs. 11-12.—Goniocidaris (Aspidocidaris) clypeata Döderlein: Mortensen, 1928-b, p. 186, pl. 15, figs. 1-7, pl. 69, fig. 9, pl. 78, figs. 17-20, text-fig. 59.

Size small, scarcely attain 20 mm in horizontal diameter; coronal plates 6-8, each with but few tubercles; median areas more or less bare; apical system about half of test-diameter, and apical discs of the outer circle distinctly eccentric, the outer side being the larger; prevailing colour whitish, pinkish, or brown of some shade, usually not greenish.

Known only from the Japanese Seas (off Boso Peninsula and Sagami Sea). 100-about 700 metres in depth.

Goniocidaris (Aspidocidaris) alba MORTENSEN, 1928

Goniocidaris alba Mortensen, 1928, p. 67.—Goniocidaris (Aspidocidaris) alba Mortensen: Mortensen, 1928-b, p. 193, pl. 15, fig. 14, pl. 69, fig. 7, pl. 79, fig. 6.

Test and apical system closely and finely tuberculated; primary radioles rather thick and robust, with a small, incomplete basal disc; the longest of radioles slightly downwards curved; upper primaries ending in a large, round disc; oral primaries

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smooth, shining; median area of interambulacra broader than half a corresponding areole, very closely and finely tuberculated; upper areoles rather distant from each other, the adjoining scrobicular circles being separated by numerous miliary tubercles; colour white.

Known only from the Japanese Seas (Bonomisaki, Kyushu). In 400 metres depth.

Genus Rhopalocidaris MORTENSEN, 1927

Rhopalocidaris Mortensen, 1927, p. 272.-Mortensen, 1928-b, p. 212.

Size small; sunken median space in both ambulacra and interambulacra broad and bare; primary radioles without basal disc; apical primaries simple or, at most, with a very small terminal widening; surface of primary radioles covered with a coat of fine, not branching or anastomosing hairs; primaries otherwise with rather coarse longitudinal ridges and furrows, more or less strongly spinous; secondary radioles club-shaped, not depressed; globiferous pedicellariae, both the large and small form, of the typical goniocidarid structure.

Rhopalocidaris gracilis (DÖDERLEIN, 1885)

Dorocidaris gracilis Döderlein, 1885, p. 78.—Porocidaris gracilis (Döderlein) Döderlein, 1887, p. 8, pl. 4, fig. 8-20.—Cidaris (Porocidaris) gracilis (Döderlein) Yoshiwara (Токилада), 1904, pl. 2, figs. 7-8 (reproduced from Döderlein, 1887).—Rhopalocidaris gracilis (Döderlein) Mortensen, 1928-b, p. 216, pl. 16, figs. 10-12, pl. 17, figs. 11-12, pl. 69, fig. 22, pl. 79, figs. 12-17, text-figs. 72-73.

A very small form, scarcely exceeding 10 mm in horizontal diameter; interambulacra about three times as broad as ambulacra; ambulacra slightly undulate; apical system rather small, only one-third of test-diameter, and with very few tubercles; primary radioles about twice the test-diameter, and provided with small longitudinally thorns on both sides; small radioles staff-like, longitudinally tuberculated; 4-6 proximal areoles confluent; test violet, radioles and tubercles white.

Known only from the Japanese Seas (Sagami Sea).

180-700 metres in depth.

Rhopalocidaris rosea MORTENSEN, 1928

Rhopalocidaris rosea MORTENSEN, 1928, p. 68.—MORTENSEN, 1928-b, p. 220, pl. 17, figs. 13-18, pl. 69, fig. 20, pl. 89, figs. 18-22, text-fig. 74.
 Discocidaris clypeata: H.L. CLARK, 1925, p. 33 (partim).

Primary radioles with confluent bands of red; secondary radioles rather coarse, adapical ones in most of the scrobicular circles distinctly brownish green; a small form, scarcely exceeding 15 mm in horizontal diameter.

Known only from the Japanese Seas (from Sagami Sea to Goto Islands, and to Kagoshima Gulf).

120-700 metres in depth.

Subfamily STEREOCIDARINAE LAMBERT, 1900

Stereocidarinae LAMBERT, 1900, p. 49 (pro parte).—Stereocidarina Mortensen, 1928-b, pp. 69, 225.—Stereocidarinae LAMBERT: NISIYAMA, 1966, p. 157.

Globiferous pedicellariae, both large and small, lacking an end-tooth; the opening subterminal, not with a well formed lower lip; pores non-conjugate or subconjugate; primary tubercles usually non-crenulate; upper primary radioles and tubercles more or less rudimentary.

Genus Stereocidaris POMEL, 1883

Stereocidaris POMEL, 1883, p. 110.—NISIYAMA, 1966, p. 157.

Logotype.—Cidaris cretosa MANTELL, 1822, p. 194, pl. 17, fig. 13 (Upper Chalk of Kent, Sussez). [H. L. CLARK, 1907, p. 177].

Test stout, usually very closely tuberculated; uppermost coronal plates 1, or 2 or even 3 in each column without primary radioles, although a tubercle may be present; primary radioles often conspicuously flaring at the tip, never smooth, but provided with longitudinal rows of granules or with ridges; apical system with irregular outline, not sharply defined; genital pores small; globiferous pedicellariae, both large and small, commonly lack conspicuous end-tooth.

Stereocidaris grandis (DÖDERLEIN, 1885)

Dorocidaris grandis DÖDERLEIN, 1885, p. 77(5).—Stereocidaris grandis (DÖDERLEIN) DÖDERLEIN, 1887, p. 3, pl. 1, figs. 1-6, pl. 2, figs. 1-11, pl. 8, figs. 2a-m.—A. AGASSIZ and H. L. CLARK, 1907, p. 22 (partim), pl. 5, figs. 18-20, pl. 36 (non pl. 33).—MORTENSEN, 1928-b, p. 233, pl. 18, figs. 4-6, pl. 19, figs. 1-3, pl. 70, figs. 1-2, pl. 80, fig. 35.

Stereocidaris microtuberculata: H.L. CLARK, 1907, p. 220, pls. 1-2 (non YOSHIWARA, 1898).

Primary radioles cylindrical with more or less evident longitudinal series of rounded granules; ambulacra rather wide, about one-third of interambulacra; secondaries not white; peristome smaller than apical system; apical system more or less elevated and aboral surface appears quite bare; primaries not white with purple collar; tridentate pedicellariae present.

From the Japanese Seas (from Sagami Sea to western Japan) to the Philippines. 70-220 metres in depth.

Stereocidaris grandis hyatorina MORTENSEN, 1928

Stereocidaris grandis var. hyatorina MORTENSEN, 1928, p. 69.—MORTENSEN, 1928-b, p. 235, pl. 19, figs. 4-6, pl. 20, fig. 3, pl. 70, fig. 3, pl. 80, figs. 28-34, text-fig. 77.
 Stereocidaris grandis: A. AGASSIZ and H.L. CLARK, 1907, p. 22 (partim), pl. 33.

Phyllacanthus dubius: UTINOMI, 1960, p. 338, pl. 37, figs. 1-2 (?) (non BRANDT, 1835).

Differs from the typical *St. grandis* in the marginal series of ambulacral tubercles. being quite regular even onto the peristomial edge, and in the secondary radioles on the oral side not being thick and club-shaped.

Known only from the Japanese Seas (from Hakodate Bay to Sado Island, on the

Japan Sea side, and from off Sunosaki to Kyushu, on the Pacific side). (?) Hawaiian Islands.

70-120-400 metres in depth.

Stereocidaris microtuberculata (YOSHIWARA, 1898)

- Cidaris (Stereocidaris) microtuberculatus YOSHIWARA, 1898, p. 57.—YOSHIWARA (TOKUNAGA), 1904, pl. 1, figs. 6-7.—MORTENSEN, 1928-b, p. 257, pl. 20, figs. 1-2, pl. 21, figs. 1-3, pl. 71, fig. 7, pl. 82, figs. 2-4, text-fig. 83.
- Non Stereocidaris microtuberculata MORTENSEN, 1927, p. 302, pls. 69-70 (=St. tubifera, and purpurascens MORTENSEN).

Primary radioles cylindrical with more or less evident longitudinal series of granules; ambulacra narrow, less than one-fourth of interambulacra, and deeply sunken; median area closely covered with six series of tubercles; all miliary tubercles minute; collar of primary radioles white; test and small radioles yellowish-brown with a greenish tinge.

Known only from the Japanese Seas (Sagami Sea).

140-700 metres in depth.

Stereocidaris indica philippinensis MORTENSEN, 1928

Stereocidaris indica var. philippinensis Mortensen, 1928, p. 71.—Mortensen, 1928-b, p. 265, pl. 81, figs. 15-20.

Stereocidaris grandis: H.L. CLARK, 1925, p. 26 (non Döderlein, 1885. Albatross Station 210).

Characterized by the more numerous series of spinules on the radioles, and by the hairs of the primary radioles being quite low and simple (an anastomosing in the forms from the Indian Ocean). The large globiferous pedicellariae are rather usually slender.

From the Japanese Sea (off Kyushu) to the Indian Ocean. (400 metres in depth, off Kyushu).

Stereocidaris sceptriferoides DÖDERLEIN, 1887

Stereocidaris sceptriferoides Döderlein, 1887, p. 5, pl. 2, figs. 12-17, pl. 8, figs. 3a-e.-Mor-TENSEN, 1928-b, p. 274, pl. 29, figs. 5-7, pl. 67, figs. 1-3, 13, pl. 70, fig. 12, pl. 81, figs. 1-4, text-figs. 85-86.

Ambulacra rather broad, about one-third of interambulacra; secondary radioles white or whitish; peristome nearly equal to apical system; no tridentate pedicellariae; globiferous pedicellariae very slender, valves often have a conspicuous end-tooth, and terminal opening long and narrow.

Known only from the Japanese Seas (Sagami Sea). 370-700 metres in depth.

Stereocidaris sceptriferoides lanceolata MORTENSEN, 1928

Stereocidaris sceptriferoides var. lanceolata Mortensen, 1928, p. 71.—Mortensen, 1928-b, p. 277, pl. 29, figs. 8-9, pl. 71, fig. 6, pl. 81, figs. 5-10.

Differs from the typical species mainly in the scrobicular radioles being slender and pointed (broad, almost rectangular in the typical form).

Known only from the Japanese Seas (Sagami Sea).

In 700 metres depth.

Subgenus Phalacrocidaris LAMBERT, 1902

Phalacrocidaris LAMBERT, 1902, p. 26.—NISIYAMA, 1966, p. 160. Orthotype.—Dorocidaris japonica Döderlein, 1885, p. 76.

Test rather flat, but rounded-conical; areoles aborally small, very shallow and indistinct, on the uppermost plates practically wanting, but at the ambitus and below deeply sunken and merging together near the peristome; ambulacra rather wide, about one-third of interambulacra; whole aboral surface more or less densely covered with very small secondaries, miliaries and pedicellariae; primary radioles slender, cylindrical with longitudinal series of minute granules, sometimes nearly smooth, often flattened and widened at tip; small globiferous pedicellariae sometimes with, more often without, end-tooth on valves.

Stereocidaris (Phalacrocidaris) japonica (DÖDERLEIN, 1885)

- Dorocidaris japonica DöDERLEIN, 1885, p. 76 (4).—Stereocidaris japonica (DöDERLEIN) DÖD-ERLEIN, 1887, pp. 6, 42, pl. 3, figs. 1-20, pl. 8, figs. 1a-h.—Stereocidaris (Phalacrocidaris) japonica (DöDERLEIN): MORTENSEN, 1928-b, p. 280, pl. 28, figs. 1-10, pl. 70, fig. 8, pl. 82, figs. 11-17.
- Cidaris (Stereocidaris) tenuispinus YOSHIWARA, 1898, p. 57.—YOSHIWARA (TOKUNAGA), 1904, pl. 1, figs. 8-10.—Anomocidaris tenuispina (YOSHIWARA) A. AGASSIZ and H. L. CLARK, 1907, p. 30, pl. 11, figs. 6-12, pl. 12, figs. 18-30, pl. 31, figs. 5-8.

Size moderate; colour of test and secondary radioles commonly some shade of brown, often reddish, sometimes greenish, while primaries grayish or brownish, often with a decidedly olive-green tinge, rarely rosy-reddish; collar brown, usually polish and shining.

Known only from the Japanese Seas (from Sagami Sea to Kyushu). 70-700 metres in depth.

Subfamily Stylocidarinae Mortensen, 1928

Stylocidarina Mortensen, 1928-b, pp. 69, 320.—NISIYAMA, 1966, p. 162,

Large globiferous pedicellariae having a well formed terminal opening, generally bordered by a fairly regular lip with teeth-like serrations; small globiferous pedicellariae well developed; pores non-conjugate or conjugate; primary tubercles crenulate or non-crenulate; secondary radioles flattened, usually not appressed or scale-like.

Genus Compsocidaris IKEDA, 1939

Compsocidaris IKEDA, 1939-c, p. 160.

Orthotype.—Compsocidaris pyrsacantha IKEDA, 1939-c, p. 161, pls. 7-10.

Test sparsely tuberculate; some of aboral tubercles with traces of crenulation; areoles rather shallow, two proximal ones confluent; pores subconjugate; primary and secondary radioles conspicuously vermilion; valves of large and small globiferous. pedicellariae subterminal, lacking the end-tooth.

Compsocidaris pyrsacantha IKEDA, 1939

Compsocidaris pyrsacantha IKEDA, 1939-c, p. 161, pl. 7, figs. 1-2, pl. 8, figs. 1-2, pl. 8, figs. 1-4,. pl. 10, figs. 1-13.

Size moderate; peristome slightly smaller than the apical system; primary radioles rather smooth, fairly thick, somewhat tapering, with 24-28 longitudinal lines; collar long; oral primaries simply club-shaped, not flattened nor curved.

Known only from south of Japan (Bonin Islands).

In moderate depth.

Genus Acanthocidaris MORTENSEN, 1903

Acanthocidaris Mortensen, 1903-b, pp. 21, 29.—H. L. Clark, 1925, pp. 6, 9, 37.—Mortensen, 1928-b, p. 321.

Haplotype.—Cidaris curvatispinis BELL, 1893, p. 303, pl. 38.—Acanthocidaris curvatispinis. (BELL): MORTENSEN, 1928-b, p. 323, pl. 83, figs. 16-18.

Primary radioles long, not at all thorny or prickly, broad and somewhat depressed at base, tapering much but gradually, often distinctly curved, and with a conspicuous light-coloured or spotted collar, which one-fifth or more of the length; all three kinds of pedicellariae present, globiferous, both large and small, lack an end-tooth on valves; stalk of large ones usually with a "limb".

Acanthocidaris maculicollis (MEIJERE, 1903)

Porocidaris maculicollis MEIJERE, 1903, p. 1.—MEIJERE, 1904, p. 15, pl. 3, figs. 18–19, pl. 11, figs. 111–116.—Acanthocidaris maculicollis (MEIJERE): KOEHLER, 1927, p. 23, pl. 5, fig. 23, pl. 23, fig. 4.—MORTENSEN, 1928-b, p. 329, pl. 43, figs. 1–2, pl. 44, fig. 1, pl. 5, figs. 5–6, pl. 83, figs. 12–15, text-figs. 92–96.—MORTENSEN, 1932-b, p. 157, pl. 5, fig. 6, pl. 11, fig. 5.

Collar of primary radioles greenish, with red spots; remainder of radioles whitish with 3 or 4 cross-bands of reddish; secondary radioles with a dark longitudinal stripe; adoral primaries serrate and with a broad collar; size small.

From the Japanese Seas (Sagami Sea) to the Malay region and to the Indian Ocean.

40-225 metres in depth.

Genus Stylocidaris MORTENSEN, 1909

Stylocidaris Mortensen, 1909, pp. 52, 54.—H. L. Clark, 1925, pp. 3, 8, 22.—Mortensen, 1928b, p. 334.

Orthotype.—Cidaris affinis PHILIPPI, 1845, p. 351.—Stylocidaris affinis (PHILIPPI): MOR-TENSEN, 1928-b, p. 336, pl. 36, figs. 1-7, pl. 72, fig. 15.
Apical system sharply defined, circular or pentagonal; primary radioles long, more or less slender and pointed, sometimes prickly, or even thorny or ridged; areoles more or less deeply sunken; peristome generally smaller than the apical system; large globiferous pedicellariae with the valves curved, with a large terminal opening and no end-tooth.

Stylocidaris reini (DÖDERLEIN, 1887)

Cidaris (Dorocidaris) reini Döderlein, 1887, p. 7, pl. 4, figs. 1–7, pl. 8, figs. 4a-d.—Yoshiwara (Tokunaga), 1904, pl. 1, figs. 2–3, (reproduced from Döderlein, 1887).—Meijere, 1904, p. 5, pl. 1, figs. 2–3, pl. 11, figs. 103–108.—*Stylocidaris reini* (Döderlein): Mortensen, 1927, p. 292, pl. 66, fig. 2, pl. 67, fig. 2.—Mortensen, 1928-b, p. 342, pl. 35, figs. 1–9, pl. 72, figs. 17–19, pl. 84, figs. 1–11, text-figs. 98–100.

Primary radioles terete, with 12-15 longitudinal series of fine, sharp granules which do not loose their individuality entirely, even near tip of old radioles; apical system larger than the peristome; median areas not bare; usually unicolor, white or pale yellowish; collar of moderate width; size small.

From the Japanese Seas (Sagami Sea) to the Philippines and to Malay region. 100-500 metres in depth.

Stylocidaris reini cladothrix Mortensen, 1927

Stylocidaris reini var. cladothrix Mortensen, 1927, p. 293, pl. 65, figs. 6-7, pl. 66, fig. 1, pl. 75, fig. 4.—Mortensen, 1928-b, p. 346.

Differs from the typical *Sty. reini* in the shape of the hairs covering the surface of the radioles, which much larger, rather coarse, and bush-shaped (in the typical form these are very small and simple). The secondary radioles are rather more slender, especially the ambulacral radioles, and also more greenish than in the typical form.

From the Japanese Seas to the Philippines and to Moluccan Seas. 197-247 metres in depth.

Stylocidaris maculosa MORTENSEN, 1928

Stylocidaris maculosa MORTENSEN, 1928, p. 72.—MORTENSEN, 1928-b, p. 364, pl. 39, figs. 7-12, pl. 72, fig. 3, pl. 85, figs. 8-15, text-fig. 107.

Small form, scarcely exceeding 15 mm in horizontal diameter; primary radioles with usually 10 sharp, strongly serrate ridges, those on adoral side lower and less serrate, which give the radioles a somewhat flattened appearance; surface of shaft, between the ridges, smooth shining, entirely without hairs; collar very short, usually with a single conspicuous spot (or patch) of reddish-brown on the adapical side of the collar; shaft of radioles banded with reddish-brown; interporiferous zone naked, except a very small tubercle adradially to the marginal one at the ambitus; test white, except interporiferous zone, which faintly brownish-pink; apical system darker, brownish-olive, especially the inner part of genital plates.

Known only from the Japanese Seas (from Sagami Sea to Bonin Islands). (90)-100-350 (700) metres in depth.

Stylocidaris? fusispina MORTENSEN, 1928

Stylocidaris? fusispina Mortensen, 1928, p. 72.—Mortensen, 1928-b, p. 382, pl. 37, figs. 11-12, pl. 72, fig. 4, pl. 84, figs. 26-30, text-fig. 112.

Small form, scarcely exceeding 15 mm in test-diameter; primary radioles fusiform, with 10-12 sharp, but perfectly smooth ridges, in the basal part of radioles transformed into series of low, rounded tubercles; surface between the ridges covered with a low, spongy coat of anastomosing hairs; collar about 0.5 mm long, with spots; shaft of radioles with 2-3 conspicuous brownish or reddish-yellow bands; interporiferous zone naked; test white, but tubercles of a pinkish tint, apical system light reddish-yellow.

Known only from the Japanese Seas (from Sagami Sea to Kagoshima Gulf). 100-185 metres in depth.

Genus 'Eucidaris' POMEL, 1883

Eucidaris Pomel, 1883, p. 109.—Nisiyama, 1966, p. 168.

Logotype.—Cidarites monilifera GOLDFUSS, 1826: COTTEAU, 1875-1880, p. 163, pls. 185-186. [COOKE, 1959, p. 8].

'Logotype'.—Cidarites metularia LAMARCK, 1816, p. 36, [H.L. CLARK, 1909, p. 88.—This species is not in syntypes of original author].

Primary radioles short, usually nearly equal to test-diameter and rather stout, often very short and even swollen, rarely slender and elongate, blunt; areoles little or not sunken; ambulacral pores close together, more or less oblique; large globi-ferous pedicellariae with the valves curved, with a large terminal opening, and without an end-tooth.

' Eucidaris' metularia (LAMARCK, 1816) (C-T)

Cidarites metularia: LAMARCK, 1816, p. 56.—Cidaris metularia (LAMARCK): A. AGASSIZ, 1872-74, pp. 98, 254, 385, pl. 1c, figs. 23-24, pl. 1g, fig. 1, pl. 35, fig. 3.—Eucidaris metularia (LAMARCK): DÖDERLEIN, 1887, p. 42, pl. 9, fig. 1.—Cidaris (Dorocidaris) metularia (LA-MARCK): YOSHIWARA (TOKUNAGA), 1904, pl. 1, fig. 1.—Cidaris metularia (LAMARCK): A. AGASSIZ and H. L. CLARK, 1907, p. 5, pl. 1, figs. 5-7.—Eucidaris metularia (LAMARCK): MORTENSEN, 1928-b, p. 386, pl. 41, figs. 1-8, pl. 73, fig. 6, pl. 86, figs. 11-14, text-figs. 113ab, 114-116.—NISIYAMA, 1942, p. 15, text-figs. 1a-b (in Japanese).—'Eucidaris' metularia (LAMARCK) NISIYAMA, 1966, p. 169.

Prionocidaris baculosa: HAYASAKA, 1948, p. 14, pl. 3, fig. 1 (non LAMARCK, 1816).

Size small, rarely exceeding 30 mm in horizontal diameter; median ambulacral areas wide and bare; apical system large, nearly a half of test-diameter; genital plates always in contact with each other; coronal plates 5 or 6 m rarely 7; primary radioles cross-banding.

From the Japanese Seas (Tanabe Bay) to Ryukyu Islands to Formosa Island, and widely distributed over the Indo-West Pacific, from Mozambique on the west to Hawaiian Islands on the east, north to the Gulf of Suez, and south of the shoals of northern Australia.

Littoral zones-20-(750-N. Australia) metres in depth.

Genus Plococidaris MORTENSEN, 1909

Plococidaris MORTENSEN, 1909, p. 53.—MORTENSEN, 1928-b, p. 428. Orthotype.—Cidarites verticillata LAMARCK, 1816, p. 56.

Ambulacra very broad; median area broad, sunken and bare; median interambulacral area also sunken; primary radioles provided with several whorls of vertical plate-like projection of flat, blunt thorns; large globiferous pedicellariae with small terminal opening and without an end-tooth on valves; small globiferous ones with an end-tooth; ambulacral pores not distinctly conjugate.

Plococidaris verticillata (LAMARCK, 1816)

Cidarites verticillata LAMARCK, 1816, p. 56.—Phyllacanthus verticillatus (LAMARCK) A. AGAS-SIZ, 1872-74, pp. 151, 392, pl. 1c, figs. 40-42, pl. 1f, fig. 3.—Leiocidaris verticillata (LA-MARCK): DÖDERLEIN, 1887, p. 22, pl. 9, figs. 8a-i.—Cidaris (Leiocidaris) verticillata (LA-MARCK): YOSHIWARA (TOKUNAGA), 1904, pl. 2, fig. 6.—Plococidaris verticillata (LAMARCK): MORTENSEN, 1928-b, p. 428, pl. 31, figs. 3-7, pl. 74, fig. 5, pl. 83, figs. 19-21, text-figs. 131-133.

Primary radioles with unspotted collar, but with two or three whorls of projecting ridges; more or less green in colouration; size rather large, attains 40 mm in horizontal diameter.

From the Japanese Seas (? Sagami Sea and Tanabe Bay) to Ryukyu Islands and to Formosa Island, and widely distributed over the Indo-West Pacific, from Zanzibar to Samoa (also recorded from Hawaiian Islands) and to the Australian east coast.

Littoral zones-54 metres in depth.

Genus Prionocidaris A. AGASSIZ, 1863

Prionocidaris A. AGASSIZ, 1863, p. 18.—NISIYAMA, 1966, p. 163. Haplotype.—Cidarites pistillaris LAMARCK, 1816, p. 55.

Apical system usually about nearly a half of horizontal diameter; periproct generally with numerous small plates, often conically raised; interambulacral areas not conspicuously widened and not densely clothed with miliaries and small globiferous pedicellariae; ambulacral pores horizontal or nearly so, distant, connected by a shallow groove; large globiferous pedicellariae, if present, with a beautiful limb on the stalk; small globiferous ones with an end-tooth.

Prionocidaris baculosa annulifera (LAMARCK, 1816) (C-T)

Cidarites annulifera LAMARCK, 1816, p. 55.—Prionocidaris baculosa var. annulifera (LAMARCK): MORTENSEN, 1928-b, p. 443, pl. 45, figs. 1-2, pl. 46, pl. 51, fig. 2, pl. 53, figs. 4-8, pl. 73, figs. 14-15, pl. 87, figs. 5, text-fig. 137.—NISIYAMA, 1966, p. 164. Primary radioles varied, cylindrical to fusiform, sometimes flattened at base, usually highly spinous in basal portion on the aboral side only, banded with red and white; collar about 1-3 mm long, with isolated purplish spots. In contrasting to the typical form, *Pr. baculosa*, the primaries and secondaries of a uniform dark, purplish colour, and secondaries with a brown median stripe. Size rather large.

From the Japanese Seas (Uraga Channel and Tanabe Bay) to the Philippines, and to Java Sea and Moluccan Seas.

Littoral zones-250 metres in depth.

Prionocidaris bispinosa (LAMARCK, 1816) (C-T)

Cidarites bispinosa LAMARCK, 1816, p. 57.—Prionocidaris bispinosa (LAMARCK): MORTENSEN, 1928-b, p. 468, pl. 44, fig. 2, pl. 47, fig. 1, pl. 53, figs. 1-3, pl. 73, fig. 19, pl. 87, fig. 12.— NISIYAMA, 1966, p. 165, pl. 1, figs. 7-14 (fossil).

Interporiferous zone of ambulacra thickly set with small tubercles; collar low, rose-red, pinkish, red-brown or brown, quite without spots or stripe. Primary radioles varying from smooth, with scarcely any thorns (var. *chinensis* DÖDERLEIN), to very thorny, and sometimes distinctly flattened in outer part, but never with longitudinal series of small thorns or serrations. Size rather large. Coronal plates rather numerous, 9-11 in specimens 70-75 mm horizontal diameter.

From the south of Formosa Island and the Philippines to the Java Sea and Moluccan Seas, and ranges as far west as Ceylon and as far south as southwestern Australia.

4-50 metres in depth.

Subfamily Rhabdocidarinae Mortensen, 1928

Rhabdocidarina Mortensen, 1928-b, pp. 69, 489.—Rhabdocidarinae Mortensen: Nisiyama, 1966, p. 169.

Ambulacral pores conjugate, they may be arranged in double series on the peristome; no groove in the sutures of coronal plates or on the plates; tubercles crenulate or non-crenulate; primary radioles large and coarse, cylindrical, smooth, or with more or less coarse thorns; large globiferous pedicellariae with a rather large subterminalopening, without an end-tooth; small globiferous ones with or without an end-tooth.

Genus Chronocidaris IKEDA, 1941

Chronocidaris IKEDA, 1941-a, p. 85. Haplotype.—Chronocidaris micca IKEDA, 1941-a, p. 85, pl. 6.

No bare groove in suture of coronal plates; pore-pairs subconjugate; pores on peristome in a single series; primary tubercles non-crenulate; areoles very shallow and distinctly separate; primary radioles spotted but not thorny; secondary radioles. blade-like, considerably flattened; large globiferous pedicellariae with subterminal: opening and an end-tooth on valves.

Chronocidaris micca IKEDA, 1941

Chronocidaris micca IKEDA, 1941-a, p. 85, pl. 6.

Primary radioles yellow, with a greenish shade, having purplish-black spots and longitudinal striae; secondary radioles dark yellow; test white; size small, scarcely .attains 30 mm in horizontal diameter.

Known only from Ryukyu Islands.

In moderate depths.

Genus Phyllacanthus BRANDT, 1835

Phyllacanthus Brandt, 1835, p. 267.—Nisiyama, 1966, p. 172.

Haplotype.—Cidarites (Phyllacanthus) dubia BRANDT, 1835, p. 268 (validated by Opinion of the International Commission on Zoological Nomenclature).

Apical system small, rarely exceeding 40% of horizontal diameter, very compact and closely covered with tubercles (radioles); ambulacra sinuate; radioles thick and stout, cylindrical or terete, sometimes with longitudinal series of small serrations or granules but never with thorns or projecting ridges or spotted collar; large globiferous pedicellariae very rare, valves with small terminal opening and without an end-tooth; small globiferous ones without an end-tooth.

Phyllacanthus imperialis (LAMARCK, 1816)

Cidarites imperialis LAMARCK, 1816, p. 54.—Phyllacanthus imperialis (LAMARCK): A. AGASSIZ, 1872-74, pp. 151, 391, pl. 1f, fig. 2.—LORIOL, 1883, p. 11, pl. 1, fig. 2.—Döderlein, 1903, p. 690, pl. 58, figs. 1-4.—Mortensen, 1928-b, p. 504, pl. 54, fig. 4, pl. 57, fig. 3, pl. 74, fig. 6, pl. 88, fig. 4-10, text-fig. 163.—NISIYAMA, 1966, p. 173, pl. 2, figs. 1-3 (fossil).

Primary radioles stout, cylindrical and inflated at the middle, rarely superpassing the test-diameter; oral primaries slender, and with numerous, about 30, close, indistinct series of granules; colour of primaries dark, often with white bands near distal end; secondaries more or less stout; denuded test white; size large, up to 75 mm in horizontal diameter; ambulacral median area broad as wide as poriferous zone.

From Ryukyu Islands to the Philippines, and widely distributed over the Indo-West Pacific, from Zanzibar and the Red Sea on the west to Tonga Islands on the east, and to the Coral Sea on the south.

Littoral zones-75 metres in depth.

Phyllacanthus dubius BRANDT, 1835

Cidarites (Phyllacanthus) dubia BRANDT, 1835, p. 268.—Phyllacanthus dubius (BRANDT): A. AGASSIZ, 1872-74, pp. 150, 389, pl. 1f, figs. 6-7.—YOSHIWARA (TOKUNAGA), 1904, pl. 2, figs. 2-5.—MORTENSEN, 1928-b, p. 510, pl. 55, fig. 1, pl. 56, figs. 1-2, pl. 63, figs. 4-6, pl. 74, fig. 7, pl. 88, figs. 13-17, text-figs. 164-166.

Primary radioles slender and long, usually tapering otherwise distal end, with about 16-20, distinct, well-spaced series of granules or serrations; secondaries very flattened, slightly curved; median ambulacral area narrower than poriferous zone; size large, up to 60 mm in horizontal diameter; colour dark purple; denuded test of a pinkish tint.

Known only from the Bonin Islands.

Family PSYCHOCIDARIDAE IKEDA, 1936

Psychocidaridae IKEDA, 1936-b, p. 486.—IKEDA, 1939-b, p. 151.—DURHAM and MELVILLE, 1957,.
 p. 252.—PHILIP, 1965, p. 56.
 Type-genus.—Psychocidaris IKEDA, 1935.

Interambulacra with only two rows of usually solid plates, with rigid sutures; primary tubercles imperforate, non-crenulate; ambulacral pores on the peristomial ambulacral plates are diploporous; peristome with pluriseriate ambulacral plates only, without interradial plates; valves of large globiferous pedicellariae flask-shaped in profile.

Genus Psychocidaris IKEDA, 1935

Psychocidaris IKEDA, 1935-c, p. 386.—IKEDA, 1936-b, p. 487.—IKEDA, 1939-b, p. 151. Orthotype.—Psychocidaris ohshimai IKEDA, 1935-c, p. 386, 1 text-fig.

Ambulacral pores non-conjugate; on peristome only pluriseriate ambulacral platespresent; aboral primary radioles acorn-shaped, ambital ones longer and somewhat flattened; all primaries but adoral club-shaped, adorned with very coarse thorns which arranged quite irregular.

Psychocidaris ohshimai IKEDA, 1935

Psychocidaris ohshimai IKEDA, 1935-c, p. 386, 1 text-fig.—IKEDA, 1936-b, p. 486, pls. 33-34.— IKEDA, 1939-b, p. 151, pls. 5-6.

Size moderate, nearly attains 40 mm in horizontal diameter; test thick, with a broad median interambulacral space, covered with small tubercles; areoles fairly large, distinctly sunken; apical system subequals peristome in diameter; primary radioles peculiar in shape; aboral primaries acorn-shaped; collar short; radioles and test dark yellow, secondary radioles greenish.

Known only from the Bonin Islands.

180 metres in depth.

Order DIADEMATOIDA DUNCAN, 1889

Diadematoida DUNCAN, 1889-a, p. 24 (pro parte).—NISIYAMA, 1966, p. 174. Aulodonta JACKSON, 1912, p. 207 (suborder).—PHILIP, 1965, p. 57. Type-family.—Diadematidae GRAY, 1855.

Test regular; coronal plates imbricating or not; only 20 columns of plates; tubercles perforate, crenulate or non-crenulate; primordial interambulacral plates. usually not persisting; perignathic girdle complete in adult; lantern of masticatory apparatus erect; epiphyses not joining above the teeth; teeth grooved or unkeeled; ambulacra compounding of usually the diadematoid type; radioles without a outer layer; gills and sphaeridia present. From the Infra-Lias to Recent.

Suborder ASPIDODIADEMATOINA MORTENSEN, 1939

Aspidodiademina MORTENSEN, 1939, p. 547.-MORTENSEN, 1940, p. 6.-Aspidodiadematina MORTENSEN: NISIYAMA, 1954, p. 352 (in Japanese).—Aspidodiademina MORTENSEN: Рнігір, 1965, р. 57.

Type-family.—Aspidodiadematidae DUNCAN, 1889.

Primary radioles with axial lumen divided into compartments, separated by fenestrate transverse plates (dissepiments), connected by longitudinal thin threads; tubercles crenulate.

Family ASPIDODIADEMATIDAE DUNCAN, 1889

Aspidodiadematidae Duncan, 1889-a, p. 56.—A. Agassiz and H. L. Clark, 1908, p. 89.—Mor-TENSEN, 1940, p. 6. Type-genus.-Aspidodiadema A. AGASSIZ, 1879.

Ambulacra consisting of simple or compound plates of the diadematoid type; only a single series of large, contiguous primary interambulacral tubercles in each column, secondary tubercles of uniform, small size; primary tubercles perforate and very strongly crenulate; coronal plates thin; apical system large, monocyclic, ringshaped, the genital and ocular plates usually of the same size and shape; periproct on the whole naked, leathery, excepting a circle of larger plates round the anus, no suranl plate; primary radioles very long, and verticillate; no C-form (bihamate) spicules.

Genus Aspidodiadema A. AGASSIZ, 1879

Aspidodiadema A. AGASSIZ, 1879, p. 199.-A. AGASSIZ and H. L. CLARK, 1908, p. 98.-MOR-TENSEN, 1940, p. 40. Haplotype.-Aspidodiadema tonsum A. AGASSIZ, 1879, p. 199.

Size small, globular; ambulacral plates distinctly compound, trigeminate, median component much larger than upper and lower component plates, and carrying a large primary tubercle almost of the same size as the primary interambulacral tubercles.

Aspidodiadema tonsum A. AGASSIZ,

Aspidodiadema tonsum A. AGASSIZ, 1879, p. 199.-A. AGASSIZ, 1881-a, p. 66, pl. 8, figs. 1-9, pl. 38, fig. 19, pl. 42, figs. 4-6, pl. 44, fig. 15.—Meijere, 1904, p. 44, pl. 13, figs. 177-182.— A. AGASSIZ and H. L. CLARK, p. 98, pl. 50, figs. 3-5.-MORTENSEN, 1940, p. 42, pl. 1, figs. 11-15, pl. 64, figs. 2-12, text-fig. 21.

Apical plates densely tuberculated; perianal plates large; ambulacra narrow, about three-fourths as wide as the interambulacra; pore-pairs in a nearly straight line; primary tubercles elongate-oval; miliary tubercles on buccal plates numerous, there are 8-12 tubercles; radioles and test light violet, tubercles white; claviform pedicellariae three-valved.

From the Japanese Seas to the Philippines and off Timor. 180-925 metres in depth.

Suborder PEDINOINA MORTENSEN, 1939

Pedinina MORTENSEN, 1939, p. 547.—MORTENSEN, 1940, p. 62.—NISIYAMA, 1954, p. 352 (in Japanese).—Philip, 1965, p. 57.
 Type-family.—Pedinidae POMEL, 1883.

Primary radioles with solid axis; tubercles perforate, non-crenulate; ambulacra compounding of the diadematoid type; test rigid.

Family PEDINIDAE POMEL, 1883

Pédiniens POMEL, 1883, p. 97.—DUNCAN, 1889-а, p. 57.—GREGORY, 1900-b, p. 309.—H. L. CLARK, 1912-b, p. 213.—MORTENSEN, 1940, p. 62.
 Type-genus.—Pedina Agassiz, 1836.

Coronal plates not imbricating; ambulacra consisting of simple or trigeminate compound plates of the diadematoid type; peristome with fairly distinct gill-cuts; primary radioles not verticillate, no outer layer; ambulacral and secondary radioles hollow; pedicellariae of the globiferous, tridentate, ophicephalous, and triphyllous types.

Genus Caenopedina A. AGASSIZ, 1869

Caenopedina A. AGASSIZ, 1869, p. 256.—H. L. CLARK, 1912, p. 216.—MORTENSEN, 1940, p. 93. Haplotype.—Caenopedina cubensis A. AGASSIZ, 1869, p. 256.—A. AGASSIZ, 1872-74, p. 291, pl. 15, fig. 235, pl. 16, figs. 236-242.

Test firm and hard; coronal plates rather few; primary interambulacral tubercles very large, contiguous throughout only a single series in each column, leaving only a narrow median and adradial space for the secondary tubercles; arcs of pore-pairs inverse, arranged more or less in arcs of three, also on the aboral side.

Caenopedina mirabilis (DÖDERLEIN, 1885)

Hemipedina mirabilis Döderlein, 1885, p. 96 (24).—Caenopeina mirabilis (Döderlein) Mortensen, 1904, p. 34, pl. 4, figs. 3, 5-6.—Hemipedina mirabilis Döderlein: Yoshiwara (Tokunaga), 1905, pl. 5, fig. 5.—Döderlein, 1906, p. 174, pl. 21, figs. 3-3a, pl. 45, fig. 5.—Caenopedina mirabilis (Döderlein): H.L. Clark, 1912-b, p. 221, pl. 91, figs. 14-17, pl. 105, fig. 8.—Mortensen, 1940, p. 99, pl. 2, figs. 13-15, pl. 3, fig. 2, pl. 66, figs. 10-22, pl. 67, fig. 17, text-figs. 56-57.

Primary radioles usually greenish, with brownish bands; tubercles of genital plates not confined to the adapical edge; ophicephalous pedicellariae with long constricted blade.

Known only from the Japanese Seas (from Mutsu Bay (Lat. 42°N.) to Kagoshima Gulf).

20-89-(360) metres in depth.

Caenopedina pulchella (A. AGASSIZ and H. L. CLARK, 1907)

Hemipedina pulchella A. AGASSIZ and H. L. CLARK, 1907-a, p. 245.—Caenopedina pulchella
 (A. AGASSIZ and H. L. CLARK) H. L. CLARK, 1912-b, p. 223, pl. 91, figs. 18-22, pl. 103, figs.
 1-3, pl. 105, figs. 6-7.—MORTENSEN, 1940, p. 114, pl. 68, figs. 7-9, text-fig. 63.

Periproctal plates few and large; apical plates brownish-rose, conspicuously sculptured in centre; secondary radioles white or reddish-white.

Okinose, Sagami Sea (It was brought from All. Owston-Mortensen, 1940). In 900 metres depth.

Off Kauai, Hawaiian Islands (400-533 metres in depth)-the type-locality.

Suborder DIADEMATOINA DUNCAN, 1889

Diadematoida Duncan, 1889-a, p. 24 (pro parte).—Diademina GREGORY, 1900-b, p. 308.— Diademina Duncan: Philip, 1965, p. 57.—Diadematoina Duncan: Nisiyama, 1966, p. 175. Type-family.—Diadematidae GRAY, 1855.

Corona more or less imbricating; primary radioles (usually) hollow, only exceptionally the axis is filled by a loose meshwork; tubercles perforate and usually crenulate, rarely non-crenulate; ambulacra compounding of the diadematoid type.

Family DIADEMATIDAE GRAY, 1855

Diademadae GRAY, 1855, p. 35.—Diadematidae Peters, 1855, p. 106.—Nisiyama, 1966, p. 176. Type-genus.—Diadema (Humphrey) Gray, 1825.

Centrechinidae JACKSON, 1912, p. 203.-H.L. CLARK, 1946, pp. 295, 296.

Type-genus.—Centrechinus JACKSON, 1912.

Ambulacral compounding of the diadematoid type; tube-feet of the outer series not transformed into large, umbrella-shaped organs; pore-pairs not arranged in double series; coronal plates more or less imbricate; no anchor-shaped spicules nor C-form (bihamate) spicules.

Genus Astropyga GRAY, 1825

Astropyga GRAY, 1825, p. 426 (1).--A. AGASSIZ and H.L. CLARK, 1908, p. 123.-MORTENSEN, 1940, p. 181, text-figs. 109-110.

Haplotype.—Cidaris radiata LESKE, 1778, p. 116, pl. 44, fig. 1 (copied from SEBA).

Normal primary radioles relatively short, rough, with central cavity so filled by a calcareous network that under low magnification they appear solid in cross-section; oral surface with normal primary tubercles; aboral side not very naked; pore-zones more or less widened aborally, and on the oral side arranged in distinct arcs of three; test low, more or less flexible.

Astropyga radiata (LESKE, 1778) (C-P)

Cidaris radiata LESKE, p. 116 (52), pl. 44, fig. 1.—Astropyga radiata (LESKE): A. AGASSIZ, 1872-74, pp. 94, 420, pl. 25, fig. 40.—Döderlein, 1903, p. 699, pl. 59, figs. 6-7.—Mortensen, 1940, p. 187, pl. 8, fig. 6, pl. 9, figs. 6-9, pls. 10-11, pl. 12, figs. 1-2, pl. 13, fig. 1, pl. 14, figs.

1-3, pl. 15, fig. 2, pl. 16, fig. 1, pl. 17, fig. 1, pl. 18, fig. 1, pl. 20, fig. 4, pl. 70, figs. 1-3, 7, 15-17, 20, pl. 71, figs. 2, 46, text-figs. 111-115.—UTINOMI, 1954, p. 344, text-fig. 1A. Astropyga mossambica PETERS, 1855, p. 110, pl. 1, fig. 1.

Astropyga pulvinata: Yoshiwara (Tokunaga), 1905, pl. 6, figs. 7-9 (non Lamarck, 1816).

Columns of primary interambulacral tubercles on adoral surface parallel with ambulacra, so that the outermost column (next to ambulacrum) at ambitus, extends to peristome, though the tubercles may become much smaller there; colour of at least the naked interambulacral bands red.

From the Japanese Seas (Tanabe Bay) to Ryukyu Islands, and widely distributed over the Indo-West Pacific, from East Africa to Hawaii in the east.

2-60 metres in depth.

Genus Chaetodiadema MORTENSEN, 1903

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Chaetodiadema MORTENSEN, 1903, p. 1.—MORTENSEN, 1940, p. 215.—H. L. CLARK, 1946, pp. 296, 301.
 Haplotype.—Chaetodiadema granulatum MORTENSEN, 1904, p. 22, pl. 1, figs. 1, 3, 21-22, pl.

3, fig. 11, pl. 4, figs. 1, 4, 13–15, 24, 32, pl. 5, figs. 10, 18, 19, 22, 35.

Primary radioles slender, rough, not very long, more or less solid; adoral surface with tubercles tending to become small and densely crowded near peristome; porepairs on the oral side arranged in a single series; test low, more or less flexible; tubercles crenulate.

Chaetodiadema japonicum MORTENSEN, 1904

Chaetodiadema japonicum Mortensen, 1904, p. 28, pl. 2, figs. 16, 19, text-fig. 2.—Mortensen, 1940, p. 223, pl. 33, figs. 7-9, pl. 72, figs. 14-21, text-figs. 128-129.—Utinomi, 1954, p. 344, text-fig. 1b.

Astropyga sp. Yoshiwara (Tokunaga), 1905, pl. 6, figs. 5-6.

Astropyga radiata: YOSHIWARA (TOKUNAGA), 1905, pl. 6, figs. 3-4 (?).

Genital plates not distally prolonged; edge of genital pores usually not much elevated; aboral side of test and apical system with numerous small miliary tubercles; 6-8 columns of primary tubercles in each interambulacrum on at ambitus; pores on oral side not forming arcs of three till after 12th-15th pore (or more) from peristome; blue spots in naked interambulacral area united into a continuous line; colour of test and radioles usually brown.

Known only from the Japanese Seas (from Sagami Sea to off Goto Islands). 50-135 metres in depth.

Genus Diadema [HUMPHREY, 1797] GRAY, 1825

Diadema HUMPHREY, 1797, p. 64.—GRAY, 1825, p. 426.—PETERS, 1855, p. 109.—A. AGASSIZ and H. L. CLARK, 1908, p. 111.—MORTENSEN, 1940, p. 241.

- Logotype.—Echinometra setosa LESKE, 1778, p. 100, pl. 37, figs. 1-2. [A. AGASSIZ and H.L. CLARK, 1908, p. 111].
- Centrechinus Jackson, 1912, p. 27-28, foot-note (pro Diadema Gray, 1825, non Schumacher, 1817, nec Ranzani, 1817).—H. L. Clark, 1946, p. 296.

Orthotype.—Cidaris (Diadema) antillarum Philippi, 1845, p. 355.

Interambulacral primary radioles rough with minute teeth and hollow; ambulacral radioles not essentially different from those of interambulacra; test moderately high, round, its vertical diameter 0.4 of horizontal or more; buccal plates without radioles; no globiferous pedicellariae; primary ambulacral tubercles conspicuous, in two regular series; ambulacra with few or no secondary tubercles aborally and narrower there than at ambitus; pore-zones not in a single series adorally.

Diadema setosum (LESKE, 1778) (Ph-APT)

Echinometra setosa LESKE, 1778, p. 100, pl. 37, figs. 1-2.—Diadema setosum (LESKE) GRAY, 1825, p. 426.—A. AGASSIZ, 1872-74, pp. 103, 274, 408 (pro parte).—YOSHIWARA (TOKUNAGA), 1905, pl. 5, figs. 1-4.—Centrechinus setosus (LESKE): H. L. CLARK, 1921, p. 146, pl. 17, figs. 3-4.—Diadema setosum (LESKE): MORTENSEN, 1934-b, p. 5, pl. 7.—IKEDA, 1939-a, p. 167, pl. 11, fig. 7.—MORTENSEN, 1940, p. 256, pl. 49, figs. 1-2, pls. 50-51, pl. 52, fig. 3, pl. 53, fig. 1, pl. 54, figs. 2-3, pl. 55, figs. 1-3, pl. 56, figs. 1-13, pl. 60, figs. 1-2, pl. 61, fig. 1, pl. 75, fig. 1, 10-12, pl. 74, fig. 15, 17-18, 20, text-figs. 140-141a.
Diadema clarki IKEDA, 1939-a, p. 165, pl. 11, figs. 1-4.

Conspicuous white or light coloured spots (or streaks) present aborally, one in each interambulacrum; second series of interambulacral tubercles begins with 5th or 6th of 7th or even 8th coronal plate; oral region red, reddish white or white; a red ring round the anal opening; blue spots on the apical plates; primary radioles rather slender, fragile, with about 20-30 longitudinal series of teeth; valves of tridentate pedicellariae compressed, and very slender.

From the Japanese Seas (from Sagami Sea to Bonin Islands) to Ryukyu Islands and Formosa, and widely distributed over the Indo-West Pacific region, from East Africa to Australia and Polynesian Islands.

Littoral zones-70 metres in depth.

Diadema savignyi (AUDOUIN) MICHELIN, 1845 (C-P)

Cidarites savignyi AUDOUIN, 1828, pl. 6, fig. 13.—Diadema savignyi (AUDOUIN) MICHELIN, 1845, p. 187 (15 of reprint).—MORTENSEN, 1904, pp. 15, 16, pl. 3, fig. 8, pl. 4, fig. 37, pl. 5, figs. 7, 9.—Centrechinus savignyi (MICHELIN) H. L. CLARK, 1921, p. 147, pl. 17, figs. 1-2.— IKEDA, 1939-a, p. 167, pl. 11, figs. 5-6.—MORTENSEN, 1940, p. 265, pl. 48, fig. 1, pl. 49, fig. 4, pl. 52, figs. 1-2, pl. 53, figs. 2-5, pl. 54, figs. 4-12, pl. 55, figs. 4-6, pl. 74, figs. 10-14, 16, 19, text-figs. 142b, 143.

Apical system large, larger than peristome; interambulacra in the adult usually with only 5 series of large tubercles, and second series of tubercles begins on 6th (sometimes 5th or 7th) coronal plate; no white anywhere, but a red purple tinge generally more or less evident, especially orally; no red ring round the anal opening; ambulacra rather wide, about one-third of interambulacra; valves of large tridentate pedicellariae without notch, simply leaf- or spoon-shaped; colour usually with more or less of a reddish cast.

From the Japanese Seas (from Tanabe Bay to Bonin Islands) to Ryukyu Islands, and widely distributed over the Indo-West Pacific region, from Natal and Zanzibar on the west to Easter Island on the east and north to Cape Gardafui.

Littoral zones-60-70 metres in depth.

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Genus Echinothrix PETERS, 1853

Echinothrix Peters, 1853, p. 484.—Nisiyama, 1966, p. 178.

Logotype.—Echinus calamaris PALLAS, 1774, p. 31, pl. 2, figs. 4-7, 8a, 8A-8B. [COTTEAU, 1861-67 (67), p. 812.—A. AGASSIZ and H.L. CLARK, 1908, p. 115].

Primary radioles rough, hollow; aboral ambulacral radioles very fine, setiform, retrorsely barbed at point; primary ambulacral tubercles very small, not forming two regular series; ambulacra with numerous secondary tubercles aborally and distinctly wider there than at the ambitus; test round; pore-zones not in a single series adorally; no globiferous pedicellariae.

Echinothrix calamaris (PALLAS, 1774) (C-P)

Echinus calamaris PALLAS, 1774, p. 31, pl. 2, figs. 4-7, 8a. 8A-8B. Echinothrix calamaris (PALLAS): NISIYAMA, 1966, p. 180, pl. 3, figs. 6-9 (fossil).

Ambulacra usually conspicuously raised aborally, a naked sunken median area aborally in interambulacra; interambulacral primary radioles fragile, diameter of inner cavity (lumen) large, more than half diameter of radioles; distinctly verticillate, minute teeth covering arranged in distinctly separated whorls; ambulacral tubercles not enlarged at ambitus; anal tube large, swollen, with numerous small, round, thick, white plates.

From the Japanese Seas (from Tanabe Bay to Bonin Islands) to Ryukyu Islands, and ranges throughout the Indo-West Pacific region, from Natal and the Red Sea to Hawaii and Tahiti, and known only from the Low Isles and Murray Islands at the northern end of the Great Barrier Reef.

Littoral zones-70 metres in depth.

Echinothrix diadema (LINNAEUS, 1758) (C-P)

Echinus diadema LINNAEUS, 1758, p. 664 (Habitat in M. Indico).—Echinothrix diadema (LINNAEUS) LOVÉN, 1887, pp. 125, 137, pl. 4.—MORTENSEN, 1940, p. 290, pl. 43, figs. 1-2, pl. 44, fig. 1, pl. 45, figs. 1-8, pl. 46, figs. 2-4, pl. 47, figs. 4, 6-7, pl. 48, fig. 4, pl. 71, figs. 1, 3, text-figs. 150-152.—NISIYAMA, 1942, p. 17, text-figs. 3a-b (in Japanese).—NISIYAMA, 1966, p. 180.

Echinothrix turcarum (SCHYNVOET): A. AGASSIZ, 1872-74, pp. 120, 416, pl. 2a, figs. 34-48, pl. 3a, fig. 3, pl. 24, figs. 33-36.—Yoshiwara (Токимада), 1905, pl. 6, figs. 1-2.

Ambulacra not raised aborally, no naked median area in interambulacra; interambulacral primary radioles rather solid, inner cavity (lumen) very small, much less than half diameter of radioles; primary radioles not verticillate, minute teeth covering arranged in crowded longitudinal series and not in distinct whorls; ambital ambulacral tubercles enlarged; interambulacral tubercles in adult specimens usually not more than three to each plate at ambitus; anal tube large, swollen, without small, round, white plates.

From the Japanese Seas (Tanabe Bay) to Ryukyu Islands and to the Philippines, and distributed as in mostly as *Ech. calamaris*.

In littoral zones.

Order ARBACIOIDA GREGORY, 1900

Arbacina Gregory, 1900-b, p. 307.—Arbacioida Gregory: Nisiyama, 1966, p. 181. Stirodonta Jackson, 1912, p. 203.—Philip, 1965, p. 57. Type-family.—Arbaciidae Gray, 1855.

Test regular; coronal plates not imbricating; ambulacra compounding of usually diadematoid or arbacioid type; primary tubercles usually imperforate or rarely perforate; lantern erect; epiphyses narrow, not joining above the teeth; keeled; perignathic girdle consisting of both auricles and apophyses; apical system compact, with or without a suranal plate; radioles solid, with or without an outer layer; external gills and sphaeridia present. From the Lias to Recent.

Suborder SALENIOINA MORTENSEN, 1903

Salenina Mortensen in Delage and Hérouard, 1903, p. 235.—Nisiyama, 1966, p. 181. Calycina Gregory, 1900-b, p. 306.—Philip, 1965, p. 57. Type-familiy.—Saleniidae Agassiz, 1838.

Ambulacra compounding of the diadematoid structure, often only in adoral region; interambulacral plates with a single large tubercles; apical system with (or exceptionally without) one or more polygonal suranal plates; primary tubercles crenulate, imperforate or perforate; primary radioles of the Cidarid-type with solid axis, a naked collar and a cortex layer on shaft.

Family SALENIIDAE AGASSIZ, 1838

Saléniens Agassiz, 1838, p. 3.—NISIYAMA, 1966, p. 183. Type-genus.—Salenia GRAY, 1835.

Ambulacra plates simple to bi- or trigeminate, or polyporous; interambulacral primary tubercles large, imperforate, but crenulate; apical system with a single large suranal plate; primary radioles usually long and slender; pedicellariae of tridentate, ophicephalous, and triphyllous types; globiferous pedicellariae not found, but claviform ones may occur.

Subfamily SALENIINAE AGASSIZ, 1838

Saleninae Mortensen, 1934, p. 165.—Saleniinae Agassiz: Nisiyama, 1966, p. 184.

Periproct eccentric, not in longitudinal axis ocular (III)-genital (5).

Genus Salenocidaris A. AGASSIZ, 1869

Salenocidaris A. AGASSIZ, 1869, p. 254.—NISIYAMA, 1966, p. 185. Haplotype.—Salenocidaris varispina A. AGASSIZ, 1869, p. 254.

Ambulacral plates bigeminate only close to peristome, otherwise simple; porezones not much widened at peristome; ambulacral tubercles rather few, usually less than 15; apical system with plates not distinctly separated and covered with small, rough papillae (tubercles); primary radioles long, slender, usually thorny, more or less distinctly verticillate.

Salenocidaris pacifica (Döderlein, 1885)

Salenia pacifica Döderlein, 1885, p. 84 (12).—Döderlein, 1887, p. 52, pl. 11, figs. 9-28.— Salenocidaris pacifica (Döderlein): Mortensen, 1935, p. 364, pl. 84, fig. 2, pl. 85, figs. 22-23.

Salenocidaris miliaris: A. AGASSIZ and H. L. CLARK, 1908, p. 60, pl. 45, figs. 5-6, pl. 45, figs. 1-8 (non A. AGASSIZ, 1898).

Primary radioles long, slender, verticillate; size relatively large, diameter sometimes exceeding 16 mm; coronal plates 6-8; vertical diameter two-thirds of horizontal; papillae of apical plates arranged partly in radiating striae; secondary radioles rather thick, much curved; ocular (I) insert in adult specimens; colours of primary radioles whitish, test with purplish pigments.

Known only from the Japanese Seas (Sagami Sea). 200 metres in depth.

Salenocidaris hastigera (A. AGASSIZ, 1879)

Salenia hastigera A. AGASSIZ, 1879, p. 198.—A. AGASSIZ, 1881-a, p. 54 (pro parte), pl. 4, figs. 4-7, pl. 38, fig. 10.—A. AGASSIZ, 1904, pl. 20, fig. 8.—Döderlein, 1906, p. 177, pl. 21, fig. 1, pl. 22, fig. 1, pl. 45, fig. 3.—Salenocidaris hastigera (A. AGASSIZ) MORTENSEN, 1935, pp. 360, 640, pl. 66, figs. 1-2, pl. 85, figs. 5-7, 31-33, pl. 86, figs. 17-20.

Ambulacral primary radioles long, and broader, almost rectangular; size moderate; coronal plates 6 or 7; ocular (I) exsert, also in adult specimens.

Western Pacific, off Japan (Albatross Station 5084).

In moderate depth.

Genus Salenia GRAY, 1835

Salenia Gray, 1835, p. 58.—Nisiyama, 1966, p. 186.

Haplotype.—Cidarites scutigera MUNSTER in GOLDFUSS, 1826-33 (29), p. 120, pl. 49, figs. 4a-b (Cenomanian of Germany).

Ambulacral plates bigeminate throughout, there being one primary tubercle to each two components; pore-zones only slightly widened at peristomial edge; primary interambulacral tubercles large, crenulate; primary radioles thorny or verticillate, usually slightly curved; suranal plate in contact with all five genital plates.

Salenia cincta A. AGASSIZ and H.L. CLARK, 1907

Salenia cincta A. Agassiz and H. L, Clark, 1908-b, p. 115.—A. Agassiz and H. L. Clark, 1908, p. 55, pl. 45, figs. 22-25, pl. 52, figs. 8-13, pl. 57, figs. 1-3.—Mortensen, 1935, p. 374, pl. 66, figs. 10-11, pl. 84, fig. 3, pl. 85, figs. 9-10.

Peristome about half of test-diameter; apical system rather large, deep purplish; ocular (I) insert; primary radioles about 10 or more (as many as 16) reddish bands, not broader than whitish or greenish bands alternating with them; tridentate pedicellariae lacking; no red-brown pigment on test or secondaries.

From the Japanese Seas (Sagami Sea to Kagoshima Gulf) to Kei Islands.

170-520 metres in depth.

Salenia unicolor MORTENSEN, 1934

Salenia unicolor Mortensen, 1934, p. 166.—Mortensen, 1935, p. 379, pl. 66, figs. 7-8, pl. 84, fig. 7, pl. 85, figs. 12-13, 39-40, pl. 86, figs. 5-8, text-fig. 197.

Primary radioles long, slender, slightly verticillate but nearly smooth; size rather small; vertical diameter slightly over half of horizontal; primary radioles white, not banded with red, and no coloured pigments on test and secondaries.

Known only from the Japanese Seas (Sagami Sea).

200 metres in depth.

Suborder PHYMOSOMATOINA Mortensen, 1904

Phymosomina MORTENSEN, 1904, p. 56.—PHILIP, 1965, p. 57.—Phymosomatoina MORTENSEN: NISIYAMA, 1966, p. 190. Tuto famile – Phymosometidae Double 1892

Type-family.—Phymosomatidae POMEL, 1883.

Ambulacra compounding usually of the diadematoid type, trigeminate or polyporous, or rarely simple throughout; apical system without an angular suranal plate; primary radioles usually with solid axis, with or without a cortex layer; interambulacral plates generally with more than one smooth tubercle, but only one in some forms and rarely crenulate; pedicellariae, in the Recent forms, ophicephalous, tridentate, triphyllous, and globiferous types; sphaeridia placed along the tube-feet, not in pits.

Family Phymosomatidae Pomel, 1883

Phymosomiens POMEL, 1883. p. 90.—Phymosomatidae POMEL: NISIYAMA, 1966, p. 191. Type-genus.—Phymosoma HAIME in D'ARCHIAC and HAIME, 1853.

Ambulacral plates simple to compound, in the more specialized forms polyporous and diploporous; primary tubercles crenulate, but imperforate; apical system dicyclic or monocyclic; periproct sometimes covered with large, polygonal plates; peristome generally rather large, with distinct gill-slits; primary radioles simple, with a thin cortex layer and a distinct collar.

Genus Glyptocidaris A. AGASSIZ, 1863

Glyptocidaris A. AGASSIZ, 1863-a, p. 356.—NISIYAMA, 1966, p. 192. Haplotype.—Glyptocidaris crenularis A. AGASSIZ, 1863-a, p. 356.

Ambulacra with polyporous plates, five pore-pairs to each compound plate, arranged in alternating arcs of three and two, and pore-pairs arranged in a single series adapically, in double series only at ambitus; a regular series of primary tuber-

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cles in ambulacra and interambulacra; the tubercles distinctly crenulate; apical system with ocular (I) insert; pedicellariae of ophicephalous, tridentate, triphyllous, and globiferous types.

Glyptocidaris crenularis A. AGASSIZ, 1863

Glyptocidaris crenularis A. AGASSIZ, 1863-a, p. 356.—NISIYAMA, 1966, p. 193 (fossil).

Median interambulacral space bare; tubercles increasing very gradually towards oral side, where they are large, crenulate; on oral side, a series of almost equally larger tubercles on each side of primary series; radioles long, stout, and longitudinally striated; colours of test and radioles yellowish cream or brownish yellow.

Known only from northern Japan and northern Sea of Japan (as far south as Onahama Bay on the Pacific side).

10-150 metres in depth.

Family STOMECHINIDAE POMEL, 1883

Stomechiniens POMEL, 1883, p. 81.—NISIYAMA, 1966, p. 197.
Type-genus.—Stomechinus DESOR, 1856.
Stomopneustidae MORTENSEN, 1903-b, p. 133.—PHILIP, 1965, pp. 57, 61.
Type-genus.—Stomopneustes AGASSIZ, 1841.

Ambulacra with compound, trigeminate, or polyporous plates, rarely with simple plates adapically; a diplopodous arrangement occurs adapically or throughout the ambulacra; apical system usually small, dicyclic or monocyclic, rarely slightly extending into posterior interambulacrum (5); primary tubercles imperforate, non-crenulate; peristome rather large; gill-slits rather large and deep.

Genus Stomopneustes AGASSIZ, 1841

Stomopneustes AGASSIZ, 1841, p. 7.—NISIYAMA, 1966, p. 198. Orthotype.—Echinus variolaris LAMARCK, 1816, p. 47.

Ambulacra with compound plates consisting of 4-6 trigeminate plates covered by a very large primary tubercle; pore-zones broad, somewhat petaloid on oral side; primary tubercles with a large, high boss, on aboral side numerous but a very narrow areole; a very conspicuous undulating, sunken median furrow in each interambulacrum on aboral side; radioles cylindrical, simply pointed; without an outer layer or collar; pedicellariae of four types, globiferous, tridentate, ophicephalous and triphyllous ones.

Stomopneustes variolaris (LAMARCK, 1816) (C-P)

Echinus variolaris LAMARCK, 1816, p. 47.—Stomopneustes variolaris (LAMARCK) AGASSIZ, 1841-a, p. x.—A. AGASSIZ, 1872-74, pp. 176, 437, pl. 4b, figs. 1-3.—YOSHIWARA (TOKUNAGA), 1906, pl. 9, figs. 9-10.—MORTENSEN, 1935, p. 507, pl. 71, figs. 3-5, pl. 72, figs. 1-2, pl. 89, figs. 16-26, text-figs. 301-302.—HAYASAKA, 1948, p. 30, pl. 5, figs. 4a-b.—NISIYAMA, 1966, p. 200, pl. 4, figs. 1-2.

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Test stout, more or less irregular in outline; primary radioles long and stout; colour very dark, greenish or purplish-black.

From the Japanese Seas (Sagami Sea and Tanabe Bay) to Ryukyu Islands, and widely distributed over the Indo-West Pacific, from East Africa to Samoa.

In littoral zones.

Suborder ARBACIOINA GREGORY, 1900

Arbacina Gregory, 1900-b, p. 307.—Arbaciina Gregory: Philip, 1965, p. 57.—Arbacioina
 Gregory: Nisiyama, 1966, p. 201.
 Type-family.—Arbaciidae Gray, 1855.

Ambulacra compounding of the arbacioid type; primary tubercles imperforate, smooth; surface of corona usually covered with an epistroma; periproct (always?) covered by four or five large plates; primary radioles with solid axis, cortex layer more or less developed.

Family Arbaciidae Gray, 1855

Arbacidae Gray, 1855, p. 36.—Arbaciidae Gray: Nisiyama, 1966, p. 201. Type-genus.—Arbacia Gray, 1835.

Test generally quite solid, coronal plates being soldered together by means of small knobs and sockets; ambulacra trigeminate, more rarely simple or polyporous; primary radioles with a cortex layer, with may be lacking on aboral ones; ocular pores usually double; pedicellariae of tridentate, triphyllous, and ophicephalous types.

Genus Coelopleurus AGASSIZ, 1840

Coelopleurus Agassiz, 1840-a, pp. 12, 19.—Mortensen, 1935, p. 605, textfigs. 361-362.—Nisiyama, 1966, p. 204.

Logotype.—Coelopleurus equis (VALENCIENNES) AGASSIZ, 1840-a, p. 12.—Cidaris coronalis LESKE, 1778, p. 136, pl. 8, figs. A-B. [A. AGASSIZ and H. L. CLARK, 1908, p. 82].

Ambulacra usually somewhat elevated, with trigeminate compound plates throughout; pore-zones simple, slightly widened at peristome; interambulacra with primary tubercles confined to oral side, rather abruptly disappearing above the ambitus; primary radioles usually very long, usually curved, pointed with a long collar, distal part with a smooth outer layer; a series of 6—12 pits in ambulacral midline adorally, each with sphaeridium; usually large forms, conspicuously coloured with red or purple; upper part of interambulacra offering a conspicuous naked, more or less sunken, median spaces.

Coelopleurus maculatus A. AGASSIZ and H. L. CLARK, 1907

Coelopleurus maculatus A. AGASSIZ and H. L. CLARK, 1907-b, p. 116.—NISIYAMA, 1966, p. 206, pl. 2, figs. 12-13 (fossil).

Ground colour of primary radioles bright green, bands of radioles red; collar about five per cent of radiole-length and rough with 12-15 conspicuous longitudinal

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ridges and with distal margin horizontal; valves of ophicephalous pedicellariae slightly constricted, the least with exceeding 0.6 of length; secondary radioles of aboral side distinctly club-shaped.

From the Japanese Seas (from Sagami Sea to Korean Strait and Kagoshima Gulf) to the Philippines and Kei Islands.

70-360 metres in depth.

Coelopleurus undulatus MORTENSEN, 1934

Coelopleurus undulatus Mortensen, 1934, p. 166.—Mortensen, 1935, p. 662, pl. 69, figs. 5-7, pl. 88, figs. 13-16, text-figs. 367-368.

Naked median area not sharply limited against lateral parts; undulating median line whitish; primary radioles curved; valves of ophicephalous pedicellariae constricted.

Known only from the Japanese Seas (Sagami Sea).

400 metres in depth.

Coelopleurus undulatus polymorphus MORTENSEN, 1935

Coelopleurus undulatus polymorphus MORTENSEN, 1935, p. 625, pl. 67, fig. 6, pl. 69, figs. 8-9, pl. 88, figs. 7-12.

Undulating median line purplish, other like the typical species.

Known only from the Japanese Seas (off Goto Islands, Lat. 33°41'N., Long. 128° 50'E.)

In 135 metres depth.

Order ECHINOIDA CLAUS, 1876

Echinideae Claus, 1876, p. 356.—Echinoida Claus: Nisiyama, 1966, p. 207. Camarodonta Jackson, 1912, p. 203.—Philip, 1965, p. 57. Type-family.—Echinidae Gray, 1825.

Test regular; coronal plates not imbricating; only 20 columns of plates; tubercles perforate or imperforate, crenulate or non-crenulate; primordial interambulacral plates not persisting; ambulacra simple or compounding, of the diadematoid or echinoid type; apical system regular, dicyclic or with oculars partly insert, or monocyclic; peristome with buccal plates or only with irregular non-ambulacral plates; radioles solid, only exceptionally with a small axial cavity; no cortex layer; lantern erect; epiphyses joining above teeth so as to form a closed foramen; teeth keeled; perignathic girdle consisting of radial auricles, usually joining at their upper ends, connecting by an interradial apophysis; peristomial gills and sphaeridia present. From the Cretaceous Period to Recent.

Suborder TEMNOPLEUROINA MORTENSEN, 1942

Temnopleurina Mortensen, 1942, p. 225.—Philip, 1965, p. 58.—Temnopleuroina Mortensen: Nisiyama, 1966, p. 209. Type-family.-Temnopleuridae A. AGASSIZ, 1872.

Ambulacra compounding of the diadematoid or echinoid type; test sculptured or not, if not sculptured the branchial slits sharp and more or less deep; tubercles perforate, or imperforate, crenulate or smooth; primary radioles with solid axis.

Family TEMNOPLEURIDAE A. AGASSIZ, 1872

Temnopleuridae A. AGASSIZ, 1872-74 (72), p. 285.—NISIYAMA, 1966, p. 210. Type-genus.—Temnopleurus A. AGASSIZ, 1841.

Ambulacra with trigeminate plates of the echinoid type; pore-zones mostly narrow without adoral widening; primary tubercles imperforate, usually crenulate or smooth; test usually more or less conspicuously sculptured, by pits or depressions in the sutures or on the plates; buccal membrane generally naked outside the buccal plates; pedicellariae of the usual four main types, tridentate type, however, often lacking in small forms; spicules usually of bihamate type (C-form).

Subfamily TEMNOPLEURINAE A. AGASSIZ, 1872

Temnopleurinae Duncan, 1889-a, p. 97.—Temnopleurinae A. Agassiz: Nisiyama, 1966, p. 211.

Angular pits or pores usually present (may be obliterate in adult specimens), but no depressions or sculpture on the plates; plates, in larger forms, united by dowelling; poison glands of globiferous pedicellariae double.

Genus Temnopleurus AGASSIZ, 1841

Temnopleurus AGASSIZ, 1841, p. 7.—NISIYAMA, 1966, p. 211. Orthotype.—Cidaris toreumatica LESKE, 1778, p. 155, pl. 10, fig. E.

Mainly larger forms with tubercles very distinctly crenulate; angular pits sharp, not widening towards the primary tubercles; ambulacral plates trigeminate, all with a primary tubercle of about same size as interambulacral primary ones; anal opening central or subcentral; 10 buccal plates; radioles simple, finely striated; globiferous pedicellariae of one kind only, with or without lateral teeth.

Temnopleurus toreumaticus (LESKE, 1778) (C-T) (Ph-APT, CPT)

Cidaris toreumatica LESKE, 1778, p. 155, pl. 10, fig. E.—Temnopleurus toreumaticus (LESKE): NISIYAMA, 1966, p. 213, pl. 4, figs. 3-4, 7, 10, 12.

Radioles, at least on oral side, usually banded, dark olive with whitish, or white with reddish bands; pits of horizontal sutures large with sharp edge; anal opening subcentral; apical system not raised; all oculars excluded from periproct; globiferous pedicellariae with 1-1 small, but distinct lateral teeth; ophicephalous pedicellariae distinctly sinuate at the edge; spicules bihamate only.

From the Japanese Seas (from Tokyo Bay to Bingo and Kagoshima Gulf) to

Ryukyu Islands and Formosa, and widely distributed over the Indo-West Pacific from East Africa to Australia.

Temnopleurus hardwickii (GRAY, 1855) (Ph-APT, CPT)

Toreumatica hardwickii GRAY, 1855, p 39.—Temnopleurus hardwickii (GRAY): NISIYAMA, 1966, p. 215, pl. 4, figs. 8-9, 13, pl. 5, figs. 1-2.

Primary radioles very dark (almost black or dark brown) at base, not banded; pits of horizontal sutures bevelled, especially in larger specimens; anal opening subcentral; system raised; poriferous zone narrow, pore-pairs small in a vertical series close to margin of ambulacrum; globiferous pedicellariae without lateral teeth; ophicephalous pedicellariae with the edge very little sinuated; spicules bihamate only.

Known only from the Japanese Seas (Hakodate Bay, Mutsu Bay, Sendai Bay, Sagami Bay, and off Kobe (Challenger)).

5-35 metres in depth.

Temnopleurus hardwickii impressus Mortensen, 1942

Temonopleurus hardwickii var. impressus Mortensen, 1942, p. 226.—Mortensen, 1943, p. 87, pl. 2, figs. 16-18.

Differs from the typical species in the radioles being much longer and in their general colour being more brownish; denuded test much more sculptured than the typical form, pits being much deeper, and apical system much more elevated than in the typical form.

Known only from the Formosan Channel. In 65 metres depth.

Subgenus Toreumatica GRAY, 1855

Toreumatica GRAY, 1855, p. 39.—NISIYAMA, 1966, p. 217. Logotype.—Toreumatica reevesii GRAY, 1855, p. 39. [Mortensen, 1943, p. 92].

Differs from typical *Temnopleurus* in the strongly eccentric position of the anal opening and the presence of a distinct suranal plate. The pits usually remain distinct also on the oral side of the test, and the test sculpture may be very strongly developed.

Temnopleurus (Toreumatica) reevesii (GRAY, 1855)

Toreumatica reevesii GRAY, 1855, p. 39.—Temnopleurus (Toreumatica) reevesii (GRAY): NISI-YAMA, 1966, p. 217, pl. 4, figs. 11, 14 (fossil), text-figs. 8a-e.

Buccal plates well developed, carrying tube-feet; primary radioles about as long as the diameter of test, light greenish-brown, not banded; ocular (I) nearly or quite insert; a distinct anal plate found, even in larger specimens; ambulacral pores distant from edge of ambulacral area; pits very small on aboral side, almost as in *Salmacis*; spicules biacerate and bihamate. From the Japanese Seas (from Sagami Sea to Kagoshima Gulf) to the Philippines, and distributed over the Indo-West Pacific, from East Africa to the Malacca Strait.

Temnopleurus (Toreumatica) apodus (A. AGASSIZ and H. L. CLARK, 1907)

Genocidaris apodus A. AGASSIZ and H. L. CLARK, 1907-b, p. 126.—H. L. CLARK, 1912-b, p. 297, pl. 93, figs. 16-17, pl. 100, figs. 1-3.—*Temnopleurns (Toreumatica) apodus (A. A. AGASSIZ and H. L. CLARK) MORTENSEN*, 1943, p. 99, pl. 3, figs. 3, 31-33, pl. 45, figs. 10-12, 17, text-figs. 61a-b, 62.

Prymnechinus proctalis KOEHLER, 1927, p. 100, pl. 17, figs. 11-12, 14.

Size small, rarely attains 7 mm in horizontal diameter; 8 coronal plates in each interambulacral column; sculpturing of test well marked in mid-zone and adorally; only 5 distinct buccal plates, and only 5 buccal tube-feet; primary radioles remark-ably long and slender; globiferous and ophicephalous pedicellariae present.

From the Japanese Seas (from Sagami Sea to Goto Islands) to the Kei Islands and to Andamann, and rather widely distributed from Malay Archipelago to Pemba Strait (East Africa).

160-500 metres in depth.

Although this species is classified with the preceding (*Tem. reevesii*) into the subgenus, it strikingly differs from the preceding in the character of the buccal plates. If there is the necessity of separating this species as a distinct genus or subgenus from the preceding, it is to be the name *Prymnechinus*.

Genus Salmacis AGASSIZ, 1841

Salmacis Agassiz, 1841-a, p. viii.-Mortensen, 1904, p. 75.-Mortensen, 1943, p. 109.-H.L. Clark, 1946, p. 109.

Orthotype.-Salmacis bicolor Agassiz, 1841-a, p. viii.

Melobosis GIRARD, 1851, p. 365.—Pomel, 1883, p. 87.

Haplotype.—Melobosis mirabilis GIRARD, 1851, p. 365.=Echinus sphaeroides LINNAEUS, 1758, p. 664.

Angular pores usually very distinct, the pits large enough to form furrow along horizontal suture; interambulacral plates at ambitus each carry 4-9 subequal primary tubercles; tubercles usually distinctly crenulated; no distinctly limited naked interambulacral area, either along vertical or horizontal sutures; globiferous pedicellariae not with the blade widened, at most with 1-1 lateral teeth.

Salmacis bicolor AGASSIZ, 1841

Salmacis bicolor. AGASSIZ, 1841-a, p. viii—AGASSIZ and DESOR, 1846, p. 359.—A. AGASSIZ, 1872-74, pp. 156, 471, pl. 8a, figs. 11-12.—Döderlein, 1903, p. 714, pl. 61, figs. 6-10.— MORTENSEN, 1904, p. 65, pl. 6, figs. 2, 4, 23, 26, 39, 40, pl. 7, fig. 1.—MORTENSEN, 1943, p. 112, pl. 4, figs. 1-8, pl. 5, figs. 1-3, 10-12, pl. 6, figs. 1-8, pl. 46, figs. 1, 13, 16, 19-20, text-fig. 67.—UTINOMI, 1962, p. 104, text-fig. 5.

.Salmacis rarispinus AGASSIZ and DESOR, 1846, p. 359.—A. AGASSIZ, 1872-74, pp. 156, 475, pl. 8a, figs. 4-6.—Döderlein, 1903, p. 719, pl. 64, figs. 3-3c.

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Pores mostly not reaching the edge of the area; tubercles occur outside the pores; primary radioles more or less bright red, at least at base, banded; small radiolesbright red; globiferous pedicellariae of two kinds, large one without lateral teeth and small ones with unpaired lateral tooth; tridentate pedicellariae with short and broad valves.

From the Japanese Seas (Tanabe Bay) to the Philippines, and rather widely distributed the Indo-West Pacific, from Zandzibar to Siam.

Littoral zones-72 metres in depth.

Genus Salmaciella MORTENSEN, 1942

Salmaciella MORTENSEN, 1942, p. 226.—NISIYAMA, 1966, p. 219. Orthotype.—Salmacis dussumieri AGASSIZ in AGASSIZ and DESOR, 1846, p. 359.

Primary ambulacral tubercles occurring fairly on every second plates on aboral side; at ambitus they found on all the plates, but on every second plate placed inwards so they form here two longitudinal series; pore-zones narrow; shape of test low, peristomial edge conspicuously sunken; anal opening eccentric, pushed out towards genital (1).

Salmaciella dussumieri (AGASSIZ, 1846)

Salmacis dussumieri AGASSIZ in AGASSIZ and DESOR, 1846, p. 359.—A. AGASSIZ, 1872-74, p. 473, pl. 8b, figs. 7-8.—Döderlein, 1903, p. 715, pl. 63, figs. 5-5c.—Mortensen, 1904, p. 72, pl. 7, fig. 15.—Salmaciella dussumieri (AGASSIZ): Mortensen, 1943, p. 139, pl. 8, fig. 9, pl. 9, fig. 7, pl. 10, fig. 3, pl. 11, figs. 8-13, pl. 56, figs. 8-9, 18, 21-22, text-figs. 77-79, 48a.
Salmacis lactea Döderlein, 1885, p. 94.—YOSHIWARA (TOKUNAGA), 1906, pl. 8, figs. 13-16.

Test low, vertical diameter less than one half the horizontal one; primary radioles white or greenish white with two or three broad bands of purple or purplish red, or the dark colour may predominate, the white disappering and the bands becoming indistinct; secondary and miliary radioles not all vermillion-red; peristome much sunken.

From the Japanese Seas (Tanabe Bay and Amakusa Islands) to the Philippines,. and distributed from Ceylon to Torres Strait.

10-180 metres in depth.

Genus Microcyphus AGASSIZ, 1841

Microcyphus Agassiz, 1841-a, p. viii.—Agassiz and Desor, 1846, p. 358 (54).—H. L. CLARK,. 1946, p. 314.—Mortensen, 1943, p. 148. Orthotype.—Microcyphus maculatus Agassiz, 1841-a, p. viii. Salmacopsis Döderlein, 1885, p. 93.

Haplotype.-Salmacopsis olivacea Döderlein, 1885, p. 93.

Usually with a distinctly limited naked area in the midline and along the horizontal interambulacral sutures; adoral interambulacral plates not noticeably different from aboral ones; coronal plates usually few, with small pits or none; globiferous. pedicellariae not with the blade widened, at most with 1-1 lateral teeth.

Microcyphus olivaceus (Döderlein, 1885)

Salmacopsis olivacea Döderlein, 1885, p. 93 (21).—Mortensen, 1904, p. 96, pl. 6, figs. 25, 30, pl. 7, fig. 23.—H. L. Clark, 1912-b, p. 324, pl. 103, figs. 6-7, pl. 112, figs. 3-4.—Microcyphus olivaceus (Döderlein) Mortensen, 1943, p. 163, pl. 19, figs. 42-44, pl. 47, figs. 6, 10, 14, 27, 29, text-figs. 87a, c, 88a-b, 89-90.

Test low, hemispherical; radioles without red bands; distinct horizontal series of larger tubercles on ambital-subambital interambulacral plates; outer part of genital plates separated from inner part by a transverse line; primary radioles smooth, ending in a mostly rather long central thorn, surrounded at its base by a circle of smaller thorns; secondary radioles faintly thorny, a little swollen at point; more or less green in colour.

Known only from the Japanese Seas (from Sagami Sea to Kagoshima Gulf). 70-170 metres in depth.

Genus Opechinus DESOR, 1856

Opechinus DESOR, 1855-58(56), p. 107.-H.L. CLARK, 1912-b, p. 310.-LAMBERT and JEANNET, 1935, pp. 7, 24.-MORTENSEN, 1943, p. 300, text-figs. 165-166.

Logotype.—Temnopleurus costatus D'ARCHIAC and HAIME, 1853-54 (53), p. 204, pl. 13, fig. 8 (Oligocene of India). [POMEL, 1883, p. 85].

Pseudopechinus LAMBERT and THIÉRY, 1911, p. 232.

Orthotype.-Temnopleurus costatus D'ARCHIAC and HAIME, 1853-54 (53), p. 204.

Test subglobular; tubercles not forming horizontal series on oral side; sculpturing of test consisting of a series of depressions along horizontal interambulacral sutures at ambitus, not elongate vertically; there are four of these on each suture at ambitus.

Opechinus variabilis (DÖDERLEIN, 1885)

Pleurechinus variabilis DÖDERLEIN, 1885, p. 90.—DÖDERLEIN, 1903, p. 706, pl. 61, figs. 4-4b.— Opechinus variabilis (DÖDERLEIN) MORTENSEN, 1904, p. 94, pl. 6, fig. 27, pl. 7, fig. 2.— Pleurechinus variabilis DÖDERLEIN: YOSHIWARA (TOKUNAGA), 1906, pl. 8, figs. 5-7 (reproduced from DÖDERLEIN, 1903).—Opechinus variabilis (DÖDERLEIN): MORTENSEN, 1943, p. 303, pl. 18, figs. 35-36, pl. 50, figs. 15, 18, 22, text-figs. 167a-b, 168a, 169.

Each horizontal interambulacral suture in mid-zone, with four large shallow depressions; a distinct suranal plate distinguishable on periproct; test dark olive, with a white spot in interambulacra.

Known only from the Japanese Seas (from Sagami Sea to Goto Islands). 100-550 metres in depth.

Genus Mespilia DESOR, 1846

Mespilia DESOR in AGASSIZ and DESOR, 1846, p. 357(53).—NISIYAMA, 1966, p. 230. Haplotype.—Echinus globulus LINNAEUS, 1758, p. 664.

Test globular or hemispherical, of moderate size; coronal plates low and numerous, with very small pits, the pits often obsolete in adult specimens; median aboral interambulacral areas more or less extensively bare and free from radioles and tubercles; naked part of a peculiar porous-radiating structure; pore-pairs distinctly biserial; valves of small globiferous pedicellariae with flattened and widened blade.

Mespilia globulus (LINNAEUS, 1758) (C-T)

Echinus globulus LINNAEUS, 1758, p. 664.—*Mespilia globulus* (LINNAEUS): MORTENSEN, 1943, p. 177, pl. 12, figs. 1–17, pl. 21, fig. 19, pl. 35, figs. 9, 18, 20, 32, text-figs. 98–102.—NISIYAMA, 1966, p. 231, pl. 6, fig. 1 (semi-fossil).

Test and radioles dark olive tinged with red; radioles often brownish yellow to reddish, or rarely purple.

From the Japanese Seas (from Sagami Sea to Kagoshima Gulf) to Ryukyu Islands, and from the Philippines to Malay region.

Littoral zones-60 metres in depth.

Mespilia globulus pellocrica H.L. CLARK, 1912

Mespilia globulus var. pellocrica H. L. Clark, 1912-b, p. 322.—Ікеда, 1935, p. 423 (in Japanese). —H. L. Clark, 1946, p. 315.

Radioles white ground with bands of purple, often dark, and lack all red tints in colouration.

Known from the islands of western Pacific (Ryukyu Islands) and the Philippines. In littoral zones.

Mespilia globulus albida H. L. CLARK, 1925

Mespilia globulus var. albida H. L. CLARK, 1925, p. 93.—IKEDA, 1935, p. 424, text-figs. 1-2 (in Japanese).

Ground colour of test light olive-green, with no trace of red; median ambulacral areas above ambitus, more or less median interambulacral areas, and nearly all tubercles, white with a slightly greenish tinge.

From the Japanese Seas (Tanabe Bay and Shimane Peninsula) to Ryukyu Islands. In littoral zones.

Mespilia globulus levituberculata YOSHIWARA, 1898

Amblypenustes vegae Lovén: Döderlein, 1885, p. 110 (38), no description.

Mespilia levituberculata Yoshiwara, 1898, p. 58.—Yoshiwara (Tokunaga), 1906, pl. 8, figs. 20-23.—Mespilia globulus levituberculata Yoshiwara: Mortensen, 1943, p. 184.

Ground colour of test reddish with yellow or green interambulacral bared area; radioles longitudinally striated with orange stripes, and tipped with white.

Known only from the Japanese Seas (from Sagami Sea to Kagoshima Gulf). Littoral zones—60 metres in depth.

Genus Temnotrema A. AGASSIZ, 1863

Temnotrema A. AGASSIZ, 1863-a, p. 358.—H. L. CLARK, 1912-b, p. 317.—NISIYAMA, 1966, p. 221.
 Haplotype.—Temnotrema sculpta A. AGASSIZ, 1863-a, p. 358.

Size small, rarely more than 20 mm in diameter; coronal plates with deep, conspicuous, usually oblong pits at sutural angles and on their horizontal sutures; angular pits rather narrow, with deep edges; poriferous zones narrow, pore-pairs in an approximately vertical series; every ambulacral plate with a primary tubercles close beside poriferous zone; primary tubercles small, usually non-crenulate; primary radioles short, rather robust, smooth, usually terminating in a small knob, or very slender; globiferous pedicellariae with a lateral tooth on each side, or without lateral teeth.

Temnotrema sculptum A. AGASSIZ, 1863

Temnotrema sculpta A. AGASSIZ, 1863-a, p. 358.—H. L. CLARK, 1912-b, p. 321, pl. 112, figs. 1-2.—Temnotrema sculptum A. AGASSIZ: NISIYAMA, 1936, p. 121, pl. 11, figs. 10-16.—MORTENSEN, 1943, p. 249, pl. 19, figs. 1-2, pl. 45, figs. 1-3, 15, text-figs. 133a-b, 134.—NISIYAMA, 1966, p. 224, text-figs. 10-14.

Pits small, the distance between the two of same horizontal interambulacral suture greater (often much greater) than the length of one; ambulacral plates equal interambulacral in height and number; pores very small; test variegated gray and whitish; radioles reddish at base, often with a small dark band distally; anal opening is not central; there is a distinct anal plate; outer part of genital plates separated from the inner part by a sinuous line.

Known only from the Japanese Seas (from Mutsu Bay to Formosan Channel). Littoral zones—ca. 500 metres in depth.

Temnotrema rubrum (DÖDERLEIN, 1885)

Pleurechinus ruber Döderlein, 1885, p. 92.—Temnotrema rubrum (Döderlein) Nisiyama, 1936, p. 125, pl. 11, figs. 1-9.—Nisiyama, 1966, p. 228, text-figs. 16a-f.

Pits small; ambulacral plates more or less lower than interambulacral ones, their number being more or less somewhat larger; colour of test reddish or reddish purple; radioles smooth, red with white bands; ocular plates showing peculiar feature of the pore completely concealed by a prominent knob; anal opening central, no distinct anal plate; globiferous pedicellariae without lateral teeth.

Known only from the Japanese Seas (Tokyo Bay and Ubara Bay, in Chiba Prefecture).

5-35 metres in depth.

Subfamily TRIGONOCIDARINAE MORTENSEN, 1903

Trigonocidarinae Mortensen in Delage and Hérouard, 1903, p. 240.—Nisiyama, 1966, p. 235.

Type-genus.-Trigonocidaris A. AGASSIZ, 1869.

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No angular pits or pores, but generally a conspicuous sculpture on plates, or depressions in horizontal sutures; plates (apparently) not united by dowelling; glands of globiferous pedicellariae simple.

Genus Prionechinus A. AGASSIZ, 1879

Prionechinus A. AGASSIZ, 1879, p. 202.—H.L. CLARK, 1912-b, p. 302.—MORTENSEN, 1943, p. 278, text-figs. 148-149.
Haplotype.—Prionechinus sagittiger A. AGASSIZ, 1879, p. 202.—A. AGASSIZ, 1881-a, pl. 6a, figs. 11-14.

No distinct sculpture on test; buccal membrane naked outside the buccal plates; periproctal plates numerous and not glassy; tubercles non-crenulate, not indented; valves of globiferous pedicellariae with usually only one, unpaired lateral tooth.

Prionechinus forbesianus (A. AGASSIZ, 1881)

- Cottaldia forbesiana A. AGASSIZ, 1881-a, p. 112, pl. 6a, figs. 15-17.—Arbacina forbesiana (A. AGASSIZ) MORTENSEN, 1903-b, p. 83, pl. 7, figs. 23, 26, 32, pl. 8, fig. 33.—Prionechinus forbesianus (A AGASSIZ) MEIJERE, 1904, p. 71, pl. 4, figs. 33-34, pl. 16, figs. 250-255.— MORTENSEN, 1943, p. 286, pl. 18, fig. 22, pl. 19, figs. 22-27, pl. 49, figs. 20-23, 27-30, 34-35, text-figs. 153-156.
- Prionechinus ruber A. AGASSIZ and H. L. CLARK, 1907-b, p. 126.—H. L. CLARK, 1912-b, p. 304, pl. 100, figs. 4-6.

Test small, attains 11 mm in horizontal diameter, 11 interambulacral and 12 ambulacral plates in each column; sculpturing almost wholly wanting; periproct covered with few, rather coarse plates, suranal plate not very conspicuous; genital pores near center of the plates; primary radioles rather short, coarse, often rather smooth; height of test not more than half the test diameter; interambulacral midline not sunken; colour of adult specimens reddish; valves of tridentate pedicellariae finely serrate distally.

From the Japanese Seas (western Japan) to Fiji Islands. 260-1370 metres in depth.

Prionechinus agassizii WOOD-MASON and ALCOCK, 1891

Prionechinus agassizii Wood-Mason and Alcock, 1891, p. 441.—Döderlein, 1906, p. 194, pl. 24, fig. 1, pl. 35, fig. 7.—Mortensen, 1943, p. 290.

Apical system not, or only slightly sculptured; height of test more than half of horizontal diameter; interambulacral midline sunken; one or more anal plates dictinctly larger than the rest; all of buccal plates large, two of each pair more or less in contact, area within their circle more or less fully plated.

From the Japanese Seas (central and western Japan) to the Indian Ocean. 270-345-3310 metres in depth.

Genus Printechinus KOEHLER, 1927

Printechinus Koehler, 1927, p. 97.—Lambert and Jeannet, 1935, p. 7. —Mortensen, 1943, p. 308.

Orthtype.-Printechinus impressus KOEHLER, 1927, p. 98, pl. 15, figs. 3-11, pl. 27, fig. 2.

Distinct depression in horizontal sutures elongate vertically; sculpture on plates little developed or lacking; periproctal plates not glassy; primary tubercles finely crenulate; buccal membrane with at least a few plates proximal to buccal plates.

Prinetechinus impressus KOEHLER, 1927

Printechinus impressus KOEHLER, 1927, p. 98, pl. 15, figs. 3-11, pl. 27, fig. 2.-MORTENSEN, 1943, p. 309, pl. 20, figs. 10-13, pl. 50, fig. 17, text-figs. 171a-b, 172a, 173.

Sutural depressions long, almost connecting primary interambulacral tubercles on aboral side; secondary tubercles well developed on oral side, forming horizontal series; large tubercles crenulate, on aboral tubercles few, leaving median part of plate bare; test subglobular, and high; radioles banded with reddish.

From the Ryukyu Islands to Andamann Islands.

110-135 metres in depth.

Genus Desmechinus H. L. CLARK, 1923

Desmechinus H. L. CLARK, 1923-c, p. 342.-MORTENSEN, 1943, p. 340. Orthotype.-Desmechinus anomalus H. L. CLARK, 1923-c, p. 342.

Gill-slits sharp and rather deep; apical system more or less distinctly obliquely elongate towards genital (1); valves of globiferous pedicellariae without lateral teeth; buccal membrane naked outside buccal plates.

Desmechinus anomalus H. L. CLARK, 1923

Desmechinus anomalus H.L. CLARK, 1923-c, p. 342.—Mortensen, 1943, p. 341, pl. 20, figs. 31-32, text-figs. 199-200.

Test of moderate size, about 30 mm in horizontal diameter; ocular plates (I) and (II) may be insert, but in the holotype (MCZ no. 4635) apical system partly broken; test depressed.

Known only from the China Sea. In ca. 100 metres depth.

Genus Lamprechinus Döderlein, 1905

Lamprechinus Döderlein, 1905, p. 622.—Döderlein, 1906, p. 190.—Mortensen, 1943, p. 334. Haplotype.—Lamprechinus nitidus Döderlein, 1905, p. 622.—Döderlein, 1906, p. 190, pl. 23, figs. 1-2, pl. 35, fig. 2, pl. 46, fig. 6.

Apical system smooth, or only very feebly sculptured, and not elongate; gillslits rather obsolete; buccal membrane naked outside buccal plates; ocular plates all exsert; valves of globiferous pedicellariae with short, open blade.

Lamprechinus sculptus MORTENSEN, 1942

Lamprechinus sculptus MORTENSEN, 1942, p. 229.—MORTENSEN, 1943, p. 336, pl. 18, figs. 19-21, pl. 49, figs. 11, 17-19, 26, text-figs. 40c, 195a, 196, 187b, 198.

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Test strongly sculptured; median area of interambulacra aborally more irregularly sculptured; tridentate pedicellariae well developed; spicules of tube-feet very numerous.

Known only from the Goto Islands. In 400 metres depth.

Family TOXOPNEUSTIDAE TROSCHEL, 1872

Toxopneustidae TROSCHEL, 1872, p. 217 (pro parte).—MORTENSEN, 1943, p. 382.—NISIYAMA, 1966, p. 238.

Type-genus.—Toxopneustes Agassiz, 1841.

Ambulacra with trigeminate to multigeminate plates of the echinoid type; porezones sometimes conspicuously widened adorally; primary tubercles imperforate, non-crenulate; test not sculptured; buccal membrane plated or more or less naked; gill-slits usually sharp and distinct; globiferous pedicellariae with single poison glands, often provided with stalk-glands, no neck; valves without lateral teeth.

Genus Nudechinus H.L. CLARK, 1912

Nudechinus H. L. CLARK, 1912-b, p. 276.—MORTENSEN, 1943, p. 399.—H. L. CLARK, 1946, p. 324. Orthotype.—Nudechinus scotiopremnus H. L. CLARK, 1912-b, pp. 276, 277, pl. 97, figs. 4-6.

Apical system not eccentric, oculars (I and V) commonly insert; a primary tubercle on each ambulacral plate; buccal membrane thin and naked save for ten buccal plates; primary radioles and tubercles not especially conspicuous; valves of globiferous pedicellariae with a large tooth at tip and no lateral teeth; size small.

Nudechinus multicolor (YOSHIWARA, 1898)

Echinus multicolor YOSHIWARA, 1898, p. 60.—Nudechinus multicolor (YOSHIWARA) H. L. CLARK, 1912-b, pp. 276, 277, pl. 111, figs. 7-8.—MORTENSEN, 1943, p. 408, pl. 22, figs. 15-17, pl. 51, figs. 9-10, 12, text-figs. 255c-d.

Test small, variegated with white and light and dark green and with purplish spots; peristome large, about half of test diameter; apical system small, about one fifth of test diameter; 14 or 15 interambulacral and 17 or 18 ambulacral plates in each column; globiferous pedicellariae with a very conspicuous, straight terminal tooth; ophicephalous pedicellariae not peculiar; primary radioles with two or three violet-purplish bands.

From the Japanese Seas (Akune, Kyushu) to Low Isles, Australia(?). Probably in shallow waters.

Genus Toxopneustes AGASSIZ, 1841

Toxopneustes Agassiz, 1841-b, p. 7.-A. Agassiz, 1872-74, pp. 167, 297 (pro parte).-Mortensen, 1943, p. 466.

Orthotype.-Echinus pileolus LAMARCK, 1816, p. 45.

Boletia DESOR in AGASSIZ and DESOR, 1846, p. 362.

Logotype.-Echinus pileolus LAMARCK, 1816, p. 45. [COTTEAU, 1861-67 (67), p. 818].

Test low, hemispherical; gill-cuts deep and deeply defined; ambulacral primary tubercle regularly on every second plate; poriferous zone not one half as broad as interporiferous one; pairs of pores in arcs of three; globiferous pedicellariae large and flower-like; valves of globiferous pedicellariae without lateral teeth; size very large.

Toxopneustes pileolus (LAMARCK, 1816) (C-T) (Ph-APT, CPT)

- Echinus pileolus LAMARCK, 1816, p. 45.—VALENCIENNES, 1846, pls. 8-9.—Toxopneustes pileolus (LAMARCK) AGASSIZ, 1841-b, p. 7.—A. AGASSIZ, 1872-74, pp. 297, 497, pl. 8b, figs. 1-2, pl. 25, figs. 20-21, pl. 38, figs. 16-17.—YOSHIWARA (TOKUNAGA), 1906, pl. 12, figs. 7-10.— MORTENSEN, 1943, p. 472, pl. 26, fig. 3, pl. 27, figs. 1-4, pl. 28, figs. 1-2, pl. 29, figs. 1-5, pl. 30, figs. 1-4, pl. 31, fig. 9, pl. 33, figs. 5-6, pl. 54, figs. 1, 3-6, 8-10, 13-16, pl. 55, fig. 13, text-figs. 293-298.
- Toxopneustes chlorocanthus H. L. CLARK, 1912-b, p. 283, pl. 93, figs. 6-7.—NISIYAMA, 1942, p. 18, text-fig. 4 (in Japanese).

On the test, several narrow concentric rings of white, purple, or green, which may, however, be reduced to small, isolated patches, or even completely disappear; test usually sunken adorally; gill-cuts rather long.

From the Japanese Seas (from Sagami Sea to Kagoshima Gulf) to Ryukyu Islands and to Formosa, and widely distributed over the Indo-West Pacific region, from East Africa to Fiji Islands.

Littoral zones-90 metres in depth.

Toxopneustes elegans Döderlein, 1885

Toxopneustes elegans Döderlein, 1885, р. 99 (27).—Mortensen, 1903-b, р. 112.—Yoshiwara (Токилада), 1906, pl. 13, figs. 5-8.—H. L. Clark, 1912-b, р. 283.—Mortensen, 1943, р. 485, pl. 28, figs. 3-4, pl. 31, figs. 6-8, pl. 54, fig. 12.—Utinomi, 1962, p. 105, text-fig. 6.

Test low; a narrow, sharply limited black ring near the point of the radioles. From Tanabe Bay to Kagoshima Gulf and to Amami-Oshima, in Ryukyu Islands. Littoral zones-20 metres in depth.

Genus Tripneustes AGASSIZ, 1841

Tripneustes AGASSIZ, 1841, p. 7.—NISIYAMA, 1966, p. 242. Orthotype.—Echinus ventricosus LAMARCK, 1816, p. 44.

An ambulacral primary tubercle on every three or four plate; a conspicuous naked median space aborally in both areas; gill-slits fairly deep and sharp; poriferous zones usually more than half as broad as the interporiferous ones; pairs of pores in three, more or less well separated vertical series; buccal membrane not plated but with more or less numerous, small, scattered plates or none in addition to primordial ambulacrals; globiferous pedicellariae small, usually darkly pigmented.

Tripneustes gratilla (LINNAEUS, 1758) (C-T)

Echinus gratilla LINNAEUS, 1758, p. 664.—LOVÉN, 1887, p. 44.—H.L. CLARK, 1921, p. 148, pl. 17, fig. 6.—ROXAS, 1928, p. 258, pl. 3, figs. 14-15, pl. 4, figs. 16-17.—MORTENSEN, 1943, p.

500, pl. 33, figs. 1-3, pl. 34, figs. 2-6, pl. 35, figs. 3-4, pl. 37, figs. 1-2, 4-10, pl. 38, figs. 1-4, pl. 56, fig. 11, text-figs. 306-307.

Hipponoe variegata (LESKE): A. AGASSIZ, 1872-74, pp. 301, 491, pl. 6a, figs. 4-6.—DÖDERLEIN, 1885, p. 99.—YOSHIWARA (TOKUNAGA), 1906, pl. 13, figs. 9-12.—HAYASAKA, 1948, p. 30, pl. 6, fig. 5.

Median areas of ambulacral and interambulacra aborally usually very bare; buccal membrane with numerous thick, moderately large plates; tubercles usually very small and irregularly scattered; primary radioles slender often very dark, but in some specimens, white.

From the Japanese Seas (from Tanabe Bay to Kagoshima Gulf) to Ryukyu Islands and Formosa, and widely distributed over the Indo-West Pacific, from East Africa to Australia and to the Hawaiian Islands.

Littoral zones-ca. 75 metres in depth.

Genus Pseudoboletia TROSCHEL, 1869

Pseudoboletia Troschel, 1869-b, p. 96.—H. L. Clark, 1912-b, p. 344.—Mortensen, 1943, p. 526.

Logotype.—Pseudoboletia stenostoma TROSCHEL, 1869-b, p. 96.=Toxopneustes indianus MICHE-LIN, 1862, p. 5. [H.L. CLARK, 1912-b, p. 344].

Test thin with deep gill-slits, having a very prominent flange on interradial side; a primary tubercle on every ambulacral plate; plates of buccal membrane carry both radioles and pedicellariae.

Pseudoboletia maculata TROSCHEL, 1869

Pseudoboletia maculata TROSCHEL, 1869-b, p. 96.—MORTENSEN, 1903-b, p. 118, pl. 21, figs. 1, 15, 17.—MORTENSEN, 1943, p. 532, pl. 42, figs. 4-5, pl. 55, figs. 2, 5-6, 16-17, 21.

Pseudoboletia indiana: A. Agassiz, 1881-a, p. 107, pl. 38, fig. 3, pl. 39, fig. 11 (non Michelin, 1862).-Döderlein, 1888, p. 835, pl. 33, fig. 8.

Pore-pairs in arcs of four; adoral radioles not banded; buccal plates rather small, widely separated; some parts of test bases of accompanying radioles, dark coloured, forming more or less distinct but indefinite blotches.

From the Japanese Seas (from Tanabe Bay to Tomioka, Kyushu) to the Philippines, and to the Timor Sea.

20-70 metres in depth.

Genus Pseudocentrotus MORTENSEN, 1903

Pseudocentrotus MORTENSEN, 1903-b, pp. 122, 137.—NISIYAMA, 1966, p. 245. Haplotype.—Toxocidaris depressa A. Agassiz, 1863-a, p. 356.

Ambulacra polyporous, with 6-7 pore-pairs in each arc; ambulacra become almost petaloid on oral side; ambulacral primary tubercle on every ambulacral plate; buccal plates carry numerous pedicellariae but no radioles; inside buccal plates the membrane densely covered with scale-like naked plates; gill-cuts rather long, but shallow; spicules of tube-feet C-shaped with outer branches.

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Pseudocentrotus depressus (A. AGASSIZ, 1863) (C-T) (Ph-APT, CPT)

Toxocidaris depressa A. AGASSIZ, 1863-a, p. 356.—Strongylocentrotus depressus (A. AGASSIZ) MORTENSEN, 1903-b, p. 121, pl. 21, figs. 8-9, 14-15.—Pseudocentrotus depressus (A. AGASSIZ): MORTENSEN, 1903-b, p. 137.—Strongylocentrotus depressus (A. AGASSIZ): YOSHI-WARA (TOKUNAGA), 1906, pl. 11, figs. 3-7.—Pseudocentrotus depressus (A. AGASSIZ): IKEDA, 1940, p. 1, pl. 1, fig. 5.—MORTENSEN, 1943, p. 541, pl. 26, figs. 1-2, pl. 34, fig. 1, pl. 39, fig. 5, pl. 44, figs. 2-5, pl. 56, figs. 4-5, 13-14, 18-26, text-figs. 240a, 318-321.—NISIYAMA, 1966, p. 246, text-figs. 21a-b, 22a-b.

Test depressed, vertical diameter usually less than half of horizontal one; adoral surface very flat; primary radioles reddish-brown, or rarely brown; globiferous pedicellariae without lateral teeth on valves.

Known only from the Japanese Seas (from Tokyo Bay to Nagasaki, Kyushu). Littoral zones-5 metres in depth.

Suborder ECHINOINA CLAUS, 1876

Echinina Mortensen, 1942, p. 225.—Echinina Claus: Philip, 1965, p. 58.—Echinoina Claus: Nisiyama, 1966, p. 249. Type-family.—Echinidae Gray, 1825.

Ambulacra compounding of the echinoid type; test not sculptured; primary tubercles imperforate, smooth; primary radioles with solid axis, without cortex layer; gill-slits not sharp nor deep.

Family ECHINIDAE GRAY, 1825

Echinidae GRAY, 1825, p. 426 (pro parte).—MORTENSEN, 1903-b, p. 134.—MORTENSEN, 1943-a, p. 1. Tuba ganus Echinus Luniaeus 1758

Type-genus.—Echinus LINNAEUS, 1758.

Ambulacra with trigeminate to multigeminate plates of the echinoid type; porezones rather narrow, usually not widened adorally; ambitus circular; buccal membrane more or less strongly plated, rarely quite naked; globiferous pedicellariae with one or more lateral teeth to each side of blade; spicules of simple bihamate type.

Subfamily ECHININAE GRAY, 1825

Echininae Mortensen, 1903-b, p. 134.-Mortensen, 1943-a, p. 16.

Valves of globiferous pedicellariae with rather broad basal part; edge of blade thickened and usually connected by transverse beams, and blade thus being converted into a more or less closed tube; one to several lateral teeth to each side of blade.

Genus Echinus LINNAEUS, 1758

Echinus LINNAEUS, 1758, p. 663 (pro parte).—Mortensen, 1903-b, p. 130.—H. L. CLARK, 1912b, p. 260.—Mortensen, 1943-a, p. 17, text-figs. 6-8.

Logotype.—Echinus esculentus LINNAEUS, 1758, p. 663.—MORTENSEN, 1903-b, pl. 3, fig. 3, pl. 15, figs. 1, 5. [WRIGHT, 1857-78 (64), p. 31].

Secondary (or miliary) radioles mostly scarce, not forming a dense coat, smooth or at most very finely thorny; periproct usually covered with large plates, among which suranal plate more or less distinct; no plates connecting buccal plates; a small rostrate-like form besides usual larger type of tridentate pedicellariae, the latter with edge of blade set with small teeth usually in transverse series.

Echinus lucidus Döderlein, 1885

Echinus lucidus Döderlein, 1885, p. 97 (25).—Mortensen, 1903-b, p. 100, pl. 19, fig. 18, p. 161 (note).—H. L. Clark, 1912-b, p. 267, pl. 107, figs. 1-3.—Mortensen, 1943-a, p. 74, pl. 3, figs. 5-8, pl. 4, fig. 2, pl. 54, figs. 14-17, 20-24, 28, 30, text-figs. 27-29.

Echinus norvegicus: A. Agassiz, 1881-a, p. 117 (non Düben and Koren, 1846).—Yoshiwara (Tokunaga), 1906, pl. 12, figs. 5-6.

Colour of test and radioles whitish; secondary tubercles well developed; porezones not very narrow, no widening of pore-zones adorally; large form of tridentate pedicellariae with narrow, slightly curved valves; valves of globiferous pedicellariae with 1-2 or 2-2, or even 3-3 lateral teeth on each side.

Known only from the Japanese Seas (from Hakodate Bay to Kagoshima Gulf). 180-1750 metres in depth.

Family SRONGYLOCENTROTIDAE GREGORY, 1891

Strongylocentrotidae GREGORY, 1891, p. 41.—PHILIP, 1965, p. 58.—NISIYAMA, 1966, p. 249. Type-genus.—Strongylocentrotus BRANDT, 1835.

Ambulacra polyporous; pore-zones not widened adorally; tubercles regularly developed in both areas; test round; apical system usually with oculars (I and V) insert; buccal membrane with a varying number of plates distally to buccal plates, larger ones carrying number of pedicellariae; gill-cuts rather shallow; globiferous pedicellariae with a well developed neck, containing both longitudinal and circular muscles; valves without lateral teeth; spicules of tube-feet and globiferous pedicellariae C-shaped with distally prominences, or simple bihamate.

Genus Strongylocentrotus BRANDT, 1835

Strongylocentrotus Brandt, 1835, p. 263 (63).—H.L. Clark, 1912-b, p. 352.—Mortensen, 1943-a, p. 193.—Nisiyama, 1966, p. 249.

Haplotype.—Echinus (Strongylocentrotus) chlorocanthus BRANDT, 1835, p. 246.=Echinus droebachiensis O. F. Müller, 1776, p. 235. [Opinion 208 of ICZN.]

Test rather strong; ambulacra with 5-9 pore-pairs to an arc, rarely only 4 as many as 10; arcs more or less oblique; ambulacra not constricted on oral side, at peristomial edge broader than interambulacra; periproct not eccentric, covered with numerous small plates; no radioles on buccal plates; globiferous pedicellariae without stalk-glands, and poison-glands single; spicules of globiferous pedicellariae with outer prominences at ends, like those on tube-feet.

Strongylocentrotus droebachiensis (O. F. MÜLLER, 1776) (C-P)

- Echinus drøbachiensis O.F. MÜLLER, 1776, p. 235.—Strongylocentrotus dröbachiensis (O.F. MÜLLER, 1776) A. AGASSIZ, 1872-74, pp. 162, 277, 441, pl. 4a, figs. 2-3, 6, pls. 9-10.—MORTENSEN, 1903-b, pp. 162, 165, pl. 1, figs. 5-6, pl. 2, figs. 3-5, pl. 16, figs. 4, 9, 11, 13, 17, 23, pl. 20, figs. 3-6, 12-13, 16, 18, 20, 25-26, 29.—JACKSON, 1912, p. 129, pl. 8, fig. 3, text-figs. 131-134, 135-139a, 140-149, 180-183, 190-195, pl. 5, figs. 1-16, pl. 6, figs. 6-10, pl. 7, figs. 3-8.—GRANT and HERTLEIN, 1938, p. 33, pl. 4, fig. 6, pl. 6, fig. 1.—MORTENSEN, 1943-a, p. 198, pl. 23, figs. 1-11, pl. 59, figs. 1-5, 10, text-figs. 89-90, 91c, 92, 93a, 94-96.—BARANOBA in USCHAKOV, 1955, p. 214, pl. 63, fig. 2.—UTINOMI, 1960, p. 340, pl. 38, figs. 5-6.
- Non Strongylocentrotus dröbachiensis: YOSHIWARA (TOKUNAGA), 1906, pl. 11, figs. 8-11 (=Str. intermedius (A. AGASSIZ, 1863)).

Test not thin and fragile; coronal plates numerous; very diverse in form, colour and length of radioles, but generally sharply pointed at tip, delicately ridged on surface; secondary radioles generally light greenish; pore-pairs 5-6, rarely 7, arcs more or less oblique.

Known from southeast of Kamtchatka Peninsula, in 220 metres depth (UTINOMI, 1960, p. 340). Distributed over the circumpolar region, in north Atlantic coast as far south as Chesapeake Bay, in the Pacific it occurs at least as far south as the state of Washington, and appears to be common all over the Bering Sea and Aleutian Islands. Its occurrence from further south than Kamtchatka is for the present unreliable.

Strongylocentrotus sachalinicus DÖDERLEIN, 1906

Strongylocentrotus droebachiensis var. sachalinicus Döderlein, 1906-a, p. 517.—Strongylocentrotus sachalinicus Döderlein: H. L CLARK, 1912-b, p. 353.—Ohshima, 1933, p. 228, text-fig. 1.—Mortensen, 1943-a, p. 215, pl. 25, figs. 15-22, pl. 59, figs. 11, 13-24, text-figs. 84, 88b, 91a, 93c, 97, 99b.

Pore-pairs usually 6 or 7; coronal plates rather few, only about 14-16 interambulacral plates in each column at a size of 50 mm diameter; small secondary radioles scarce; colour usually whitish green.

From the Bering Sea (63°52'N.) and Sakhalin to Hokkaido (42°48'N.) and Sendai Bay (38°15'N.)

Littoral zones-1600 metres in depth.

Strongylocentrotus echinoides A. AGASSIZ and H. L. CLARK, 1907 (C-P)

Strongylocentrotus echinoides A. AGASSIZ and H. L. CLARK, 1907-b, p. 122.--NISIYAMA, 1966, p. 253, pl. 8, figs. 5-6 (fossil).

Pore-pairs 7 in an arc, at midzone, occasionally 6; arcs vertically oblique; small secondary radioles very numerous; colour more or less reddish white, darkest on aboral interambulacral areas, which may be deep purple; primaries light red or light green or both.

On the Asiatic Coast, from the Bering Sea to Sendai Bay, and near Abashiri on the Ochotsk Sea side.

45-770 metres in depth.

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Strongylocentrotus polyacanthus A. AGASSIZ, and H. L. CLARK, 1907

Strongylocentrotus polyacanthus A. AGASSIZ and H. L. CLARK, 1907-b, p. 123.—H. L. CLARK, 1912-b, p. 362, pl. 94, figs. 30-33, pl. 113, fig. 2.—IKEDA, 1940, p. 3, pl. 1, figs. 2-3.—MOR-TENSEN, 1943-a, p. 223, pl. 25, figs. 1-3, pl. 55, figs. 11-13, 18, 23, text-figs. 97a, 100a, 101a.

Pore-pairs 6 in an arc, in midzone, occasionally 7; arcs horizontally oblique; coronal plates rather numerous, about 20 interambulacral plates in each column at size of 50 mm diameter; end-teeth of globiferous pedicellariae much shorter than blade; valves of ophicephalous pedicellariae broad triangular; colour uniform dull rose-purple.

Known only from Kurile Islands (Simushir Island). Littoral zones-25 metres in depth.

Strongylocentrotus intermedius (A. AGASSIZ, 1863)

Psammechinus intermedius A. AGASSIZ, 1863-a, p. 357.—Strongylocentrotus intermedius (A. AGASSIZ): NISIYAMA, 1966, p. 252, pl. 8, fig. 9 (fossil).
Strongylocentrotus dröbachiensis: YOSHIWARA (TOKUNAGA), 1906, pl. 11, figs. 8-11.

Pore-pairs typically 5, in adult usually arranged in three vertical series, two in outer and inner, one in middle series; arcs nearly horizontal at ambitus; poriferous zone much wider than half interporiferous; secondary radioles (tubercles) strongly developed; test usually green, primary radioles greenish or reddish or both; endtooth of globiferous pedicellariae much shorter than blade.

From Sakhalin to Hokkaido and Sendai Bay, also to the Sianukhu Bay.

Littoral zones-35 metres in depth.

Strongylocentrotus pulchellus A. AGASSIZ, and H. L. CLARK, 1907

Strongylocentrotus pulchellus A. AGASSIZ and H. L. CLARK, 1907-b, p. 121.—H. L. CLARK, 1912-b, p. 356, pl. 94, figs. 24-27, pl. 98, figs. 1-2, pl. 111, figs. 9-10.—MORTENSEN, 1943-a, p. 229, pl. 25, figs. 4-11, pl. 59, figs. 6-9, 12, text-figs. 88a, 96c, 101c.

Test radially striped, median areas dark, brownish or greenish, pore-zones lighter; radioles typically red brown with white tip, more rarely white or green; oral ones often faintly banded; secondary radioles (tubercles) less strongly developed; poriferous zone about equal to half of interporiferous, the arcs very oblique at ambitus; porepairs generally arranged in three at outer, two at inner side of poriferous zone; valves of globiferous pedicellariae with a short blade and terminal tooth nearly as long.

Known from east coast of Kamtchatka, southwest coast of Sakhalin, Sea of Japan, and Bay of Aniwa.

8-225 metres in depth.

Strongylocentrotus nudus (A. AGASSIZ, 1863)

Toxocidaris nuda A. AGASSIZ, 1863-a, p. 356.—Strongylocentrotus nudus (A. AGASSIZ) A. AGASSIZ, 1872-74, pp. 165, 448, pl. 24, figs. 26-30.—YOSHIWARA (TOKUNAGA), 1906, pl. 12,

figs. 1-2.—H. L. CLARK, 1912-b, p. 363, pl. 94, figs. 17-23.—MORTENSEN, 1929, p. 475, pl. 19, fig. 1, text-fig. 1.—IKEDA, 1940, p. 2, pl. 1, fig. 4.—MORTENSEN, 1943-a, p. 232, pl. 26, figs. 9-11, pl. 27, figs. 1-4, 6, pl. 61, figs. 1-3, 8-9, 13, text-figs. 102a, 103a, 104.—CHANG and Woo, 1954, p. 131, pl. 1, fig. 1, pl. 2, fig. 2.—UTINOMI, 1960, p. 343, pl. 39, figs. 13-14. Strongylocentrotus hokkaidensis Döderlein, 1906-a, p. 518.

Primary tubercles large and conspicuous; primary radioles long and stout, usually purplish or dark brown; pore-pairs 6 or commonly 7 in an arc; coronal plates few, about 30 ambulacral and 20 interambulacral plates in each column at a size of about 80 mm diameter; large, almost globular form.

Known from Hokkaido to Sagami Sea on the Pacific coast, and from southern Sakhalin to Dairen through Korea on the Japan Sea side.

Littoral zones-180 metres in depth.

Strongylocentrotus franciscanus (A. AGASSIZ, 1863) (C-P)

Toxocidaris franciscana A. AGASSIZ, 1863, p. 22.—Strongylocentrotus franciscanus (A. AGASSIZ) A. AGASSIZ, 1872-74, pp. 163 (in part), 442 (in part), pl. 5b, figs. 1-2, pl. 7, figs. 10-10a.—YOSHIWARA (TOKUNAGA), 1906, pl. 12, figs. 3-4 (reproduced from A. AGASSIZ, 1872-74).—JACKSON, 1912, p. 171, text-fig. 199.—GRANT and HERTLEIN, 1938, p. 34, pl. 2, fig. 6, pl. 6, fig. 3, text-fig. 14.—MORTENSEN, 1943-a, p. 242, pl. 28, figs. 1-7, pl. 29, figs. 1-4, pl. 30, figs. 2-3, pl. 31, figs. 1-2, pl. 32, figs. 1-3, pl. 61, figs. 10, 15-19, 23, text-figs. 91b, 106-110.—H. L. CLARK, 1948, p. 278, pl. 45, fig. 23.—UTINOMI, 1960, p. 343, pl. 40, figs. 15-16.

Test very large, stout; primary radioles long and stout; usually 8-9 pore-pairs to each arc on adoral side, exceptionally as many as 10, or only 7; only two longitudinal series of large primary tubercles, otherwise rather densely covered with smaller secondary or miliary tubercles so as to leave no bare median space in interambulacra; spicules of tube-feet typically bihamate, but rather scarce.

Known from Canada and Oregon to California on the East Pacific side, and Alaskan Coast, and Hokkaido on the West Pacific side.

Littoral zones-125 metres in depth.

Genus Hemicentrotus MORTENSEN, 1942

Hemicentrotus MORTENSEN, 1942, p. 231.—MORTENSEN, 1943-a, p. 248. Orthotype.—Psammechinus pulcherrimus A. AGASSIZ, 1863-a, p. 357. Psammocentrotus NISIYAMA, 1939, p. 332 (indication incomplete). Orthotype.—Psammechinus pulcherrimus A. AGASSIZ, 1863-a, p. 357.

Test rather strong; poriferous zone very broad; ambulacral plates 4-geminate, the arcs almost horizontal, pores arranged so as to form four vertical series; ambulacra somewhat narrowed at peristomial edge; tubercles small, secondaries numerous; radioles short; spicules of tube-feet and globiferous pedicellariae simply C-shaped, ends not branched.

Hemicentrotus pulcherrimus (A. AGASSIZ, 1863) (C- 0-45) (Ph-APT, CPT)

Psammechinus pulcherrimus A. AGASSIZ, 1863-a, p. 357.—Sphaerechinus pulcherrimus (A. AGASSIZ) A. AGASSIZ, 1872-74, p. 160.—Döderlein, 1885, p. 87.—Strongylocentrotus pul-

cherrimus (A. AGASSIZ) MORTENSEN, 1903-a, p. 121.—Sphaerechinus pulcherrimus (A. AGASSIZ): YOSHIWARA (TOKUNAGA), 1906, pl. 13, figs. 1-4.—Hemicentrotus pulcherrimus (A. AGASSIZ): MORTENSEN, 1943-a, p. 248, pl. 30, figs. 4-9, pl. 32, figs. 5-10, pl. 55, figs. 16-17, 20-22, 24-25, text-figs. 111-112, 113a, 114-116.

Radioles (tubercles) small and very numerous; primary radioles green and tubefeet nearly white, but radioles may be white tipped.

Known only from the Japanese Seas (from Hokkaido to Kagoshima Gulf). Littoral zones-ca. 45 metres in depth.

Family PARASALENIIDAE MORTENSEN, 1903

Parasaleniinae Mortensen, 1903-b, p. 138.—Nisiyama, 1966, p. 260. Type-genus.—Parasalenia A. Agassiz, 1863.

Test more or less elongate, long axis about in line ocular (III)-genital (5); ambulacra with trigeminate plates of the echinoid type; pore-zones narrow; primary tubercles large, imperforate, non-crenulate; anal plates typically four of subequal size; buccal membrane plated; gill-slits shallow; globiferous pedicellariae without neck, but with stalk-glands; valves without lateral teeth.

Genus Parasalenia A. AGASSIZ, 1863

Parasalenia A. AGASSIZ, 1863, p. 22.—NISIYAMA, 1966, p. 261. Haplotype.—Parasalenia gratiosa A. AGASSIZ, 1863, p. 22.

Test of pronounced elliptical shape; ambulacral primary tubercles filling out most of interporiferous zone; pore-zone very narrow; interambulacra with a single series of large primary tubercles in each column; secondary tubercles little developed, not forming vertical or horizontal series.

Parasalenia gratiosa A. AGASSIZ, 1863 (C-T)

Parasalenia gratiosa A. AGASSIZ, 1863, p. 22.—A. AGASSIZ, 1872-74, p. 435, pl. 3d, figs. 1-2.—
MORTENSEN, 1930-a, p. 388, pl. 1, figs. 6-7.—MORTENSEN, 1943-a, p. 269, pl. 29, figs, 5-11, pl. 30, fig. 1, pl. 31, figs. 3-5, 7-13, pl. 57, figs. 4-10, 17, text-figs. 120b, 121c-d, 122-124, 126a-b, 127a-b.

Radioles rather robust, only about as long as longer diameter of test, usually of uniform dark colour, in the young (or adoral radioles of the adult) often with indistinct bands of dusty green and whitish; no red on genital plates; each genital plate with at least one well developed tubercle; genital (3) not excluded; periproct large, about one-third of long axis of apical system.

From the Japanese Seas (Nagasaki) to the Philippines, and widely distributed over the Indo-West Pacific, from Zanzibar to Palmira Islands.

Littoral zones-70 metres in depth.

Parasalenia gratiosa boninensis MORTENSEN, 1930

Parasalenia gratiosa var. boninensis MORTENSEN, 1930-a, p. 388, pl. 1, figs. 1-5.-MORTENSEN, 1943-a, p. 270, pl. 29, figs. 5-10, pl. 31, figs. 4, 9-10, 12, text-figs. 120a-c, 121a, 125.
Radioles rather slender usually longer than long diameter of test; test more slender than the typical form.

From the Japanese Seas (from Sagami Sea to Kyushu) to Bonin Islands, and to Palao Islands.

Probably in littoral zones.

Family ECHINOMETRIDAE GRAY, 1855

Echinometradae GRAY, 1855, p. 37.—Echinometridae GRAY: MORTENSEN, 1943-a, p. 276.—NISI-YAMA, 1966, p. 263.

Type-genus.—Echinometra [BREYNIUS] GRAY, 1825.

Test round to elliptical, transversely elongate; ambulacra with trigeminate to multigeminate plates of the echinoid type; pore-zones often petaloid widened adorally; apical system usually oculars (I and V) insert; buccal membrane usually with scattered plates carrying pedicellariae; primary radioles mostly long and strong, sometimes very long and thick or flattened, shield-like; globiferous pedicellariae mostly without neck, with double poison-glands; valves of globferous pedicellariae with a single, unpaired lateral tooth.

Genus Echinostrephus A. AGASSIZ, 1863

Echinostrephus A. AGASSIZ, 1863, p. 20.—NISIYAMA, 1966, p. 264. Haplotype.—Echinostrephus aciculatus A. AGASSIZ, 1863, p. 20.

Test with ambitus above equator, aboral side quite flat; ambulacral plates triquadrigeminate; ocular plates all exsert; primary ambulacral tubercles form very regular vertical series; primary radioles longest on flat aboral surface; buccal membrane with scattered plates carrying pedicellariae; gill-slits very shallow; globiferous pedicellariae with or without stalk-glands; valves with an unpaired lateral tooth; poison-glands double.

Echinostrephus aciculatum A. AGASSIZ, 1863

Echinostrephus aciculatus A. AGASSIZ, 1863, p. 20.—Echinostrephus aciculatum A. AGASSIZ: NISIYAMA, 1966, p. 265, pl. 9, fig. 3, pl. 10, figs. 2-3 (fossil).

Echinostrephus molaris: A. AGASSIZ, 1872-74, p. 457 (partim), pl. 5a, figs. 10-12, pl. 6, fig. 20 (non BLAINVILLE, 1825).

Ambulacra quadrigeminate, except adorally; ambitus usually circular; genital and ocular plates with more or less numerous tubercles; test dull purplish, black or greenish.

From the Japanese Seas (from Tanabe Bay to Kyushu) to the Philippines, and widely distributed in the Indo-West Pacific, from the Hawaii to Sulu Islands.

Littoral zones-50 metres in depth.

Echinostrephus molare (BLAINVILLE, 1825)

Echinus molaris BLAINVILLE, 1825, p. 88.—Echinostrephus molaris (BLAINVILLE) LORIOL, 1883-a, p. 31 (16), pl. 4, figs. 2-2c.—KOEHLER, 1927, p. 119, pl. 18, fig. 9, pl. 27, fig. 5.—

MORTENSEN, 1943-a, p. 311, pl. 33, figs. 1-10, pl. 58, figs. 1-2, 4, 9, text-figs. 131, 146b,. 149-150.

Echinostrephus pentagonus Yoshiwara, 1898, p. 59.

Ambulacra trigeminate; ambitus more or less evidently pentagonal; genital and ocular plates without tubercles except on outer margin; test usually more or less bright green or dark.

From Bonin Islands to the Indian Ocean and Australia.

Littoral zones-50 metres in depth.

Genus Anthocidaris LÜTKEN, 1864

Anthocidaris Lütken, 1864, p. 165.—NISIYAMA, 1966, p. 267.

Logotype.—Anthocidaris homalostoma Lütken, 1864, p. 165.=Toxocidaris crassispina A. Agassiz, 1863-a, p. 356. [Cotteau, 1861-67 (67), p. 820.—Mortensen, 1943-a, p. 327].

Test rather strong and low; ambulacra polyporous, 7-8, or rarely 9 pore-pairs. in arc; distinctly petaloid on oral side; radioles rather long and stout; globiferous pedicellariae small, with a small lateral tooth, no stalk-glands; spicules of tube-feet bow-shaped ("biacerate), with pointed ends and usually prominence on middle of arched side.

Anthocidaris crassispina (A. AGASSIZ, 1863) (C-P) (Ph-APT, CPT)

Toxocidaris crassispina A. AGASSIZ, 1863-a, p. 356.—Heliocidaris crassispina (A. AGASSIZ).
H. L. CLARK, 1912-b, p. 350.—Anthocidaris crassispina (A. AGASSIZ): MORTENSEN, 1929,
p. 474, text-fig. 2.—Heliocidaris crassispina (A. AGASSIZ): CHANG, 1932, p. 14, text-figs.
5-6, pl. 2, fig. 8.—Anthocidaris crassispina (A. AGASSIZ): MORTENSEN, 1943-a, p. 328, pl.
39, figs. 1-2, pl. 40, figs. 1-9, pl. 63, figs. 16-17, pl. 64, figs. 1-16, 18-19, 25-26, text-figs. 134, 158-163.—NISIYAMA, 1966, p. 267, text-figs. 24-25.

Anthocidaris homalostoma Lütken, 1864, p. 165.

Toxocidaris purpurea MARTENS, 1866, p. 137.—Anthocidaris purpurea (MARTENS) DÖDERLEIN, 1906-a, p. 520.—Strongylocentrotus purpureus (MARTENS) H. L. CLARK, 1908, p. 304.

Strongylocentrotus tuberculatus: A. Agassiz, 1872-74, pp. 163, 443 (pro parte), pl. 5b, figs. 4-5 (non Lamarck, 1816).-Yoshiwara (Tokunaga), 1906, pl. 10, figs. 13-14, pl. 11, figs. 1-2.

Test flat; diameter of peristome about one-third of test diameter; colour very dark, blackish, purplish or brownish; radioles rather slender, in spite of the name, usually asymmetrically developed on aboral side.

From the Japanese Seas (from south of Onahama Bay to Kyushu) to Formosa. and Hongkong, China.

Littoral zones-3 metres in depth.

Genus Echinometra [BREYNIUS] GRAY, 1825

Echinometra Breynius: Gray, 1825, p. 426.—Mortensen, 1943-a, p. 352.—Nisiyama, 1966,. p. 267.

Logotype.—Echinus lucunter LINNAEUS, 1758, p. 665. [Original implicit designation.—Cot-TEAU, 1861-67 (67), p. 820.—LAMBERT, 1910-b, p. 48].

Test usually elongate, longitudinal axis through I.A.3 and A.I; ambulacra polyporous, with 4-10 pore-pairs to each arc; pore-zone may be distinctly petaloid.

adorally, or not at all widened; periproctal plates of moderate size, not very numerous; buccal plates with a few or numerous small radioles; radioles not peculiar; auricles may have a large superstructure; valves of globiferous pedicellariae with a lateral tooth.

Echinometra mathaei (BLAINVILLE, 1825) (C-P)

Echinus mathaei BLAINVILLE, 1825, p. 94.—NISIYAMA, 1966, p. 271, pl. 10, figs. 4-6 (fossil).

Pore-pairs usually only four to each arc aborally; colour very rarely black; primary radioles variable but usually pointed and their thickness generally much less than ten per cent of their length; height of test usually about half of length; apical system about one-third of test diameter; secondary tubercles usually on each genital plate; colour of primary radioles very variable, often dark purplish or reddish, light fawn-colour or greenish, frequently tipped with white or red.

From the Japanese Seas (from Sagami Sea to Kagoshima Gulf) to Formosa and Australia.

In littoral zones.

Echinometra mathaei oblonga (BLAINVILLE, 1825) (C-P)

Echinus oblongus BLAINVILLE, 1825, p. 95.—Echinometra oblonga (BLAINVILLE) BLAINVILLE, 1834, p. 225.—YOSHIWARA (TOKUNAGA), 1906, pl. 10, figs. 8-12.—H. L. CLARK, 1912-b, p. 373, pl. 114, figs. 1-2.—A. H. CLARK, 1931, p. 5, pl. 3, fig. 3, pl. 7, fig. 3.—Echinometra mathaei oblonga (BLAINVILLE): MORTENSEN, 1943-a, p. 393, pl. 48, figs. 1-20.—Echinometra oblonga (BLAINVILLE): H. L. CLARK, 1948, p. 281, pl. 45, fig. 24.

Colour usually black, rarely dull purplish gray or even dull red; pore-pairs in arcs of 5 or 4; primary radioles short, stout, and usually blunt, their thickness —.12 —.22 of their own length; primary tubercles correspondingly big, especially noticeable aborally; height of test usually .55—.60 of its longer diameter.

From Ryukyu Islands to the Philippines, and widely distributed over the Indo-West Pacific region.

In littoral zones.

Genus Heterocentrotus BRANDT, 1835

Heterocentrotus BRANDT, 1835, p. 265.—H. L. CLARK, 1912-b, p. 377.—MORTENSEN, 1943-а р. 407.

Logotype.—Echinus mamillatus LINNAEUS, 1758, p. 664. [H. L. CLARK, 1912-b, p. 377]. Acrocladia Agassiz, 1840-a, p. 19.

Logotype.—Echinus trigonarius LAMARCK, 1816, p. 51. [COTTEAU, 1861-67 (67), p. 820].

Test very stout; long axis through I.A.4a—A.IIa; ambulacral plates of 9-19 components; primary tubercles very large; primary radioles very strongly developed, long, thick and heavy.

Heterocentrotus mammillatus (LINNAEUS, 1758) (C-P)

Echinus mamillatus LINNAEUS, 1758, p. 664.—Heterocentrotus mammillatus (LINNAEUS) BRANDT, 1835, p. 266.—A. AGASSIZ, 1872-74, p. 428, pl. 3c.—Yoshiwara (Tokunaga), 1906, pl. 9, figs. 6-8.—H. L. CLARK, 1912-b, p. 378, pls. 115-117.—Roxas, 1928, p. 261, pl. 5, figs. 25-26.—Mortensen, 1943-a, p. 409, pl. 51, figs. 1-6, pl. 52, figs. 68, pl. 66, figs. 7, 9-20, text-figs. 204a-b, 205a, 206, 207a-b, 208a, 209-210.—Науаsака, 1948, p. 16, pl. 3, figs. 2-4.—Utinomi, 1962, p. 105, text-fig. 7.

Usually 9-12 (commonly 11) pore-pairs to an arc in ambital region; primary ambulacral tubercles above ambitus abruptly very much reduced in size and their radioles truncate, like secondaries; secondary radioles short, flaring and truncated at tip; no large primary tubercles on aboral part of ambulacra; valves of tridentate pedicellariae narrow, somewhat curved, widened at tip where alone they are in contact; colour often very light, never shows any indication of purple, when dark coloured, shade always a rich chocolate-brown.

From Ryukyu Islands and Bonin Islands to Formosa and the Philippines, and widely distributed over the Indo-West Pacific region.

Heterocentrotus trigonarius (LAMARCK, 1816) (C-P)

Echinus trigonarius LAMARCK, 1816, p. 51.—Heterocentrotus trigonarius (LAMARCK) BRANDT, 1835, p. 266.—A. AGASSIZ, 1872-74, p. 430, pl. 3d, fig. 6, pl. 6, fig. 13.—H. L. CLARK, 1912-b, p. 379, pls. 118-120.—A. H. CLARK, 1931, p. 10, pl. 4, fig. 2, pl. 8.—NISIYAMA, 1942, p. 20, text-fig. 7 (in Japanese).—MORTENSEN, 1943-a, p. 42, pl. 50, figs. 3-6, pl. 52, figs. 4-5, pl. 53, pl. 66, figs. 1-6, 8, text-figs. 132c, 204c, 205, 206c-d, 208b.

Usually 13-19 (commonly 15) pore-pairs to an arc in ambital region; primary ambulacral tubercles gradually decreasing in size aborally, and their radioles likewise gradually becoming shorter, not truncate; secondary radioles, short, usually tapering and pointed at tip; tridentate pedicellariae with leaf-shaped valves, contiguous in their whole length; general colouration deep purple and there is little difference in shade between primaries and secondaries.

From the Philippines and Saribabu Islands to Palao and Marshall Islands. In littoral zones.

Genus Colobocentrotus BRANDT, 1835

Colobocentrotus BRANDT, 1835, p. 266.—A. AGASSIZ, 1908, p. 1.—MORTENSEN, 1943-a, p. 425. Haplotype.—Colobocentrotus mertensii BRANDT, 1835, p. 366.

Test rather stout; long axis through A.IVb-I.A.1b; ambulacral plates of 9-12 components; aboral radioles flattened, thick and very short, forming like a dense mosaic; primary tubercles moderate, in midzone 10-12 in two horizontal series on each interambulacral plate.

Coloboentrotus mertensii BRANDT, 1835

Colobocentrotus mertensii BRANDT, 1835, p. 266.—Colobocentrotus martensii BRANDT: YOSHI-WARA (TOKUNAGA), 1906, pl. 10, figs. 1-2.—Colobocentrotus mertensii BRANDT: A. AGAS-SIZ, 1908, p. 7 (mertensii), p. 9 (stimpsoni), pls. 33-39.—IKEDA, 1939-d, p. 194, pls. 9-10.— MORTENSEN, 1943-a, p. 429, pl. 51, fig. 7, pl. 52, fig. 3, pl. 65, figs. 1, 9-10, text-figs. 211a, 212a, 213a-b, 214. Test low and flattened, its short diameter about nine-tenths of the long; colour grey-green.

Known from Bonin Islands (type-locality), Shibushi in Kyushu, Shionomisaki in Kii, Hachijô-jima, Tokara Islands, Ryukyu Islands, and Formosa.

In littoral zones.

Order HOLECTYPOIDA DUNCAN, 1889

Holectypoida DUNCAN, 1889-a, pp. 25, 135.—PHILIP, 1965, p. 58.—NISIYAMA, 1966, p. 272. Type-family.—Holectypidae LAMBERT, 1900.

Test irregular, exocyclic; ambulacra simple, not forming petals aborally or phyllodes adorally; peristome central; dental apparatus present or more or less reduced or completely resorbed; lantern usually inclined; teeth keeled and with lateral flanges; apical system of discrete plates, never truely monobasal; gills usually present or not; test usually high. From the Lias to Recent.

Suborder ECHINONEOINA H. L. CLARK, 1925

Echinoneina HAWKINS: H. L. CLARK, 1925, p. 176.—PHILIP, 1965, p. 58.—NISIYAMA, 1966, p. 274. Type-family.—Echinoneidae WRIGHT, 1857.

Peristome oblique; test often elongate; gill-slits and buccal plates absent; no petals; lantern and perignathic girdle absent in adults, auricles interradial in position or present only in juveniles.

Family ECHINONEIDAE WRIGHT, 1857

Echinonidae WRIGHT, 1857-78 (57), pp. 20, 23.—MORTENSEN, 1948-a, p. 65.—NISIYAMA, 1966, p. 275.

Type-genus.-Echinoneus LESKE, 1778.

Pores arranged in single series throughout; poriferous zones depressed; periproct on oral side; apical system compact, genital plates not separate; pores with distinct peripodium throughout the ambulacrum; four kinds of pedicellariae present.

Echinoneus cyclostomus LESKE, 1778 (C-P)

Echinoneus cyclostomus LESKE, 1778, p. 173, pl. 37, figs. 4-5.—MORTENSEN, 1948-a, p. 75, pl. 1, figs. 14, 26, pl. 12, figs. 21-23.—NISIYAMA, 1966, p. 276 (fossil).
 Echinoneus abruptus H. L. CLARK, 1925, p. 177, pl. 10, figs. 1-3.

Primary tubercles imperforate; glassy tubercles well developed; test very variable in form but apical system central or a little anterior; interambulacrum (5) not conspicuously narrower than other interambulacra; ambulacra all subequal in width; colour whitish or yellowish with a more or less marked reddish tinge.

From the Japanese Seas (from Tanabe Bay to Kagoshima Gulf) to Ryukyu Islands and Formosa, and widely distributed over the tropical regions. Mainly littoral form, but occurs down to depth of ca. 120 metres.

Order CASSIDULOIDA CLAUS, 1880

Cassidulideae CLAUS, 1880, p. 364.—Cassiduloida DUNCAN, 1889-a, p. 166.—MORTENSEN, 1948a, p. 94.—Philip, 1965, p. 58. Type-family.—Cassidulidae Agassiz, 1847.

Test irregular, exocyclic; plastron undifferentiated. Anbulcara petaloid adapically (except the Neolampadidae). Phyllodes and bourrelets well developed, forming a "floscelle". Petals usually all similar. Apical system with discrete genital plates or monobasal. Dental apparatus present, or resorbed completely before the adult stage is reached. Gills not present. No fasciole.

From the Lower Jurassic to Recent.

Suborder CASSIDULOINA CLAUS, 1880

Cassidulina CLAUS: PHILIP, 1965, p. 59.

Dental apparatus lacking in the adult stage. Ambulacra petaloid adapically.

Family PLIOLAMPADIDAE KIER, 1962

Pliolampadidae KIER, 1962, p. 192. Type-genus.—Pliolampas POMEL, 1888.

Apical system monobasal, three to four genital pores. Periproct inframarginal, usually longitudinal; peristome anterior, usually higher than wide. Poriferous zones of same petal of same length; single pore in all ambulacral plates beyond petals. Bourrelets well developed, a few or many pores; buccal pores present. Usually no naked, granular zone in posterior interambulacrum (5).

Genus Oligopodia DUNCAN, 1889

Oligopodia DUNCAN, 1889-a, p. 176.—H. L. CLARK, 1917, p. 107.—H. L. CLARK, 1946, pp. 355-356.—MORTENSEN, 1948-a, p. 143. Orthotype.—Nucleolites epigonus MARTENS, 1865, p. 143.

Genital pores four. Periproct supramaginal in a furrow, longitudinal; peristome central, higher than wide. Poriferous zone diverging, not definitely petaloid, pores of petals of about equal size. No double keel carrying larger tubercles. No frontal depression. Floscelle well developed. Vertical diameter of test half horizontal diameter, or less.

Oligopodia epigona (MARTENS, 1865)

Nucleolites epigonus MARTENS, 1865, p. 143.—A. AGASSIZ, 1872-74, pp. 147, 558, pl. 19b, figs. 4-6.—Echinobrissus (Oligopodia) epigonus (MARTENS) MEIJERE, 1904, p. 141, pl. 19, figs. 369-371.—Oligopodia epigonus (MARTENS): H. L. CLARK, 1917, p. 108, pl. 144, figs. 12-13. —HAWKINS, 1920-a, p. 396, pl. 7, figs. 3-4.—MORTENSEN, 1948-a, p. 228, pl. 1, figs. 5-13., pl. 12, figs. 13-14, 17, 19, 24, text-figs. 211-214, 215a-b, 216.

Test broadly rounded in front. Colour whitish, pale grey, or very light brown. From Bonin Islands and Jolo to the Malay and Kei Islands. 5-390 metres in depth.

Family ECHINOLAMPADIDAE GRAY, 1851

Echinolampidae GRAY, 1851-a, p. 37 (pro parte).—Echinolmpadidae GRAY: KIER, 1962, p. 99. Type-genus.—Echinolampas GRAY, 1825.

Test usually highly inflated. Apical system tetrabasal or monobasal. Periproct marginal to inframarginal, transverse or longitudinal. Petals long, open distally, usually with poriferous zones of unequal length in the same petal; single pores in ambulacral plates beyond petals. Bourrelets well developed; phyllodes widened, single pored; buccal pores present. A narrow, naked, granular zone in posterior inter-ambulacrum (5).

Genus Echinolampas GRAY, 1825

Echinolampas GRAY, 1825, p. 429.—MORTENSEN, 1948-a, p. 270.—KIER, 1962, p. 106. Logotype.—Echinus oviformis GMELIN, 1788-93 (89), p. 3187. [POMEL, 1883, p. 62]. Planilampas MORTENSEN, 1948, p. 68.—MORTENSEN, 1948-a, p. 297. Orthotype.—Echinolampas sternopetala A. AGASSIZ and H. L. CLARK, 1907-b, p. 130.

Apical system monobasal. Periproct inframarginal, transverse. Petals moderately developed, sometimes lanceolate, open, or closing distally; poriferous zones usually unequal, interporiferous zones wide. Three kinds of pedicellariae, tridentate, ophice-phalous, and triphyllous ones present.

Echinolampas alexandri LORIOL, 1876

Echinolampas alexandri LORIOL, 1876-a, p. 4, pl. 1, figs. 1-3.—H-L. CLARK, 1917, p. 114, pl. 144, figs. 14-16, pl. 153, figs. 3-4.—KOEHLER, 1922, p. 144, pl. 4, fig. 10.—MORTENSEN, 1948-a, p. 282, pl. 2, figs. 20-24, pl. 3, figs. 1-3, pl. 14, figs. 1, 4, 7, text-figs. 268c, 272a-c, 273a.

Ambulacra moderately wide, more or less petaloid adapically; poriferous zones rather short; inner poriferous zones of petals I and V much more than half as long as the outer; tuberculation rather coarse, median areas of petals II and IV with not more than 8 (usually 4-8) vertical series of primary tubercles; peristome broadly transverse; floscelle quite rudimentary.

From south of Ryukyu Islands and the Philippines to Indian Ocean, Mauritius, and Gulf of Martaban.

8-365 metres in depth.

Echinolampas koreana H. L. CLARK, 1925

Echinolampas koreana H. L. CLARK, 1925, p. 183, pl. 10, figs. 4-5.—MORTENSEN, 1948-a, p. 281, pl. 4, fig. 9, text-fig. 271.—NISIYAMA, 1966, pl. 11, fig. 10.

Test relatively high, more than a half of test length; inner poriferous zones of petals I and V much more than half as long as the outer; peristome pentagonal;

tuberculation rather fine, median zones of petals II and IV with 4-6 longitudinal series (but very irregular) of primary tubercles; petals narrow, short; colour dull-greyish with poriferous zones more or less purple.

From th Eastern Channel to Wakasa Bay, in the Sea of Japan.

72-120 metres in depth.

Echinolampas sternopetala A. AGASSIZ and H.L. CLARK, 1907

Echinolampas sternopetala A. AGASSIZ and H. L. CLARK, 1907-b, p. 130.—H. L. CLARK, 1917, p. 115, pl. 144, figs. 20-24, pl. 147, figs. 1-2, pl. 153, figs. 5-7.—Planilampas sternopetala (A. AGASSIZ and H. L. CLARK) MORTENSEN, 1948-a, p. 298, pl. 5, figs. 1-6, pl. 12, fig. 13, pl. 13, figs. 3-4, text-figs. 257b, 266b, 267c, 269a, 270e.—NISIYAMA, 1966, pl. 10, figs. 13-14, pl. 11, figs. 7-8, 10.

Aboral side low vaulted, oral side flat, edge of test fairly sharp; poriferous zones of petals very unequal; peristome transversely oval; only two longitudinal series of primary tubercles in interporiferous zone; floscelle moderately developed; glassy ridges or warts well developed, mainly on aboral side.

From Sagami Sea to Kagoshima Gulf, in the Pacific side only.

150-500 metres in depth.

Suborder NEOLAMPADOINA PHILIP, 1963

Neolampadina Philip, 1963-c, p. 725.—Philip, 1965, p. 59. Type-family.—Neolampadidae LAMBERT, 1918.

Lantern absent in adult stages. Petals lacking, and adapical ambulacral plates with single pores.

Family NEOLAMPADIDAE LAMBERT, 1918

Neolampadidae LAMBERT, 1918-a, pp. 12, 40.—LAMBERT and THIÉRY, 1924, p. 388—MORTEN-SEN, 1948-a, p. 330.

Type-genus.-Neolampas A. AGASSIZ, 1869.

Apical system with discrete genital plates in some genera. Phyllodes very poorly developed. Ambulacra simple, with single, more or less rudimentary pores.

Genus Anochanus GRUBE, 1869

Anochanus Grube, 1869, p. 178.—LAMBERT and THIÉRY, 1924, p. 389.—Mortensen, 1948-a, p. 343.

Haplotype.—Anochanus sinensis GRUBE, 1869, p. 178.

Apical system deeply sunken, forming a marsupium. Tube-feet in a complete series from peristome to apical system. Periproct on aboral side, in a groove.

Anochanus sinensis GRUBE, 1869

Anochanus sinensis Grube, 1869, p. 178.—A. Agassiz, 1872-74, pp. 89, 356.—H. L. Clark, 1917, p. 110.—Mortensen, 1948-a, p. 343.

Known only from the China Sea, in small depths.

Order CLYPEASTEROIDA A. AGASSIZ, 1873

Clypeasteroideae A. AGASSIZ, 1872-74 (73), p. 309.—Clypeastroida DUNCAN, 1889-a, pp. 25, 143. -MORTENSEN, 1948-c, p. 1.-Clypeasteroida L. AGASSIZ: DURHAM, 1955, p. 113.-PHILIP, 1965, pp. 52, 58.

Type-family.-Clypeasteridae AGASSIZ, 1835.

Test usually flattened, usually with internal skeletal supports. Ambulacra petaloid adapically, secondary tube-feet often extending outside ambulacra; no phyllodes or bourrelets. Apical system usually central, monobasal. Masticatory apparatus well developed and persistent in adults; lantern without compass; keeled teeth lacking lateral flanges.

From the Cretaceous (Senonian) to Recent.

Suborder CLYPEASTEROINA A. AGASSIZ, 1873

Clypeastrina GREGORY, 1900-b, p. 316 (pro parte).-MORTENSEN, 1948-c, p. 5.-Clypeasterina Agassiz: Durham, 1955, p. 117.—Philip, 1965, p. 58.

Auricles separate, radial in position. Petals with complex structure, plates of petals alternating primaries and demi-plates. Interambulacra discontinuous on adoral surface, terminated adapically by a pair of plates. Aboral miliary radioles simply serrate, not terminating in a crown or in a sac of glandular skin.

Family CLYPEASTERIDAE AGASSIZ, 1835

Clypeastres AGASSIZ, 1835, pp. 170, 182, 185 (in part).-Clypeastridae DUNCAN, 1889-a, p. 148. -MORTENSEN, 1948-c, p. 10.-Clypeasteridae Agassiz: Durham, 1955, p. 118. Type-genus.—Clypeaster LAMARCK, 1801.

Test moderately high or flattened but rarely discoidal. Ambulacra petaloid adapically; on oral side reduced to simple, poorly defined furrows; ambulacral plates "clypeasterid", no "combed" areas. Basicoronal interambulacral plates usually greatly reduced, never larger than ambulacral plates. Anus inframarginal or marginal. Apical system usually central; 5 genital pores. Buccal membrane naked.

Genus Clypeaster LAMARCK, 1801

Clypeaster LAMARCK, 1801, p. 349.—MORTENSEN, 1948-c, p. 37,—DURHAM, 1955, p. 118.

Logotype.—Echinus rosaceus LINNAEUS, 1758, p. 665. [DESMOULINS, 1835-37 (35), p. 15.—H. L. CLARK, 1911, p. 604].

Echinanthus LESKE, 1778, p. 185.—GRAY, 1825, p. 427.—A. AGASSIZ, 1872-74, pp. 106, 310. Logotype:-Echinus rosaceus LINNAEUS, 1758, p. 665. [GRAY, 1851-a, p. 35].

Rhaphidoclypus A. Agassiz, 1863, p. 25.—Koehler, 1922, p. 14.—Checchia-Rispoli, 1925-a, p. 64.—MORTENSEN, 1948-c, p. 71 (section).

Haplotype.—Clypeaster scutiformis LAMARCK, 1816, p. 14.=Echinus reticulatus LINNAEUS, 1758, p. 666 (pro parte).

Stolonoclypus A. Agassiz, 1863, p. 25.—Checchia-Rispoli, 1925-a, p. 57.—Mortensen, 1948-

c, p. 87 (section).

Logotype.—Clypeaster prostratus RAVENEL, 1848, p. 3.=Echinanthus subdepressus GRAY, 1825, p. 427. [H. L. CLARK, 1911, p. 605].

Logotype.—Scutella placunaria LAMARCK, 1816, p. 12.=Echinanthus humilis LESKE, 1778, p. 185, pl. 17, fig. A, pl. 18, fig. B, pl. 19. [LAMBERT, 1912-b, p. 91].

Plesianthus DUNCAN, 1889-a, p. 154.—CHECCHIA-RISPOLI, 1923-a, p. 61.

Orthotype.-Echinanthus testudinarius GRAY, 1851-a, p. 36.

Pavaya POMEL, 1883, p. 68.—LAMBERT and THIÉRY, 1914, p. 297.—MORTENSEN, 1948-c, p. 131 (section).

Haplotype.-Clypeaster corvini PAVAY, 1874, p. 98, pl. 9, figs. 1-7 (Oligocene of Hungary).

Test more or less tall, ovoid. Poriferous zones of petals more or less incurved distally. Periproct inframarginal or marginal; peristome usually in a well-defined infundibulum. Tuberculation dense, uniform, the primary tubercles perforate, more or less distinctly crenulate. Internal supports variable in abundance, consisting of thin laminae and pillars; walls of test sometimes double.

Clypeaster reticulatus (LINNAEUS, 1758)

Echinus reticulatus LINNAEUS, 1758, p. 666 (pars).—Clypeaster reticulatus (LINNAEUS) : H. L. CLARK, 1914, p. 34, pl. 124, figs. 3-6.—Rhaphidoclypus reticulatus (LINNAEUS) : KOEHLER, 1922, p. 68, pl. 6, figs. 3-4, pl. 15, fig. 10.—Clypeaster (Rhaphidoclypus) reticulatus (LINNAEUS) : MORTENSEN, 1948-c, p. 71, pl. 18, figs. 1-21, pl. 26, fig. 3, pl. 65, figs. 2, 13, 16, text-figs. 8, 47.

Clypeaster scutiformis LAMARCK, 1816, p. 14.—A. AGASSIZ, 1872-74, pp. 101, 512, pl. 13, figs. 1-4.—Meijere, 1904, p. 131, pl. 18, figs. 344-351.—Yoshiwara (Tokunaga), 1907, pl. 15, figs. 1-4.

Test small, usually under 50 mm long and never over 80 mm; width usually not four-fifths of test-length; antero-lateral petals (II and IV) short, scarcely threefourths of the frontal (III); lower surface strongly concave; frontal petal (III) nearly closed, with rather few pore-pairs, 28 on each side in petal 14 mm long; petaloid area in adult usually somewhat depressed, at least the distal portion lying lower than the thickened test margin though the apical system may be much thicker; tuberculation rather coarse with only 2-5 primary tubercles on ridges between porepairs.

From the Japanese Seas (Tanabe Bay) to Ryukyu Islands and Formosa, and distributed over the Indo-West Pacific Oceans.

Littoral zones-ca. 120 metres in depth.

Clypeaster fervens hiradicus MORTENSEN, 1948

Clypeaster fervens var. hiradicus Mortensen, 1948, p. 69.—Clypeaster (Rhaphidoclypus) fervens var. hiradicus Mortensen: Mortensen, 1948-c, p. 86, pl. 22, figs. 8, 10-11, pl. 65, fig. 12.

Differs from typical *Cl. fervens* KOEHLER, 1922, in the shape of petals, which are oval, not broad distally as in *fervens*. Tridenrate pedicellariae from those of *fervens* in the blade being much more spoon-shaped, more as in *Cl. japonicus*.

Known only from Hirado Strait, Kyushu.

In moderate depths.

Clypeaster humilis (LESKE, 1778)

Echinanthus humilis LESKE, 1778, p. 185, pl. 17, fig. A, pl. 18, fig. B, pl. 19.—Clypeaster humilis (LESKE): A. AGASSIZ, 1872-74, pp. 100, 510, pl. 11a, figs. 1-8.—DUNCAN, 1885-b, p. 205, pl. 31, figs. 56-58.—H. L. CLARK, 1914, p. 36, pl. 123, fig. 23, pl. 137, pl. 138, fig. 4.—KOEHLER, 1922, p. 51, pl. 3, figs. 1-5, 12, pl. 14, fig. 5.—Clypeaster (Stolonoclypus) humilis (LESKE): MORTENSEN, 1948-c, p. 88, pl. 17, fig. 1, pl. 28, figs. 1-4, pl. 29, figs. 1-3, 5-8, pl. 30, fig. 1, pl. 40, figs. 2-3, pl. 67, figs. 3, 8, 11, 15-18, text-figs. 53a-b.

Test rather low, about one-fifth of test-length; margin thin; aboral surface more or less flat distal to petals; oral surface flat or slightly and gradually concave orally; frontal petal (III) with poriferous zones converging distally and petal closed distally, or very nearly so; frontal petal (III) with relatively few pore-pairs, about 50 on each side in petal 40 mm long; median area of petals markedly obovate, narrow proximally and broadest distally, and interporiferous zone usually conspicuously elevated; primary tubercles rather numerous, small, on each ridge between pore-pairs of frontal petal (III) there is a single regular series of 6-15.

From Formosa and the Philippines to Malay, and distributed over the Indo-West Pacific Oceans.

Littoral zones-usually 20 metres in depth.

Clypeaster virescens Döderlein, 1885

Clypeaster virescens Döderlein, 1885, p. 102 (30).—YOSHIWARA (TOKUNAGA), 1907, pl. 14, figs. 9-10.—H. L. CLARK, 1914, p. 39, pl. 122, fig. 15, pl. 123, figs. 28-31, pl. 128, fig. 8, pl. 138, fig. 4, pl. 140, figs. 1-2.—Clypeaster (Stolonoclypus) virescens Döderlein: Mortensen, 1948-c, p. 96, pl. 33, fig. 1, pl. 38, figs. 1-5, pl. 40, figs. 1, 10, pl. 67, figs. 5-7, 12-14, 20-21, 23, pl. 69, fig. 6, text-figs. 56, 57a-b.

Test large and flat, rounded, nearly as wide as long, not depressed at distal end of petals; flat on the oral side, only sunken close to peristome; petals short, widely open, their width more than half their length; frontal petal (III) short, with diverging poriferous zones; tuberculation coarse, primary tubercles scattered, rather large especially on interambulacral areas orally; on each ridge between pore-pairs of frontal petal there are only 1-4 (3-4 on other petals) primary tubercles; colour of test yellowish brown becoming deep green after death and then gradually changing to brown, dull greenish, greenish yellow or pale buff, that of denuded test whitish.

From the Japanese Seas (Sagami Sea to Kagoshima Gulf) to the Philippines, and to Indo-China and Australia(?)

100-300 metres in depth.

Clypeaster japonicus Döderlein, 1885 (Ph-APT)

Clypeaster japonicus Döderlein, 1885, p. 100 (28).—Yoshiwara (Tokunaga), 1907, pl. 14, figs. 5-8.—H. L. Clark, 1914, p. 32, pl. 128, fig. 5, pl. 136, figs. 2-4, pl. 138, fig. 5.—Clypeaster (Stolonoclypus) japonicus Döderlein: Mortensen, 1948-c, p. 99, pl. 31, fig. 1, pl. 34, figs. 4, 6-7, pl. 35, fig. 2, pl. 42, fig. 3, pl. 67, figs. 1-2, 9-10.

Clypeaster excelsior DÖDERLEIN, 1885, p. 101 (29).

S. NISIYAMA

Test distinctly longer than wide, ambitus usually rounded but often pentagonal with nearly straight side; rather high, about one-third of test-length, with thick margin, about one-sixth of test-length; paired petals more or less open distally, especially on postero-lateral petals (I and V); tuberculation rather coarse, ridge between pore-pairs of frontal petal only 4-8 primary tubercles; primary interambulacral tubercles on oral side not very conspicuous; adoral surface not usually markedly concave, though peristome distinctly sunken; size large, length up to 100 mm and more; width exceeding four-fifths to test-length; denuded test usually (in well preserved specimen) strikingly coloured aborally, the plates dark brownish, the edge white.

Known only from the Japanese Seas, from Sagami Sea to Kagoshima Gulf. In littoral zones—100 metres depth.

Clypeaster japonicus clypeus Döderlein, 1885

Clypeaster clypeus Döderlein, 1885, p. 100 (28).—Clypeaster (Stolonoclypus) japonicus var. clypeus Döderlein: Mortensen, 1948-c, p. 101. pl. 34, figs. 4-7.

Colour of denuded test being a uniform white; paired petals being not quite closed.

Type-locality.—Kagoshima Gulf—31°20'N., 130°10'E.

In 110 metres depth.

Clypeaster japonicus ogasawarensis (YOSHIWARA, 1898)

Plesianthus ogasawarensis YOSHIWARA, 1898, p. 60.—Clypeaster (Stolonoclypus) ogasawarensis (YOSHIWARA) MORTENSEN, 1948-c, p. 102, pl. 69, fig. 7.

Uniformly white colour of test markedly differs from *Cl. japonicus*; petals wholly closed distally, but number of tubercles in interporiferous zone much smaller than in *japonicus* of a corresponding size; valves of tridentate pedicellariae somewhat different.

Known only from the Bonin Islands. In small depths.

Clypeaster ohshimensis IKEDA, 1936

Clypeaster ohshimensis IKEDA, 1936, p. 103, pl. 7.—Clypeaster (Pavaya) ohshimensis IKEDA: MORTENSEN, 1948-c, p. 131, pl. 34, figs. 1-3.

Test pentagonal with sides slightly concave; paired petals completely closed distally; tuberculation rather fine on aboral surface, on adoral surface large and close together; ridge between pore-pairs of petals with 1-3 small but distinct primary tubercles; each peristomial interambulacral edge much swollen like a wart, bourrelets (infundibulum); oral ambulacral furrows conspicuous and considerable sunken. Size rather large, up to 85 mm in test-length.

From Amami-Ohshima to 24°40'S., 165°24'E.

In probably small depths.

The Echinoid Fauna from Japan and Adjacent Regions

Family ARACHNOIDIDAE DUNCAN, 1889

Arachninae Duncan, 1889-a, pp. 158, 165.—Arachnoidinae Gregory, 1900-b, p. 318.—Arachnoididae Gregory: H.L. Clark, 1914, p. 43.—Mortensen, 1948-c, p. 132.—Arachnoididae Duncan: Durham, 1955, p. 122.
Type-genus.—Arachnoides Leske, 1778.

Test usually flattened. Ambulacral furrows simple, well defined, continuing from peristome to the apical system. Secondary tube-feet outside petals in dense oblique series (combs in advanced species), restricted to ambulacral areas, no secondary tubefeet in furrows. Tubercles partly arranged in regular oblique series. Four genital pores. Buccal membrane plated. Basicoronal interambulacral plates externally larger than the ambulacral plates. Pedicellariae with two valves.

Subfamily ARACHNOIDINAE DUNCAN, 1889

Arachnoidinae Duncan: Durham, 1955, p. 122.

Periproct supramarginal. Petals raised above the interambulacra. Internal skeletal supports in outer marginal zone only. Combed areas large; oral ambulacral furrows extending to the apical system.

Genus Arachnoides LESKE, 1778

- Arachnoides Leske, 1778, p. 72 (26) (Klein, 1734, p. 26—pre-Linnean).—Agassiz, 1841-b, p. 94.—Mortensen, 1948-c, p. 142.—Durham, 1955, p. 125.
- Haplotype.—Arachnoides echinarachnius LESKE, 1778, p. 154.=Echinus placenta LINNAEUS, 1758, p. 666. [Bull. zool. Nomencl., vol. 4, 1950, p. 534].

Echinarachnius LESKE, 1778, p. 217.-LAMBERT and THIÉRY, 1914, p. 315.

Type-species.—Echinus placenta LINNAEUS, 1758, p. 666. [Suppressed if necessary—Bull. Zool. Nomencl., vol. 4, 1950, p. 534].

Test very flat, discoidal; margin of test very thin; petals relatively large, raised; poriferous zones of petals straight, divergent; periproct just slightly supramarginal; only one pair of interambulacral plates extending onto oral surface, so that there are two pairs of ambulacral plates meeting in interambulacrum (5), and a half pair in interambulacra 1 and 4, and three pairs in the anterior interambulacra 2 and 3; periproct between second and third pair of post-basicoronal interambulacral plates, with only the first pair on the oral surface.

Arachnoides placenta (LINNAEUS, 1758) (C-P)

Echinus placenta LINNAEUS, 1758, p. 666.—Arachnoides placenta (LINNAEUS): AGASSIZ, 1841–
b, p. 94.—A. AGASSIZ, 1872-74, p. 530 (pro parte) (non pl. 13b, figs. 1-4=Fellaster zelandiae (GRAY, 1845)).—H. L. CLARK, 1914, p. 43 (pro parte) (non pl. 125, figs. 1-3=F.
zelandiae).—MORTENSEN, 1921, p. 181, pl. 6, figs. 26-27.—ROXAS, 1928, p. 263, pl. 7, figs.
33-34.—HAYASAKA, 1948, p. 3, pl. 1, figs. 2a-4b, pl. 2, figs. 1-3.—MORTENSEN, 1948-c, p.
145, pl. 44, fig. 1-2, pl. 45, figs. 1, 3-5, 8, 10, pl. 69, figs. 21-23, text-figs. 81b, 83, 84a-b,
85a-b, 86a-d, 88a.—DURHAM, 1955, p. 125, text-fig. 29a.

Ambulacral plates 2-4 join in the interambulacral midline, there being only one pair of interambulacral plates close to the edge of oral side; interambulacra at margin 1/4-1/3 as wide as ambulacra; periproct near edge of test; a naked furrow, like a gutter, leads from the periproct to edge of test.

From Foochou (Lat. 26°N.) to Formosa and the Philippines, and distributed Andamann Islands to Australia.

Littoral zones-rarely 45 or 57 metres in depth.

Suborder LAGANOINA MORTENSEN, 1948

Laganina Desor: Mortensen, 1948-c, pp. 3, 156 (pro parte).—Durham, 1955, p. 131. Type-family.—Laganidae Desor, 1858.

Auricles fused, interradial in position. Ambulacral structure within the petals simple or compound. Interambulacra narrow, continuous on adoral surface, terminated adapically by a single plate. Aboral miliary radioles with terminal crown.

From the Senonian to Recent.

Family FIBULARIIDAE GRAY, 1855

Fistularina GRAY, 1855-a, p. 27 (Fibularina in systematic index).—Fibulariidae DUNCAN, 1889a, p. 144.—MORTENSEN, 1948-c, p. 156.—DURHAM, 1955, p. 131.
Type-genus.—Fibularia LAMARCK, 1816.
Eoscutidae LAMBERT and THIÉRY, 1914, p. 287.
Type-genus.—Eoscutum LAMBERT, 1914.

Usually small forms, shape variable. Ambulacra broad, forming more or less distinct petals or not; ambulacral structure within the petals simple. Oral ambulacral furrows lacking, or at most small and indistinct. Primordial basicoronal plates not specialized. Internal simple radiating partition walls present or lacking. Primary radioles short, simple, with a regular axial canal. Pedicellariae of the ophicephalous, tridentate, and triphyllous types, very rarely also globiferous pedicellariae found.

Genus Echinocyamus VAN PHELSUM, 1774

Echinocyamus van Phelsum, 1774, pp. 131–136, pl. 1, figs. 1–35, pl. 2, figs. 1–35 (Explicatio Tabulae).—Leske, 1778, p. 213.—A. Agassiz, 1872–74, pp. 304, 505.—Mortensen, 1948-c, p. 170.—Durham, 1955, p. 133.

Logotype.—Echinocyamus angulosus LESKE, 1778, p. 151.=Spatangus pusillus Müller, 1776, p. 18 (Adriatic Sea). [BLAINVILLE, 1830, p. 194.—Bull. Zool. Nomencl., 1950, vol. 4, p. 519]. Fibularia LAMARCK: LAMBERT, 1891, p. 751.—LAMBERT and THIÉRY, 1914, p. 289.

Logotype.—Fibularia angulosa (LESKE) LAMARCK, 1816, p. 17. [LAMBERT, 1907-b, p. 36].

Test of small size, low, with more or less developed internal radiating partition walls, and they may continue to the auricles or be much shorter. Petals more or less imperfect to well formed; poriferous zones of petals slightly curved and slightly converging. Peristome central; buccal membrane naked. Periproct close to peristome, situated at junction between first and second pair of post-basicoronal plates. No spicules in tube-feet. Hydropores few in number, often only one, not or is in a groove.

Echinocyamus crispus MAZZETTI, 1893

Echinocyamus crispus MAZZETTI, 1893, p. 239, pl. 13, figs. a-d.—MEIJERE, 1904, p. 105, pl. 6, figs. 48-50, pl. 18, fig. 300.—H. L. CLARK, 1914, p. 61, pl. 126, figs. 9-11.—KOEHLER, 1922, p. 137, pl. 12, figs. 16-17, 21.—MORTENSEN, 1948-c, p. 185, pl. 46, figs. 46-47, 55, text-fig. 112a.

Test distinctly longer than wide; aboral side low, flattened; posterior edge rounded; apical system central; peristome pentagonal, markedly concave orally; periproct small, round or transversely elongate, and at midway between peristome and margin; poriferous zones slightly depressed with intervening parts of test usually elevated; interambulacra often form more or less evident keel-like ridges proximally; pore-pairs in specimen about 7 mm test-length, six to seven on each side.

From the Japanese Seas (Tanabe Bay to Eastern Channel, Lat. 23°20'N.) to the Philippines, and widely distributed in the Indo-West Pacific Oceans, from Red Sea to Hawaiian Islands.

18-192 metres in depth.

Echinocyamus provectus MEIJERE, 1903

Echinocyamus provectus Meijere, 1903, p. 6.—Meijere, 1904, p. 109, pl. 6, figs. 51-52, pl. 17, fig. 306, pl. 18, figs. 307-310.—Mortensen, 1948-c, p. 192, pl. 46, figs. 37-39.

Petals well developed; pore-series parallel or a little converging; periproct elongate oval, with covered with usually five quite regular, radiating plates, which are never covered with radioles.

From China Sea (Lat. 22°N.) to Malay region. 133-275 metres in depth.

Subgenus Mortonia GRAY, 1851

Mortonia GRAY, 1851-a, p. 38 (genus).—GRAY, 1855-a, p. 36 (genus).—MORTENSEN, 1948-c, p. 196 (subgenus).—DURHAM, 1955, p. 134 (genus). Haplotype.—Fibularia australis DESMOULINS, 1835-37 (37), p. 240 (South Sea).

Petals open, well defined, a ridge between members of pore-pairs. Periproct close to the peristome, transversely ovate, situated between first and second pair of postbasicoronal plates, and covered with irregular plates carrying radioles. Madreporite with a single hydropore. Internal partition walls well or poorly developed (a single posterior pair only in type-species).

Echinocyamus (Mortonia) australis (DESMOULINS, 1837)

Fibularia australis DESMOULINS, 1835-37 (37), p. 240.—Mortonia australis (DESMOULINS) GRAY, 1851, p. 38.—GRAY, 1855-a, p. 37, pl. 3, figs. 3-3a.—Fibularia australis DESMOULINS: A. AGASSIZ, 1872-74, pl. 13, figs. 8-9.—YOSHIWARA (TOKUNAGA), 1907, pl. 14, figs. 1-2.—NISIYAMA, 1942, p. 22, text-figs. 8a-b (in Japanese).—Echinocyamus (Mortonia) australis (DESMOULINS) MORTENSEN, 1948-c, p. 197, pl. 46, figs. 63-69, pl. 69, figs. 5, 8, text-figs. 101, 102a-b, 104, 115a.—Mortonia australis (DESMOULINS): DURHAM, 1955, p. 134, text-fig. 28c on page 124.

Petals well formed, pores more or less connected by a groove; periproct large, rhomboidal in outline; test low, height about 0.4 of test-length; size large, up to 18. mm in longitudinal diameter.

From the Formosan Sea and Palao Islands to the Hawaiian Islands.

Littoral zones-20-(75) metres in depth.

Genus Fibularia LAMARCK, 1816

Fibularia Lamarck, 1816, p. 16.—H. L. Clark, 1911, pp. 598, 605.—Mortensen, 1948-c, p. 203. —Durham, 1955, p. 132.

Logotype.—Fibularia ovulum LAMARCK, 1816, p. 17. [AGASSIZ and DESOR, 1847, p. 142.—Bull. Zool. Nomencl., 1950, vol. 4, p. 519].

Echinocyamus VAN PHELSUM: LAMBERT, 1891, p. 749.—LAMBERT and THIÉRY, 1914, p. 287. Logotype.—Echinocyamus craniolaris Leske, 1778, p. 150, pl. 48, figs. 1-3. [LAMBERT and THÉRIY, 1914, p. 287].

Test usually more or less elevated; total absence of internal radiating partition walls. Petals usually short, but the pores usually remarkably large and not conjugate. Peristomial membrane wholly naled. Periproct covered with five radiating plates. Hydropores in a groove. Oral tube-feet without calcareous sucking disc. Usually no globiferous pedicellariae.

Fibularia ovulum LAMARCK, 1816

Fibularia ovulum LAMARCK, 1816, p. 17.—A. AGASSIZ, 1872-74, pp. 129, 507, pl. 13e, figs. 1-3.—
 Fibularia craniolaris: H. L. CLARK, 1914, p. 57 (non LESKE, 1778).—KOEHLER, 1922, p. 138, pl. 15, fig. 4.—NISIYAMA, 1942, p. 22, text-figs. 9a-b.—Fibularia ovulum LAMARCK: MORTENSEN, 1948-c, p. 208, pl. 46, figs. 15-17, 21-24, text-figs. 101d, 102c-d, 104e, 106, 118.

Test high, nearly as 0.8 of test-length, more or less egg shaped, and almost globular; poriferous zones nearly or quite parallel in each petal; pores of petals not so few, not very large, usually smaller than the genital pores; periproct round (exceptionally irregularly quadrangular or transverse oval), usually not two-thirds as large as the peristome, placed near to the peristome than to the posterior margin, being covered with radiating periproctal plates.

Distributed over the Indo-West Pacific Oceans, from the Indian Ocean to the South Sea Islands.

Littoral zones-rarely 385 metres in depth.

Fibularia ovulum trigona LAMARCK, 1816

Fibularia trigona LAMARCK, 1816, p. 16.—Fibularia ovulum var. trigona LAMARCK: MORTEN-SEN, 1948-b, p. 109.—MORTENSEN, 1948-c, p. 210, pl. 46, figs. 8-9, 25, text-figs. 117a, 119 (type).

Petals somewhat less developed, the pores larger than in the typical *ovulum*. From Korean Strait to Kei Islands. Probably in small depths.

Fibularia volva AGASSIZ, 1847

Fibularia volva AGASSIZ in AGASSIZ and DESOR, 1847, p. 142.—MORTENSEN, 1918, p. 18, pl. 5, figs. 12-13, 16, 20, 27-28.—H. L. CLARK, 1921, p. 195, pl. 35, figs. 6-9.—MORTENSEN, 1948-c, p. 213, pl. 46, fig. 18, text-fig. 117b (type).

Test more or less distinctly pointed in both ends; test low, more or less flattened above; pores of petals not so few, not very large; periproct rounded, not half as large as the peristome.

Type-locality uncertain, presumably—Red Sea.—The record of this species from western Japan is mistaken for *Fibularia* (*Fibulariella*) acuta YOSHIWARA, 1898. This species occurs all along the northern coast of Australia from Torres Strait to Cape Jaubert, west of Broome, western Australia, and the range extends northward to India and probably to China.

Subgenus Fibulariella MORTENSEN, 1948

Fibulariella MORTENSEN, 1948, p. 72.—MORTENSEN, 1948-c, p. 219.—DURHAM, 1955, p. 133 (genus). Orthotype.—Fibularia acuta Yoshiwara, 1898, p. 60.

Buccal membrane containing numerous small plates; periproct covered with small irregular plates; tube-feet contain a small but well developed calcareous disc; hydropores not in groove; peculiar type of globiferous pedicellariae, but no ophicephalous ones.

Fibularia (Fibulariella) acuta YOSHIWARA, 1898

Fibularia acuta Yoshiwara, 1898, p. 60.—Tokunaga, 1803, p. 7, pl. 2, figs. 5-6 (fossil).—
Yoshiwara (Tokunaga), 1907, pl. 14, figs. 3-4.—H. L. Clark, 1914, p. 58, pl. 126, figs. 1-4.—Mortensen, 1948-c, p. 219, pl. 46, figs. 27-28, pl. 69, figs 3-4, 9, 11, 14, text-figs. 104d, 125.

Test low, about less than 0.4 of test-length, and not very broad, about less than 0.8 of test-length; pores of petals round, usually smaller than the genital pores. Test pointed usually at the anterior margin; periproct small, usually not half as large as the peristome, elongate longitudinally.

Known only from the Japanese Seas (Sagami Sea to Kyushu), and Korean Strait to Bonin Islands and to Formosan Channel.

Fibularia (Fibulariella) acuta septemtrionalis NISIYAMA, 1968

(Pl. 13, figs. 5, 12)

This form differs from the typical species in having the clearly pointed posterior end of test and more regular arrangement of primary tubercles on the test, particularly on the petaloid area.

Known only from northern Japan (Miyako Bay, Sendai Bay, and near Kyurokushima in the Japan Sea).

S. Nisiyama

Family LAGANIDAE DESOR, 1857

Laganes DESOR, 1855-58 (57), p. 216.—Laganidae DESOR: A. AGASSIZ, 1872-74 (73), p. 516.— DUNCAN, 1889-a, p. 156.—MORTENSEN, 1948-c, p. 238.—DURHAM, 1955, p. 138. Type-genus.—Laganum LINK, 1807.

Test generally flattened, with a complicate structure of internal supports. Petals. well developed, open, pores usually conjugate; ambulacral structure within the petals simple, all primaries. Genital pores 4 or 5, exceptionally 6. Oral ambulacral furrows simple, not reaching margin. Interambulacra continuous on oral surface, very narrow; adapical terminal interambulacral plate rhomboidal. Basicoronal plates forming welldefined pentameral star. Periproct on oral side. Primary radioles simple, short, with a regular axial canal. Hydropores numerous, scattered or in a groove. Pedicellariae of tridentate, triphyllous and ophicephalous types. No spicules in tube-feet or internal organs.

From the Eocene to Recent.

Genus Laganum LINK, 1807

- Laganum Link, 1806-08 (07), p. 161 (Klein, 1734, p. 25—pre-Linnean).—Laganum Klein: Bell, 1883, p. 130.—Mortensen, 1948-c, p. 301, text-figs. 191a-b, 192a-b.—Laganum Link: Durham, 1955, p. 139.
 - Tautotype.—Laganum petalodes LINK, 1806-08 (07), p. 161.=Echinodiscus laganum LESKE, 1778, p. 140, pl. 22, fig. C.
- Lagana KLEIN: GRAY, 1825, p. 427 (by error).—BLAINVILLE, 1834, p. 214.

Tautotype.—Lagana minor GRAY, 1825, p. 427.=Echinodiscus laganum LESKE, 1778, p. 140. Jacksonaster LAMBERT in LAMBERT and THIÉRY, 1914, p. 313.—DURHAM, 1955, p. 143.

Orthotype.—Echinarachnius conchatus M'CLELLAND, 1841, p. 181, pl. 4, figs. 8-9.=Laganum depressum LESSON in AGASSIZ, 1841-b, p. 110, pl. 23, figs. 1-7.

Genital pores 5 or rarely 6, present in all the interambulacra; hydropores in a groove, not individually distinct. Periproct on oral surface, situated at junction between first and second post-basicoronal interambulacral plates.

Laganum laganum (LESKE, 1778) (C-P)

Echinodiscus laganum LESKE, 1778, p. 140, pl. 22, fig. C.—Laganum laganum (LESKE): H. L. CLARK, 1914, p. 45, pl. 124, fig. 17.—NISIYAMA, 1942, p. 22, text-fig. 10 (in Japanese).— MORTENSEN, 1948-c, p. 308, pl. 52, figs. 1-11, 13, 15-17, pl. 70, figs. 1-7, text-figs. 153a. 154-156, 163a, 164, 193a, 194a 195.

Laganum bonani KLEIN: AGASSIZ, 1841-b, p. 108, pl. 22, figs. 25-29, pl. 23, figs. 8-12.—A. AGASSIZ, 1872-74, p. 517, pl. 13e, figs. 6-7.—KOEHLER, 1922, p. 83, pl. 9, fig. 4, pl. 14, fig. 6.

Test flat but thick, with depressed petaloid area and swollen margin; periproct longitudinally elongate, placed in middle between peristome and posterior edge of test; valves of tridentate pedicellariae with expanded upper blade and finely crenulated.

From the Eastern Seas and the Philippines to Micronesia and Java Sea to Australia.

In littoral zones.

Laganum depressum LESSON, 1841 (C-P)

Laganum depressum Lesson in Agassiz, 1841-b, p. 110, pl. 23, figs. 1-7.-A. Agassiz, 1872-74, pp. 138, 518, pl. 13f, figs. 5-8.—Meijere, 1904, p. 114, pl. 6, fig. 57, pl. 18, figs. 317-318.— YOSHIWARA (TOKUNAGA), 1907, pl. 15, figs. 5-8 (reproduced from A. AGASSIZ).-H.L. CLARK, 1914, p. 45, pl. 124, figs. 7-12.—KOEHLER, 1922, p. 88, pl. 9, figs. 1-2, 7-8, pl. 13, fig. 3, pl. 14, fig. 2.-Mortensen, 1948-c, p. 313, pl. 52, figs. 12, 14, pl. 53, figs. 3-4, 6-32, pl. 70, fig. 20, text-figs. 153b, 157, 161b, 162c, 163c, 165, 167, 196a, 197.

Jacksonaster conchatus (M'CLELLAND) LAMBERT and THIÉRY, 1914, p. 313.

Test with more or less pentagonal ambitus, its length usually decidedly greater than breadth, the length being 1.6 or more its breadth; the posterior end usually re-enteringly curved; margin of test usually distinctly thickened; periproct near posterior edge of test, about 25 per cent of distnace from the peristome to posterior edge of test, e.g., a pair of first post-basicoronal plates very long, transversely elongate.

From Macao, China and the Philippines to Marshall Islands and to Queensland. Ebb-zone-85 (rarely 290) metres in depth.

Laganum putnami A. AGASSIZ, 1863

Laganum putnami A. AGASSIZ, 1863-a, p. 359.-H.L. CLARK, 1914, p. 50, pl. 142, figs. 14-16 (MCZ no. 2251—syntypes).—MORTENSEN, 1948-c, p. 325.

Genital pores outside the apical system; periproct distinctly near to posterior margin than to peristome; petals lanceolate, pointed; oral ambulacral furrows distinct; peristome not sunken orally.

Known only from "Ousima" (Amami-Ohshima), in Ryukyu Islands. Probably in small depths.

Laganum boninense MORTENSEN, 1948

Laganum boninense Mortensen, 1948, p. 70.-Mortensen, 1948-c, p. 328, pl. 55, figs. 1-3, pl. 70, fig. 12, text-fig. 162b.

Test of round, or rounded polygonal outline; marginal part of test flat, central part moderately elevated; petaloid area less than half of test-length; petals narrow, nearly closed distally; pores conjugate; periproct about 30 per cent or more distance from peristome to posterior edge of test, anal plates with radioles.

Known only from the Bonin Islands.

120-220 metres in depth.

Laganum fudsiyama Döderlein, 1885

Laganum fudsiyama Döderlein, 1885, p. 104 (32).—Yoshiwara (Tokunaga), 1907, pl. 16, figs. 1-4.—H. L. CLARK, 1914, p. 46, pl. 124, figs. 13-16, pl. 127, figs. 7-8, pl. 140, figs. 3-4, pl. 141, figs. 4-9.-MORTENSEN, 1948-c, p. 338, pl. 54, figs. 5-6, 10-13, pl. 70, figs. 8-9, 14-15, text-figs. 194b, 199b, 200a-c, 201.

Laganum conicum MEIJERE, 1904, p. 120, pl. 6, fig. 68, pl. 18, figs. 325-328.

Laganum solidum MEIJERE, 1904, p. 121, pl. 6, figs. 64, 66.

Laganum diploporum A. AGASSIZ and H. L. CLARK, 1907-b, p. 129.-H. L. CLARK, 1914, p. 46, pl. 127, figs. 9-12, pl. 142, figs. 2-4.

Test high, vertical diameter more than one-fifth of test-length; petaloid area distinctly less than half of test-length; petals small and narrow, not lyriform; poriferous zones little curved and tips widely open; posterior interambulacrum (5) with one or two genital pores; distance of periproct from posterior edge of test about 30 per cent of distance from peristome to posterior edge of test; tuberculation rather coarse (within a petal 10 mm long there are about 20-40 primary tubercles); colour usually green.

From the Japanese Seas (from Sagami Sea to Kagoshima Gulf) to Malay region. 50-645 metres in depth.

Genus Hupea POMEL, 1883

Hupea Pomel, 1883, р. 69.— Durham, 1955, р. 141 (defined).

Orthotype.—Hupea decagonalis POMEL, 1883, p. 69.=Scutella decagonalis BLAINVILLE, 1827, p. 229.=Laganum decagonum LESSON: AGASSIZ, 1841-b, p. 112, pl. 23, figs. 16-20 (fide DURHAM, 1955, p. 142).

Genital pores 5, in all the interambulacra; hydropores not in a groove, and individually distinct. Periproct submarginal, situated at junction between third and fourth post-basicoronal interambulacral plates.

Hupea decogonalis (BLAINVILLE, 1827)

Scutella decagonalis BLAINVILLE, 1827, p. 229.—Laganum (Peronella) decagonale (BLAINVILLE): MEIJERE, 1904, p. 117, pl. 6, figs. 58-62, 65, pl. 18, figs. 318-324.—Laganum decagonale (BLAINVILLE): KOEHLER, 1922, p. 85, pl. 8, fig. 5, pl. 11, fig. 3, pl. 15, fig. 13.—MORTEN-SEN, 1948-c, p. 331, pl. 55, fig. 14-29, pl. 70, fig. 10, 16, 17, 19, 21-22, text-figs. 161a, 162a, 163c, 193c, 196b, 199a.—Hupea decagonalis (LESSON): DURHAM, 1955, p. 141, text-fig. 31a (reproduced from AGASSIZ, 1841-b).

Laganum decagonum LESSON: AGASSIZ, 1841-b, p. 112, pl. 23, figs. 16-20.

Outline of test usually decagonal or round; test low, usually less than one-fifth of test-length, and very thin; margins usually not thickened (except young specimens); petaloid area small, generally less than half of test-length; frontal petal (III) somewhat the longest; petals small but relatively broad, with curved poriferous zones, converging to nearly or quite closed tip; periproct much nearer the posterior margin than the peristome, and with radioles, at least on the marginal plates.

As north as Macao and the Philippines to Java Sea.

Littoral zones-26 (rarely 194) metres in depth.

Genus Peronella GRAY, 1855

Peronella Gray, 1855-a, p. 13.—Bell, 1882, p. 134.—H. L. Clark, 1911, pp. 599, 605.—Mortensen, 1948-c, p. 251, text-figs. 171a-b, 172-174.—Durham, 1955, p. 139.

Haplotype.-Laganum peronii Agassiz, 1841-b, p. 123, pl. 22, figs. 21-24.

Rumphia Desor, 1855-58 (57), p. 229.—LAMBERT and THIÉRY, 1914, p. 312 (partim).—DURHAM, 1955, p. 142.

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Orthotype.—Laganum rostratum AGASSIZ, 1841-b, p. 118, pl. 25.

Polyaster Michelin, 1859-a, p. 397 (4) (non GRAY, 1840).—Michelinia Dujardin and Hupé, 1962, p. 560 (pro Polyaster Michelin, 1859; non Koninck, 1842).

Haplotype.—Polyaster elegans Michelin, 1859-a, p. 397 (4), pl. 14, fig. 1.—Peronella lesueuri var. elegans (Michelin) H. L. CLARK, 1925, p. 160, pl. 8, figs. 1-2.

Genital pores 4, wanting in posterior interambulacrum (5), variably situated. Petals well formed, closed or open at their distal ends. Hydropores in isolated pores scattered irregularly over the apical disc, and individually visible, not in sunken groove. Periproct on oral surface, situated at junction between first and second or second and third post-basicoronal interambulacral plates.

Peronella lesueuri (VALENCIENNES, 1841)

Laganum lesueuri VALENCIENNES in AGASSIZ, 1841-b, p. 116, pl. 24, figs. 3-6.—MEIJERE, 1904, p. 122, pl. 6, figs. 63, 67, 70, pl. 18, figs. 329-333.—Peronella lesueuri (AGASSIZ): H.L. CLARK, 1914, p. 53, pl. 124, figs. 23-24.—KOEIILER, 1922, p. 110, pl. 8, figs. 1-4, 6-8, 10, pl. 11, fig. 4, pl. 15, fig. 5.—H. L. CLARK, 1938-a, p. 417, pl. 15, fig. 3.—MORTENSEN, 1948-c, p. 263, pl. 47, figs. 1-4, 6-7, pl. 47, figs. 1-2, pl. 50, figs. 4-11, pl. 72, figs. 2-3, text-figs. 159, 177a-b, 178b, 179, 180a.

Peronella decagonalis: A. AGASSIZ, 1972-74, pp. 147, 520 (pro parte), pl. 13e, figs. 8-11 (non BLAINVILLE, 1827).

Peronella aphnostina H.L. CLARK, 1914-a, p. 167, pl. 24.

Test very flat and distinctly longer than wide; margin thin, about 0.07 of testlength; petaloid area about half of test-length or more; petals usually more or less nearly closed; tubercles on ridges in poriferous zones all miliaries; posterior end of test not restricted; periproct about 0.2 of long radius; oral ambulacral furrows rather distinct, but short.

As north as Hongkong to the Philippines and Indo-China, from Malay to Australian Seas.

Littoral zones-70 metres in depth.

Peronella rubra Döderlein, 1885

Peronella (Laganum) rubra Döderlein, 1885, p. 106 (34).—H. L. CLARK, 1914, p. 54, pl. 124, figs. 18-20, pl. 142, figs. 5-7.—Mortensen, 1948-c, p. 274, pl. 51, figs. 23, 29, text-figs. 170b, 183c, 188b.

Test about nine-tenths as wide as long or wider; petals open; poriferous zones little curved; periproct 0.4-0.5 long radius from the posterior margin; height of test less than one-fifth of test-length; petaloid area more than half of test-length; margins about 0.09 of test-length; periproct covered with radioles; colour red, pink, or white.

From the Japanese Seas (Mutsu Bay, Sagami Sea to Inland Sea) to Java Sea (?). 5-60 metres in depth.

Peronella japonica MORTENSEN, 1948 (Ph-APT)

Peronella japonica MORTENSEN, 1948, p. 71.—MORTENSEN, 1948-c, p. 277, pl. 49, figs. 1, 6-12, text-figs. 168-169, 177c, 178c, 180b, 184a, 187a.

Peronella decagonalis: A. Agassiz, 1872-74, pp. 148, 520 (pro parte) (non Blainville, 1827).—
Döderlein, 1885, p. 105 (33).—Tokunaga, 1903, p. 8.—Yoshiwara (Tokunaga), 1907, pl. 15, figs. 9-13, pl. 16, figs. 7-8.

Test flat, low, roughly and irregularly decagonal in marginal outline, elongate, posterior end more or less restricted; margins of test thin, being 0.06 or more of test-length; petaloid area more than half of test-length; petals rather narrow and long, more or less nearly closed distally; tubercles on ridges in the poriferous zones interrupted by a few primaries; periproct oval, more or less transversely elongate, placed about twice its length from the posterior edge of test, and naked; oral ambulacral furrows rather well marked and distinct, reaching over a half in length of respective radii.

Known only from the Japanese Seas (from Tokyo Bay and Sagami Sea to Kagoshima Gulf).

Littoral zones-50 metres in depth.

Peronella pellucida Döderlein, 1885

Peronella (Laganum) pellucida Döderlein, 1885, p. 104 (32).—Laganum pellucidum Döderlein: Yoshiwara (Tokunaga), 1907, pl. 16, figs. 5-6(?).—Peronella pellucida Döderlein: H. L. Clark, 1914, p. 53, pl. 142, figs. 1, 8-10.—Mortensen, 1948-c, p. 281, pl. 47, fig. 5, pl. 48, figs. 3-4, pl. 72, figs. 1, 11, text-figs. 160c, 166, 170a, 185a, 187.

Test about as wide as long; height of test less than one-fifth of test-length; petaloid area small, less than half of test-length; margin of test very thin; periproct round or transversely oval, not elongate, about 0.5 of long radius from the posterior margin; anal plates without radioles; oral ambulacral furrows distinct.

From the Japanese Seas (from Sagami Sea to Kagoshima Gulf) to Kei Islands(?). 75-550 metres in depth.

Peronella minuta (MEIJERE, 1904)

Laganuu minutum Meijere, 1904, p. 125, pl. 6, figs. 76-77, pl. 18, fig. 334.—Peronella minuta (Meijere) H.L. Clark, 1914, p. 51.—Mortensen, 1948-c, p. 295, pl. 51, figs. 19-22, pl. 72, fig. 6, text-figs. 185b, 190.

Small forms, but genital pores present already at size of about 11-15 mm length of test, and placed within the apical system; margin of test thick; periproct more or less posterior, covered with radioles.

From the Japanese Seas (from Tanabe Bay to Kagoshima Gulf) to Sulu Archipelago.

13-35 metres in depth.

Peronella orbicularis (LESKE, 1778)

Echinodiscus orbicularis LESKE, 1778, p. 144.—Laganum orbiculare (LESKE) AGASSIZ, 1841-b,
 p. 120, pl. 22, figs. 16-20.—Peronella orbicularis (LESKE) : A. AGASSIZ, 1872-74, pp. 149,
 521.—Laganum orbiculare (LESKE) : MEIJERE, 1904, p. 126, pl. 6, figs. 69, 73-75, pl. 18, figs.
 335-339.—MORTENSEN, 1948-c, p. 286, pl. 51, figs. 1-18, text-figs. 170c, 188a.

Small forms; test rather stout, usually round in outline; aboral side low, oral side flat or slightly concave; margin of test usually thickened, about 0.12 of test-length; petaloid area rather large, about 0.6 or more of test-length; petals generally closed and pointed; a single, regular series of tubercles on the ridge between the pore-pairs in the poriferous zones; periproct near the posterior end than the peristome.

From 'Formosa' and the Philippines to Malay region and Queensland.

5-70 metres in depth.

Suborder SCUTELLOINA HAECKEL, 1896

Scutellaria HAECKEL, 1896, p. 231.—Scutellina GRAY: DURHAM, 1955, p. 149 (non Scutellina Agassiz, 1841).—Scutellina HAECKEL: DURHAM and MELVILLE, 1957, p. 259.—PHILIP, 1965, p. 58.

Type-family.—Scutellidae GRAY, 1825.

Test flattened; internal supports usually well developed. Ambulacral structure within the petals simple; pore-pairs conjugate. Interambulacra terminating adapically in a pair of plates, often discontinuous on oral surface. Peristome central, buccal membrane naked. Auricles fused and interradial. Primary radioles simple or club-shaped; aboral miliary radioles terminating in glandular bag. Oral ambulacral furrows present, often highly complicated, with terminal projection extending over buccal tube-feet pores. Tube-feet with two spicules in sucking disc.

From the Eocene to Recent.

Family Scutellidae Gray, 1825

Scutellidae GRAY, 1825, p. 427 (pro parte).—Scutellinae LAHILLE, 1895, p. 33.—MORTENSEN, 1948-c, pp. 359, 360. Type-genus.—Scutella LAMARCK, 1816.

Test very flat, usually more or less discoidal, but without marginal slits, lunules, or indentations. Interambulacra continuous or discontinuous on oral surface, nearly as wide as or less the ambulacra at ambitus. Oral ambulacral furrows bifurcating or trifurcating outside basicoronal plates, rarely simple. Genital pores four.

Subfamily DENDRASTERINAE LAMBERT, 1900

Dendrasteridae LAMBERT, 1900, table opp. p. 50.—LAMBERT and THIÉRY, 1914, p. 316.—DUR-HAM, 1955, p. 157 (partim).

Type-genus.—Dendraster AGASSIZ, 1847.

Phelsumasteridae LAMBERT and THIÉRY, 1914, p. 316 (partim).—Echinarachniidae LAMBERT: DURHAM, 1955, p. 163 (emended for Phelsumasteridae LAMBERT and THIÉRY, 1914; partim). Type-genus.—Echinarachnius GRAY, 1825.=Phelsumaster LAMBERT and THIÉRY, 1914.

Petals well formed, a few isolated pores outside petals; outer member of porepairs elongated. Posterior interambulacrum (5) generally discontinuous on oral surface; basicoronal interambulacral plates larger than ambulacral plates. Oral ambulacral furrows bifurcating or trifurcating outside basicoronal plates or with lateral branches near ambitus, rarely simple. Pedicellariae bivalved.

S. NISIYAMA

Genus Ecninarachnius GRAY, 1825

Echinarachnius Gray, 1825, p. 428.—Agassiz, 1841-b, p. 88.—Nisiyama, 1940, pp. 804, 826.— Mortensen, 1948-c, p. 363, text-figs. 215-216.

Logotype.—Scutella parma LAMARCK, 1816, p. 11. [AGASSIZ, 1841-b, p. 88].

- Phelsumia POMEL, 1883, p. 70 (pro Echinarachnius GRAY, 1825, non LESKE, 1778; nec Phelsuma GRAY, 1840).—Phelsumaster LAMBERT and THIÉRY, 1914, p. 316 (pro Phelsumia POMEL, 1883).
 - Orthotype.—Echinarachnius parma (LAMARCK) : A. AGASSIZ, 1872-74, p. 316, pl. 11d, figs. 4-5, pl. 11e, figs. 4-5.

Test usually of round outline. Petals usually well developed, usually broadly open distally. Oral ambulacral furrows with a pair of simple side branches distally, issuing at angle of about 45 degrees at the height of second post-basicoronal plates. Apical system usually central. Periproct usually marginal, between third pair of post-basicoronal plates. Primordial interambulacral plates continuous or discontinuous with the post-basicoronal interambulacral plates. Pedicellariae of any kinds have two valves.

Echinarachnius parma obesus H.L. CLARK, 1914 (C-P)

Echinarachnius parma var. obesa H. L. CLARK, 1914, p. 67, pl. 143, figs. 5-8.—Echinarachnius parma obesus H. L. CLARK: IKEDA, 1935-a, p. 205, pl. 4, fig. 9.—NISIYAMA, 1940, p. 827, pl. 43, fig. 10, text-fig. 10.—MORTENSEN, 1948-c, p. 372, no figures.—MORISHITA, 1955, p. 235, pl. 11, fig. 2 (reproduced from IKEDA, 1935).

Test stout and high, about one-fourth of test-length; petals long and widely open distally; apical system central; oral side flat; oral ambulacral furrows bifurcating on the second post-basicoronal ambulacral plates; colour changes into green in alcohol.

From east coast of Sakhalin and Hokkaido to northern Japan (41°N.).

Littoral zones-40 metres in depth.

Echinarachnius asiaticus MICHELIN, 1859

Echinarachnius asiaticus MICHELIN, 1859-a, p. 3.—H. L. CLARK, 1914, p. 68, pl. 143, figs. 1-4 (MCZ no. 4215).—NISIYAMA, 1940, p. 826, pl. 43, fig. 11.—MORTENSEN, 1948-c, p. 373, no figures.

Test thick and stout; height about one-fourth of test-length; petals widely open distally; poriferous zones very narrow; primordial interambulacral slightly depressed; oral ambulacral furrows distinct beyond the bifurcating point; aboral primary radioles stout and conspicuously swollen at tip; colour of test violet, especially on oral surface.

Known only from east coast of Sakhalin and Kamtchatka.

Genus Scaphechinus A. AGASSIZ, 1863

Scaphechinus A. Agassiz, 1863-a, p. 359.—Nisiyama, 1940, p. 832 (subgenus).—Mortensen, 1948-c, p. 374.--Durham, 1955, p. 162.

Haplotype.-Scaphechinus mirabilis A. AGASSIZ, 1863-a, p. 359.

Chaetodiscus Lütken, 1864, p. 172.

Haplotype.—Chaetodiscus scutella LÜTKEN, 1864, p. 172.=Scaphechinus mirabilis A. AGASSIZ,

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1863-a, p. 359.

Scutella MARTENS, 1865, p. 140.

Haplotype.—Scutella japonica MARTENS, 1865, p. 140.=Scaphechinus mirabilis A. AGASSIZ, 1863-a, p. 359.

Oral ambulacral furrows bifurcating just outside basicoronal ambulacral plates into two diverging main branches, which have a varying number of small sidebranches distally. Apical system usually central, or more or less eccentric in front. Periproct marginal or slightly supramarginal. Primordial interambulacral plates usually discontinuous with post-basicoronal interambulacral plates. Pedicellariae of bidentate and biphyllous types present.

Scaphechinus mirabilis A. AGASSIZ, 1863 (Ph-APT)

Scaphechinus mirabilis A. AGASSIZ, 1863-a, p. 359.—Echinarachnius mirabilis (A. AGASSIZ)
A. AGASSIZ, 1872-74, pp. 107, 526, pl. 13a, figs. 5-6.—YOSHIWARA (TOKUNAGA), 1907, pl. 16, figs. 9-10.—H. L. CLARK, 1914, p. 69, pl. 125, fig. 6.—IKEDA, 1935-a, p. 202, pl. 6, figs. 5-8.—Echinarachnius (Scaphechinus) mirabilis (A. AGASSIZ): NISIYAMA, 1940, pp. 813, 835, pl. 43, figs. 1-4, pl. 44, figs. 1-6, text-figs. 13-36, 61-62.—Scaphechinus mirabilis A. AGASSIZ: MORTENSEN, 1948-c, p. 375, pl. 61, fig. 9. pl. 63, fig. 4, pl. 71, figs. 19-21, text-figs. 208d, 210b, 218b, 220.—Echinarachnius mirabilis (A. AGASSIZ): MORISHITA, 1955, p. 231, pl. 8, figs. 3-6.—Scaphechinus mirabilis A. AGASSIZ: UTINOMI, 1960, p. 344, pl. 40, fig. 17.

Test rather large; margins rather thick; test round or pentagonal, not distinctly broader than long; depressed in interambulacral spaces on aboral surface and slightly depressed around the petaloid area; colour of test and radioles usually dark purple or dark violet; periproct marginal.

Known only from the Japanese Seas (from Ishikari Bay to the south of Kyushu). Littoral zones—125 metres in depth.

Scaphechaus mirabilis tenuis (YOSHIWARA, 1898)

Echinarachnius tenuis Yoshiwara, 1898, p. 61.—Echinarachnius (Scaphechinus) mirabilis tenuis Yoshiwara: Nisiyama, 1940, p. 838, pl. 43, fig. 5, text-fig. 63.—Scaphechinus tenuis (Yoshiwara) Mortensen, 1948-c, p. 378, pl. 62, fig. 4 (with brevis Ikeda, 1936).

Test thin and small; margins thin and largely undulating; colours of test and radioles violet to dark brownish.

Known only from central Japan (Kominato, Chiba Prefecture, is the type-locality). Probably in littoral zones to small depths.

Scaphechinus griseus (MORTENSEN, 1927)

Echinarachnius griseus MORTENSEN, 1927-a, p. 195, pl. 1, figs. 1-4, text-figs. 2a, 2f.—Echinarachnius (Scaphechinus) griseus MORTENSEN: NISIYAMA, 1940, p. 841, pl. 43, fig. 6, text-fig. 65.—Scaphechinus griseus (MORTENSEN): MORTENSEN, 1948-c, p. 379, no figures.—Echinarachnius griseus MORTENSEN: MORISHITA, 1955, p. 234, pl. 9, figs. 1-2.—Scaphechinus griseus (MORTENSEN): UTINOMI, 1960, p. 345, pl. 40, fig. 19.

Test moderate; margins thin; rather delicate; apical system slightly eccentric in front; periproct distinctly but slightly supramarginal, even in adult individuals it

aparts from the posterior edge of test in length as equal as its diameter; no depression of interambulacral spaces on aboral surface and a slightly depression around the petaloid area; colours of test and radioles grey or greyish green, or dark greenish.

Known only from northwestern Pacific, from northern Kuriles and southern Sakhalin to Tohoku district.

7-10 metres in depth.

Scaphechinus brevis (IKEDA, 1936)

Echinarachnius brevis IKEDA, 1936-a, p. 1231, text-figs. a-c.—IKEDA, 1939, pl. 3, figs. 1, 8.—
Echinarachnius (Scaphechinus) brevis IKEDA: NISIYAMA, 1940, p. 843, pl. 43, figs. 7-9, text-figs. 38-60, 64.—Scaphechinus tenuis (IKEDA): MORTENSEN, 1948-c, p. 378, pl. 61, figs. 3-5 (pro parte).—Echinarachnius brevis IKEDA: MORISHITA, 1955, p. 234, pl. 8, figs. 1-2.—
Scaphechinus brevis (IKEDA): UTINOMI, 1960, p. 345, pl. 40, fig. 18.

Test large, decidedly wider than long; no depression of interambulacral spaces on aboral surface and a slight depression around the petaloid area; periproct marginal; margins of test thin and undulating posteriorly, aboral side gently elevated; colours of test and radioles usually purple or brownish purple.

Known only from the Japanese Seas (from Muroran, Hokkaido to central Japan). Probably from littoral zones to small depths.

Family ASTRICLYPEIDAE STEFANINI, 1912

Astriclypeinae Stefanini, 1912, pp. 747, 748, 749.—Mortensen, 1948-c, p. 398.—Astriclypeidae Stefanini: Durham, 1955, p. 175 (partim). Type-genus.—Astriclypeus Verrill, 1867.

Test of usually large forms, very flat, low discoidal, oral side usually very flat. Petals well formed; pores conjugate; a few primary pore-pairs outside the petals. There are lunules or marginal slits in ambulacra or in posterior interambulacrum (5) or in the both areas, never in anterior lateral interambulacra (2 and 3). Apical system subcentral, with four or five genital pores. Interambulacra generally discontinuous on oral surface, about as wide as ambulacra at ambitus. Oral ambulacral furrows bifurcating just outside basicoronal row. Pedicellariae bivalved or trivalved, ophicephalous pedicellariae may occur.

Subfamily ASTRICLYPEINAE STEFANINI, 1912

Astriclypeidae STEFANINI: DURHAM, 1955, p. 175 (family).

Test usually of large size, with lunules or marginal slits in ambulacra, but none in interambulacra. Posterior interambulacrum (5) discontinuous on oral surface; antero-lateral interambulacra may be discontinuous. Four genital pores. Periproct on oral surface. Pedicellariae three-valved.

Genus Echinodiscus LESKE, 1778

Echinodiscus Leske, 1778, p. 195 (pro parte).-A. Agassiz, 1872-74, pp. 112, 531.-H.L. Clark,

1911, p. 605.—Mortensen, 1948-c, p. 398.—Durham, 1955, p. 176.

Logotype.—Echinodiscus bisperforatus LESKE, 1778, p. 196.—MORTENSEN, 1948-c, p. 406, pl. 53, figs. 2, 6-8, pl. 71, figs. 6-9, 18, text-figs. 202b, 241a, 242a. [H. L. CLARK, 1911, p. 605.—Bull. Zool. Nomencl., vol. 4, 1950, p. 535].

Lobophora Agassiz, 1841-b, p. 64.—Agassiz and Desor, 1847, p. 136.

- Logotype.—Lobophora biforis (GMELIN) AGASSIZ, 1841-b, p. 64, pl. 12, figs. 1-11.=Echinodiscus bisperforatus LESKE, 1778, p. 196. [DESOR, 1855-58 (57), p. 235].
- Tretodiscus POMEL, 1883, p. 71 (pro Lobophora Agassiz, 1841, non Curtis, 1825, nec Serville, 1839).—Tetrodiscus POMEL: LAMBERT and THIÉRY, 1921, p. 323 (corruption of Tretodiscus POMEL, 1883).

Type-species.—Echinodiscus bisperforatus LESKE, 1778, p. 196.

Test flat, low discoidal, mostly truncate at the posterior end. Only 2 lunules or marginal slits present, one in each posterior ambulacrum. Periproct on oral surface. Pedicellariae of tridentate, ophicephalous, and triphyllous types.

Echinodiscus auritus siamensis MORTENSEN, 1948 (C-P)

Echinodiscus auritus LESKE: MEIJERE, 1904, p. 138, pl. 19, figs. 336-368.—H. L. CLARK, 1914, p. 71, 115, figs. 9-10.—KOEHLER, 1922, p. 123, pl. 4, fig. 10, fig. 14, pl. 11, figs. 5-6, pl. 15, fig. 12.—ROXAS, 1928, p. 266, pl. 7, figs. 25-26.—HAYASAKA, 1948, p. 19, pl. 4, figs. 1a-b, pl. 5, figs. 1a-b.
Totradiscus rumphii KLEIN: LANDERT and TULENY, 1921, p. 323 (pro. parte).

Tetrodiscus rumphii KLEIN: LAMBERT and THIÉRY, 1921, p. 323 (pro parte).

Echinodiscus auritus var. siamensis Mortensen, 1948, p. 72.-Mortensen, 1948-c, p. 404.

Test very thin and delicate; postero-lateral ambulacra (I and V) with deep, narrow, marginal slits, depths of which may equal or even exceed length of frontal petal (III); test often longer than wide, of yellowish or straw colour contrast to dark purplish colour of typical series. Ophicephalous pedicellariae exceedingly small (in typical species, fairly large); valves of tridentate pedicellariae finely serrate at subtruncate distal end.

From southern Japan and Formosa to the Philippines and Indo-China, and also to Malay region and the Indian Ocean.

Ebb-zone to about 50 meters in depth.

Echinodiscus tenuissimus (AGASSIZ, 1847)

Lobophora tenuissima AGASSIZ in AGASSIZ and DESOR, 1847, p. 136.—Echinodiscus tenuissimus (AGASSIZ) GRAY, 1855-a, p. 20.—MORTENSEN, 1948-c, p. 411, pl. 15, fig. 1, pl. 58, fig. 1. Lobophora deplanchei MICHELIN, 1861, p. 326, pl. 9, fig. 1. Tretodiscus laevis (KLEIN): LAMBERT and THIÉRY, 1921, p. 323.

Test very flat with thin margins, with closed lunules; lunules very short, at most about as long as the petals; antero-lateral petals (II and IV) little if any longer than the postero-laterals (I and V); length of test usually exceeds its width; no clear differences between ambulacral and interambulacral radioles of oral side.

From southern Japan(?) (Ousima, Japan-MCZ no. 2372) to Indo-China and Indian •Ocean.

Littoral zones-20 meters in depth.

S. Nisiyama

Genus Astriclypeus VERRILL, 1867

Astriclypeus VERRILL, 1867-71(67), p. 311.—A. AGASSIZ, 1872-74, p. 538.—H.L. CLARK, 1911, p. 605.—NISIYAMA, 1935, p. 132.—MORTENSEN, 1948-c, p. 414.—DURHAM, 1955, p. 175. Haplotype.—Astriclypeus mannii VERRILL, 1867-71(67), p. 311 (China ?).

Crutulum TROSCHEL, 1868, p. 1.—TROSCHEL, 1869-a, p. 52.

Haplotype.—Crustulum gratulans TROSCHEL, 1868, p. 1.=Astriclypeus mannii VERRILL, 1867-71(67), p. 311.

Test discoidal, rather stout and heavy, nearly circular, slightly truncated posteriorly. Five lunules, one in each ambulacrum (I, II, III, IV, and V). Petals rather broad, or open distally in Recent forms; periferous zones rather broad. No internal pillars separating buccal cavity from intestinal space within the test. Pedicellariae of tridentate and triphyllous types; ophicephalous pedicellariae present in young individuals only.

Astriclypeus mannii VERRILL, 1867

Astriclypeus mannii VERRILL, 1867-71(67), p. 311.—Astriclypeus manni VERRILL: A. AGASSIZ, 1872-74, pp. 93, 539, pl. 13d, figs. 2-4.—YOSHIWARA (TOKUNGAGA), 1907, pl. 16, figs. 11-12.—
H. L. CLARK, 1914, p. 72, pl. 125, figs. 13-15.—NISIYAMA, 1935, p. 134, text-figs. 1a-b.—IKEDA, 1939, pl. 2, figs. 8-11, pl. 3, figs. 6-7, pl. 12, fig. 9, pl. 13, figs. 4-6.—MORTENSEN, 1948-c, p. 416, pl. 59, figs. 1-3, pl. 62, fig. 1, pl. 72, figs. 17-18, 20-21, text-figs. 219c, 221, 244.

Size moderate or large, 75-100 mm or more in diameter; colour fawn or brown; petals rather broad, open distally; poriferous zones more or less markedly truncated at their distal end; each oral ambulacral furrow has a fairly conspicuous, well limited median keel that bends downwards at its inner end.

From the Japanese Seas (from Tokyo Bay to Kagoshima Gulf) to China and Indo-China (Riam, Cambodia-reliable).

In littoral zones.

Order SPATANGOIDA CLAUS, 1876

Spatangoideae CLAUS, 1876, p. 386 (pro parte).—Spatangoida DUNCAN, 1889-a, p. 205.—Spatangoida AGASSIZ: MORTENSEN, 1950-a, p. 1.—PHILIP, 1965, p. 59. Type-family.—Spatangidae GRAY, 1825.

Test usually very irregular, exocyclic. Posterior interambulacrum (5) usually different from paired interambulacra orally, forming a more or less petaloid adapically, or quite rudimentary; ambulacral structure within the petals simple; anterior ambulacrum (III) often differs markedly in character from paired ambulacra adapically. Apical system and peristome usually eccentric in front. No branchial slits; no distinct floscelle, phyllodes may be fairly conspicuous, but no bourrelets. Masticatory apparatus absent, at least in adults. Fascioles often present.

From the Lower Cretaceous to Recent.

Suborder URECHINOINA H.L. CLARK, 1925

Urechinina HAWKINS: H.L. CLARK, 1925, p. 185.—NISIYAMA, 1954, p. 330 (in Japanese). Meridosterni Lovén, 1883, p. 91.—Meridosternata Lovén: Mortensen, 1950-a, pp. 5, 37.— Meridosternina MORTENSEN: PHILIP, 1965, p. 60. Holasteroida DURHAM and MELVILLE, 1957, p. 260 (order; partim). Type-family.—Urechinidae DUNCAN, 1889.

In posterior interambulacrum (5) labrum (primordial interambulacral plate (1)) joining at its posterior end only a single plate no. 2 (meridoplaceous). Apical system usually intercalary. Fascioles of irregular occurrence and of no great classifactory value.

Family HOLASTERIDAE PICTET, 1857

Holasteridées PICTET, 1854-73(57), p. 276.—Holasteridae ZITTEL, 1879, p. 532 (pro parte).— MORTENSEN, 1950-a, p. 38. Type-genus.—Holaster AGASSIZ, 1836. Echinocorythidae GREGORY, 1900-b, p. 321.—H. L. CLARK, 1917, p. 124.

Type-genus.—Echinocorytes [BREYNIUS] LESKE, 1778.

Meridosternous echinoids of very varying size and shape, with at least paired ambulacra biporous, simple, flush with test or subpetaloid and more or less sunken. Mouth horizontally placed on oral surface of test. Interambulacra (2) and (3) amphiplaceous. Apical system intercalary, oculars (II) and (IV) meeting in aboral midline, separating thus anterior from posterior genital plates. Fascioles present in some genera.

Subfamily Holasterinae Pictet, 1857

Holasterinae MORTENSEN, 1950-a, p. 47.

Peristome not being placed at end of a deep sharply limited oral groove.

Genus Stereopneustes MEIJERE, 1903

Stereopneustes MEIJERE, 1903, p. 2.-MEIJERE, 1904, p. 147.-MORTENSEN, 1950-a, p. 69. Haplotype.-Stereopneustes relictus MEIJERE, 1903, p. 2.

Test thick, oval. Apical system central, with four genital pores. Buccal area semi-lunular. Ambulacra not petaloid, subequal; ambulacral pores in pairs and round; poriferous zones rather broad. No large aboral primary tubercles. Subanal fasciole present.

Stereopneustes relictus MEIJERE, 1903

Stereopneustes relictus MEIJERE, 1903, p. 2.—MEIJERE, 1904, p. 148, pl. 5, figs. 41-43, pl. 19, figs. 390-393.—Mortensen, 1950-a, p. 70, pl. 3, fig. 5, pl. 20, figs. 2-3, 6, 8-9, 11, text-figs. 62a-b, 63.

Size large, attains 90 mm in test-length; small labrum contiguous with a large single plate; conspicuously sunken in peristomial region; phyllodes quite conspicuous; valves of ophicephalous pedicellariae considerably variable, but broad-form common; colour dark purplish.

From off Kagoshima Gulf (MCZ no. 1023) to the Philippines and Sulu Sea. 250-900 metres in depth.

S. NISIYAMA

Family URECHINIDAE DUNCAN, 1889

Urechininae DUNCAN, 1889-a, p. 311 (pro parte).—Urechinidae MEISSNER, 1904, p. 1402.— MORTENSEN, 1950-a, p. 103. Type-genus.—Urechinus A. AGASSIZ, 1879.

Small to large forms of regular ovoid outline. Ambulacra uniporous, all alike, flush with test. Interambulacra all meridoplaceous orally. Mouth horizontally placed on oral surface of test. Apical system of "holasterid" type. A subanal fasciole may present. All the five usual type of pedicellariae represented.

Genus Urechinus A. AGASSIZ, 1879

Urechinus A. Agassiz, 1879, p. 207.—A. Agassiz, 1881-a, p. 145.—H. L. Clark, 1917, p. 122.— Mortensen, 1950-a, p. 108.

Haplotype.—Urechinus naresianus A. Agassiz, 1879, p. 207.

Cystechinus A. AGASSIZ, 1879, p. 207.—A. AGASSIZ, 1881-a, p. 149.

Haplotype.—Cystechinus wyvillei A. AGASSIZ, 1879, p. 149.—A. AGASSIZ, 1881-a, p. 152, pls. 29-29b.

Test not so high, not flexible. Periproct at or below ambitus, not in a marked depression. Plates around mouth of moderate size; primordial interambulacral plates much larger than buccal plates. No anal snout. Valves of globiferous pedicellariae terminating in two or more hooks. Large form.

Urechinus loveni (A. AGASSIZ, 1898)

Cystechinus loveni A. AGASSIZ, 1898, p. 79.—A. AGASSIZ, 1904, p. 158, pls. 75-79.—Urechinus loveni (A. AGASSIZ): H. L. CLARK, 1917, p. 123, pl. 147, fig. 3.—MORTENSEN, 1950-a, p. 113.
 Cystechinus purpureus A. AGASSIZ and H. L. CLARK, 1907-b, p. 131.

Genital pores three; valves of globiferous pedicellariae with two teeth on either side of terminal opening; apical system rather compact.

Known from Bearing and Ochtosk Seas on northern Pacific, and from Acapulco to Lower California on eastern Pacific side.

3070-3610 meters in depth.

Urechinus naresianus A. AGASSIZ, 1879

Urechinus naresianus A. Agassiz, 1879, p. 207.—A. Agassiz, 1881-a, p. 146, pl. 29, figs. 1-4, pl. 30a.—Mortensen, 1950-a, p. 111, text-fig. 105.

Genital pores three; globiferous pedicellariae with large terminal opening surrounded by 6-7 long slender teeth, none on lower margin; colour rather diverse.

Doubted known from Bering and Ochotsk Seas: southeast of Sakhalin.

In 3276 metres depth.

Family POURTALESIIDAE A. AGASSIZ, 1881

Pourtalesinae A. AGASSIZ, 1881-a, p. 155.—Pourtalesiadae Lovén, 1883, p. 82.—Pourtalesiidae Lovén: Duncan, 1889-a, p. 279.—H.L. CLARK, 1917, p. 125.—Mortensen, 1950-a, p. 131. Type-genus.—Pourtalesia A. AGASSIZ, 1869. Test more or less elongate and often of very unusual form. Frontal ambulacrum (III) continuous as a deep, sharply limited, groove on peristome, which placed vertically at end of groove. Pores of ambulacra simple at least adapically. Fascioles present.

Genus Pourtalesia A. AGASSIZ, 1869

Pourtalesia A. Agassiz, 1869, p. 272.—A. Agassiz, 1881-a, p. 156.—Lovén, 1883, p. 15.— Mortensen, 1950-a, p. 142.

Haplotype.—Pourtalesia miranda A. AGASSIZ, 1869, p. 272.—A. AGASSIZ, 1872-74, p. 345, pl. 18. Phyale POMEL, 1883, p. 40 (non KOCH, 1847).

Haplotype.—Pourtalesia jeffreysi Thomson, 1874, p. 747.

Test fragile, more or less distinctly bottle-shaped. Anterior end of test not widened, not forming like a head. Bivial ambulacra discontinuous, interrupted by interambulacra (1) and (4) meeting in midline on side. Dorsal plates of interambulacrum (5) paired. Only one pore in posterior paired ambulacra (Ia1 and Vb1) orally. Subanal rostrum conspicuous. Subanal fasciole present.

Pourtalesia laguncula A. AGASSIZ, 1879

Pourtalesia laguncula A. Agassiz, 1879, p. 205.—A. Agassiz, 1881-a, p. 157, pl. 31, figs. 1-6.—
 Lovén, 1883, p. 19, pl. 6, figs. 37-41, pl. 7, fig. 52.—Yoshiwara (Tokunaga), 1908, pl. 21, figs. 15-17 (reproduced from A. Agassiz, 1881-a.)—Mortensen, 1950-a, p. 147.

Test moderate, 20-30 mm in test-length; width about half of length; side not nearly parallel; subanal rostrum with sides nearly or quite parallel, tip truncate and more or less markedly elevated; genital plates completely fused together; ophicephalous pedicellariae more or less abundant; rostrate ones rare or wanting.

From the Japanese Seas (from Sagami Sea (MCZ no. 2776) to Kyushu) to Malay region and New Zealand.

220-1370 metres in depth.

Suborder SPATANGOINA CLAUS, 1876

Spatangina JACKSON, 1912, p. 204 (pro parte).—H. L. CLARK, 1925, p. 192.—NISIYAMA, 1954, p. 330 (in Japanese).—Spatangoida CLAUS: DURHAM and MELVILLE, 1957, p. 261 (order). Type-family.—Spatangidae GRAY, 1825.

Amphisternata Mortensen, 1907, p. 90.—Mortensen, 1950-a, p. 174.—Amphisternina Mortensen: Philip, 1965, p. 60.

In posterior interambulacrum (5) labrum joins at its posterior end two large, equally, or nearly equally, developed sternal plates (amphisternous). Apical system compact, never opposite peristome. Fascioles generally represent and of very constant arrangement.

Family PALAEOPNEUSTIDAE A. AGASSIZ, 1904

Palaeopneustidae A. Agassiz, 1904, p. 150.—H. L. Clark, 1917, p. 138.—Mortensen, 1950-a, p. 181.

S. NISIYAMA

Type-genus.—Palaeopneustes A. AGASSIZ, 1873. Antillasterinae LAMBERT and THIÉRY, 1924, p. 439 (tribus). Type-genus.—Antillaster LAMBERT, 1909.

Mainly large forms of ovoid or rounded outline. Ambulacra more or less conspicuously petaloid, but not sunken, or flush on aboral surface, or rudimentary. Phyllodes usually strongly developed. Apical system ethmolytic. Peristome more or less conspicuously labiate. Primary radioles usually strongly developed. Fascioles variable or lacking. All the different types of pedicellariae may present.

Subfamily PALAEOPNEUSTINAE A. AGASSIZ, 1904

Palaeopneustinae Mortensen, 1950-a, p. 186.

Ambulacra petaloid or subpetaloid adapically. Large primary radioles generally present.

Genus Linopneustes A. AGASSIZ, 1881

Linopneustes A. AGASSIZ, 1881-a, p. 167.—A. AGASSIZ, 1904, p. 178.—H. L. CLARK, 1917, p. 223.— MORTENSEN, 1950-a, p. 203. Haplotype.—Palaeopneustes murrayi A. AGASSIZ, 1879, p. 210.

A marginal and subanal fascioles present. Petals rather well developed, but widely open distally and not abruptly limited by marginal fasciole. Test highest at apical system. Primary radioles (tubercles) on aboral side without deeply sunken areoles.

Linopneustes murrayi (A. AGASSIZ, 1879)

Palaeopneustes murrayi A. AGASSIZ, 1879, p. 210.—Linopneustes murrayi (A. AGASSZ) A. AGASSIZ, 1881-a, p. 168, pl. 25.—YOSHIWARA (TOKUNAGA), 1908, pl. 21, figs. 1-4 (reproduced from A. AGASSIZ, 1881-a).—MORTENSEN, 1950-a, p. 206, pl. 12, figs. 2-3, pl. 15, figs. 1-2, pl. 23, figs. 5, 18, pl. 24, figs. 2-3, 6-8, text-figs. 153a, 154a, 155, 163a.

Marginal fasciole somewhat above ambitus and near tips of petals; vertex before apical system, which subcentral or slightly anterior; poriferous zones of each petal nearly parallel or diverging distally; primary radioles not much longer secondaries, only ca 15 mm long, fairly numerous; a series of primary tubercles to each side along upper part of frontal ambulacrum (III); periproct marginal.

From the Japanese Seas (Sagami Sea) to the Philippines and Malay region. 620-1615 metres in depth.

Linopneustes fragilis (MEIJERE, 1904)

Palaeopneustes fragilis MEIJERE, 1904, p. 175, pl. 9, figs. 90-93, pl. 21, figs. 427-432, pl. 22, figs. 433-437.—Linopneustes fragilis (MEIJERE) MORTENSEN, 1948-b, p. 114.—MORTENSEN, 1950-a, p. 210, pl. 13, fig. 1, pl. 14, fig. 1, pl. 23, figs. 4, 7, 15, pl. 24, figs. 1, 10, 19, 23, text-figs. 154b, 156, 157, 158a-b, 162c.

Frontal ambulacrum (III) depressed as a shallow furrow; labrum thrice as long as. wide; plates 6-8 of ambulacral series adjoining sternum adproctally prolonged; primary aboral radioles very numerous, short, scarcely 10 mm long, not distinctly backwards directed, forming a dense, uniform coat; colours red-brown with violet tinge.

From the Japanese Seas (between Kobe and Yokohama) to the Philippines and Celebes.

560-1170 metres in depth.

Genus Argopatagus A. AGASSIZ, 1879

Argopatagus A. Agassiz, 1879, p. 209.—A. Agassiz, 1881-a, p. 159.—H. L. Clark, 1917, p. 145.— Mortensen, 1950-a, p. 221.

Haplotype.—Argopatagus vitreus A. Agassiz, 1879, p. 209.

Meijerea Döderlein, 1906, p. 242.

Haplotype.—Phrissocystis humilis MEIJERE, 1904, p. 148, pl. 10, figs. 99-100, pl. 23, figs. 494-500.

Subanal faciole present, more than twice as wide as long; no peripetalous fasciole. Petals rudimentary. Primary radioles (tubercles) on aboral side without deeply sunken areoles.

Argopatagus vitreus A. AGASSIZ, 1879

Argopatagus vitreus A. AGASSIZ, 1879, p. 209.—A. AGASSIZ, 1881-a, p. 160, pl. 32, figs. 1-6.— MORTENSEN, 1950-a, p. 223, pl. 8, fig. 2, pl. 21, figs. 1, 7, 9, 11, 13, 15-23, text-figs. 164-166.
Phrissocystis humilis MEIJERE, 1904, p. 198, pl. 10, figs. 99-100, pl. 23, figs. 494-500.—Meijerea humilis (MEIJERE) DÖDERLEIN, 1906, p. 243, pl. 31, figs. 1-4, pl. 49, fig. 7.
Meijerea excentrica A. AGASSIZ and H. L. CLARK, 1907-a, p. 252.

Test very fragile, low, highest at or just behind middle, and gently sloping from middle of aboral side towards posterior end; colours usually deep brown and with distinct reddish tinge; size large, attains 100 mm in test-length.

From the Japanese Seas to the Philippines and Banda Sea.

700-1310 meters in depth.

Argopatagus planus (A. AGASSIZ and H. L. CLARK, 1907)

Meijerea plana A. AGASSIZ and H. L. CLARK, 1907-b, p. 132.—Argopatagus planus (A. AGASSIZ and H. L. CLARK) H. L. CLARK, 1917, p. 148, pl. 151, figs. 6-8.—MORTENSEN, 1950-a, p. 225, text-fig. 167.

Test small, attains 30 mm in test-length; test flattened in middle of aboral side, rising towards posterior end, which strait cut; subanal fasciole at all angular; partically narrow labrum.

Known only from Kagoshima Gulf.

In 792 metres depth.

Genus Platybrissus GRUBE, 1865

Platybrissus Grube, 1865, p. 61.—A. Agassiz, 1872-74, p. 563.—H. L. Clark, 1917, p. 246.—Mortensen, 1950-a, p. 278.

Haplotype.-Platybrissus roemeri GRUBE, 1865, p. 61.

Subanal fasciole distinct only in the young. Test markedly depressed, height

usually less than 0.4 of test-length. Frontal ambulacrum (III) not depressed and anterior ambitus evenly convex. Petals nearly flush and tending to close distally.

Platybrissus roemeri GRUBE, 1865

Platybrissus roemeri GRUBE, 1865, p. 61.—A. AGASSIZ, 1872-74, p. 563, pl. 21b, figs. 3-4.—IKEDA,.
1942, p. 141, pl. 1, figs. 1-3, pl. 2, figs. 2-4, 6, 8-12.—MORTENSEN, 1950-a, p. 280, pl. 6, figs.
3-5, pl. 8, fig. 4, text-figs. 199a-b, 200-201.

Test depressed and aboral surface flattened; anterior ambitus evenly convex; petals nearly flush and open their extremity; subanal fasciole wholly obliterated in the adult; aboral surface purple in colour, oral surface light grey; aboral primary radioles with some dark-purply bands.

From the Japanese Seas (near Mino-shima, in Japan Sea) to Banda Sea. From shallow water down to 100 metres depth.

Subfamily PALAEOTROPINAE LAMBERT, 1896

Palaeotropinae LAMBERT, 1896, p. 324.—LAMBERT and THIÉRY, 1924, p. 434.—MORTENSEN, 1950-a, p. 285.

Type-genus.-Palaeotropus Lovén, 1872.

Ambulacra not petaloid adapically, or even quite rudimentary. A subanal fasciole usually present. No frontal depression of test; no large primary radioles.

Genus Palaeotrema KOEHLER, 1914

Palaeotrema Koehler, 1914, p. 45.—LAMBERT and THIÉRY, 1924, p. 434.—Mortensen, 1950-a, p. 299.

Orthotype.—Palaeotropus loveni A. AGASSIZ, 1879, p. 204.

Subanal fasciole present and not twice as wide as long; no peripetalous fasciole. No ambulacra at all petaloid adapically. No large primary tubercles with deeply sunken areoles.

Palaeotrema loveni (A. AGASSIZ, 1879)

Palaeotropus loveni A. AGASSIZ, 1879, p. 204.—A. AGASSIZ, 1881-a, p. 158, pl. 21, figs. 3-16, pl. 39, fig. 33, pl. 41, figs. 28-29.—A. AGASSIZ, 1904, p. 168, pl. 87, figs. 1-11.—Palaeotrema loveni (A. AGASSIZ) KOEHLER, 1914, p. 45.—MORTENSEN, 1950-a, p. 300, pl. 25, figs. 9, 12, 19-20, 27, text-figs. 206b, 207c, 208a-b, 209.

Test usually narrower in front than behind; posterior end conspicuously sloping; periproct distinctly visible from above; rudimentary phyllodes extend only for 2 or 3 ambulacral plates; ambulacra on oral side bare; labrum longer than wide.

From the Japanese Seas (from Sagami Sea to Kagoshima Gulf) to the Philippines. 176-251-400 metres in depth.

Family PALAEOSTOMATIDAE LOVÉN, 1867

Palaeostomidae Lovén, 1867, p. 432.—Gregory, 1900-b, p. 323.—Palaeostomatidae Lovén: MEISSNER, 1904, p. 1402.—H. L. CLARK, 1917, p. 133.—MORTENSEN, 1950-a, p. 308. Leskiadae GRAY, 1855-a, p. 63. Type-genus.-Palaeostoma LOVÉN in A. AGASSIZ, 1872 (=Leskia GRAY, 1851)

Peristome pentagonal, covered with five large, equally triangular plates. Petals well developed, surrounded by a peripetalous fasciole.

Genus Palaeostoma Lovén in A. AGASSIZ, 1872

Palaeostoma Lovén in A. Agassiz, 1872-74(72), pp. 80, 147 (pro Leskia Gray, 1851, non ROBINEAU-DESVOIDY, 1830).—Lovén, 1883, p. 25.—Mortensen, 1950-a, p. 312.
Haplotype.—Leskia mirabilis Gray, 1851, p. 134.
Leskia Gray, 1851, p. 134.—Gray, 1855-a, p. 63.

Leskia GRAY, 1051, p. 154.—GRAY, 1655-a, p. 05.

Test high and wide. Periproct in a depression on aboral surface, near posterior end.

Palaeostoma mirabile (GRAY, 1850)

Leskia mirabilis GRAY, 1851, p. 134.—GRAY, 1855-a, p. 63, pl. 4, figs. 4-4a.—Palaeostoma mirabilis (GRAY) A. AGASSIZ, 1872-74, p. 583, pl. 32, figs. 13-15.—LOVÉN, 1883, p. 27, pl. 16, figs. 184-196.—YOSHIWARA (TOKUNAGA), 1908, pl. 21, figs. 12-14 (reproduced from A. AGASSIZ, 1872-74).—KOEHLER, 1914, p. 36, pl. 3, figs. 1-2, 6, 8-9, pl. 17, figs. 19-29.—MORTENSEN, 1950-a, 314, pl. 4, figs. 3-4, pl. 5, figs. 3-5, pl. 25, figs. 28-29, 35, 37-39, 41, text-figs. 213-214.

Size small, attains 14 mm in test-length, oval, white or light-coloured spatangoid, remarkable peristome characteristic of the family.

From as far north as the Ryukyu Islands to Java Sea.

20-110 metres in depth.

Family AEROPSIDAE LAMBERT, 1896

Aeropsidae Lambert, 1896, p. 324.—Meijere, 1904, p. 243.—H.L. Clark, 1917, p. 133.—Mortensen, 1950-a, p. 322.

Type-genus.—Aeropsis Mortensen, 1907.

Frontal ambulacrum (III) strongly petaloid, with very large tube-feet. Paired ambulacra very faintly developed, not petaloid. A conspicuous peripetalous fasciole surrounding frontal part of test; no other fascioles. Peristome circular, with small plates surrounding central mouth.

Genus Aceste Thomson, 1877

Aceste THOMSON, 1877-78(77), p. 376.—H.L. CLARK, 1925, p. 194.—MORTENSEN, 1950-a, p. 330. Acestina LAMBERT and THIÉRY, 1924, p. 432 (pro Aceste THOMSON, 1877, non Acesta ADAMS, 1858).

Haplotype.—Aceste bellidifera THOMSON, 1877-78(77), p. 376.—A. AGASSIZ, 1881-a, p. 195, pl. 32, figs. 7-11, pl. 33a, figs. 1-7.

Test wide and flattened. Mouth vertical. Frontal ambulacrum (III) greatly enlarged and deeply depressed adapically. Genital pores two.

Aceste ovata A. AGASSIZ and H.L. CLARK, 1907

Aceste ovata A. AGASSIZ and H. L. CLARK, 1907-b, p. 258.—MORTENSEN, 1950-a, p. 333. Aceste annandalei Koehler, 1914, p. 18, pl. 1, figs. 15-17, pl. 2, figs. 1-16, figs. 16-34, pl. 17, figs. 1-5.—Acestina annandalei (KOEHLER) LAMBERT and THIÉRY, 1924, p. 433.

Aboral side rising more or less distinctly to a posterior vertex; height of test not more than half test-length; large frontal tube-feet (and pores) numerous, continuing to frontal notch; a form of very coarse, short valved tridentate pedicellariae present; sternum and labrum not projecting.

Known from the Japanese Seas to the Indian Ocean and Hawaian Islands. 435-4755 metres in depth.

Family Hemiasteridae H.L. Clark, 1917

Hemiasteridae H. L. CLARK, 1917, p. 159 (pro parte).—H. L. CLARK, 1925, p. 197 (pro parte).— MORTENSEN, 1950-a, p. 374. Type-genus.—Hemiaster DESOR, 1847.

Peristome transverse, labrum usually well developed. Apical system ethmophract or rarely ethmolytic. Ambulacra more or less distinctly petaloid adapically. A peripetalous fasciole present, but no other fascioles.

Genus Hemiaster DESOR, 1847

Hemiaster Desor in Agassiz and Desor, 1847, p. 16.—A. Agassiz, 1872-74, p. 585 (pro parte).— H. L. Clark, 1917, p. 165.—Mortensen, 1950-a, p. 378.

Logotype.—Spatangus bufo BRONGNIART, 1822, pp. 84, 289, pl. 5, fig. 4.—Hemiaster bufo (BRONGNIART): D'ORBIGNY, 1853-55(53), p. 277, pl. 873, figs. 1-10. [SAVIN, 1903, p. 22].

A peripetalous fasciole well developed; petals well developed, but frontal depression inconspicuous, with the pores in single, regular series. Apical system central, ethmophract, with four genital pores. Pedicellariae of the Recent forms of five types.

Hemiaster expergitus gibbosus A. AGASSIZ, 1881

Hemiaster gibbosus A. AGASSIZ, 1881-a, p. 184, pl. 20, figs. 5, 16, 22.—YOSHIWARA (TOKUNAGA), 1907, pl. 17, figs. 3-6 (reproduced from A. AGASSIZ, 1881-a).—Hemiaster expergitus var. gibbosus A. AGASSIZ: MORTENSEN, 1907, p. 103.—MORTENSEN, 1950-a, p. 389.
Hemiaster expergitus LOVÉN: H.L. CLARK, 1925, p. 200 (pro parte).

Test high, about 0.7 of length; peristome distinctly anterior, about one-fifth of test-length from anterior end; petaloid area small; posterior petals not more than half the length of anterior ones; peripetalous fasciole near ambitus; sternum short and broad.

From the Japanese Seas (from Sagami Sea to Kagoshima Gulf) to Malay region. 445-1865 metres in depth.

Hemiaster clarki LAMBERT, 1924

Hemiaster rotundus A. AGASSIZ and H. L. CLARK, 1907-b, p. 135 (non SEGUENZA).-H. L. CLARK, 1917, p. 166, pl. 146, fig. 11, pl. 150, fig. 5, pl. 154, figs. 7-10.

Hemiaster clarki LAMBERT in LAMBERT and THIÉRY, 1924, p. 505 (pro H. rotundus A. AGASSIZ and H. L. CLARK, 1907, non SEGUENZA).—MORTENSEN, 1950-a, p. 389.
Test very high, about 0.9 of length; peristome subcentral or rather anterior, about more than one-third of test-length from anterior margin; sternum short and broad, almost as broad as long; peripetalous fasciole not close to ambitus; posterior petals somewhat more than half as long as the anterior; madreporite separate posterior genitals and reaches posterior oculars; postero-lateral interambulacra (1 and 4) orally shut off from peristome.

Known only from northern Sea of Japan.

140-145 metres in depth.

Family Spatangidae Gray, 1825

Spatangidae Gray, 1825, p. 430 (pro parte).—A. Agassiz, 1872–74, p. 561 (pro parte).—H.L. Clark, 1917, p. 197 (pro parte).—Mortensen, 1951, p. 1.

Prospatangidae LAMBERT, 1905-a, p. 34.—LAMBERT and THIÉRY, 1924, p. 435 (pro parte). Type-genus.—Spatangus [MÜLLER] GRAY, 1825 (=Prospatangus LAMBERT, 1902).

Peristome transverse, labrum and sternum well developed, the latter usually much longer than wide and fully covered with tubercles. Apical system usually ethmolytic, with four genital pores. Ambulacra more or less distinctly petaloid adapically, with rather few pore-pairs. Only a subanal fasciole present, but no other fascioles. Small number of large primary tubercles present on aboral surface.

Genus Spatangus [MÜLLER] GRAY, 1825

Spatangus Müller: Gray, 1825, p. 430 (Spatangus Müller, 1776, p. 236).—A. Agassiz, 1872-74, pp. 158, 564.—H. L. Clark, 1917, p. 233.—Mortensen, 1951, p. 6.

Prospatangus LAMBERT, 1902, p. 55.—LAMBERT and THIÉRY, 1924, p. 459.

Orthotype.—Prospatangus purpureus (MÜLLER).—Spatangus purpureus MÜLLER: A. AGASsız, 1872-74, pp. 331, 565, pl. 11, figs. 19-22, pl. 14a, fig. 1, pl. 19a, figs. 5-6, pl. 26, figs. 24-27, pl. 32, figs. 17-18, pl. 34, figs. 3-4, pl. 37, fig. 16, pl. 38, figs. 34-35.

Frontal ambulacrum (III) in a deep groove, the pores distant and in regular single series. Petals distinct, but not sunken, at least 10 distal pore-pairs developed in anterior series of antero-lateral petals (II and IV). Tuberculated portion of sternum extending more than half-way from subanal plastron to peristome. Labrum short and wide.

Spatangus luetkeni A. AGASSIZ, 1872

Spatangus lütkeni A. AGASSIZ, 1872, p. 57.—DÖDERLEIN, 1906, p. 262, pl. 33, fig. 3, pl. 38, fig. 3.—H. L. CLARK, 1917, p. 238, pl. 146, fig. 17, pl. 157, figs. 5-6.—Prospatangus lütkeni (A. AGASSIZ): LAMBERT and THIÉRY, 1924, p. 463.—Spatangus lütkeni A. AGASSIZ: MORTEN-SEN, 1951, p. 18.

Primary tubercles of aboral surface few; postero-lateral interambulacra (1 and 4) with 6-12 primaries each; sternum with little or no keel; subanal fasciole narrow, 1-1.5 mm wide, and only two pore-pairs to each side within the subanal fasciole; colour deep purple; two kinds of pedicellariae, tridentate and triphyllous ones present.

Known only from the northern Japan.

80-200 metres in depth.

Haplotype.-Spatangus purpureus Müller, 1776, p. 236.

S. Nisiyama

Spatangus pallidus H.L. CLARK, 1908

Spatangus pallidus H. L. CLARK, 1908, p. 307.—H. L. CLARK, 1917, p. 239, pl. 146, fig. 18, pl. 149, fig. 5, pl. 157, figs. 1-4.—*Prospatangus pallidus* (H. L. CLARK) : LAMBERT and THIÉRY, 1924, p. 463.—*Spatangus pallidus* H. L. CLARK : MORTENSEN, 1951, p. 19.

Primary tubercles of aboral surface few; postero-lateral interambulacra (1 and 4) with 6-12 primaries each; sternum with conspicuous keel; subanal fasciole broad, 1.5 mm wide, and only two pore-pairs to each side within the fasciole; colour greyish lavender; only tridentate pedicellariae found.

Known only from the Japanese Seas (from Sagami Sea to off Kyushu). 90-110 metres in depth.

Spatangus altus LÜTKEN in MORTENSEN, 1907

Spatangus altus LÜTKEN in MORTENSEN, 1907, p. 131, pl. 1, figs. 1-3, pl. 16, figs. 11, 19.-H. L. CLARK, 1917, p. 236.-Prospatangus altus (LÜTKEN) LAMBERT and THIÉRY, 1924, p. 463.-Spatangus altus LÜTKEN (MS): MORTENSEN, 1951, p. 17.

Three penicillate tube-feet (pores) to each side within the subanal fasciole; no primary tubercles present in ambulacra outside petals; subanal plastron more or less shield-shaped.

Known only from China Sea (SALMIN).

Depth unknown, but probably in small depths.

This species seems to be closely related to *Sp. luetkeni*, as MORTENSEN inclined to conspecific of the two species, or to *Sp. pallidus*; but the fact that it has three porepairs to each side within the subanal fasciole prevents identifying with any of these two.

Subgenus Granopatagus LAMBERT, 1915

Granopatagus LAMBERT, 1915-b, p. 193.—LAMBERT and THIÉRY, 1924, p. 460.—MORTENSEN, 1951, p. 8.

Orthotype.—Spatangus loncophorus MEMEGHINI in DESOR, 1855-58 (58), p. 422.—DAMES, 1877, p. 83, pl. 9, fig. 6 (Eocene of Vicentin).

No primary tubercles aborally in postero-lateral interambulacra (1 and 4); primary tubercles only along frontal groove and in posterior interambulacrum (5). Subanal fasciole has a slight re-entering curve on adproctal side.

Spatangus (Granospatangus) paucituberculatus A. AGASSIZ and H.L. CLARK, 1907

Spatangus paucituberculatus A. AGASSIZ and H. L. CLARK, 1907-a, p. 253.—H. L. CLARK, 1917, p. 237, pl. 146, fig. 19, pl. 157, figs. 7-9.—Prospatangus paucituberculatus (A. AGASSIZ and H. L. CLARK) LAMBERT and THIÉRY, 1924, p. 463.—Spatangus (Granopatagus) paucituberculatus A. AGASSIZ and H. L. CLARK: MORTENSEN, 1951, p. 19, pl. 2, fig. 3.

Paired interambulacra have no large tubercles aborally, only a very few larger tubercles along midline of posterior interambulacrum (5); frontal depression usually

distinct; only two pore-pairs to each side within the subanal fasciole.

Known from the west coast of Japan (Nagasaki), also from Hawaiian Islands and the Kei Islands.

230-520 metres in depth.

Family MARETIIDAE LAMBERT, 1905

Maretinae LAMBERT, 1905-a, p. 162 (groupe).—MORTENSEN, 1951, pp. 5, 21.—Maretiidae LAMBERT: DURHAM and MELVILLE, 1957, p. 261 (emend.). Type-genus.—Maretia GRAY, 1855.

Peristome transverse, labrum and sternum well developed, the latter usually small, usually wider than long, with tubercles confined to posterior end or more or less extensively naked. Apical system ethmolytic, with four or three genital pores. Ambulacra more or less distinctly petaloid adapically, with rather few pore-pairs. Only a subanal fasciole present, but no other fascioles.

Genus Maretia GRAY, 1855

Maretia Gray, 1855-а, p. 48.—А. Agassiz, 1872, pp. 159, 568.—Н. L. Clark, 1917, p. 226.— Mortensen, 1951, p. 31.

Haplotype.—Spatangus planulatus LAMARCK, 1816, p. 31.

Hemipatagus DESOR, 1855-58 (58), p. 416.—DUNCAN, 1889-a, p. 222.—LAMBERT and THIÉRY, 1924, p. 456.

Haplotype.—Spatangus hoffmannii GOLDFUSS, 1826-33 (29), p. 152, pl. 47, fig. 3.

Paired ambulacra form conspicuous petals; frontal ambulacrum (III) simple. Subanal fasciole well developed. Large, perforate, crenulate, tubercles aborally in paired interambulacra, but none in posterior interambulacrum (5). Apical system with four genital pores. Labrum very long and narrow.

Maretia planulata (LAMARCK, 1816)

Spatangus planulatus LAMARCK, 1816, p. 31.—Maretia planulata (LAMARCK): A. AGASSIZ, 1872-74, pp. 140, 570, pl. 19b, figs. 7-12, pl. 25, figs. 33-34, pl. 26, figs. 21-22, pl. 37, figs. 13-14.—YOSHIWARA (TOKUNAGA) 1907, pl. 19, figs. 11-14.—KOEHLER, 1914, p. 106, pl. 11, figs. 18-19, pl. 20, figs. 8-13.—MORTENSEN, 1951, p. 27, pl. 4, figs. 1-5, 10-11, pl. 5, figs. 3-17, pl. 44, figs. 1-4, 18, 26-27, 29, 32-33, text-figs. 6a-b, 7a-b, 8, 10, 11-12, 13a, 14.
Maretia ovata ([LESKE]): H.L. CLARK, 1917, p. 226.—TORTONESE, 1933-a, p. 168, pl. 13, fig. 58.

Test low, less than half its length, and wide, more than three-fourths of length; frontal depression very shallow; primary tubercles in paired interambulacra (1, 2, 3, and 4) aborally numerous and not conspicuous; only two (three) tube-feet to each side within the subanal faciole; no globiferous and ophicephalous pedicellariae found.

From the Japanese Seas (from Sagami Sea to Kagoshima Gulf) to Port Jackson, and widely distributed over the Indo-West Pacific, from East Africa to Fiji and the Gilbert Islands; in the Red Sea it is known only from the southernmost part.

From the ebb-zone to ca. 60 meters in depth.

S. NISIYAMA

Maretia tuberculata A. AGASSIZ and H.L. CLARK, 1907

Maretia tuberculata A. AGASSIZ and H.L. CLARK, 1907-b, p. 134.—H.L. CLARK, 1917, p. 246, pl. 160, figs. 5-7.—MORTENSEN, 1951, p. 45.

Test low and wide; three or four very large and deeply sunken primary tubercles in each of paird interambulacra; five tube-feet (pores) to each side within the subanal fasciole; three kinds of pedicellariae, ophicephalous, rostrate and triphyllous ones present; colour generally purplish grey.

Known only from the Japanese Seas, west of Shimonoseki.

108 metres in depth.

Genus Pseudomaretia KOEHLER, 1914

Pseudomaretia KOEHLER, 1914, p. 107.—H. L. CLARK, 1917, p. 249.—MORTENSEN, 1951, p. 55. Orthotype.—Maretia alta A. AGASSIZ, 1863-a, p. 360.

Goniomaretia H.L. CLARK, 1917, p. 240.-H.L. CLARK, 1925, p. 226.

Orthotype.—Goniomaretia tylota H. L. CLARK, 1917, p. 241.=Maretia alta: A. AGASSIZ, 1881a, pl. 37, figs. 1-4 (non A. AGASSIZ, 1863).

Apical system ethmolytic, with three genital pores. Sternum small, wide, tubercles confined to posterior end. Labrum very long and narrow. Only very few primary aboral radioles (tubercles), arranged in a horizontal series near ambitus, or none at all. Subanal fasciole well developed.

Pseudomaretia alta (A. AGASSIZ, 1863)

Maretia alta A. AGASSIZ, 1863-a, p. 360.—LORIOL, 1883-a, p. 49, pl. 5, figs. 7-7е.—YOSHIWARA (Токинада), 1908, pl. 20, figs. 7-8.—*Pseudomaretia alta* (A. AGASSIZ) KOEHLER, 1914, p. 111, pl. 11, figs. 14-17, 20, figs. 1-7.—MORTENSEN, 1951, p. 58, pl. 3, figs. 12-14, pl. 46, figs. 1-6, 8-11, 13, 19-20, text-figs. 25, 26a-c, 27a, 28, 30.

Test highest posteriorly; height about half of test-length; postero-lateral interambulacra (1 and 4) with three or four primary tubercles in a series near ambitus aborally; periproct deeply sunken and overhang by posterior end of test; colour usually reddish purple.

From the Japanese Seas (from Sagami Sea to Kagoshima Gulf-type-locality) to the Indian Ocean.

Family LOVENIIDAE LAMBERT, 1905

Lovenidae LAMBERT, 1905-a, p. 162 (sousfamille).—LAMBERT and THIÉRY, 1924, p. 447.— MORTENSEN, 1951, p. 83. Type-genus.—Lovenia DESOR, 1847.

Peristome transverse, labrum and sternum well developed, the latter covered with tubercles or almost quite naked. Apical system ethmolytic, with four or three genital pores. Ambulacra petaloid adapically, petals usually short and pointed distally. Large, deeply sunken primary tubercles usually present at least within a peripetalous fasciole. An "inner" (or "internal") fasciole present, surrounding only frontal ambulacrum (III) and apical system.

Subfamily LOVENIINAE LAMBERT, 1905

Loveniinae Mortensen, 1951, p. 88.

Large, deeply sunken primary tubercles (areoles) present in interambulacra on both aboral and oral surfaces, and the sunken tubercles produced interiorly to form the internal ampullae.

Genus Lovenia DESOR, 1847

- Lovenia Desor in Agassiz and Desor, 1847, p. 10.— A. Agassiz, 1872-74, pp. 139, 574.—H. L. Clark, 1917, p. 251.—Mortensen, 1951, p. 89.
 - Haplotype.-Lovenia hystrix AGASSIZ and DESOR, 1847, p. 11, pl. 16, fig. 16.=Spatangus elongatus GRAY, 1845, p. 436, pl. 6, fig. 2.
- Sarsella POMEL, 1883, p. 28 (non HAECKEL, 1879).—Vasconaster LAMBERT, 1915-b, p. 191 (pro Sarsella POMEL, 1883).—LAMBERT and THIÉRY, 1924, p. 466.
 - Type-species.—Breynia sulcata HAIME in COTTEAU, 1885-89(86), p. 103, pls. 22-23, pl. 24, figs. 1-3 (Tongrian of Biarritz).

Large, deeply sunken primary tubercles present in paired interambulacra aborally, none in posterior interambulacrum (5); their areoles very deep, primary large ampullae on the inside of test. Labrum very long and narrow. Sternum with tubercles confined only posterior part. Multidentate pedicellariae found.

Lovenia elongata (GRAY, 1845)

Spatangus elongatus GRAY, 1845, p. 436, pl. 6, fig. 2.—Lovenia elongata (GRAY): A. AGASSIZ, 1872-74, pp. 139, 575, pl. 19c, figs. 1-4, pl. 25, fig. 31, pl. 26, figs. 35-36, pl. 37, figs. 18-19, pl. 38, figs. 27-28.—A. AGASSIZ, 1881-a, p. 175, pl. 39, figs. 13, pl. 40, figs. 45-46.—YOSHIWARA (TOKUNAGA), 1908, pl. 21, figs. 5-8.—DÖDERLEIN, 1911, p. 247, pl. 10, fig. 14K.—KOEHLER, 1914, p. 111, pl. 11, figs. 5-6, pl. 12, fig. 10, pl. 13, fig. 8, pl. 19, figs. 25-32.—MORTENSEN, 1951, p. 97, pl. 7, figs. 1-10, pl. 8, fig. 1, pl. 12, fig. 5, pl. 47, figs. 10-23, text-figs. 41a, 42, 58a, 49-51, 52a, 53a.

Spatangus crux-andreae Audouin in Savigny, 1809, pl. 7, fig. 4.

Test low and wide, broader anteriorly, with more than three-fourths of length; test highest at, or anterior to, apical system; genital pores four; periproctal region markedly sunken into posterior end of test; pore-pairs (tube-feet) to each side within the subanal fasciole, 6-10 (but in young specimens, ca. 20-25 mm long, only five of them); long aboral primary radioles banded; tridentate pedicellariae with three valves only, the valves with serrate edges.

From the Japanese Seas (from Sagami Bay and Sea of Japan to Kagoshima Gulf) to the Australian east coast, and widely distributed over the Indo-West Pacific Oceans, from the east coast of Africa to Mozambique to the Australian Coast.

From the ebb-zone down to ca. 90 metres in depth.

Lovenia gregalis ALCOCK, 1893

Lovenia gregalis Alcock, 1893, p. 175, pl. 8, fig. 9.—KOEHLER, 1914, p. 115, pl. 12, figs. 6-9, 11, pl. 19, figs. 33-45.—MORTENSEN, 1951, p. 120, pl. 9, figs. 7-9, pl. 12, fig. 4, pl. 48, figs. 12-14, 18-19, 21-23, text-figs. 41b, 58b, 59a-b.

Test elongate, not heart-shaped, low and wide, about 0.8 of length or more; genital pores four; periproctal region little or not at all sunken; large aboral primary tubercles numerous; three pore-pairs to each side within the subanal fasciole; labrum reaching posteriorly only to the end of adjoining ambulacral plates no. 2; globiferous pedicellariae of one kind only.

From southwestern Japan to the Indian Ocean (Bay of Bengal). 285-930 metres in depth.

Lovenia subcarinata (GRAY, 1845)

Spatangus subcarinatus GRAY, 1845, p. 436.—Lovenia subcarinata (GRAY) GRAY, 1855-a, p. 45, pl. 5, fig. 3.—A. AGASSIZ, 1881-a, p. 175, pl. 35, figs. 5-7, pl. 37, figs. 7-9.—YOSHIWARA (TOKUNAGA), 1908, pl. 21, fig. 11 (reproduced from A. AGASSIZ, 1881-a).—KOEHLER, 1914, p. 110, pl. 8, figs. 2-13, pl. 48, figs. 1, 3, 10, 20.—MORTENSEN, 1951, p. 114, pl. 19, figs. 47-50, text-figs. 54, 55a-b, 57.

Test elongate, not heart-shaped, about three-fourths of length or less; posterior end of test being vertical, periproctal region not sunken; genital pores four; large aboral primary tubercles few; labrum reaching posteriorly to the middle of adjoining ambulacral plates no. 3.

From the east coast of Africa to Hongkong, particularly common in the Java Sea. Kagoshima Gulf doubtful.

10-35 metres in depth.

Lovenia triforis KOEHLER, 1914

Lovenia triforis KOEHLER, 1914, p. 124, pl. 13, figs. 9-13.—MORTENSEN, 1951, p. 123, pl. 13, figs. 31-34, 36, pl. 45, figs. 1-2, pl. 49, figs. 7, 10, 12-19, 23-24, text-figs. 60c, 61a-b, 62.

Genital pores three; periproctal region scarcely sunken; large primary tubercles in paired interambulacra relatively large and very few (3-5) in each aborally.

From southwestern Japan (32° North) to the Indian Ocean. 80-250 metres in depth.

Genus Pseudolovenia A. AGASSIZ and H.L. CLARK, 1907

Pseudolovenia A. AGASSIZ and H.L. CLARK, 1907-a, p. 255.—H.L. CLARK, 1917, p. 258.— LAMBERT and THIÉRY, 1924, p. 467.—MORTENSEN, 1951, p. 127. Haplotype.—Pseudolovenia hirsuta A. AGASSIZ and H.L. CLARK, 1907-a, p. 255.

A subanal fasciole present, but no peripetalous fasciole. Sternum almost quite naked. Apical system ethmolytic, with four genital pores. Paired ambulacra not distinctly petaloid adapically.

Pseudolovenia hirsuta A. AGASSIZ and H. L. CLARK, 1907

Pseudolovenia hirsuta A. AGASSIZ and H. L. CLARK, 1907-a, p. 255.—H. L. CLARK, 1917, p. 258, pl. 146, figs. 32-33, pl. 160, figs. 8-12.—MORTENSEN, 1951, p. 127.

Test low and wide, higher anteriorly than posteriorly; posterior end of test nearly

vertical; periproctal region scarcely depressed; no globiferous pedicellariae found; colour of test grey to brown.

Southwest of Koshiki Island not beyond doubt. Hawaiian Islands. 350-740 metres in depth.

Subfamily Echinocardiinae Cooke, 1942

Echinocardiidae Сооке, 1942, p. 59 (family; pro parte).—Echinocardiinae Сооке: Mortensen, 1951, pp. 89, 149.

Type-genus.—Echinocardium GRAY, 1825.

Primary tubercles of aboral side inconspicuous, their areoles not deeply sunken and lacking the internal ampullae.

Genus Echinocardium GRAY, 1825

Echinocardium Gray, 1825, p. 430.—А. Agassiz, 1872-74, p. 349.—Duncan, 1889-а, p. 261.—H. L. Clark, 1917, p. 261.—Mortensen, 1951, p. 149.

Logotype.—Spatangus pusillus LESKE, 1778, p. 230.=Echinus cordatus PENNANT, 1777, p. 58, pl. 34, fig. 2. [H. L. CLARK, 1917, p. 261.—Validated by Opinion of the International Commission on Zoological Nomenclature].

Amphidetus Agassiz, 1836, p. 184.—Agassiz and Desor, 1847, p. 11.

Type-species.—Spatangus arcuarius LAMARCK, 1816, p. 13.=Echinus cordatus PENNANT, 1777, p. 58.

Echinospatangus [BREYNIUS]: POMEL, 1883, p. 28.

Orthotype.—Echinospatangus cordatus (PENNANT) POMEL, 1883, p. 28.

Paired ambulacra form conspicuous petals adapically, which may be more or less sunken; frontal ambulacrum (III) varying from flush with the test to markedly sunken. Subanal fasciole well marked, shield-shaped, and anal branch issued from it. Apical system subcentral, with four genital pores. Sternum well covered with tubercles, and labrum short and wide.

Echinocardium cordatum (PENNANT, 1777) (C-P) (Ph-AP)

- Echinus cordatus PENNANT, 1777, p. 58, pl. 34, fig. 2.—Echinocardium cordatum (PENNANT):
 A. AGASSIZ, 1872-74, pp. 109, 349, 580, pl. 19, figs. 10-17, pl. 20, figs. 5-7.—LOVÉN, 1874, pl. 1, figs. 2-7, pl. 3, fig. 38, pl. 12, fig. 107, pl. 39.—MORTENSEN, 1907, p. 145, pl. 16, fig. 21, pl. 17, figs. 15, 21-23, 30, 34, 37-38, 43, 48-49.—MORTENSEN, 1951, p. 152, pl. 18, figs. 6-7 (1-3, 8-australe GRAY), text-fig. 78.
- *Echinocardium australe* GRAY, 1851, p. 131.—GRAY, 1855-a, p. 44, pl. 4, fig. 1.—A. AGASSIZ, 1872-74, pp. 109, 580, pl. 37, fig. 15.

Frontal ambulacrum (III) conspicuously depressed, beginning at apical system and becoming deep at ambitus; pores of frontal ambulacrum within internal fasciole usually crowded, forming irregular series; large primary tubercles in antero-lateral interambulacra (2 and 3) above ambitus.

Northern, central and southwestern Japan. Widely distributed over the European Seas, east coast of America, west coast of America, and Australian Seas.

From littoral zones to 90 or rearly 230 metres in depth.

S. Nisiyama

Echinocardium lymani (LAMBERT, 1924)

Echinocardium dubium A. AGASSIZ and H.L. CLARK, 1907-b, p. 134 (non PERON and GAU-THIER).-H.L. CLARK, 1917, p. 265, pl. 150, figs. 1-3.

Amphidetus lymani LAMBERT in LAMBERT and THIÉRY, 1924, p. 471 (pro Ech. dubium A. AGASSIZ and H. L. CLARK, 1907, non PERON and GAUTHIER).—Echinocardium lymani (LAMBERT) MORTENSEN, 1951, p. 164.

Test rounded, almost as broad as long; frontal ambulacrum (III) only slightly sunken; pores of frontal amlacrum in regular single series; primary tubercles above ambitus evident only in antero-lateral interambulacra (2 and 3); internal fasciole rather large, about one-third the length of test; apical system somewhat depressed; posterior petals of about same length as the anterior; mouth reniform, twice as wide as long; labrum long and narrow; colour of test yellowish-brown.

Known only from the Japanese Seas (northern and central Japan). 195-350 metres in depth.

Family PERICOSMIDAE LAMBERT, 1905

Pericosmidae LAMBERT, 1905-a, p. 153.—LAMBERT and THIÉRY, 1925, p. 512.—MORTENSEN, 1951, p. 166.

Type-genus.-Pericosmus Agassiz, 1847.

Peristome transverse, labrum forms a more or less prominent lip. Apical system ethmolytic, with usually three or four (some fossil forms) genital pores. Paired ambulacra form very distinct, more or less sunken petals. Frontal ambulacrum (III) more or less deeply sunken; the pores small, distant, forming regular series. Both a peripetalous and a marginal fasciole present, usually entirely separated from each other, but no subanal fasciole.

Genus Pericosmus AGASSIZ, 1847

Pericosmus Agassiz in Agassiz and Desor, 1847, p. 19.—MacCoy, 1882, p. 15.—Duncan, 1889-a, p. 232.—H. L. Clark, 1917, pp. 161, 164.—Mortensen, 1951, p. 169.

Logotype.—Pericosmus latus (AGASSIZ) AGASSIZ and DESOR, 1847, p. 19, pl. 16, fig. 1. [LORIOL, 1875, p. 114].

Victoriaster LAMBERT, 1918-a, p. 27.—SANCHEZ ROIG, 1949, p. 248.

Orthotype.-Pericosmus gigas MACCOY, 1882, p. 15, pls. 53-54 (Miocene of Australia).

Petals well developed, usually distinctly sunken; the distalmost plates occluded. No large tubercles (radioles), test being densely and uniformly covered with small radioles 'tubercles). Sternum broad, tuberculated throughout. Labrum short. Peripetalous fasciole sometimes double anteriorly; marginal fasciole passes all round the test, near edge, passing below periproct. Pedicellariae of usual five types.

Pericosmus cordatus MORTENSEN, 1950

Pericosmus cordatus MORTENSEN, 1950, p. 158.—MORTENSEN, 1951, p. 182, pl. 16, figs. 1-7, pl. 50, fig. 15, 18, 23-27, 31, text-figs. 84b, 86c, 88a, 91b.

Large form, ca. 80 mm long; test heart-shaped, with a very deep frontal depression; petals very narrow, distinctly sunken; frontal tube-feet without distinct sucking disc, or, if developed, not supported by calcareous laminae.

Known only from near Goto Islands (32°17'N., 128°11'E.)

200 metres in depth.

Pericosmus melanostomus MORTENSEN, 1948

Pericosmus melanostomus MORTENSEN, 1948-b, p. 119.—MORTENSEN. 1951, p. 194, pl. 13, figs. 5-8, 21, 35, pl. 51, figs. 10, 13-14, 16, 19, 23, 29-30, text-figs. 95c, 96a-c, 97a.

Frontal depression shallow; frontal tube-feet with a well developed sucking disc, supported by calcareous laminae; posterior edge of test vertical; petals slightly sunken, short, but broad; fascioles very conspicuous; peripetalous fasciole not bending inwards between petals; peristome and periproct almost black, standing out very markedly against the whitish test; two sorts of ophicephalous pedicellariae, the larger one with a broad blade, shorter than basal part of valves.

From China Sea (21°42′N., 114°50′E.—near Hongkong) to Java Sea and Sunda Strait. 18-70 metres in depth.

Family Schizasteridae Lambert, 1905

Schizasterinae LAMBERT, 1905-a, p. 154 (tribus).—LAMBERT and THIERY, 1925, p. 517 (tribus).— Schizasteridae LAMBERT: MORTENSEN, 1951, p. 204.

Peristome transverse, labrum well developed. Apical system usually ethmolytic or rarely ethmophract, with four, three, or two genital pores. Ambulacra usually deeply sunken and petaloid to slit-like adapically. Both a peripetalous and a lateroanal fasciole (excepting *Amphipneustes*) usually complete and distinct.

Genus Linthia DESOR, 1853

- Linthia Desor, 1853, p. 395 (pro Escheria Merian, 1853, non Heer, 1847).—Cotteau, 1885-89(86), p. 206.—Lambert and Thiéry, 1924, p. 518.—Mortensen, 1951, p. 233.—Kier, 1957, p. 886.
 - Logotype.—Escheria insignis MERIAN in DESOR, 1853, p. 279.—Linthia insignis (MERIAN): LORIOL, 1875, p. 101, pl. 16, figs. 1-1a, pl. 17, figs. 1a-b (Eocene of France). [DESOR, 1855-58(58), p. 395].

Frontal ambulacrum (III) deep; the pores small, in regular single series on each side. Petals long straight, well sunken. A peripetalous fasciole well developed; a latero-anal fasciole distinct, passes deep below periproct. Apical system subcentral, ethmolytic, with four genital pores. Periproct elongate longitudinally.

Linthia (?) species

Linthia(?) species: MORTENSEN, 1951, p. 236, pl. 19, fig. 3, text-fig. 118.

Frontal ambulacrum (III) rather deep; the pores very small, wide apart, arranged

in a single series on each side. The shape and size of the petals, and the course of the peripetalous fasciole apparently nearly related to *Lin. nipponica* YOSHIWARA, 1899 (TOKUNAGA, 1903, p. 18, pl. 1, fig. 5).

Known only from off Iki Island (33°41'N., 128°50'E.).

Genus Faorina GRAY, 1851

Faorina GRAY, 1851, p. 132.—A. AGASSIZ, 1872-74, pp. 129, 607.—DUNCAN, 1889-a, p. 231.—H. L.
 CLARK, 1917, p. 174.—MORTENSEN, 1951, p. 243.
 Logotype.—Faorina chinensis GRAY, 1851, p. 132 (China Sea).

Atrapus TROSCHEL, 1851, p. 72 (subgenus of Triphylus Philippi, 1845).

Haplotype.—Tripylus (Atrapus) grandis TROSCHEL, 1851, p. 72, pl. 1, figs. 1-8.=Faorina chinensis GRAY, 1851, p. 132.

Sinaechinus HAYASAKA, 1948-a, p. 94.

Haplotype.—Sinaechinus kawaguchii HAYASAKA, 1948-a, p. 94, pl. 3, figs. 1-5.

Test high. Apical system nearly central, ethmolytic, with three genital pores. Paired petals narrow, but rather deeply sunken. A peripetalous fasciole conspicuous, broad and well marked, and at the anterior end it is double, or even triple. A narrow, inconspicuous, but distinct latero-anal fasciole traverses the periproctal plates. Pedicellariae of four types, globiferous one wanting.

Faorina chinensis GRAY, 1851

Faorina chinensis GRAY, 1851, p. 132.—GRAY, 1855-a, p. 57, pl. 6, figs. 1-1a.—A. AGASSIZ, 1872-74, pp. 129, 607, pl. 19a, figs. 4-6.—LOVÉN, 1874, pl. 4, fig. 41, pl. 27.—KOEHLER, 1914, p. 129, pl. 13, figs. 14-15, pl. 19, figs. 14-24.—MORTENSEN, 1951, p. 245, pl. 20, figs. 1-8, pl. 52, figs. 8, 10, 14, 16-17, 20, 23-27, text-figs. 123-125.
Triphylus (Atrapus) grandis TROSCHEL, 1851, p. 72, pl. 1, figs. 1-8.
Sinaechinus kawaguchii HAYASAKA, 1948-a, p. 94, pl. 3, figs. 1-5.

Test nearly globular, height about three-fourths of length, which is little more than wide; paired ambulacra rather deeply sunken, closed; frontal ambulacrum (III) deeply sunken, but not petaloid; peristome very close to anterior end, about one-eighth from anterior margin or more.

HAYASAKA (1948-a, p. 94), in describing his *Sinaechinus kawaguchii*, seems to fail to notation of the latero-anal fasciole, if there were this fasciole in this species, the writer believes its presence, it is quite agrees with GRAY's *Faorina chinensis*; the species was already described about ninty years ago from the same locality.

From Hongkong and China Sea (MCZ no. 2866-Shanghai) to the Sulu Sea and Flores Sea.

Genus Brisaster GRAY, 1855

Brisaster GRAY, 1855-a, p. 16.-H. L. CLARK, 1917, p. 178.-MORTENSEN, 1951, p. 280. Logotype.-Brissus fragilis DÜBEN and KOREN, 1846, p. 280, pl. 10, figs. 47-49.-Brisaster

fragilis (DÜBEN and KOREN): MORTENSEN, 1907, p. 108, pl. 1, figs. 6-7, pl. 13, pl. 14, figs. 3, 7, 11, 13-16, 18, 20, 24-25, 31, 39, 43, 46, 50-51. [LAMBERT, 1907-c, p. 112].

Test low, usually less than 0.6 of length. Vertex posterior. Frontal ambulacrum (III) deep, the pores in single, regular series on each side. Apical system posterior, ethmolytic, with three genital pores. Postero-lateral petals (I and V) conspicuously shorter than the antero-laterals, and the latter at first little divergent, then becoming more so, and at tip markedly incurved outward. Latero-anal fasciole usually distinct or may be reduced in some cases. Valves of globiferous pedicellariae terminating in a single teeth.

Brisaster latifrons (A. AGASSIZ, 1898)

Schizaster latifrons A. AGASSIZ, 1898, p. 81 (non pl. 11, figs. 2-3=Br. townsendi (A. AGASSIZ, 1898)).—A. AGASSIZ, 1904, p. 205, pl. 102, figs. 1-4, text-figs. 297, 297b.—MORTENSEN, 1951, p. 289, pl. 23, figs. 2-3, 9, pl. 53, fig. 16.

Test low, vertical diameter about half length or less; latero-anal fasciole reduced to only a slender piece below periproct, or wanting; sternum not twice as long as wide; frontal ambulacrum (III) very wide, one-third to one-half its own length; postero-lateral petals (I and V) very short, one-third the antero-laterals; rostrate pedicellariae present or wanting.

On East Pacific, from Alaska to southern California, and Gulf of California. On West Pacific, from Bearing and Ochotsk Seas to Sakhalin and Hokkaido.

57-1800 metres in depth.

Brisaster owstoni MORTENSEN, 1950

Schizaster ventricosus: A. Agassiz, 1881-a, p. 204, pl. 36, figs. 1-3 (non Gray, 1851).—Yoshiwara (Tokunaga), 1907, pl. 17, figs. 7-9.

Brisaster owstoni MORTENSEN, 1950, p. 160.-MORTENSEN, 1951, p. 291, pl. 23, figs. 7-8, 11-15, pl. 53, figs. 11, 14, 17-19.

Test rather high posteriorly, vertical diameter more half of length; latero-anal fasciole reduced, only the subanal part remaining; postero-lateral petals (I and V) very short; rostrate pedicellariae well developed. Resembles *Br. latifrons* (A. AGASSIZ, 1898) by its very short and broad posterior petals, but its test is distinctly higher and more abruptly truncated, so that it recalls *Sch. ventricosus* GRAY, 1851.

Known only from the Japanese Seas (central and western Japan).

10-530 metres in depth.

Genus Schizaster AGASSIZ, 1836

Schizaster A. Agassiz, 1836, p. 185(18).—Duncan, 1889-a, p. 234 (pro parte).—H. L. Clark, 1917, p. 192.—Mortensen, 1951, p. 285.

Logotype.—Schizaster studeri AGASSIZ, 1836, p. 185.—COTTEAU, 1885-89(87), p. 344, pl. 104, figs. 4-5 (Tertiary of Italy). [LAMBERT, 1907-c, p. 112.—Bull. Zool. Nomencl., vol. 4, 1950, p. 527].

Test high, sloping anteriorly, vertex posterior. Frontal ambulacrum (III) deeply excavate, the pores in a single, regular series on each side. Paired petals fairly deeply sunken, postero-lateral petals much shorter and smaller than the antero-laterals.

S. NISIYAMA

Latero-anal fasciole distinct, complete. Apical system posterior, ethmolytic, with only two genital pores.

Schizaster lacunosus (LINNAEUS, 1758)

Echinus lacunosus LINNAEUS, 1758, p. 665.—Schizaster lacunosus (LINNAEUS) LOVÉN, 1887, p. 168.—H. L. CLARK, 1917, p. 193.—MORTENSEN, 1951, p. 300, pl. 21, figs. 5-10, 14-18, pl. 54, figs. 1-3, 5, 7-9, 12, 14-17, text-figs. 140a-b, 141a-b.

Schizaster japonicus A. Agassız, 1879, p. 212.—A. Agassız, 1881-a, p. 202, pl. 36, figs. 8-13, pl. 43, fig. 26, pl. 65, figs. 7-10.—Yoshiwara (Tokunaga), 1907, pl. 17, figs. 10-14.

Frontal ambulacrum (III) rather narrow, about one-fourth of test width or less, the adjoining interambulacra rising steeply, almost covering the pore-series; posterolateral petals (I and V) little divergent, distance between tips only about one-third of petal length; sternum broad, its posterior width about two-thirds of its length; posterior interambulacrum (5) not rising into a marked keel.

From the Japanese Seas (from Sagami Sea to Kagoshima Gulf) to the Natal coast, and to N. Australia, but not recorded from Malay Archipelago.

5-ca. 90 metres in depth.

Genus Hypselaster H.L. CLARK, 1917

Hypselaster H. L. CLARK, 1917, p. 185.—H. L. CLARK, 1946, p. 367.—MORTENSEN, 1951, p. 312. Orthotype.—Schizaster (Periaster) limicola A. AGASSIZ, 1878, p. 193.

Test high, usually more than 0.6 of length. Frontal ambulacrum (III) rather deep, the pores in regular, single series on each side. Apical system subcentral, ethmolytic, with only two genital pores. Latero-anal fasciole rudimentary, incomplete or wanting. Paired petals rather considerably sunken.

Hypselaster(?) fragilis (A. AGASSIZ and H. L. CLARK, 1907)

Periaster fragilis A. AGASSIZ and H. L. CLARK, 1907-b, p. 138.—Hypselatser fragilis (A. AGASSIZ and H. L. CLARK,): H. L. CLARK, 1917, p. 189, pl. 148, figs. 5-8.—Opissaster (Ditremaster) fragilis (A. AGASSIZ and H. L. CLARK) LAMBERT and THIÉRY, 1924, p. 509.—Hypselaster fragilis (A. AGASSIZ and H. L. CLARK): H. L. CLARK, 1925, p. 208, pl. 11, figs. 1-3(?).— MORTENSEN, 1951, p. 321.

Test distinctly higher at posterior than anterior end; apical system a little eccentric anteriorly; frontal ambulacrum (III) not conspicuously deepened; petaloid area small, paired petals rather considerably sunken; postero-lateral interambulacra (1 and 4) orally excluded from peristome; only tridentate pedicellariae present.

Known only from southwest of Koshiki Island.

715 metres in depth.

Hypselaster pacificus (LAMBERT, 1924)

Periaster rotundus A. AGASSIZ and H. L. CLARK, 1907-b, p. 138 (non LAUBE).-Hypselaster rotundus (A. AGASSIZ and H. L. CLARK) H. L. CLARK, 1917, p. 187, pl. 146, figs. 9-10, pl. 148, figs. 1-2, pl. 154, figs. 11-14.—MORTENSEN, 1951, p. 315. Opisssater (Ditremaster) pacificus LAMBERT in LAMBERT and THIÉRY, 1924, p. 509.

Test nearly as high anteriorly as at posterior end; no bare band from peripetalous fasciole to periproct; antero-lateral petals (II and IV) twice as long as the postero-laterals (I and V); frontal petal (III) over twice as long as the postero-laterals; five kinds of pedicellariae, globiferous, rostrate, tridentate, ophicephalous and triphyllous types present; valves of tridentate pedicellariae very coarsely thorny.

Known only from the Japanese Seas (Inland Sea and between Kobe and Kagoshima). 71 metres in depth.

Genus Moira A. AGASSIZ, 1872

Moira A. Agassiz, 1872-74(72), pp. 146, 365 (pro Moera Michelin, 1855, non Leach, 1816).— Duncan, 1889-a, p. 238.—H. L. Clark, 1917, p. 195.—Nisiyama, 1935, p. 155.—Mortensen, 1951, p. 325.

Type-species.—Spatangus atropos LAMARCK, 1816, p. 32. [Type validated by Opinion 209 of the International Commission on Zoological Nomenclature].

Moera Michelin, 1855, p. 246 (non Leach, 1816, nec Hübner, 1819).—Desor, 1855-58(58), p. 394.

Haplotype.—Spatangus atropos LAMARCK, 1816, p. 32.

Petals deeply sunken, but the entrance to them very narrow, interambulacra almost meeting above them, especially, as to be enterable only through narrow slits; postero-lateral petals (II and IV) much shorter than the antero-laterals; frontal ambulacrum (III) likewise deeply sunken, but the entrance not so narrow as that of paired petals, and antero-lateral petals not longer and wider than sunken part of frontal ambulacrum; peripetalous fasciole well developed; apical system subcentral, more or less sunken, with only two genital pores.

Moira lachesinella Mortensen, 1930

Moira lachesis Mortensen, 1930-a, p. 389, pl. 2, figs. 1-7, pl. 3, figs. 5-8, pl. 4, figs. 1-14 (non Girard).

Moira lachesinella Mortensen, 1930-c, p. 45 (pro M. lachesis Mortensen, 1930).—NISIYAMA, 1935, pp. 159, 168, pl. 7, fig. 17, text-figs. 11a-c.—Mortensen, 1951, p. 333, text-fig. 150b.

Antero-lateral interambulacra (2 and 3) within peripetalous fasciole slightly and not abruptly depressed; posterior end of test conspicuously sloping, its lower margin projecting very distinctly beyond its upper part; a very conspicuous deepening just above subanal part of the fasciole, but not sharply limited; labrum with a short posterior prolongation; petals not so very narrow, antero-laterals only slightly exceeding the frontal (III) in length.

Known only from the Japanese Seas (Tateyama Bay and Hakata Bay, and from western Sea of Japan).

Littoral zones-5 metres in depth.

Family BRISSIDAE GRAY, 1855

Brissina GRAY, 1855-a, p. 49 (pro parte).-A. AGASSIZ, 1872-74, p. 585 (pro parte).-Brissidae

LAMBERT, 1905-a, p. 153 (pro parte).—Brissidae GRAY: MORTENSEN, 1951, p. 353. Type-genus.—Brissus [KLEIN] GRAY, 1825.

Peristome transverse, labrum well developed. Apical system ethmolytic, or ethmophract, with four, three, or rarely two genital pores. Ambulacre more or less distinctly petaloid adapically, usually long and more less divergent. Large primary tubercles (areoles) within peripetalous fasciole often present. Both a peripetalous and a subanal fasciole present. Anal branches from the subanal fasciole may be present, but no other fascioles.

Genus Brissopsis AGASSIZ, 1840

- Brissopsis Agassiz, 1840-a, pp. 3, 16.—Agassiz and Desor, 1847, p. 14.—A. Agassiz, 1872-74, pp. 95, 354.—Duncan, 1889-a, p. 248.—H. L. CLARK, 1917, p. 199.—Mortensen, 1951, p. 371.
 - 'Haplotype'.—Brissopsis elegans AGASSIZ, 1840-a, pp. 3, 16.—COTTEAU, 1885-89 (86), p. 184, pls. 52-53 (Priabonian of France).
- Kleinia GRAY, 1851, p. 133.—DESOR, 1855-58(58), p. 423.—LAMBERT and THIÉRY, 1924, p. 490. Haplotype.—Kleinia luzonica GRAY, 1851, p. 133 (Philippines).
- Toxobrissus Desor, 1855-58(58), p. 399.—Pomel, 1883, p. 34.—A. Agassiz, 1904, p. 193.

Logotype.-Brissopsis elegans AGASSIZ, 1840-a, pp. 3, 16. [LAMBERT, 1907-c, p. 107].

- Brissoma POMEL, 1887-a, p. 41.
- Logolype.—Brissopsis duclei WRIGHT, 1855, p. 185, pl. 6, fig. 1 (Miocene of Malta). [LAMBERT and THIÉRY, 1924, p. 487].
- Zeugaster LAMBERT, 1907-c, p. 106.
- Orthotype.—Brissopsis lamberti GAUTHIER in FOURTAU, 1900-a, p. 42, pl. 3, figs. 7-8 (Eocene of Egypt).

A peripetalous fasciole well-marked, a single band throughout its course; a subanal fasciole well developed, usually not tending to disappear in the adult. Anal fasciole proceeds from the subanal fasciole to each side of periproct. Subanal plastron usually reniform. Paired ambulacra petaloid, more or less sunken; the petals of about equal size, or postero-laterals (I and V) often the shortest. Frontal ambulacrum (III) not petaloid, but depressed, forming a more or less distinct frontal notch. No large primary tubercles on aboral side. Plastron not extending posteriorly to form a "anal snout". Apical system central, ethmolytic, with four genital pores. Sternum rather broad, densely tuberculated throughout.

Brissopsis luzonica (GRAY, 1851)

Kleinia luzonica GARY, 1851, p. 133.—GRAY, 1855-a, p. 49, pl. 4, figs. 5-5a.—Brissopsis luzonica (GRAY): Meijere, 1904, p. 188, pl. 5, figs. 7-10, 44-45, pl. 23, figs. 469-476.—Yoshiwara (Токимада), 1907, pl. 19, figs. 7-10.—Koehler, 1914, p. 207, pl. 13, fig. 16, pl. 14, figs. 4-5, 7, 12-13, pl. 20, figs. 51-54.—H. L. Clark, 1917, p. 204, pl. 152, figs. 5-8, pl. 155, fig. 2.— Mortensen, 1951, p. 397, pl. 32, figs. 2-4, 12-14, 19, 21, pl. 39, fig. 12, pl. 56, figs. 2, 4-5, 8-11, 13-15, 18-29, text-figs. 190b, 192, 194a, 195, 196a, 199c.

Petaloid area about half of test-length or more; postero-lateral petals (I and V) more or less merged proximally, with only distal ends diverging; antero-lateral petals ascending, diverging but little; posterior end of test low, vertically truncate, so periproct not visible from above; first ambulacral plate in subanal fasciole is no. 6; labrum

posteriorly not reaching beyond the first adjoining ambulacral plates; plates of anterolateral ambulacra (II and IV) outside the petals narrow, and each with a tubercle; four penicillate tube-feet to each side within the aubanal fasciole; valves of the coarse form of a globiferous pedicellaria terminating in two strong teeth.

From the Japanese Seas (from Sagami Sea to Kagoshima Gulf) to New Zealand, and widely distributed over the Indo-West Pacific, from Red Sea to Hawaiian Islands.

18-744 metres in depth.

Brissopsis oldhami ALCOCK, 1893

Brissopsis oldhami Alcock, 1893, p. 174, pl. 8, figs. 7-8.—A. Agassız and H. L. Clark, 1907-b, p. 136.—Koehler, 1914, p. 218, pl. 14, figs. 1-3, 8-9, 15, pl. 15, fig. 12, pl. 20, figs. 28-43.— Mortensen, 1951, p. 409, pl. 31, fig. 10, pl. 58, figs. 1-3, 5-20, text-fig. 198a.

Test not very low; forms of large size; petaloid area very small, occupying only about half of test-length, and petals conspicuously sunken; postero-lateral petals (I and V) more or less merged proximally, with about distal half diverging; antero-lateral petals ascending, diverging but little; posterior end of test truncate; plates of anterolateral ambulacra (II and IV) outside the petals very narrow and each with 2-5 tubercles; subanal fasciole very broad; no anal fasciole; four ambulacral plates enter subanal plastron and only three penicillate tube-feet to each side within the subanal fasciole.

From the Japanese Seas (southwestern Japan) to the Malay region and Bay of Bengal.

780-2140 metres in depth.

Brissopsis bengalensis KOEHLER, 1914

Brissopsis bengalensis KOEHLER, 1914, p. 230, pl. 15, figs. 1-11, pl. 20, figs. 63-64.—MORTENSEN, 1948-b, p. 128.—MORTENSEN, 1951, p. 412, pl. 30, fig. 6, pl. 31, figs. 1-2, 4, pl. 33, figs. 1-3, pl. 59, figs. 8-9, 14-15.

Test not very low; forms of large size; petaloid area large, but not occupying nearly the whole aboral side; postero-lateral petals (II and IV) with about distal half diverging; plates of antero-lateral ambulacra outside the petals each with 4-6 tubercles; five ambulacral plates enter subanal plastron and four penicillate tube-feet to each side within the subanal fasciole.

From the Japanese Seas (Sagami Sea) to the Malay region and to Ceylon. 130-2986 metres in depth.

Genus Anametalia MORTENSEN, 1950

Anametalia MORTENSEN, 1950, p. 161.—MORTENSEN, 1951, p. 435. Orthotype.—Brissus sternaloides BOLAU, 1873, p. 177.

Plastron extending posteriorly as to form a more or less conspicuous "anal snout", encircled by the subanal fasciole. Frontal ambulacrum (III) not forming a deep furrow on oral side, and frontal depression slight, but broad. Apical system ethmolytic,

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with four genital pores. Globiferous pedicellariae with a beautiful wreath of long, curved thorns at upper end of stalk. Ophicephalous pedicellariae very conspicuous, long-stalked, with a large head; the valves have a large basal part and a very small blade.

Anametalia sternaloides (BOLAU, 1873)

Brissus sternaloides BOLAU, 1873, p. 177.—Anametalia sternaloides (BOLAU) MORTENSEN, 1951, p. 436, pl. 29, figs. 3, 6-7, pl. 60, figs. 1-6, 9-11, 13-14, 18, 25-26, text-figs. 212-214.

Posterior end of test being produced, not vertical; periproct almost visible from above; front of test low, rounded; petals being not distinctly sunken.

Known only from Hongkong (22°N.) and Gulf of Siam.

Genus Gymnopatagus Döderlein, 1901

Gymnopatagus Döderlein, 1901, p. 22.—H. L. CLARK, 1917, p. 229.—MORTENSEN, 1951, p. 446. Haplotype.—Gymnopatagus valdiviae Döderlein, 1901, p. 23.—Döderlein, 1906, p. 266, pl. 19, fig. 7, pl. 32, figs. 2-2a (off the east coast of Africa).

Frontal ambulacrum (III) more or less deep and conspicuous, at least at ambitus. Anterior interambulacra not sunken adapically. Petals short, well formed and terminated by a peripetalous fasciole; posterior-lateral petals usually much narrower near their bluntly pointed tips than near the middle. Plastron not extending posterior to form a "anal snout". Apical system ethmolytic, with four genital pores. Large primary tubercles present in posterior interambulacrum (5) on aboral side.

Gymnopatagus magnus A. AGASSIZ and H.L. CLARK, 1907

Gymnopatagus magnus A. AGASSIZ and H. L. CLARK, 1907-b, p. 133.—H. L. CLARK, 1917, p. 231, pl. 146, fig. 12, pl. 159, fig. 1.—Brissoides (Gymnopatagus) magnus (A. AGASSIZ and H. L. CLARK) LAMBERT and THIÉRY, 1924, p. 453.—Gymnopatagus magnus A. AGASSIZ and H. L. CLARK: MORTENSEN, 1951, p. 447, pl. 26, figs. 7-9, pl. 27, figs. 8-10, pl. 61, figs. 19-26, text-figs. 219a-c, 220a.

Gymnopatagus sewelli KOEHLER, 1914, p. 98, pl. 13, figs. 1-7, pl. 19, figs. 51-60.

Test highest anterior to apical system; size large, attains 100 mm in test-length; numerous large primary tubercles (25-30) in posterior interambulacrum (5) within the peripetalous fasciole; no ophicephalous pedicellariae found; colour of test and primary radioles pale fawn-coloured to reddish.

From the Japanese Seas (Sagami Sea) to the Indian Ocean. 780-1730 metres in depth.

Genus Eupatagus AGASSIZ, 1847

Eupatagus Agassiz in Agassiz and Desor, 1847, p. 9.—A. Agassiz, 1872-74, pp. 128, 572.— Duncan, 1889-a, p. 253.—H. L. Clark, 1917, p. 226.—Mortensen, 1951, p. 456.—Kier, 1957, p. 896.

Logotype.—Eupatagus valenciennesii AGASSIZ in AGASSIZ and DESOR, 1847, p. 9.—A. AGASSIZ, 1872-74, pp. 128, 572, pl. 15a, figs. 3-4 (Southern Australia). [POMEL, 1883, p. 28].

Pseudopatagus POMEL, 1887, p. 18.

Haplotype.—Spatangus (Pseudopatagus) cruciatus POMEL, 1887, p. 18.—COTTEAU, 1889-94(93), p. 642, pl. 355, figs. 2-7, pl. 356, fig. 1 (Oligocene of Algeria).

Heterospatangus Fourtau, 1905-a, p. 606.—LAMBERT and TRIÉRY, 1924, p. 454.

Haplotype.—Macropneustes lefebvrei LORIOL, 1880, p. 131, pl. 9, figs. 7-9 (Eocene of Egypt). Melitia FOURTAU, 1913-b, p. 68.

Haplotype.-Metalia meltensis GREGORY, 1892-c, p. 621, pl. 2, figs. 5a-c (Eocene of Malta).

Brissoides [KLEIN]: LAMBERT, 1902, p. 48.—LAMBERT and TEIÉRY, 1924, p. 450.—CHECCHIA-RISPOLI, 1944, p. 103.

Type-species.—Spatangus veronensis AGASSIZ, 1840-a, p. 2.—Peripneustes veronensis (AGASSIZ) DAMES, 1877, pl. 10, fig. 4a (non 4b), pl. 11, fig. 1 (Eocene of Verona) (non Macropneustes brissoides ([LESKE]) COTTEAU, 1885-89(86), p. 148, pls. 36-38).

Paired ambulacra petaloid, not sunken, closed distally, with definite interporiferous zones; postero-lateral petals (I and V) usually as wide near their rounded tips as at the middle. Frontal ambulacrum (III) narrow, not depressed, and anterior ambitus evenly convex. A well developed peripetalous fasciole surrounds petals, not bending inwards between petals. Subanal fasciole more or less distinctly shield-shaped, but no anal fasciole. Large aboral tubercles only within the peripetalous fasciole. Sternum well tuberculated. Apical system anterior, ethmolytic, with four genital pores. Pedicellariae of usually four types.

Eupatagus micropetalus (H. L. CLARK, 1917)

Gymnopatagus micropetalus H. L. CLARK, 1917, p. 227, pl. 146, fig. 14, pl. 154, figs. 4-6, pl. 158, fig. 5.—Brissoides micropetalus (H. L. CLARK) LAMBERT and THIÉRY, 1924, p. 450.—Eupatagus micropetalus (H. L. CLARK) MORTENSEN, 1951, p. 474, pl. 61, fig. 14, text-figs. 243-245.

Test low, flattened on oral side, widest across postero-lateral petals (I and V), which are a little curved, and not raised before apical system; naked postero-laterals (I and V) on oral side very broad; aboral primary tubercles of antero-lateral interambulacra (2 and 3) inconspicuous, few or none, and no primaries in posterior interambulacrum (5); subanal plastron rounded triangular, nearly as long as wide; three tube-feet on each side within the subanal fasciole; four kinds of pedicellariae, rostrate, ophicephalous, tridentate, and triphyllous types present.

Known only from the Japanese Seas (Sagami Sea).

145-270 metres in depth.

Genus Rhinobrissus A. AGASSIZ, 1872

Rhynobrissus A. AGASSIZ, 1872, p. 590.—Rhinobrissus A. AGASSIZ: A. AGASSIZ, 1872-74, pp. 154, 590.—MORTENSEN, 1951, p. 486.—Rhynobrissus A. AGASSIZ: COOKE, 1957-a, p. 9. Haplotype.—Rhynobrissus pyramidalis A. AGASSIZ, 1872, p. 590.

Subanal plastron cordiform, shield-shaped, more or less distinctly projecting downwards or backwards, and periproct not visible from above. Anal fasciole present. Frontal ambulacrum (III) not at all differentiated aborally, flush with the adjoining interambulacra, and frontal notch faint or none. Anterior ambulacra not sunken adapically. Apical system ethmolytic, with four genital pores. No large primary tubercles on aboral side.

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Rhinobrissus pyramidalis A. AGASSIZ, 1872

Rhynobrissus pyramidalis A. AGASSIZ, 1872, p. 590.—Rhinobrissus pyramidalis A. AGASSIZ: A. AGASSIZ, 1872-74, pp. 154, 590, pl. 23a, figs. 4-6.—MORTENSEN, 1951, p. 488, pl. 61, figs. 9, 16.

Test highest posterior to apical system, but not very marked and sloping thence to anterior margin; ambitus rounded pentagonal; subanal plastron projecting backwards beyond the periproct; secondeary radioles delicate, silky white.

Known from the China Coast, Gulf of Siam, Singapore, and off Madras. In shallow water.

Genus Brissus GRAY, 1825

Brissus KLEIN: GRAY, 1825, p. 431 (KLEIN, 1734, p. 29—pre-Linnean).—A. AGASSIZ, 1872-74, p. 356.—DUNCAN, 1889-a, p. 241.—H. L. CLARK, 1917, p. 217.—MORTENSEN, 1951, p. 505.
Tautotype.—Spatangus brissus unicolor LESKE, 1778, pp. xx, 248, pl. 26, figs. B, C.—Brissus unicolor (LESKE): A. AGASSIZ, 1872-74, pp. 97, 357, pl. 22, figs. 1-2, pl. 37, fig. 19. [(The designation validated by Opinion 209 of the International Commission on Zoological Nomenclature)].

Frontal ambulacrum (III) flush with test, narrow; the pore-pairs usually united into a narrow vertical slit. Paired ambulacra distinctly petaloid, somewhat sunken. Apical system anterior, ethmolytic, with four genital pores. Sternum large and broad, densely covered with tubercles. Subanal fasciole broad, complete, surrounding a distinct subanal plastron, with a more or less conspicuous lobe on each side towards periproctal region, but without anal fasciole. Peripetalous fasciole bends inwards between petals. Test of large forms. Pedicellariae of usual five types.

Brissus latecarinatus (LESKE, 1778)

Spatangus brissus latecarinatus LESKE, 1778, pp. 185, 249, pl. 48, figs. 4-5.—Brissus latecarinatus (LESKE): H. L. CLARK, 1917, p. 219, pl. 146, fig. 15.—NISIYAMA, 1942, p. 24, text-fig. 12 (in Japanese).—MORTENSEN, 1951, p. 514, pl. 33, fig. 8, pl. 34, figs. 3-5, pl. 63, figs. 8-10, 22, 25-26, text-fig. 264.

Brissus carinatus (LAMARCK): GRAY, 1855-a, p. 55.—A. AGASSIZ, 1872-74, pp. 96, 596, pl. 21a, figs. 1-3, pl. 25, figs. 36-37, pl. 26, fig. 38.

Posterior end of test obliquely downwards truncate; posterior interambulacrum (5) markedly carinate aborally and producing somewhat beak like above periproct; subanal plastron rather high; subanal fasciole also rather high and usually five tube-feet to each side within the fasciole; peristome semicircular; madreporite not so strongly widened posteriorly so as to remove posterior petals from apical system; periproct broadly oval in outline; valves of globiferous pedicellariae terminating in a small transverse-oval opening surrounding by some 6-7 quite short teeth.

From Ryukyu Islands and Formosa to Australia, and widely distributed over the Indo-West Pacific Oceans.

Little zones-45 metres in depth.

Brissus agassizii Döderlein, 1885

Brissus agassizii Döderlein, 1885, p. 108(36).—Yoshiwara (Tokunaga), 1907, pl. 18, figs. 1-6.—Mortensen, 1951, p. 520, pl. 33, fig. 7, pl. 34, fig. 2, pl. 35, figs. 1, 6-8, pl. 62, figs. 9-10, 12, 16-21, 23-28.
Brissus latearingtus L pour ILL. Conten 1995. 210 (2010).

Brissus latecarinatus Leske: H.L. CLARK, 1925, p. 219 (pro parte).

Test not so high, subanal plastron low and angular; posterior end of test vertically truncate and somewhat concave; posterior interambulacrum (5) not at all overhang and periproct not visible from below; periproct narrow, somewhat pointed above and below; apical system more or less anterior than in *Br. latecarinatus*; posterolateral petals (I and V) longer than the antero-laterals (II and IV); usually three tube-seet to each side within the subanal fasciole; valves of globiferous pedicellariae terminating in a long slit with 2 strong, curved lateral teeth and 2-4 similar teeth along the distal edge; large rostrate pedicellariae very coarse, with rather broad valves.

Known only from the Japanese Seas (northern, central, and western Japan, and western Sea of Japan).

Littoral zones—10 metres in depth.

Genus Metalia GRAY, 1855

Metalia Gray, 1855-a, p. 51.—A. Agassiz, 1872-74, pp. 144, 597.—Duncan, 1889-a, p. 206.— H. L. Clark, 1917, p. 209.—Mortensen, 1951, p. 532.

Haplotype.—Spatangus sternalis LAMARCK, 1816, p. 31.

Xanthobrissus A. AGASSIZ, 1863, p. 28.

Haplotype.—Xanthobrissus garretti A. AGASSIZ, 1863, p. 28 (Kingsmills Islands).=Spatangus sternalis LAMARCK, 1816, p. 31.

Prometalia POMEL, 1883, p. 34.-LAMBERT and THIÉRY, 1924, p. 496.

Haplotype.—Brissus robillardi LORIOL, 1876-a, p. 665, pl. 2, fig. 1 (Mauritius). Eobrissus Bell, 1904, p. 236.

Haplotype.—Eobrissus townsendi BELL, 1904, p. 236 (Gulf of Oman).

Metaliopsis FOURTAU, 1913-b, p. 68.

Haplotype.—Echinus maculosus GMELIN, 1788-93(91), p. 3199.=Echinus spatangus LINNLEUS, 1758, p. 665.

Test large, usually wide and high. A distinct anal fasciole arises from subanal fasciole on each side of periproctal area, with an adoral median point and no posterior lobes. Subanal plastron being shield-shaped, and not projecting. Apical system more or less anterior, ethmolytic, with four genital pores. Frontal ambulacrum (III) more or less differentiated aborally, rather conspicuously depressed, or almost flush with test. No large tubercles within peripetalous fasciole. Pedicellariae of usual five types.

Metalia sternalis (LAMARCK, 1816)

Metalia sternalis (LAMARCK): A. AGASSIZ, 1872-74, pp. 145, 600, pl. 21a, figs. 4-5, pl. 21c, figs. 5-9, pl. 32, figs. 11-12, pl. 37, fig. 20.—MEIJERE, 1904, p. 185, pl. 22, fig. 464, pl. 23, figs. 465-468.—YOSHIWARA (TOKUNAGA), 1907, pl. 19, figs. 1-6.—H. L. CLARK, 1917, p. 209, pl. 146, fig. 30.—MORTENSEN, 1951, p. 535, pl. 64, figs. 13, 17, 19, 22, text-fig. 269a.

Apical system distinctly anterior; postero-lateral petals (I and V) coalescing adapically, more or less confluent; no primary tubercles at adapical end of posterior interambulacrum (5); size often very large, rarely attains 190 mm in test-length; frontal ambulacrum (III) conspicuously deepened; many tube-feet to each side enclosed by by the subanal fasciole, up to eleven.

From the Japanese Seas (southwestern Japan) to the Phillipines, and widely distributed over the Indo-Pacific, and Red Sea, African Coast, to the Hawaiian Islands.

Littoral zones-90 metres in depth.

Metalia spatangus (LINNAEUS, 1758)

Metalia spatangus (LINNAEUS): LOVÉN, 1887, p. 162.—NISIYAMA, 1942, p. 23, text-fig. 11 (in Japanese).—MORTENSEN, 1951, p. 540, pl. 38, figs. 7-9, pl. 39, figs. 1-2, 4, pl. 64, figs. 1, 5, 9-10, 25, text-fig. 271a.—UTINOMI, 1962, p. 106, text-figs. 8A-C (in Japanese).

Metalia maculosa (GMELIN): A. AGASSIZ, 1872-74, pp. 144, 598, pl. 21b, figs. 8-9, pl. 38, fig. 29.—Yoshiwara (Tokunaga), 1908, pl. 20, figs. 1-6.—Koehler, 1914, p. 127, pl. 19, figs. 61-70.

Postero-lateral petals (I and V) not at all confluent and not coalescing adapically, but remain separate to apical system; small primary tubercles at adapical end of interambulacrum (5); frontal ambulacrum (III) flush with test; four (or three) tubefeet to each side within the subanal fasciole; sternum (in the adult) concave adorally, and with a single median point where it meets subanal fasciole; vertex of test not very anterior; apical system eccentric in front, less than two-thirds of test-length from posterior margin; vertical diameter less than half test-length; frontal side of test not vertical; valves of tridentate pedicellariae three, with edges slightly serrate.

From the Japanese Seas (western Japan) and Formosa to the Malay region, and widely distributed over the Indo-West Pacific, from the Red Sea and East Africa to Hawaiian Inlands and Society Islands.

Littoral zones-130 metres in depth.

Metalia dicrana H.L. CLARK, 1917

Metalia dicrana H. L. CLARK, 1917, p. 211, pl. 146, fig. 16, pl. 160, figs. 1-4.—H. L. CLARK, 1925, p. 215.—Mortensen, 1951, p. 546, pl. 37, figs. 1-3, pl. 64, figs. 1-2.

Apical system eccentric in front, less than one-third of test-length from anterior margin; posterior-lateral petals (I and V) not coalescing adapically, not at all confluent; small primary tubercles present at adapical end of posterior interambulacrum (5); vertical diameter more than half test-length; frontal ambulacrum (III) almost flush with test; sternum ending posteriorly in two distinct points, 3-5 mm apart, where it meets subanal fasciole.

From the Ryukyu Islands to the Philippines, and distributed from the Malay region to the Fiji Islands and Samoa Islands.

Littoral zones-21 metres in depth.

Among the figures given by YOSHIWARA (lately TOKUNAGA) in his "Japanese Echini : Plate.—Plates 1 (1904)-21 (1908), the followings are removed from the Japanese faunal province and referred to the other provinces of the Echinoidea. *Coelopleurus maillardi* MICHELIN (1906, pl. 9, figs. 7-10) seems to be composite, as pointed

out by MORTENSEN (1935, p. 620), two distinct species: figures 7 and 8 represent Co. longicollis A. AGASSIZ and H. L. CLARK, 1908 (A. AGASSIZ and H. L. CLARK, 1908, p. 49, figs. 29-30, pl. 53, fig. 10), which is known only from the Philippines, and figures 9 and 10 probably represent Co. maillardi (MICHELIN, 1862) (Keraiophorus maillardi MICHELIN, 1862, p. 2, pl. 14), from Mauritius in South Indian Ocean. Microcyphus maculatus AGASSIZ (1906, pl. 9, figs. 13—reproduced from A. AGASSIZ, 1873), and Mic. zigzag AGASSIZ (1906, figs. 4-5—reproduced from A. AGASSIZ) are not be trusted, the specimens in the Museum of Comparative Zoology said to be from Japan were purchased long ago in Hamburg. Breynia australasiae GRAY (1908, pl. 20, figs. 9-10 reproduced from A. AGASSIZ, 1881-a) is a characteristic echinoid of the Australian province and known with certainty only from East Australia, from the Queensland coast to Port Jackson.

Note 1—Through his continuous studies on the crystallographic orientation of the calcite of echinoid test, RAUP (1962-66) has found that the c-axes of the calcite are variably disposed among the different groups, but invariably in the same group. The data from RAUP's determination are given after the name of the species examined in parentheses as follows, e.g., (C-P). The index letters represent as indicated below—

- C: crystallographic orientation.
- P: c-axes uniformly perpendicular to plate surface.
- T: c-axes uniformly tangent to plate surface and aligned longitudinally on the corona.
- P-T: perpendiuclar c-axes in ambulacral columns and tangential c-axes in interambulacral columns.
- 0-45: ontogenetic variation in c-axes orientation of 45 degrees or less.
- 0-90: ontogenetic variation approaching 90 degrees.

Note 2—In the biochemical studies on the phosphagens contained in muscular tissues of echinoids, GRIFFITHS et al. (1957) and YANAGISAWA (1959-60) has found an interesting fact that they have some taxonomic and phylogenetic significance in the Echinoidea. The data from these authors are also given after the name of species in parentheses as follows, e.g., (Ph-AP). The index letters represent as indicated below—

Ph: phosphagens, AP: arginine phosphate, APT: arginine phosphoryl-transferase, CP: creatine phosphate, CPT: creatine phosphoryl-transferase.

VI. CONCLUDING REMARKS

THE RECENT ECHINOID FAUNA OF JAPAN AND THE ADJACENT REGIONS

In giving the synopsis, in the preceding chapter, of the Recent Echinoid Fauna of Japan and the adjacent regions, with the zoogeographical distribution and bathymetrical range, it is noticed that some genera and species are particular to Japan proper and others are in common with the forms of other regions outisde the area. In his "Zoogeographical Remarks" MORTENSEN (1951, pp. 574-477) distinguishes thirteen zoogeographical regions or provinces of the Recent Echinoidea, and mentioned only a few of the main forms, not of detailed supervision, characteristic of these diverse zoogeographical regions or provinces. They may be summarized as follows (excluding the Japanese, Malay and the North Pacific regions), with indication of their characteristic forms.

1. The European (or Lusitanian) region—Echinus esculentus LINNAEUS, 1758, Ech. acutus LAMARCK, 1816, Psammechinus miliaris (MÜLLER, 1771), Spatangus purpureus MÜLLER, 1776, and Sp. raschi LOVÉN, 1869.

2. The West African tropical region—genus *Rotula* confined to this region; *Clypeaster rangianus* DESMOULINS, 1837, and the following species being in common to those of the West Indian region, viz., *Tripneustes ventricosus* (LAMARCK, 1816), *Diadema antillarum* (PHILIPPI, 1845), *Lytechinus callipeplus* and *Echinometra lucunter*.

The Mediterranean subregion—Schizaster (Ova) canaliferus (LAMARCK, 1816).

3. The West Indian region—Cidaris blakei (A. AGASSIZ, 1878), Coelopleurus floridanus A. AGASSIZ, 1872, Plethotaenia spatangoides (A. AGASSIZ, 1883), Meoma grandis (LAMARCK, 1816), Moira atropos (LAMARCK, 1816), Mellita (Leodia) sexiesperforata (LESKE, 1778), Encope emarginata (LESKE, 1778), and Enc. michelini AGASSIZ, 1841. The four latter genera prove the very close relation between the West Indian and the tropical West American regions.

4. The tropical coast of West America (South American West Coast) region the genera *Caenocentrotus* H. L. CLARK, 1912, *Loxechinus* DESOR, 1856, and *Tetrapygus* AGASSIZ, 1846, also *Diadema mexicanum* A. AGASSIZ, 1863, *Astropyga pulvinata* (LAMARCK, 1816), *Moira clotho* (MICHELIN, 1855), and *Rhyncholampas pacificus* (A. AGASSIZ, 1863). The enormous development of the genera *Encope* and *Mellita*.

5. The Magellanic region—Pseudechinus magellanicus (PHILIPPI, 1857), Arbacia dufresnii (BLAINVILLE, 1825), Tripylus excavatus (PHILIPPI, 1845), Tripylaster philippi (GRAY, 1851), and the genera Loxechinus and Tetrapygus.

6. The South African region—Parechinus angulosus (LESKE, 1778), Polyechinus agulhensis (DÖDERLEIN, 1905), Echinolampas crassa (BELL, 1880), Tropholampas loveni (STUDER, 1880), and Spatangobrissus mirabilis H.L. CLARK, 1923.

7. The East Indian region (intimately connected with the Malay region)—*Phyllacanthus forcipulatus* MORTENSEN, 1935, and *Centrostephanus nitidus* MORTENSEN, 1939.

The African Coast subregion-Salmacis erythracis H. L. CLARK, 1912, Diploporaster

barbatus MORTENSEN, 1950, and Metalia robillardi (LORIOL, 1876).

10. The Australian region (intimately connected with the Malay region)—*Centrostephanus rodgersii* (A. AGASSIZ, 1863), *Goniocidaris tubaria* (LAMARCK, 1816), and species of the genera *Microcyphus* AGASSIZ, 1841, *Amblypneustes* AGASSIZ, 1841, *Holopneustes* AGASSIZ, 1846, and *Phyllacanthus* BRANDT, 1835.

The New Zealand subregion—Pseudechinus albocinctus (HUTTON, 1882), Evechinus chloroticus (VALENCIENNES, 1846), and Apatopygus recens (MILNE-EDWARDS, 1836).

11. The South-Sea region-not mentioned.

13. The Subantarctic—Antarctic region—the genera *Notocidaris* MORTENSEN, 1909, *Ctenocidaris* MORTENSEN, 1910, and *Sterechinus* KOEHLER, 1901, and the mostly brood-protecting species of the genera *Amphipneustes* KOEHLER, 1900, and *Abatus* TROSCHEL, 1851.

As for (8) the Malay (or Ambonese) region and its characteristic forms MORTEN-SEN, (1951, p. 576) stated that this is the richest of all and here is in the Recent period the paradise of the sea-urchins. In the region the Temnopleuridae and Toxopneustidae are highly developed, and further the Cidaridae, Diadematidae and Echinothuriidae, as well as the Laganidae, the Cassidulidae and Spatangidae are flourishing. A special mention should be made of such forms as *Isopatagus*, *Sternopatagus* and *Stereopneustes*, isolated survivals of the formerly flourishing Toxasteridae and Holasteridae, and also the remarkable *Palaeostoma* should be mentioned. Here may be added *Cyclaster recens* MORTENSEN 1950, as one of exampes of survivals, and *Stereopneustes* and *Palaeostoma* are extending in their distribution northwards as to the Japanese Seas and Ryukyu Islands.

As to the character of (12) the North Pacific and Arctic region MORTENSEN (1951, p. 577) stated that the region has only the single genus *Stronglyocentrotus* well developed, and single species *Pourtalesia jeffreysi* should be mentioned.

As for the characteristic forms of (9) the Japanese region (including the Bonin Islands) MORTENSEN, (1951, p. 576) stated that—" The Japanese region is almost as rich as the Malayan region, and has such characteristic forms as *Hemicentrotus pulcherrimus, Anthocidaris homalostoma* (the specific name must be emended to *crassispina*), and *Glyptocidaris crenularis*, the last survival of the large Phymosomatid family. Likewise *Psychocidaris ohshimai* of the Bonin Islands, descendant of the Cretaceous *Tylocidaris*, is of very great interest." Other endemic genera and subgenera of the Japanese region may be enumerated as follows—the subgenera *Petalocidaris* MORTENSEN, 1903, and *Aspidocidaris* MORTENSEN, 1928 of *Goniocidaris, Phalacrocidaris* LAMBERT, 1902, of *Stereocidaris*, and the genera *Pseudocentrotus* MORTENSEN, 1903, *Colobocentrotus* BRANDT, 1835, *Scaphechinus* A. AGASSIZ, 1863, and *Astriclypeus* VERRILL, 1867. Although the last genus continuing down into the northern part of the Malay region (Riam, Cambodja), the center of present and past distribution of the genus falls in the Japanese region (together with Formosa).

As might be expected from the geographical position, the Recent echinoid fauna of Japan and the adjacent regions is characterized by the mingling, though it is not completely mingle but has more or less certain limits, of the forms endemic to the Japanese region, the tropical or subtropical forms of the Malay region, and the boreal forms of the North Pacific region. Particularly, on the area covers the main islands of Japan, viz., Hokkaido, Honshu, Shikoku and Kyushu, the warm Kuroshio current and the cold Oyashio current exsert considerable influence on the littoral assemblage of echinoids. Common and rather widely distributed tropical or subtropical forms and species are more characteristically found in the vicinity of coral reefs of the Malay, East Indies, and South Sea regions. They thrive on the Pacific coast of Japan proper as far north as Latitude 35 degrees North-such as Acanthocidaris maculicollis (MEI-JERE, 1903), Plococidaris verticillata (LAMARCK, 1816), Prionocidaris baculosa annulifera (LAMARCK, 1816), Diadema setosum (LESKE, 1778), Coelopleurus maculatus A. AGASSIZ and H.L. CLARK, 1907, Temnopleurus toreumaticus (LESKE, 1778), Temu. (Toreumatica) reevesii (GRAY, 1855), Mespilia globulus (LINNAEUS, 1758), Toxopneustes pileolus (LA-MARCK, 1816), Parasalenia gratiosa boninensis MORTENSEN, 1930, Echinometra mathaei (BLAINVILLE, 1825), Platybrissus roemeri GRUBE, 1865, Maretia planulata (LAMARCK, 1816) and Lovenia elongata (GRAY, 1845)-, and on the Japan Sea coast to Latitude 36 degrees North or a little more. Some more characteristic forms of the tropical region—such as 'Eucidaris' metularia (LAMARCK, 1816), Astropyga radiata (LESKE, 1778), Diadema savignyi [AUDOUIN] MICHELIN, 1826, Echinothrix calamaris (PALLAS, 1774), Ech. diadema (LINNAEUS, 1758), Stomopneustes variolaris (LAMARCK, 1816), Salmaciella dussumieri (AGASSIZ, 1846), Salmacis bicolor AGASSIZ, 1841, Tripnepneustes gratilla (LINNAEUS, 1578), Pseudoboletia maculata TROSCHEL, 1869, Echinostrephus aciculatum A. AGASSIZ, 1863, Echinoneus cyclostomus LESKE, 1778, Clypeaster reticulatus (LINNAEUS, 1758), Echinocyamus crispus MAZZETTI, 1892 and Peronella minuta (MEIJERE, 1904) (UTINOMI, 1954, pp. 341-354)—thrive on the Pacific coast of Japan as far north as 34 degrees North. They have apparently the northern limit there (Kii Peninsula) and are found rather commonly in the littoral zones. The Bonin Islands and the neighbourhood have very characteristic forms, viz., Compsocidaris pyracantha IKEDA, 1939, Chronocidaris micca IKEDA, 1941, Phyllacanthus dubius BRANDT, 1835, Psychocidaris ohshimai IKEDA, 1935 and Colobocentrotus mertensii BRANDT, 1835; the last species, however, is known with certainty from Kii Peninsula, Hachijô Island, southern Kyushu (Shibushi), Tokara Islands, Ryukyu Islands and Formosa and with uncertainty from Pagan Island in the Mariana Islands.

One of the typical boreal forms of the North Pacific region, *Echinarachnius parma* obesus H. L. CLARK, 1914, having spread from Alaskan Peninsula over the northern Asiatic coast (Kamtchatka, Kurile Islands, Sakhalin, and Hokkaido) and passed down into North Honshu, about Latitude 41 degrees North. The other species, *Strongylocentrotus droebachiensis* (MULLER, 1776) on the Pacific region seems to be confined to northeast coast of North America (southeast of Kamtchatka—UTINOMI, 1960, p. 340) from Alaska to at least as far south as the state of Washington. On the contrary, a large number of species of this boreal genus *Strongylocentrotus*, excepting for North Atlantic and North Pacific *Str. droebachiensis* and a Californian *Str. purpuratus* (STIMPSON, 1857), seem to be confined to the northern Asiatic coast or northwestern Pacific, viz., *Str. sachalinicus* DÖDERLEIN, 1906 (from Bering Sea, Lat. 63°52'N., to Kinkasan Light house, 38°15'N.), *Str. echinoides* A. AGASSIZ and H. L. CLARK, 1907 (from Bering Sea to North Honshu, Lat. 38°N. and from Alaska to Oregon), *Str. polyacanthus* A. AGASSIZ and H. L. CLARK, 1907 (Simushir Island, Kurile Islands, ca. Lat. 47°N.), *Str. intermedius* (A. AGASSIZ, 1863) (from Sakhalin to North Honshu, Lat. 38°N.), Str. pulchellus A. AGASSIZ and H. L. CLARK, 1907 (from East coast of Kamtchatka to North Sea of Japan, ca. Lat. 44°N.), and Str. nudus (A. AGASSIZ, 1863) (from Hokkaido to Sagami Sea? on the Pacific side, and to Tsushima? on Japan Sea side); a Californian Str. franciscanus (A. AGASSIZ, 1863) is known to occur (UTINOMI, 1960, p. 343) from Hokkaido on the West Pacific side. Str. nudus is extending as southwards as about Latitude 35 degrees North, e. g., the Sagami Sea on the Pacific side and the coast of Hagi, western Sea of Japan, at the latter locality it is found together with other echinoids, such as Stereocidaris (Phalacrocidaris) japonica (DÖDERLEIN, 1885), Hemicentrotus pulcherrimus (A. AGASSIZ, 1863), Pseudocentrotus depressus (A. AGASSIZ, 1863), Brissus agassizii DÖDERLEIN, 1885 and Platybrissus roemeri GRUBE, 1865 (IKEDE, 1942, p. 142); among them, the last species is regarded as a tropical form, Str. nudus a boreal form, and the remaining four species are temperate water forms, and hence the three forms of the tropical, temperate water and boreal, are intermingled there.

A unique boreal form of the genus *Temnopleurus*, *Tem. hardwickii* (GRAY, 1885), which flourishes on the Pacific coast of North Honshu, e.g., in the Sendai Bay and the neighbourhood (ca. Lat. 38°N.), is found together with *Glyptocidaris crenularis* A. AGASSIZ, 1863, *Strongylocentrotus intermedius*, *Str. sachalinicus*, *Hemicentrotus pulcherrimus*, *Fibularia* (*Fibulariella*) acuta septemtrionalis NISIYAMA, and Scaphechinus brevis (IKEDA, 1936), of boreal or more or less temperate water forms. *Tem. hardwickii*, however, passed down into central Japan (ca. Lat. 35°N.) and is found together with temperate water or subtropical forms, and interrupted from its southern form (subspecies) *impressus* by a length of about 10 degrees or more latitude of unoccurred zone.

In the Japan Sea side the boreal forms—such as *Glyptocidaris crenularis, Stron-gylocentrotus intermedius,* and *Temnopleurus hardwickii*—are particularly strongly developed on the coasts of Sakhalin, Sikhota Alin and North Korea and South Korea and eastern part where the Tsushima warm current has been chilled by mingling with the cold northern waters.

The writer gave (NISIYAMA, 1956, pp. 81-87) a list of the geographical and bathymetrical distribution of the Recent echinoids of Japan and the adjacent regions, and this is deduced from the synopsis given in the preceding chapter. The area dealing with herein—Japan and the adjacent regions—comprising in the main the Japanese region of MORTENSEN, northern part of the Malay region, and southern part of the North Pacific (and Arctic) region, and consequently its fauna is more varied than that of a single region.

The Recent echinoid fauna of Japan and the adjacent regions, as seen in the list (NISIYAMA, 1965) and the synopsis, comprises as nearly large number as 190 species (with many subspecies). Of the fauna the Echinothuriidae are represented by 8 genera of the East Indian and Malay region, a greater part of the living Echino-thuridae, but lacking representatives of the following 3 genera, viz., *Hemiphormosoma* MORTENSEN, 1934, *Paraphormosoma* MORTENSEN, 1934, and *Kamptosoma* MORTENSEN, 1903. The Cidaridae are represented by 14 genera (with 4 subgenera), but totally lacking representatives of the following genera, viz., *Poriocidaris* MORTENSEN, 1909, *Cidaris* LESKE, 1778, *Calocidaris* H. L. CLARK, 1907, and *Tretocidaris* MORTENSEN, 1903,

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of the Lusitanian (European) and West Indian, *Schizocidaris* MORTENSEN, 1903, of the Malay, *Actinocidaris* MORTENSEN, 1928, *Hesperocidaris* MORTENSEN, 1928 and *Centrocidaris* A. AGASSIZ, 1904, of the tropical coast of West America, *Chondrocidaris* A. AGASSIZ, 1863, of the South Sea, and *Austrocidaris* H. L. CLARK, 1907, *Notocidaris* MORTENSEN, 1909, and *Ctenociaris* MORTENSEN, 1910, of the Antarctic.

The family Aspidodiadematidae are represented by a single Malayan genus *Aspidodiadema* A. AGASSIZ, 1879, but lacking representatives of the genus *Plesiodia-dema* POMEL, 1883, of the West Indian region. The family Pedinidae are represented by two species of a single living genus *Caenopedina* A. AGASSIZ, 1869, one species is evidently of the Japonic and the other of the Pacific region. The Diadematidae are represented by 4 genera of the Malay and East Indian, but lacking representatives of the following genera, viz., *Eremopyga* A. AGASSIZ and H. L. CLARK, 1908 of the South Sea, *Goniodiadema* MORTENSEN, 1939, of the East Indian, *Centrostephanus* PETERS, 1855, of the East Indian, Australian and the tropical coast of West America, and *Lissodiadema* MORTENSEN, 1903, and *Leptodiadema* A. AGASSIZ and H. L. CLARK, 1907.

The family Saleniidae are represented by 4 species of the living two genera, Salenocidaris A. AGASSIZ, 1869, and Salenia GRAY, 1835. Any representative of the Micropygidae is not found in the Recent echinoid fauna of Japan and the adjacent regions. The large family Phymosomatidae are represented by the survival genus *Glyptocidaris* in North Japan. Also the large family Stomechinidae (Stomopneustidae) are represented by the last survival genus *Stomopneustes*, which is extending as northwards as about Latitude 34 degrees North in Japan. The family Arbaciidae are only represented by some species of a single genus *Coelopleurus*, but quite lacking in representatives of the following 7 genera, which make a majority of the family, viz., *Habrocidaris* A. AGASSIZ and H. L. CLARK, 1907, of the South Sea, *Dialithocidaris* A. AGASSIZ, 1898, of the South Sea, *Pygmaeocidaris* DODERLEIN, 1905, of the Malay, *Podocidaris* A. AGASSIZ, 1869, of the West Indian, *Arbacia* of the West Indian, Magellanic, tropical coast of West American and Lusitanian, *Arbaciella* MORTENSEN, 1910, of the East Indian, and *Tetrapygus* AGASSIZ, 1846, of the tropical coast of West America and Magellanic.

The family Temnopleuridae, the highly developed forms of the Malay region, are represented by numerous species of the following genera, viz., Temnopleurus (with subgenus Toreumatica), Salmacis, Salmaciella, Mespilia, Microcyphus, Temnotrema, Opechinus, Printechinus, Prionechinus, Lamprechinus and Desmechinus H. L. CLARK, 1923; but the family is lacking in representatives of the following genera, viz., Ambly-pneustes AGASSIZ, 1841, and Holopneustes AGASSIZ, 1841, of the Australian, Pseudechinus MORTENSEN, of the New Zealand and Magellanic, Erbechinus JEANNET, 1935 and Paratrema KOEHLER, 1927, of the Malay, Trigonocidaris A. AGASSIZ, 1869, of the West Indian, East Indian and Malay, Hypsiechinus MORTENSEN, 1903, of the Lusitanian, Orechinus DÖDERLEIN, 1905, of the New Zealand, Asterechinus MORTENSEN, 1942, of Malay, and Genocidaris A. AGASSIZ, 1869, of the West Indian. The family Toxopneustidae, also the highly developed forms of the Malay region, are represented by characteristic species of the following 5 genera, viz., Nudechinus, Toxopneustes, Tripneustes, Pseudoboletia, and Pseudocentrotus of the Japonic, and a species (pentagonus)

of the genus *Gonipneustes* DUNCAN, 1889, is said to inhabit the China Sea; but the family being lack representatives of the following genera, viz., *Cyrtechinus* MORTEN-SEN, 1942, of the East Indian, *Sphaerechinus* DESOR, 1855, of the Lusitanian, *Gymnechinus* MORTENSEN, 1903, of the East Indian, and *Lytechinus* AGASSIZ, 1863, of the tropical coast of West American and West Indian.

The family Echinidae are very poorly developed, as only one species of *Echinus* is represented and it contrasts to the highly developed, about 12 species, of the Lusitanian regions of the genus, and further being lack the representatives of remaining the whole genera of the family. The family Strongylocentrotidae, on the contrary, are highly developed and represented by a greater part of the species of *Strongylc-centrotus*, and a species of *Hemicentrotus*, which is endemic to Japan, but are lacking in representative of the genus *Allocentrotus* MORTENSEN, 1942, of the tropical coast of West American and north.

The Parasaleniidae are represented by a single species (gratiosa) with a subspecies (boninensis) of the single living genus Parasalenia. The large family Echinometridae, which are flourishing in the Recent South Sea, Malay, and East Indian regions, are represented by characteristic species of the following 5 genera, viz., Echinostrephus, Anthocidaris, Echinometra, Heterocentrotus, and Colobocentrotus; but the family is lacking in representatives of the following genera, viz., Selenechinus MEIJERE, 1903, of the Malay, Evechinus VERRILL, 1871 of New Zealand and Australian, Pachycentrotus H. L. CLARK, 1912 of the tropical coast of West America and Magellanic, Heliocidaris AGASSIZ and DESOR, 1846 (=Toxocidaris AGASSIZ, 1863) of the Australian, Zenocentrotus A. H. CLARK, 1931 of the South Sea, and Podophora AGASSIZ, 1840 (or subgenus of Colobocentrotus) of the East Indian and South Sea.

The Echinoneidae are represented by a single species (cyclostomus) of the living genus Echinoneus, and another living genus, Micropetalon A. AGASSIZ and H.L. CLARK, 1907, of the South Sea, is not found in the echinoid fauna of Japan. The living representatives of the family Cassidulidae, e.g., Cassidulus and Rhyncholampas, and family Apatopygidae, e.g., Apatopygus, are not represented in the Recent echinoid fauna of Japan. The family Pliolampadidae are represented by single species of the genus Oligopodia, and are lacking in representative of the genus Studeria DUNCAN, 1891. The family Echinolampadidae are represented by three species of Echinolampas, which is regarded as a rather survival member of the order.

The interesting and puzzling family Neolampadidae are represented by a single species (*sinensis*) of the genus *Anochanus* GRUBE, 1868, which is said to inhabit the China Sea; while being lack representatives of remaining the whole genera of the living, viz., *Neolampas* A. AGASSIZ, 1869, of the West Indian, *Nannolampas* MORTEN-SEN, 1950, of the Malay, *Aphanopora* MEIJERE, 1902, of the Malay and *Tropholampas* H. L. CLARK, 1923, of the South African.

The family Clypeasteridae are represented by no less than 5 species of single genus *Clypeaster*. The family Arachnoididae are represented by a single species (*placenta*) of *Arachnoides* and Amoy of China coast seems to be the northernmost limit of its geographical distribution; the family is lacking in representatives of the following genera (or subgenera), viz., *Fellaster* DURHAM, 1955, of the New Zealand, and *Ammotrophus* H. L. CLARK, 1928 (=*Hesperaster* H. L. CLARK, 1938) of the Aus-

tralian.

The family Fibulariidae, the rather highly developed forms of the Malay region, are represented by characteristic species of the two living genera, *Echinocyamus* and *Fibularia*, with a subgenus in each of them. The family Laganidae, also the highly developed forms of the Malay, are represented by characteristic species of three genera, *Peronella*, *Laganum* and *Hupea*; the genera are splitted by LAMBERT and THIÉRY (1914), JEANNET and MARTIN (1937) and DURHAM (1955) into several genera.

The family Scutellidae comprise only a subfamily Dendrasterinae and they are represented by two living species of the boreal genus *Echinarachnius* in northern Japan and further north and three species (with a subspecies) of the Japonic genus. *Scaphechinus*; however the subfamily is totally lacking in the living representatives of the genus *Dendraster* of the western coast of North America and tropical coast of West America; this composition of the Dendrasterinae is a characteristic feature in the echinoid fauna of Japan and the adjacent regions. The family Astriclypeidae are represented by the living representatives of a subfamily Astriclypeinae, i.e., one of which is the genus *Echinodiscus* of the East Indian and Malay and the other is the Japonic *Astriclypeus*; but the family is totally lacking in representatives of the other subfamily Mellitinae, e.g., *Mellita* and *Encope*, of the West Indian and tropical coast of West America.

The peculiar and very characteristic family Rotulidae, peculiar to the tropical coast of West Africa, of course, are not represented in the Recent echinoid fauna of Japan and the adjacent regions.

The large family Holasteridae are represented by a single species of the last survival genus *Stereopneustes* of the Malay region, but is lacking in representatives of the other survival genus *Sternopatagus* MEIJERE, 1902, of the Malay. The family Urechinidae are represented by two northern Pacific and deep-sea forms of *Urechinus*, but lacking in representatives of *Pilematechinus* A. AGASSIZ, 1904, of the Magellanic and Antarctic, and *Plexechinus* A. AGASSIZ, 1904, of the tropical coast of West America, Lusitanian, Subarctic and Malay regions. The family Calymnidae are not represented in the Recent echinoid fauna of Japan and the adjacent regions; a single genus *Calymne* THOMSON, 1877, has been found to be represented in the Lusitanian region in deep-sea.

The family Pourtalesiidae are represented by a single, deep-sea form (*laguncula*) of *Pourtalesia*, while other species of the genus are known from the South African, Lusitanian and Antarctic regions; the family, however, is lacking in representatives of remaining the whole genera, viz., *Helgocystis* MORTENSEN, 1907, of the Sub-Antarctic, *Echinosigra* MORTENSEN, 1907, *Spatangocystis* A. AGASSIZ, 1879, *Echinocrepis* A. AGASSIZ, 1879, *Cystocrepis* MORTENSEN, 1907, and *Ceratopyga* POMEL, 1883, of the Antarctic region.

The large and perplexing family Palaeopneustidae are represented by characteristic species of the following genera, viz., *Linopneustes*, *Argopatagus*, *Platybrissus*, and *Palaeotrema*. But, the family is lacking in representatives of the following numerous genera, viz., *Palaeopneustes*, A. AGASSIZ, 1873, of the West Indian, *Archaeopneustes* of the West Indian, *Heterobrissus* MANZONI and MAZZETTI, 1880, of the East Indian, *Phrissocystis* A. AGASSIZ, 1898, of the tropical coast of West America, *Pycnolampas*. A. AGASSIZ and H. L. CLARK, of the South Sea, *Plesiozonus* MEIJERE, 1902, of the Malay, *Genicopatagus* A. AGASSIZ, 1879, of the Antarctic, *Eurypatagus* MORTENSEN, 1948, of the Malay, *Homolampas* A. AGASSIZ, 1872, of the West Indian, Lusitanian and Malay, *Elipneustes* KOEHLER, 1914, of the East Indian, and *Palaeotropus* LOVÉN, of the Lusitanian regions.

The peculiar family Palaeostomatidae are represented by a single species (*mirabile*) of a unique genus *Palaeostoma* of the Malay region, the species extends as northward as the Ryukyu Islands in its geographical distribution. The family Aeropsidae are represented by a single species (*ovata*) of *Aceste* of the Lusitanian, East Indian and Malay regions, but being lack representatives of *Aeropsis* MORTENSEN, 1907, of the Lusitanian, Arctic, East Indian and Malay regions.

The family Toxasteridae have been supposed to comprise only of fossil forms, but the last survival genus *Isopatagus* MORTENSEN, 1948, has recently been found in the Sulu sea; but the species (*obovatus*) is not represented in the Recent echinoid fauna of Japan and the adjacent regions. The family Hemiasteridae are represented by two species of *Hemiaster*, the one (*gibbosus*) of them is regarded as a subspecies of the Lusitanian *expergitus*, and the other (*clarki*) is an endemic to Japan; representatives of the other living genus *Sarsiaster* MORTENSEN, 1950, of the Lusitanian region, of course, are not represented in the Recent echinoid fauna of Japan.

The family Spatangidae are represented by 4 species of the single living genus *Spatangus* (with subgenus *Granopalagus*); the living species of the genus are rather widely distributed over the greater part of zoogeographical regions, viz., the Lusitanian, New Zealand, South Sea, Japanese and South African regions. The family Maretiidae are represented by two species of *Maretia* and one of *Pseudomaretia*, but lacking in representatives of the following genera, viz., *Paramaretia* MORTEN-SEN, 1950, of the Australian, *Hemimaretia* MORTENSEN, 1950, of the Australian, *Hemimaretia* MORTENSEN, 1950, of the East Indian, and *Nacospatangus* A. AGASSIZ, 1873, of the tropical coast of West American and West Indian regions. The family Loveniidae (with subfamily Echinocardiinae) are represented by 3 species of *Lovenia*, a questionable one of *Pseudolovenia*, and a cosmopolitan species and a Japonic one of *Echinocardium*; but lacking in the living species of *Breynia*, which comprises 4 or 5 living species known from the Australian, Malay and East Indian regions.

The family Pericosmidae are represented by two living species of a single living genus *Pericosmus*; the genus has been thought to be extinct, but the discovery of many living species (about 10) proves this genus to be still living in full vigor in the East Indian and Malay regions. The large family Schizasteridae are represented by characteristic species of the following genera, viz., *Schizaster, Hypselaster, Brisaster, Moira, Faorina* and *Linthia*?; the last genus was hitherto thought to be extinct; but lacking in representatives of the following genera, viz., *Ova* (a subgenus of *Schizaster*) of the Mediterranean, *Paraster* POMEL, 1869 of the East Indian and tropical coast of West America, *Protenaster* POMEL, 1883 of the Australian and South Sea, *Prymnaster* KOEHLER, 1914, of the East Indian and South African, *Diploporaster* MORTENSEN, 1950, of the East Indian, *Abatus* TROSCHEL, 1851, of the Antarctic and Magellanic, *Amphipneustes* KOEHLER, 1900, of the Antarctic, *Tripylaster* MORTENSEN, 1907, of the Magellanic, *Tripylus* PHILIPPI, 1845, of the Magellanic, *Parapneustes* KOEHLER,

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1912, of the Antarctic, *Moiropsis* A. AGASSIZ, 1881 (or a subgenus of *Moira*), of the Malay and *Agassizia* VALENCIENNES, 1846, of the tropical coast of West America and West Indian regions.

The large and rather ill-defined family Brissidae are represented by many species of the following 7 genera, viz., Brissopsis, Anametalia, Rhinobrissus (Rhynobrissus), Metalia, Brissus, Eupatagus, and Gmnopatagus. But the family is lacking in representatives of the following genera, viz., Anabrissus MORTENSEN, 1950, of the West Indian, Neopneustes DUNCAN, 1889, of the West Indian, Cionobrissus A. AGASSIZ, 1879, of the Malay, a survival species of the genus Cyclaster COTTEAU, 1856, from the coast of Indo-China, Lissopatagus MORTENSEN, 1950, of the Australian, Plethotaenia H. L. CLARK, 1917, of the West Indian, Spatangobrissus H. L. CLARK, 1923, of the South African, Plagiobrissus POMEL, 1883 (=Plagionotus GRAY, 1855, non MULSANT, 1842) of the West Indian and West African, Rhabdobrissus COTTEAU, 1889 (or a subgenus of Plagiobrissus) of the Lusitanian (with the Mediterranean) and the tropical coast of West America, Meoma GRAY, 1851, of the tropical coast of West America and West Indian and Idiobryssus H. L. CLARK, 1939, of the tropical coast of West America regions.

The zoogeographical distribution of almost all the genera of the Recent echinoid fauna may be roughly summarized as follows. Of about 260 genera (with subgenera) of the Recent echinoid fauna over 110 (about 43 per cent) are known to occur in Japan and the adjacent regions. This large number of the genera is almost equal to that of the Malay region, the richest of all regions, and three-fourths (ca. 82) of them are common to the two regions. Thus, there can be no question that this very rich Recent echinoid fauna of Japan and the adjacent regions is closely allied to the still richer Malay fauna, while there is a reason to expect that further investigation and collecting would show more genera (and species) common to the two regions. Of the remaining one-fourth of the genera of Japan and the adjacent regions nearly a half is endemic forms of the region, several (3 or more) are common to the Arctic, and the rest is mostly the genera of rather world-wide distribution.

The Recent echinoid fauna of the West Indian region, one of the very rich faunae, comprises about 46 or more genera (with subgenera), the number being slightly less than 20 per cent of the Recent fauna of the world. Of these genera about 15 are common to those of Japan and the adjacent regions. The Recent echinoid fauna of the East Indian region comprises about 76 genera, the number being slightly less than 30 per cent of the Recent fauna of the world. Of these genera about 52 (68 per cent) are common to those of Japan and the adjacent regions, and 57 (75 per cent) are common to those of the Malay region. Thus the Recent echincid fauna of the East Indian region is intimately connected with that of the Malay region, less so with the Japanese region. The Lusitanian (or European) fauna comprises about 38 genera, the number being slightly less than 15 per cent of the fauna of the world. Of these genera about 20 (ca. 52 per cent) are common to those of Japan and the adjacent regions. The fauna of the tropical coast of West America comprises also about 38 genera, the number being equal to the Lusitanian, and of these genera about 15 (ca. 39 per cent) are common to those of Japan and the adjacent regions. The Recent echinoid fauna of the Australian region comprises about 58 or more genera (with subgenera), the number being about 23 or more per cent of the fauna of the world. Of these genera about 38 (ca. 66 per cent) are common to those of the Malay region and slightly less so to Japan and the adjacent regions. The Recent fauna of the South Sea region (including the Hawaiian Islands) comprises about 60 genera, the number being about 24 per cent of the fauna of the world. Of these about 42 genera (ca. 70 per cent) are common to those of the Malay region and about 39 (ca. 65 per cent) are common to those of the Malay regions. The rich fauna of the Antarctic region comprises over 22 genera, about 9 per cent of the fauna of the world, of which 2 (ca. 8 per cent) are common to those of Japan and the adjacent regions.

The genera-composition of the Recent echinoid fauna of the main zoogeographical regions may be roughly expressed in tabular form as follows.

The genera-composition of the Recent echinoid fauna of the main zoogeographical regions

Abbreviations

JA Japan and the adjacent regions

ML The Malay (or Ambonese) region

EI The East Indian region

SS The South Sea region

AT The Australian region

LT The Lusitanian region, including the Mediterranean Sea.

WI The West Indian region

AM The Tropical West American region

AA The Antarctic-Subantarctic region

		••••••								
	JA	ML	EI	SS	AT	LT	WI	AM	AA	ł
NO	110	111	76	60	58	38	46	38	22	
W%	43	43	30	24	23	14	18	14	9	i I
\mathbf{NT}		82	52	39	38	20	15	15	2	!
Т%		75	68	65	66	52	32	39	8	-
NM	82		57	42	39	21	16	13	1	
${ m M}\%$	75		75	70	67	55	33	34	4	

NO: Number of genera (subgenera) of each region

W%: Its percentage of the whole echinoid fauna

NT: Number of genera common to Japan and the adjacent regions

T%: Its percentage of the fauna of the region

NM: Number of genera common to the Malay region

M%: Its percentage of the fauna of the region.

Intimately connected with the Recent echinoid fauna of Japan and the adjacent regions, particularly southern Japan and its south, in the genera-composition as shown above, are the East Indian, South Sea, and Australian regions, and especially so the Malay region. The fauna of these regions comprises more than 60 per cent, particulary in the Malay region 75 per cent, of the genera common to Japan and the adjacent regions. Of the other main zoogeographical regions the Antarctic is very slightly connected with Japan and the adjacent regions; in the West Indian and the

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tropical coast of West America less than 40 per cent, the Lusitanian 50 percent, of the genera are common to Japan and the adjacent regions.

As for the minor zoogeographical provinces of Japan proper, i.e., the seas surrounding the main islands of Japan, Hokkaido, Honshu, Shikoku and Kyushu, YOKO-YAMA (1920, p. 22) recognized four zoological provinces based on the study of the molluscan fauna. YOKOYA (1933, pp. 219-220) established zoological provinces in the Japanese Seas from a study of the decapod crustaceans. YOKOYA's method is by taking generally the northernmost limit of southwards distributing forms and the southernmost limit of northwards distributing forms as the general boundaries. HIRO (now UTINOMI) from his study of the Cirripedia has established the existence of several important zoological provinces in the Japanese Seas; his provinces as recognized from the distribution of the cirripeds are summarized as follows.—A. Pacific Ocean side: Section I, Mutsu region, Section II, Kanto and Tokaidô region, Section III, Kii and Shikoku region; Japan Sea side: Section V, Korea Strait, Section VI, Japan Sea region.

NOMURA and HATAI (1936, A Note on the Zoological Provinces in the Japanese Seas. Bull. Biogeogr. Soc. Japan, vol. 6, no. 21, pp. 207-214, pl. 1), from their study of the molluscan fauna, divided the seas surrounding Japan into seven zoological provinces. HATAI in his great monographic work on the Brachiopoda (1940, pp. 41-43), from his study of the brachiopod fauna of Japan, dealt with the following zoological provinces; namely—Pacific Ocean: Sanriku-Jôban province, Kantô-Kii province, Shikoku-Kyushu province; Japan Sea: Noto-San'in province and Uetsu province. Recently, KURODA and HABE (1952, p. 2), in carrying out their detailed faunistic studies of the molluscs, have come to recognition of the molluscan province of Japan and published an opinion that the Japonic province is characterized more particularly by the mollusca found at depths exceeding 50 metres.

The minor zoogeographical provinces of Japan proper recognized by many authors seem to be, as stated by HATAI (1940, p. 44) and as in the case of zoogeographical regions of MORTENSEN (1951, p. 575), more or less overlapping and no sharp and definite limits can be given. From the standpoint of the echinoid fauna, owing to less numerous species than the molluscan fauna, these minor zoogeographical provinces of Japan may be more or less uncertain to recognize. However, from the geographical and bathymetrical distribution of the Recent echinoids of Japan and the adjacent regions we are led to the recognition of certain Japonic zoogeographical provinces. Among the provinces to be dealt with, the following ones are to be mentioned.

On the Pacific side, the southernmost part of the Bôsô Peninsula (Latitude 35° North, Longitude 140° East), including the Sagami Sea, has apprently the northern limit of some characteristic Japonic and tropical or subtropical species; the following characteristic ones to be mentioned.—

Japonic species:	Araeosoma owstoni	(60–115 m)
	Goniocidaris (Petalocidaris) biserialis	(80-360 m)
	Goniocidaris (Discocidaris) mikado	(50-700 m)
	Goniocidaris (Aspidocidaris) clypeata	(100-700 m)

	Chaetodiadema japonicum	(50-135 m)
	Microcyphus olivaceus	(70–170 m)
	Pseudocentrotus depressus	(0-5 m)
	Opechinus variabilis	(100-550 m)
	Echinolampas sternopetala	(150-500 m)
	Clypeaster japonicus	(1-75 m)
	Peronella japonica	(0-50 m)
	Asthenosoma ijimai	(20-120 m)
	Astriclypeus mannii	(0-5 m)
	Spatangus pallidus	(90–110 m)
	Moira lachesinella	(0-5 m)
Malayan species:	Acanthocidaris maculicollis	(40-225 m)
	Plococidaris verticillata	(0-45 m)
	Prionocidaris baculosa annulifera	(0-250 m)
	Diaema setosum	(0-70 m)
	Coelopleurus maculatus	(70-360 m)
	Toxopneustes pileolus	(0-90 m)
	Parasalenia gratiosa boninensis (South Sea ty	ype) (0-5 m)
	Echinometra mathaei	(0-5 m)
	Clypeaster virescens	(100-300 m)
	Laganum fudsiyama	(50-645 m)
	Hemiaster expergitus gibbosus	(445-1865 m)
	Maretia planulata	(0-60 m)
	Pseudomaretia alta	(1.5-62 m)
	Lovenia elongata	(0-90 m)
	Brissopsis bengalensis	(130-2986 m)
	Metalia sternalis	(0-90 m)
	Pourtalesia laguncula	(220-1370 m)

A characteristic species of Japonic littoral form, *Anthocidaris crassispina*, however, spreads over the area as northwards as 36° or more North Latitude.

On the Sea of Japan side, a similar condition of the northern limit of some characteristic Japonic and tropical species is found at near the Wakasa Bay, west coast of Noto Peninsula (ca. Lat. 36°N., Long. 136°E.); on the other hand, there are a few species which do not occur in the Sea of Japan but do occur in the Sagami Sea, so that the echinoid fauna of the Sea of Japan is apparently far less varied than those of the Pacific side; the following characteristic ones to be mentioned.

Japonic species:	Asthenosoma ijimai	(20–120 m)
	Goniocidaris (Petalocidaris) biserialis	(80-360 m)
	Opechinus variabilis	(100-550 m)
	Pseudocentrotus depressus	(0-5 m)
	Clypeaster japonicus	(1-100 m)
	Peronella japonica	(0-50 m)
	Astriclypeus mannii	(0-5 m)
	Echinolampas koreana	(72–120 m)

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	Moira lachesinella	(0-5 m)
Malayan species:	Diadema setosum	(0-70 m)
	Temnopleurus toreumaticus	(0-45 m)
	Toxopneustes pileolus	(0-90 m)
	Stereocidaris grandis	(70-200 m)
	Pseudomaretia alta	(1.5-62 m)
	Lovenia elongata	(0-90 m)

Anthocidaris crassispina also spreads over the areas as northwards as 37° or more North Latitude on the Sea of Japan side.

The southernmost part of Kii Peninsula (ca. Lat. 33°30'N., Long. 135°30'E.) also has the northern limit of the characteristic species of the Malayan (tropical) region; many of them has not hitherto been recorded from Japan proper with certainty till UTINOMI (1954, pp. 339-340) has found them there. The following species to be mentioned.

Malayan species:	' Eucidaris 'metularia	(0-20 m)
	Astropyga radiata	(2-60 m)
	Echinothrix calamaris	(0-70 m)
	Ech. diadema	(0-5 m)
	Stomopneustes variolaris	(0–10 m)
	Salmacis bicolor	(0-72 m)
	Salmaciella dussumieri	(10-180 m)
	Tripneustes gratilla	(0-25 m)
	Pseudoboletia maculata	(20-75 m)
	Echinostrephus aciculatum	(0-50 m)
	Echinocyamus cyclostomus	(0-120 m)
	Clypeaster reticulatus	(0-120 m)
	Echinocyamus crispus	(18–192 m)
	Peronella minuta	(13-35 m)

The Japonic species of the warm temperate, of course, and the Malayan species which are extending to the southernmost part of Bôsô Peninsula are fairly well found there together with the species mentioned above: they are—The Japonic species;-Asthenosoma ijimai, Goniocidaris (Petalocidaris) biserialis, Gon. (Discocidaris) mikado, Chaetodiadema japonicum, Pseudocentrotus depressus, Echinolampas sternopetala, Clypeaster japonicus, Fibularia (Fibulariella) acuta, Peronella japonica and Astriclypeus mannii; the Malayan species; - Plococidaris verticillata, Prionocidaris baculosa annulifera, Diadema setosum, Did. savignyi, Coelopleurus maculatus, Temnopleurus toreumaticus, Tem. (Toreumatica) reevesii, Mespilia globulus, Toxopneustes pileolus, Parasalenia gratiosa (boninensis), Echinometra mathaei, Clypeaster virescens, Laganum fudsiyama, Pourtalesia laguncula, Lovenia elongata and Brissopsis luzonica. A peculiar species, Colobocentrotus mertensii BRANDT, 1835, was originally known to occur at Bonin Islands, and thereafter come to known with certainty from many localities, of which the Hachijô-jima (ca. Lat. 33°N., Long. 139°50'E.) is the east, and the southernmost part of Kii Peninsula is the northern limit; but Phyllacanthus dubius, which was at first reported from Bonin Islands together with Col. mertensii, is not known

to occur on Kii Peninsula.

In the Sea of Japan, the similar distribution of the echinoid fauna of Japan may be found at the neighbourhood of the Goto Islands (ca. Lat. 33°30'N., Long. 129°E.), where, as noticed by YOKOYA (1933, p. 220) on the crustacean species, many of the characteristic species are not distributed over far northwards. The following may be mentioned.

Malayan species:	Temnopleurus (Toreumatica) apodus	(160-500 m)
	Salmaciella dussumieri	(10-180 m)
	Lamprechinus sculptus	(400 m)
	Echinometra mathaei	(0-5 m)
	Clypeaster fervens hiradicus	(120 m)
	Echinocyamus crispus	(18-192 m)
	Laganum fudsiyama	(50-645 m)
	Maretia tuberculata	(108 m)

A typica! Malayan species, *Platybrissus roemeri*, however, is distributed over there northwards as to off Hagi, Yamaguchi Prefecture (ca. Lat. 35°N., Lat. 131°30'E.), in 100 metres depth.

The southernmost part of Kyushu (ca. Lat. 31°30'N.) on the Pacific side and slightly more northwards on the East China Sea side, has apparently the southern limit of many species of the characteristic Japonic ones and the northern limit of some of the Malayan region; the following species to be mentioned.

The Japonic species which have apparently the southern limit-

(185-400 m)
(60-155 m)
(80-360 m)
(100-700 m)
(50-700 m)
(180-700 m)
(120-400 m)
(70-700 m)
(100-185 m)
(20-360 m)
(50-135 m)
(70-170 m)
(100-550 m)
(120 m)
(0-5 m)
(180-1750 m)
(0-45 m)
(150-500 m)
(1-100 m)
(0-90 m)
(0-50 m)
(0-125 m)

Spatnagus pallidus	(90-110 m)
Hypelaster pacificus	(71 m)
Moira lachesinella	(0-5 m)
Brissus agassizii	(0-10 m)

The Malayan species which have apparently the northern limit-

Histocidaris elegans		(200-1440 m)
Stereocidaris indica philippinensis		(400 m)
Echinodiscus auritus siamensis?		(0-50 m)
Ech.	tenuissimus ?	(0-20 m)
Stereopneu	stes relictus	(250-900 m)
Lovenia gregalis		(275–930 m)
Lovenia subcarinata?		(10-35 m)
Lovenia triforis		(80-250 m)
Pseudolove	enia hirsuta?	(350-1265 m)
Brissopsis oldhami		(780-2140 m)
Metalia spatangus		(0-130 m).

To the Japonic species of this faunule, Echinolampas koreana may be added; the species has been originally reported from Korean Strait (ca. Lat. 33°N., Lat. 129° E.) in 72 metres depth and now known with certainty from the Sea of Japan (ca. Lat. 35°N.), and the southern limit of the species may be expected to become more southwards than the present known area. Two very characteristic and endemic species of Japan, Hemicentrotus pulcherrimus and Scaphechinus mirabilis, which are vigoroursly and highly developed almost over Japan proper, from the southern part of Hokkaido (ca. Lat. 43°N.) to the southernmost part of Kyushu (ca. Lat. 31°N.). The former inhabitats littoral zones, rarely down to about 45 metres in depth, under rocks or stones or gravelly bottom, and is found together with Anthocidaris crassispina and *Pseudocentrotus depressus* of the nearly same habitat in central and western Japan; while in northern Japan it is found together with Strongylocentrotus nudus and St. intermedius; however, this species usually exceeds other species in individual number of the nearly same habitat. The writer has been sometimes asked from biologists for reliable specific distinction between Hem. pulcherrimus and Str. intermedius in dried specimens, and the writer met few cases of difficulty in separating specifically in bared specimens of the two species and it leads the writer that there would be occurred an hybridization between the two species by overlapping of breeding season of them.

Scaphechinus mirabilis inhabitats small depths, but rarely down to about 125 metres depth, of sandy bottoms and greatly exceeds in individual number other echinoids of the nearly same habitat, such as *Peronella japonia* and *Fibularia* (*Fibulariella*) acuta. The surveying ship Fusa-maru of the Chiba Fisheries Experimental station, during September of 1927, dredged numerous young individuals of probably *Scaph. mirabilis* from the central part of the Pacific side of Bôsô Peninsula at a depth of about 4 metres to 20 metres, and they seem to be limited in distribution to the sandy bottom from the tidal mark to 20 metres depth and they are especially abundant in a zone from 5 metres to 15 metres depth, where it is estimated that there are
probably from 2,000 to 3,000 young individuals in one area (10 m^2) and where the bottom temperature ranges from 20.3°C to 22.3°C in September.

The differences in colour of radioles and in the tuberculation on the test between the specimens of Hem. pulcherrimus from northern Japan and from western Sea of Japan are observable, and the breeding season of this species seems to have a rather wide range throughout Japan proper. The differences, however, seem to be insufficient to warrant subspecific separation in this species and be regarded as, if they present, local variation. Hem. pulcherrimus seems to be of Recent origin and is not known with certainty to occur as fossil. The writer (NISIYAMA, 1940, pp. 685-694) once discriminated three local forms (not as a taxonomical unit) of Scaph. mirabilis from the ambital outline and stoutness of test. The writer then regarded that the stoutness of test seems to be related with the temperature of the sea water where they live and the supply of the carbonate in the sea water may be also related. RAUP's interpretation (RAUP, 1956, pp. 685-695; 1958, pp. 668-677) on the relation between taxonomy or morphology of the genus Dendraster and water temperature or currents of the sea water would be correlate with the case of local forms of Scaph. mirabilis of the writer. Scaph. mirabilis dates back to the Pliocene and occurs as fossil in Japan proper and Formosa. In the present state of our knowledge, the minor zoogeographical provinces of Japan proper cannot be certainly divided from these two characteristic species of Japan on sound ground.

On the Pacific side, the area south of Sendai Bay (ca. Lat. 38°N.) has apparently the southern limit of some characteristic boreal forms; the following species to be mentioned.

Strongylocentrotu	s intermedius	(8-225 m)
Str.	sachalinicus	(0?–1600 m)
Str.	echinoides	(45-770 m)
Spatangus luetkeni		(80-200 m)

Of other species of the boreal genus Strongylocentrotus, Str. polyacanthus and pulchellus are distributing more northwards (ca. Lat. 48°N.) than the area and Str. nudus is distributing over the area southwards. A species (subspecies) of the other characteristic boreal genus Echinarachnius, Ech. parma obesus has been dredged from off Hachinohe City, Iwate Prefecture (ca. Lat. 40°30'N.), which is known to the southern limit of the species (subspecies). Glyptocidaris crenularis and Temnopleurus hardwickii, two characteristic species of northern forms of Japan, are commonly found together with Str. intermedius, Str. sachalinicus and Str. nudus, at north of Sendai Bay, distributed more southwards over the area. Scaphechnus griseus, the typical boreal form of the genus, is not found at south of Miyako Bay, Iwate Prefecture (ca. Lat. 39°30'N.). Brissus agassizii, which is highly developed in central and western Japan, has been collected from Ôfunato Bay, Iwate Prefecture (ca. Lat. 39°N.) in littoral zones. In the Sea of Japan on the coast of Honshu Island the southern limit of Str. intermedius and sachalinicus is not certainly detected, but at south of 40° North Latitude they are not known to occur there.

The minor zoogeographical provinces of Japan proper on the echinoid fauna as worked out by the writer are slightly differ, in general, from the provinces recognized by the previous authors on the molluscan, crustacean, cirripedian, and brachiopodan faunae. However, the provinces of the writer has proposed are used herein for the sake of convenience, and rather as a datum for regarding the composition and relation of the Recent echinoid fauna of Japan and the adjacent regions.

By using his zoogeographical provinces for the Japanese Seas, viz., northern, central, western and southern Japan, YOKOYAMA (1920) has published his ideas of the climatic changes in geological ages in Japan, considering the living forms of molluscs of a certain province have occurred in the past as fossil in other province of the present. In the studying of fossil echinoid fauna of Japan the writer has found that the similar distribution of a species of the living and fossil has occurred as in the molluscs. The subtropical or warm temperate forms of the present day occurred in the past as fossil in northern cold temperate province of the present or the northern cold temperate forms of the present or the northern cold temperate forms of the past as fossil in warm temperate province of the present. This phenomenon is more confirmed by using the more available material of the associated fauna, which are found together with fossil echinoids, such as the fossil molluscs, brachiopods, and higher and smaller foraminifers.

A smaller number of the Recent echinoid species of Japan are known to occur as fossil from Japan in geological ages, dating back at least to the Pliocene, and some others of them are not known to occur as fossil from Japan but known from outside Japan, as indicated in the following list.

Rhopalocidaris gracilis (DÖDERLEIN, 1885)—Ceram, Pliocene (JEANNET, 1935, p. 9). The precise identification of this species seems to be doutful.

Stylocidarisi reini (DÖDERLEIN, 1885)—Java, Miocene (JEANNET and MARTIN, 1937, p. 218). The precise identification of this species also seems to be doutful.

Plococidaris verticillata (LAMARCK, 1816)—Nias, Pleistocene (JEANNET and MARTIN, 1937, p. 220)—Ceram, Pliocene (JEANNET, 1935, p. 1).

Phyllacanthus dubius BRANDT, 1835—Java, Miocene and Madura, Pliocene (JEAN-NET and MARTIN, 1937, p. 223).

Stomopneustes variolaris (LAMARCK, 1816)-Java, Miocene (MARTIN, 1880, p. 3).

Salmacis bicolor AGASSIZ, 1841 (with rarispina AGASSIZ, 1846)—Java, Pliocene (JEANNET and MARTIN, 1937, pp. 225, 226).

Echinodiscus auritus siamensis MORTENSEN, 1948—Aru Islands, Pliocene and Java, Pliocene (CURRIE, 1924, p. 66.—JEANNET and MARTIN, 1937, p. 266).

Heterocentrotus mammillatus (LINNAEUS, 1758)—Ceram, Pleistocene (MARTIN, 1935, p. 6). This is not a typical Japonic species, but it may be added herein.

The other living species of Japan, such as *Echinostrephus aciculatum*, *Echinometra* mathaei, Clypeaster japonicus and Peronella pellucida, are not known to occur as fossil in Japan proper, but occur as fossils in Ryukyu Islands and Formosa. A comparison of the geographical and geological distribution of the Recent and fossil echinoid fauna of Japan and the adjacent regions gives us an important ground for considering the composition and origin of the fauna.

THE ECHINOID FAUNA FROM JAPAN AND THE ADJACENT REGIONS

The writer gave (NISIYAMA, 1965, pp. 76-81) a list of the species (and subspecies) of the fossil echinoids of Japan and the adjacent regions described in this article with their respective localities and geological ages. From the two foregoing lines, the one containing data of the geographical and geological distributions of the fossil echinoids of Japan and the adjacent regions, and the other of the geographical and bathymetrical distribution of the Recent forms, it is noticed that the Recent fauna comprises about 190 living species (with several subspecies) and fossil echinoid fauna about 165 species. The sum of the both faunas becomes about 355 species in total, but with the deduction of 43 species in common with both the living and fossil, the number of species of the whole echinoid fauna of Japan and the adjacent regions becomes about 310. The total number of the species of these regions decidedly exceeds the species of the echinoid fauna of Australia (192 spp.-H.L. CLARK, 1946, and plus ca. 40 spp., PHILIP and others). Among the species of Japan and the adjacent regions, a smaller number seems to have developed autochthonously in the Japanese region, particularly of the area covering the main islands of Japan throughout the geological ages, or impoverished remnants of the predecessors, while the rest; majority may be regarded as immigrants (or descendants of immigrants) of their predecessors which have developed in other zoogeographical regions outside Japan in the geological ages.

As for the Japonic genera and subgenera, among the echinoid fauna of Japan and the adjacent regions, and their geological occurrence and distribution, the following ones are at first to be mentioned. The Japonic subgenus *Phalacrocidaris* (=*Anomocidaris* A. AGASSIZ and H. L. CLARK, 1907), the characters of which reach the extreme of the genus *Stereocidaris*, dates back to the Pliocene of central Japan with a fossil subspecies of a single living species. The very characteristic genus of Japan, *Glyptocidaris*, the last survival of the large family Phymosomatidae, dates back at least to the Pliocene of central Japan, and its fossil occurrence is more southwards (ca. Lat. 35°N.) than the distribution of its living species; the probable ancestor of this genus may be traced to as old as the Oligocene genus *Eoglyptocidaris* from Hokkaido, northern Japan. Another Japonic genus *Pseudocentrotus*, a Toxopneustid, dates back to the Miocene of central Japan with a fossil species which may be regarded as an ancestral form of the Recent *Ps. depressus*.

Another characteristic genus of Japan, *Scaphechinus* dates back at least to the lower Pliocene of northern Japan with a fossil species, and during the following Pliocene and Pleistocene epochs the genus was highly developed throughout the Japanese region. The common living species *Scaph. mirabilis* dates back to the Pliocene and at that time it was distributed from about 40° North Latitude to the north to about 24°30' North Latitude to the south, distinctly more southwards than the present day. The development of this genus would be regarded as an example of parallelism with that of the Californian genus *Dendraster*.

The genus *Pseudoastrodapsis*, an *Astrodapsis*-like genus of the western Pacific although it shows considerable convergence with the typical *Astrodapsis* from the Pacific coast of North America in the characters of the oral surface, it demonstrate the lack of affinity with the latter-dates back to the Miocene of northern Japan and ranges to the Pliocene, as in the case of *Astrodapsis*, with at least three fossil species. The probable ancestor of this genus may be traced to the primitive *Pseudoastrodapsis*-like genus *Allaster* from the Oligocene or Lower Miocene of Hokkaido.

The characteristic genus Astriclypeus, as it differs from all other Astriclypeidae in having a lunule in each ambulacrum and none in the posterior interambulacrum (5), dates back to the lower Miocene and was distributed during the Miocene epoch from southern part of Hokkaido (ca. Lat. 42°N.) at the north to the northern part of Formosa (ca. Lat. 23°N.) at the south, with several fossil (or local) subspecies. The distribution of this genus in the Miocene has evidently prolonged the area northwards than the present time. As for the origin of the genus Astriclypeus the writer once suggested that the possibility of derivation of it from some form of the genus Echinodiscus (including Amphiope) by getting a specimen which has just intermediate characters between the former and later genera from the lower Neogene formation of Formosa (NISIYAMA, 1935, pp. 139-140, text-fig. 2) and from affinity of Astriclypeus and Echinodiscus and also in considering the geological and geographical distribution of the two genera. The living species, Ast. mannii, dates back to the Pliocene and is known from the Pliocene formations of Shikoku and Formosa and the Pleistocene formation of Ryukyu Islands. It seems beyond doubt that the fossil forms of Astriclypeus have been dwelling in a shallow water under a warm current.

The Japanese living species, which have dated back to the Pliocene epoch in Japan, are known to the writer in rather small number; the following ones are to be mentioned.

Strongylocentrotus intermedius, a rather primitive form of the genus, is found in the Pliocene formations of northern Japan, viz., Shibikawa formation of Akita Prefecture (ca. Lat. 40°N.), Chikagawa formation of Aomori Prefecture (ca. Lat. 41°N.), and Setana formation of southern Hokkaido (ca. Lat. 42°30'N.), and now lives in shallow water from the littoral zones to a depth of about 35 metres of northern Japan. Another species, *Str. echinoides*, closely allied to *Str. droebachiensis* and widely ditributed over the northern Pacific Ocean, is found in the Setana formation of southern Hokkaido (ca. Lat. 42°30'N.), and the species now lives in moderate depths from 45 metres to a depth of about 770 metres.

Scaphechinus griseus, a boreal form of the genus and allied to Scaph. brevis and also superficially resembles Echinarachnius parma obesus, is found in the Pliocene Shibikawa formation of Akita Prefecture (ca. Lat. 40°N.) associated with Scaph. mirabilis and Echinocardium cordatum, and in the Pleistocene Kiyokawa formation of Chiba Prefecture (ca. Lat. 35°20'N.). The species now lives in shallow water from the littoral zones to a depth of about 10 metres of northern Japan and its north.

Of the Japanese living species, which are identified with the Japanese Pleistocene forms with certainty, the following ones to be mentioned.

Glyptocidaris crenularis occurs as fossil in Narita formation of Chiba Prefecture (ca. Lat. 35°30'N.), and the species is found associated with a large number of following molluscs, viz., Patinopecten tokyoensis (TOKUNAGA), Mercenaria stimpsoni (GOULD), Tellina venulosa SCHRENCK, Glycymeris yessoensis (SOWERBY), Callista brevisiphonata (CARPENTER), Leptothyra amussitata (GOULD), and Neptunea arthritica (BER- NARDI). The named species are characteristic of the cold water situated in latitudes higher (north of 36°N. Lat.) than that of this locality. *Temnopleurus hardwickii*, a unique boreal form of the genus, occurs as fossil in the Pleistocene Narita formation of Chiba Prefecture (ca. Lat. 35°40'N.) and the Tokyo formation of Tokyo and Kanagawa Prefecture (Lat. 35°30'-45'N.), and the species now lives in shallow water from the littoral zones to a depth of about 35 metres. *Temnotrema sculptum*, a Japanese common species of the genus, occurs as fossil in the Jizôdô formation of Chiba Prefecture (ca. Lat. 35°20'N.) associated with other echinoids, such as *Coelopleurus maculatus* and *Temnopleurus (Toreumatica) reenesii; Tem. sculptum* ranges from northern Japan (ca. Lat. 42°N.) to Formosan Channel at the south, and lives in rather shallow water, but rarely down to a depth of 500 metres. *Temnotrema rubrum*, a peculiar form of the genus, also occurs as fossil in the Narita (Tokyo) formation of Kanagawa Prefecture (ca. Lat. 35°30'N.) together with *Temnopleurus hardwickii; Tem. rubrum* is restricted in its present distribution to central Japan and known from small depths, from 5 to 35 metres.

Clypeaster japonicus, a common species of the Japanese Clypeasters, occurs as fossil in the Pleistocene Ryukyu Limestone of Ryukyu Islands and southern part of Formosa; the species is known only from Japanese waters with certainty and lives in shallow water from the littoral zones rarely down to a depth of about 100 metres. Fibularia (Fibulariella) acuta, the type-species of the subgenus, occurs as fossil in the Pleistocene Narita formation of Chiba Prefecture (ca. Lat. 35°50'N.) and Tokyo (ca. Lat. 35°40'N.). The species can be discriminative as local subspecies in the form of posterior end and arrangement of primary tubercles on the test, the southwestern forms as the typical acuta and the northern forms as septemtrionalis; the fossil forms from the Pleistocene formation of central Japan can be rather referred to septemtrionalis. Peronella japonica, a common Japanese species of the genus, occurs as fossil in the Pleistocene Tokyo formation of Tokyo (ca. Lat. 35°40'N.); the species differs from Per. lesueuri in the tubercles on ridges in the pore-zones, longer oral ambulacral furrows, and in the naked periproct. This species now lives in shallow water from the littoral zones to a depth of about 50 metres, and the fossil from the Pleistocene of central Japan much resembles the living specimens from Tateyama Bay, central Japan, in the delicate test and thin margin.

Spatangus pallidus, which is known to be distributed from the Sagami Sea to Ose-Zaki, Japan, occurs as fossil in the Pleistocene Jizôdô formation of Chiba Prefecture together with other echinoids, such as *Temnotrema sculptum*, *Coelopleurus maculatus*, *Temnopleurus (Toreumatica) reevesii*. The species now lives in moderate depths from 90 to a depth of 110 metres. *Brisaster owstoni*, a rather common species of central and western Japan, occurs as fossil in the Pleistocene Sanuki formation of Chiba Prefecture (ca. Lat. 35°15′N.); this species is known with certainty only from central Japan and lives from shallow water to moderate depths, from 10 to a depth of 530 metres.

Ten or more Malayan living species, which occur as fossil in Japan and the adjacent regions, are also known to occur as fossil in the Malay and other regions outside Japan; the following ones to be mentioned.

Prionocidaris baculosa annulifera, the highly polymorphous subspecies of the

polymorphous species *Pri. baculosa*, occurs as fossil in the Pleistocene Ryukyu Limestone of Kikai-jima, Ryukyu Islands. It is known from the Pliocene of Ceram (JEANNET, 1935, p. 11, pl. 1, figs. 10-11) and the upper Miocene of Madura (JEANNET and MARTIN, 1937, p. 221) and also lives from Malay Archipelago to Japan, as far north as Sagami Sea, in the littoral zones rarely down to a depth of 250 metres. *Prionocidaris bispinosa* occurs as fossil also in the Pleistocene Ryukyu Limestone of Kikai-jima, Ryukyu Islands. It now lives in Ceylon, Java, Moluccan seas, the Philippines and Southwest Australia, in the littoral zones to a depth of 50 metres. *Phyllacanthus imperialis*, a widely distributed species of the genus, occurs as fossil in the Pleistocene Peliliu Limestone of Angaur Island, Palao Islands. This species is also known from the Pliocene of Timor and Ceram (JEANNET, 1935, p. 13, pl. 1, figs. 13-15 (pars)), and Java (JEANNET and MARTIN, 1937, p. 222), and the Pliocene of Fiji Islands (H. L. CLARK, 1945, p. 313, pl. 41, fig. C). It lives in shallow water from the littoral zones to a depth of about 73 metres.

Coelopleurus maculatus, a common Malayan and Japanese species of the genus, occurs as fossil in the Pleistocene Jizôdô formation of Chiba Prefecture, and is known from the Pliocene of Ceram (Amboina) under the name *Coel. maillardi* (JEANNET, 1935, p. 57, pl. 1, figs. 7-9 (pars)). This species lives in the Sagami Sea, Korean Straits, Kagoshima Gulf, the Philippines, Kei Islands and Amboina, from 70 to a depth of 360 metres. *Temnopleurus toreumaticus*, the widely distributed species of the genus, occurs as fossil in the Pliocene Byôritsu formation of Formosa and the Pleistocene Maiko formation of Hyôgo Prefecture (ca. Lat. 34°30'N.). This species is known to occur as fossil from many localities, viz., the Pliocene of Zanzibar, East Africa, India, Java, and Madura, and now lives in shallow water from the littoral zones to a depth of about 45 metres.

Echinostrephus aciculatum, the species with quadrigeminate ambulacral plates, occurs as fossil in the Pleistocene Ryukyu Limestone of Ishigaki-jima, Ryukyu Islands. This species is not known as fossil from the Malay region, but is reported from the Pleistocene of Fiji Islands (H. L. CLARK, 1945, p. 318, pl. 41, figs. JM), and now distributed in the Indo-Pacific, from Hawaii to Sulu Islands and to southern Japan, and now lives in shallow water from the littoral zones to a depth of about 50 metres. *Echinometra mathaei*, a very widely distributed species of the genus, occurs as fossil in the Ryukyu Limestone of Ishigaki-jima, Ryukyu Islands. This species is known to occur as fossil in the Pleistocene of Farsan Islands in the Red Sea (BRIGHTON, 1931, p. 324) and the upper Miocene of Java (JEANNET, 1935, p. 55, text-figs. 74-75) with some doubt. This species is widely distributed all over the Indo-West Pacific and now lives in shallow water from the littoral zones to a depth of about 50 west 50 metres.

Echinolampas alexandri, a Malayan species of the genus, occurs as fossil in the Ryukyu Limestone of Tokuno-shima, Ryukyu Islands. This species is also known to occur as fossil from the upper Miocene of Java (JEANNET and MARTIN, 1937, p. 276, figs. 49a-d—*Ech. depressus*) and the Pliocene of Java; the species is originally described from Mauritius and known from the Indian Ocean, Gulf of Martaban, and the Philippines, and lives in moderate depths from 8 m. rarely down to a depth of 365 metres.

Clypeaster humilis, a rather variable and widely distributed species of the genus, occurs as fossil in the Pliocene Byôritsu formation of northern Formosa. This species is known from the upper Miocene of Java (JEANNET and MARTIN, 1937, p. 242, text-fig. 26), and distributed in the Indo-West Pacific, ranges from the Red Sea to the Philippines, and lives in shallow water from the littoral zones to a depth of about 40 metres, usually less than 20 metres. *Clypeaster reticulatus* occurs as fossil in the Pleistocene Ryukyu Limestone of Tokuno-shima, Ryukyu Islands, and is also known to occur as fossil from the following places, viz., the upper Miocene of Java, the Pliocene of Zanzibar, East Africa, Java, Philippines, and the Pleistocene of Farsan Islands in the Red Sea. The species is widely distributed over the Indo-West Pacific and lives in shallow water from the littoral zones to rarely a depth of 120 metres.

Echinocyamus crispus occurs as fossil in the Pleistocene Ryukyu Limestone of Kikai-jima, Ryukyu Islands, and is known from the Pleistocene of Ceram (JEANNET and MARTIN, 1937, p. 239). It is rather widely distributed in the Indo-West Pacific, from Red Sea to Hawaiian Islands to southern Japan, and lives in shallow water to moderate depths, from about 20 to a depth of 564 metres. Fibularia cribellum, a small form well characterized by its few but large rounded pores of the petals, occurs as fossil in the Pleistocene Ryukyu Limestone of Kikai-jima, Ryukyu Islands, and is also known from the Pleistocene of Ceram (JEANNET and MARTIN, 1937, p. 238). This species is common in the Malay region, from Sulu Sea to Timor Sea, and Kei Islands and spreads to the Philippines, and its bathymetrical range seems to be from 15 to 400 metres, very rarely down to a depth of 522 metres. Laganum depressum, a rather widely distributed and characteristic species of the genus, occurs as fossil in the Pliocene Byôritsu formation of Formosa and in the Pleistocene Ryukyu Limestone of Kikai-jima and Tokuno-shima, Ryukyu Islands, and is also known from the following localities, viz., the Pliocene of Zanzibar, East Africa, Java, Fiji Islands, and in the Pleistocene of Farsan Islands and Billiton Islands. It is widely distributed in the Indo-West Pacific and lives in shallow water from the ebb-zone to a depth of 85 metres.

Brissopsis luzonica, a very fragile and perplexing species, is reported from the Pliocene formation of Shizuoka Prefecture (ca. Lat. 35°N., Long. 138°E.), central Japan, and also known with some doubt from the upper Miocene of Java (MARTIN, 1880, p. 5). This species is said to be widely distributed over the Indo-West Pacific and to live in variable depths from 10 to a depth of some 1,000 metres. Brissus latecarinatus, the common Indo-West Pacific species of the genus, occurs as fossil in the Pleistocene Ryukyu Limestone of Kita-Daitô-jima (North Borodino Island) and Ishigaki-jima, Ryukyu Islands, and of Formosa, and also in the Older Angaur Limestone of Angaur Island, South Sea Islands. It is also known to occur as fossil in the Pleistocene of Farsan Islands and Billiton Island, the Pliocene of Fiji Islands, and the upper Miocene of Java. Br. latecarinatus is widely distributed over the Indo-West Pacific, from Red Sea to Hawaiian Islands, and Ryukyu Islands to East Australia, and lives in shallow water from the littoral zones to a depth of about 45 metres. To these species may be added, herein, Maretia planulata, which does not occur as fossil in Japan, but occurs in the Pleistocene Angaur Limestone of Angaur Island, South Sea Islands, and also in the Pleistocene of Farsan Islands and Borneo, and the Pliocene of Java

and East Africa. This species is widely distributed over the Indo-West Pacific and lives in shallow water from the littoral zones rarely down to a depth of about 60 metres.

A few species, which now live in the Japanese seas and also occur as fossil in Japan, are regarded as cosmopolitan in the geographical distribution and known to occur as fossil in various parts of the world; the following ones to be mentioned.

Echinoneus cyclostomus, a highly variable and wide-spread species of the genus, occurs as fossil in the Pleistocene Limestone of Formosa and the Pleistocene or Miocene formation of Shirahama, Wakayama Prefecture (ca. Lat. 33°42′N., Long. 135°28′E.). DESOR (1855-58(57), p. 197) reported the occurrence of this species as fossil in the "Tufs calcaires de la Guadaloupe", and JACKSON (1922, p. 54) also mentioned records of this species occurring as fossil in the West Indies in the Oligocene, Miocene, and Pliocene, further COTTREAU (1913, p. 106, pl. 12, figs. 3-6) described a variety (subspecies) *haugi* from the upper Aquitanian of a region in the Mediterranean basin (at the coast west of Sausset), and H. L. CLARK (1945, p. 181) reported it from the Pliocene of Fiji Islands. In the geographical distribution this species is regarded as a cosmopolitan, and in the Japanese seas it is known to occur in Formosa, Yaeyama Islands, Tokara Islands, and Kagoshima Gulf, and further in the Kii Peninsula. In lives in shallow water from the littoral zones to rarely a depth of about 120 metres.

Echinocardium cordatum, a very variable and remarkably wide-spread species of the genus, occurs as fossil in the Pliocene Shibikawa formation of Akita Prefecture (ca. Lat. 39°55'N., Long. 139°53'E.) and the Pliocene Byôritsu formation of Formosa (ca. Lat. 24°N., Long. 122°E.), the rather widely separated localities. This species is known with certainty to occur as fossil in the the various parts of the Lusitanian (European) and western part of the East regions, viz., the Pliocene of England, the Pliocene of Italy and Sicily, and the Pliocene of Barcelone. *Ech. cordatum* is indeed wide-spread in the geographical distribution, but it is not known to occur on the western side and the northeastern shores of Africa, the southern and western part of South America, the western coast of the United States and British North America, the southwestern coast of Asia, and the islands of the tropical Pacific. It lives mainly in shallow waters but rarely down to a depth of about 250 metres; in the Japanese seas it is very common in shallow waters of bays or inlets and usually buried in sand.

The living species which are endemic to the Japanese seas (or the Japanese region) and have the fossil records in Japan, as mentioned in the preceding pages, can be regarded with almost certainty as having descended from their ancestors during the geological ages in Japan and its neighbourhood. Among them, Strongylo-centrotus intermedius, Scaphechinus mirabilis, Scaph. griseus, and Astriclypeus mannii appeared during the Pliocene in Japan and its neighbourhood and have become characteristic of the Recent Japanese seas. Glyptocidaris crenularis, Temnopleurus hardwickii, Temnotrema sculptum, Temn. rubrum, Clypeaster japonicus, Fibularia (Fibulariella) acuta (with subspecies septemtrionalis), Peronella japonica, Spatangus pallidus, and Brisaster owstoni have appeared during the Pleistocene in Japan and its neigh-

bourhood and most of them have also become characteristic of the Japanese seas in the present days.

From the faunal facies of the Pleistocene Narita formation of Chiba Prefecture, in which the echinoids, *Glyptocidaris crenularis, Temnopleurus hardwickii*, and *Scaphechinus mirabilis*, occurred as fossil, the sea water temperature at that time when the fauna lived was probably more or less cooler than that of the present sea adjacent to Chiba Prefecture, and the depth of the sea in which the fossils lived seems to have been less than 100 metres and was mainly in the range from about 5 to 30 metres. Again from the faunal facies of the Pleistocene Jizôdô formation of Chiba Prefecture, in which such echinoids as *Coelopeurus maculatus, Temnopleurus (Toreumatica) reevesii, Temnotrema sculptum*, and *Spatangus pallidus*, occur as fossil, it appears that the sea water temperature at that time was not much different from, or slightly warmer than, that of the present seas adjacent to Chiba Prefecture, and the depth of that sea seems to have been less than 200 metres and was probably in the range from about 20 to 60 or 80 metres.

The Malayan or Indo-West Pacific living forms, which are known from the Pleistocene formations of Japan and the adjacent regions, viz., *Prionocidaris baculosa annulifera*, *Pr. bisinosa*, *Phyllacanthus imperialis*, *Coelopleurus maculatus*, *Temnopleurus toreumaticus*, *Echinometra mathaei*, *Echinolampas alexandri*, *Clypeaster humilis*, *Clypeaster reticulatus*, *Echinocyamus crispus*, *Fibularia cribellum*, *Laganum depressum*, and *Brissus latecarinatus*, were not originated in Japan and its neighbourhood, but probably migrated from the center of their development to Japan and the adjacent regions during the geological ages. Almost all of them occur as fossil in the upper Miocene, Pliocene and Pleistocene of the Malayan and Indo-West Pacific regions (including the South Sea), and were widely distributed over the Indo-West Pacific Oceans at least in the Pleistocene epoch.

The two cosmopolitan species, *Echinoneus cyclostomus* and *Echinocardium cordatum*, which are now living in the Japanese seas and occur as fossil in the Neogene and Quaternary deposits of Japan and the adjacent regions, may not have originated in the past Japanese seas, but probably migrated from other regions of their home to Japan and the adjacent regions. The two species are known to occur as fossil in trather remotely separated zoogeographical regions and were widely distributed over the different zoogeographical regions at least in the Pliocene epoch.

Among the Echinoid Fauna of Japan and the adjacent regions, the suborder Echinothurioina should be at first mentioned. The family Echinothuriidae of this suborder have a leathery flexible test, which tends to become scattered plates due to easy corrosion of the leathery skin after the animal died and before the bury of it by sediments, and accordingly the complete fossil record of them is by no means common. This family has a wide-spread distribution in deep water, e.g., *Tromiko-soma tenue* is known from east of Japan and from 1530 to a depth of 3375 metres, and *Hygrosoma hoplacantha* known from 360 to a depth of 2068 metres. But, an oriental genus *Asthenosoma*, a rather brilliantly coloured form, lives in shallow water from the littoral zones to a depth of about 120 metres, and *Asth. varium* GRUBE, 1868, has been observed feeding on human feces along the shore (MORTENSEN, 1935, pp. 112, 279). Of the Echinothuriidae of Japan and the adjacent regions 9 species

(with a subspecies) belonging to 8 genera, viz., Phormosoma, Tromikosoma, Sperosoma,. Hygrosoma, Calveriosoma, Haplosoma, Araeosoma, and Asthenosoma, are known from the Recent Japanese seas, and 5 (with a subspecies) out of 9, viz., Tr. tenue, Sp. giganteum, Hap. gemmiferum, Ar. owstoni, Ar. owstoni bicolor, and Asth. ijimai, seem to be endemic to the Japanese region, the others, viz., Ph. bursarium, Sp. quincuciale, Hyg. hoplacantha, and Cal. gracile, are in common with the species of the Malayan or East Indian regions. Owing to very poor condition of our knowledge on the fossil evidence of the family, particularly the blank of the fossil record in the Malay and Japanese regions, the history and origin of genera and species of the Echinothuriidae of Japan and the adjacent regions cannot be ascertained. However, by considering the present distribution, relationships and morphological features of the members of the family, the probable development of them in the Japanese region could be assumed. The species which are now endemic to the Japanese seas may have either developed autochthonously or differentiated to the distinct species from their predecessors since the Pliocence epoch and persisted to the Recent. Particularly, Asth. ijimai and Ar. owstoni (with subspecies bicolor) may have originated in the past. Japanese seas from their ancestors, and by the future investigation on the marine Tertiary system of Japan it is expected that these two echinothuriids, rather common. and comparatively shallow water forms, would be found as fossil in the deposits. Haplosoma gemmiferum, a Japonic species of the Malay genus, may have differentiated from allied species, e.g., Hapl. pellucidum of the Philippines, to a different species. in the Japanese region, by specialization of the globiferous pedicellariae. Sperosoma giganteum, a large-sized form of the genus, is uncertain in origin, but is the Japanese species in its zoogeographical distribution. Also the origin of Tromikosoma tenue, a very deep-water species, is quite uncertain; this species is classified by H. L. CLARK. (1925, p. 56) in the *Echinosoma* with Hyr. hoplacantha and seems to have a certain. affinity with some species of the genus Hygrosoma. The Malayan or East Indian species of the Echinothuriidae which is now living in the Japanese region, viz., Ph. bursarium, Sp. quincunciale, Hyg. hoplacantha, and Cal. gracile, may have immigrated during the geological age or very recently from the center of distribution or of their development to the Japanese region and mingled with the endemic species of Japan.

Although OZAKI (1939, p. 565, pl. 30, figs. 1-7) reported the occurrence of *Lovene-chinus hunanensis* of the Melonechinoida from the Fengninian series (lower Carboniferous) of central Hunan, South China, in the Carboniferous and Permian systems of Japan, the true representatives of this order are not known.

The order Cidaroida are represented in Japan and the adjacent regions by the Miocidaridae, Cidaridae, and Psycocidaridae. Two species of the genus *Miocidaris* occur in the Akasaka Limestone of Gifu Prefecture and they are the oldest representatives of the echinoids in Japan. One of the two Japanese species, *Mio. spinulifera*, has long, cylindrical primary radioles with sharp lateral spinules, and the other, *Mio. platyacantha*, has compressed primary radioles and the sharp and regularly serrated lateral margins. The primary radioles of the latter species are very characteristic and there seems no comparable radioles among the species of this genus. *Miocidaris spinulifera* from the Permian of Japan has a certain affinity with *Mioc. permica* WANNER, 1948 from Timor Islands, but the origin of *Mio. spinilifera* is

uncertain. At any rate the occurrence of the two species of *Miocidaris* in the Permian system of Japan is noteworthy.

In Japan and the adjacent regions the family Cidaridae comprise the subfamilies Histocidarinae, Ctenocidarinae, Goniocidarinae, Stereocidarinae, Stylocidarinae, and Rhabdocidarinae. The subfamily Histocidarinae are regarded by MORTENSEN (1928-b, p. 70) as the most primitive among the Recent Cidaridae on account of the unspecialized character of the secondary radioles and the complete lacking of globiferous pedicellariae. In Japan they are represented by a single genus Histocidaris. Although Histocidaris is characterized by the primitive characters of the secondary radioles and the pedicellariae, it is not ascertained whether the age of its geological occurrence is the oldest among the true Cidaridae or not always older than other more specialized forms. The marine formations of Japan have no fossil representatives of this genus. From the Japanese regions 3 living species are known with certainty, viz., Hist. elegans, Hist. misakiensis, and Hist. carinata; the first is the Malayan species and the latter two seem to be endemic to Japan proper. Hist. misakiensis and carinata, which are more or less specialized than the former in the feature of radioles, seem to have probably developed autochthonously from their ancestors since the Pliocene epoch and persist to the Recent, while Hist. elegans may have immigrated during the geological age or very recently from the center of its distribution or of its development to the Japanese regions.

The subfamily Ctenocidarinae are represented in Japan and the adjacent regions by a single genus *Aporocidaris*. *Apor. fragilis* is known from southwest of Kamtchatka, in deep water from 2800 to a depth of 3550 metres. This is a puzzling little form and its fossil record is qutie uncertain to the writer.

The subfamily Goniocidarinae are represented in Japan and the adjacent regions by 2 genera, Goniocidaris (with 3 subgenera, Petalocidaris, Discocidaris, and Aspidocidaris) and Rhopalocidaris. The history of the subfamily was traced back to former geological ages and discussed by MORTENSEN (1928-b, pp. 145-146) from several records of fossil Goniocidaris in literature. He concluded that the typical Goniocidaris now almost confined to the Australian region has probably originated in the Miocene series of the East Indian region, but the fossil representatives of this genus from the Malay region are not known with certainty, excepting imperfect radioles mentioned by CURRIE (1924, p. 67) from the Pliocene series of Aru Islands. The typical Goniocidarids seem to have differentiated into several subgenera of much delicate appearance by development of basal disc and well developed terminal disc of primary radioles in the Malay and Japanese regions. Irrespective of the situation whether the typical Goniocidaris was derived, as suggested by MORTENSEN (1928-b, p. 230), from Stereocidarid-like forms of the Stereocidarinae or Ctenocidarid-like ones of the Ctenocidarinae, the subgenera of delicate appearance of Goniocidaris could not be developed from the Stereocidarid-like forms or the Ctenocidarids, but may have descended from the typical Goniocidarids, and they seem to be of recent origin (probably not older than the Pliocene). The Malayan and Japonic subgenus Petalocidaris, with 2 living species, Gon. (Pet.) florigera of the Malay region and Gon. (Pet.) biserialis known only from the Japanese seas, has primary radioles with more or less well developed basal and terminal discs and flattened secondary radioles which are more

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or less thorny at base. The subgenus seems to have developed during the very young geological ages and differentiated into two distinct species in the Japanese and Malay regions. The Japonic and Malayan subgenus Discocidaris, with a Japanese species Gon. (Dis.) mikado and a Malayan Gon. (Dis.) peltata, has primary radioles with very strongly basal disc and more or less well developed terminal disc and flattened secondary radioles which are sometimes thorny at base. The latter species, *peltata*, on one hand, is allied to the character of its primary radioles the former, mikado, and may have some relation also to the Petalocidaris-species in the spiny secondary radioles at the base and in the valves of the large globiferous pedicellariae, on the other hand, and these characters of Gon. peltata suggest probable differentiation and relationships between the subgenera Petalocidaris and Discocidaris. The subgenus Discocidaris was probably developed from a certain typical Goniocidarid-ancestor along parallel line of development from that of Petalocidaris, and differentiated into two distinct species during the very young geological ages. In the Japonic subgenus Aspidocidaris, with 2 Japanese species, Gon. (Asp.) clypeata and alba, there are primary radioles with more or less developed basal disc and well developed terminal disc, which is often large and rounded, and flattened secondary radioles with straight and rather short outgrowth. The subgenus seems to have developed autochthonously in the Japanese region during the very young geological ages. The Malayan subgenus *Cyrtocidaris* seems to have developed from the typical Goniocidarids by specialization of the secondary radioles and taking a parallel line of development from that of Petalocidaris, and the representatives of this subgenus, of course, are not known from the Japanese region.

The genus *Rhopalocidaris*, which is closely related to the typical *Goniocidaris* and to the subgenus Aspidocidaris in some degree, comprises 3 living species, viz., Rh. hirsutispina of the Malay, and Rh. gracilis and rosea of the Japanese region, is characterized by the primary radioles without basal disc and with a very small terminal widening and particularly by the secondary radioles which are club-shaped and not appressed. This genus may have developed either from the typical Goniocidarids by specialization of the secondary radioles or from a common progenitor of both groups, Rhopalocidaris and Goniocidaris, by taking a different line of development from that of the typical Goniocidarids or of Aspidocidaris. The living species now being known only from the Japanese seas, Rh. gracilis, is reported by JEANNET (1935, p. 9) to occur as fossil with an imperfect primary radiole from the Pliocene series of Ceram; however, the precise identification of it to this species seems to leave some doubt, and it is scarcely certain to say that Rh. gracilis has already existed since the Pliocene epoch in the Malay region. The genus Rhopalocidaris, in general, has probably developed from a certain form of Goniocidarid-progenitors taking different line of development from that of Goniocidaris and along parallel line of development from that of Aspidocidaris, and differentiated into distinct species in the Malay and Japanese regions.

The subfamily Stereocidarinae are represented in Japan and the adjacent regions by a single genus *Stereocidaris* (with the Japonic subgenus *Phalacrocidaris*). This is rather perplexing genus and dates back to at least the Cenomanian and is usually recognized by the absence of primaries on the uppermost coronal plates. MORTENSEN (1928-b, p. 230) suggested that Stereocidaris originated in the European seas of the Cretaceous and descended to the flourishing Indo-West Pacific species of the Recent days. In regarding the absence of primaries on the uppermost coronal plates of the European Cretaceous species and that of the Indo-West Pacific living species as the feature of genetic relation and not as convergence of development, it is very interesting and curious that in the Japanese region remotely separated from the European (Lusitanian) during at least the Pliocene, there is evidence for the existence of Stereocidaris, which could be regarded either as the descendant of older progenitor of the regions or the immigrant from the Lusitanian or other regions. A fossil subspecies of the variable species St. grandis is known with certainty from the Pliocene series of Chiba Prefecture, central Japan. Although its predecessor of the Miocene or older age is uncertain, it is the oldest record of Stereocidaris in Japan. The rather polymorphous St. grandis (with a subspecies hyatorina of the Japanese region) seems to have been derived from this fossil subspecies or a very related species during the young geological age. A Japanese living species, St. microtuberculata, seems to have also been derived from this subspecies or its alliance, and probably have developed autochthonously in the Japanese region. As for the origin of other living species of Japan, St. sceptriferoides (with a subspecies lanceolata of the Japanese region), which is more or less differing from species-group of grandis-microtuberculata, is not known with certainty, but it seems to have derived from the Stereocidarid-predecessor of the region. The Malayan subspecies *philippinensis* of the East Indian living species St. indica, seems to have distributed to the Japanese region (off Kyushu) from its center of distribution and development during the very young geological age. The Japonic subgenus Phalacrocidaris is noticed by the writer in the preceding pages.

The large subfamily Stylocidarinae comprise in Japan and the adjacent regions the following Recent genera, viz., Acanthocidaris, Stylocidaris, 'Eucidaris,' Plococidaris, Compsocidaris, and Prionocidaris, and also comprise practically the following fossil genera, viz., Balanocidaris and Firmacidaris. The genus Acanthocidaris seems to be a very recent type, not known with certainty as fossil, and its relation to other members of the subfamily is obscure. A living species of the genus, Acanth. maculicollis is known from the Japanese region, and it seems to have very recently migrated to Japan from the center of its distribution. The genus Compsocidaris is only known near the Bonin Islands in the living, and it seems to be a very recent type. This genus seems to have a relation to the typical Stylocidarids, and probably have originated recently from some form of the typical Stylocidarids. The genus 'Eucidaris' is tropical and wide-spread in the Recent and has a strong tendency to develop short and very stout radioles. 'Eu.' metularia was probably derived from a certain form of the Stylocidarids and distributed over the Indo-West Pacific in the young geological age, as far north as southern Japan, from the center of its development.

The genus *Stylocidaris* does not seem to be a satisfactory one and its living species are distributed over the tropical and subtropical regions of the Indo-West Pacific and Atlantic Oceans. JEANNET and MARTIN (1937, p. 218, fig. 1) reported the occurrence of Stylocidarid-like radioles from the Miocene series of Java and referred them to *Stylocidaris reini* of the Malayan and Japanese living species. This is, in believing their precise identification, the oldest occurrence of the Stylocidarids in the

Indo-Pacific regions. The Indo-Pacific Oceans now have a greater part of the living species, which seem to make a somewhat heterogeneous group from the Atlantic, and the Oceans seem to be a center of their development and distribution. Of the Japanese living species, *Styl. reini* has probably originated in the Malay region and has been quite recently distributed to Japan from there. *Styl. maculosa* has probably descended from a radical species, such as *Styl. reini* or its alliance of the earlier origin, and differentiated into 2 species (*Styl. maculosa* of the Japanese and *bracteata* of the Malay regions) by taking somewhat different lines of development in the separate regions. *Styl.*? *fusispina* which is an aberrant species of the genus and apparently bears no relation to any of the living species of the genus. Its origin is not ascertained to the writer.

The genus *Plococidaris*, with a single living species, *Ploc. verticillata*, bears so close relation to the genus *Prionocidaris* that H. L. CLARK (1925, pp. 2, 17) classified the species into the genus *Prionocidaris* with other typical *Prionocidaris*; the genus is probably derived from a certain species of the Prionocidarids of the early development. *Ploc. verticillata* is known to occur as fossil from the Pliocene of Ceram (JEANNET, 1935, p. 10, pl. 1, figs. 5-6) and the Pleistocene of Nias Island (JEANNET and MARTIN, 1937, p. 220). This species in the living is widely distributed over the Indo-West Pacific and has probably distributed from the center of its development and distribution to the Japanese region during the very young geological age.

The genus Prionocidaris comprises rather a fairly homogeneous group of the Indo-West Pacific living species, in which *Ploc. verticillata* is to be eliminated. MOR-TENSEN (1928-b, p. 435) stated on the distribution of the genus, mentioning various fossil species from the Cretaceous, Eocene, and Miocene series, that probably belong to this genus. His idea is that this genus was formerly rather richly represented in the European seas, with one representative in American seas, whereas in the Recent it is confined to the Indo-Pacific. Some of the East Indian and Malayan living species have probably descended from the pre-existing fossil forms of these regions, i.e., Leiocidaris canaliculata DUNCAN and SLADEN, 1884 (1884, p. 109, pl. 21, figs. 1-9-Eocene) may be mentioned as an example of these forms; nevertheless the origin of the genus Prionocidaris cannot be ascertained in the present state of our knowledge. Four Malayan living species are known as fossil from the Neogene formations of that region, viz., Pr. baculosa from the Miocene of Java and the Pliocene of Aru Islands, Pr. baculosa annulifera from the Miocene of Madura Island and the Pliocene of Ceram, Pr. bispinosa from the Pliocene of Ceram, and Pr. pistillaris from the Pliocene of Ceram, of which Pr. baculosa seems to be nearly a radical species in view of its oldest geological occurrence and its character of the primary radioles and the test. From the Japanese region two out of these four species are known to occur as fossils, Pr. baculosa annulifera and bispinosa from the Pleistocene of Kikaijima, Ryukyu Islands, and the former in the living now distributed as far north as Uraga Channel, central Japan. The two species have probably distributed from the center of their development and distribution (the Malay region) to the Japanese region during the very young geological age.

The genus *Balanocidaris*, which is practically referred to this subfamily, dates back to the Carnian and ranges to the Senonian. This genus of Japan is represented by a single species, *Bal. japonica*, known from the Torinosu Limestone of western Japan. This species resembles *Bal. glandifera* (MUNSTER, 1829) in the features of the primary radioles, and there may be a genetic connexion between the two species. *Bal. japonica* would have originated from *Pal. glandifera* or its alliance in the region at that time. The genus *Firmacidaris*, which is quite practically referred to the subfamily Stylocidarinae, of the Japanese region is represented by a single species, *Fir. neumayri*, known from the Torinosu Limestone of western Japan. This species resembles *Fir. precincta* (LAMBERT, 1933) from the Domerian of Morocco, and there may be a close relationship between the two species.

The subfamily Rhabdocidarinae, which is not very well defined, in Japan and the adjacent regions, comprise following genera, viz., Chondrocidaris, Chronocidaris, and Phyllacanthus. The genus Chondrocidaris occurs in the Recent from Mauritius to Hawaiian Islands. A fossil species, Ch. marianica, is known from the Miocene Donney formation of Saipan Island, and it closely resembles Ch. sundaica from the Miocene of Java and the Pliocene of Aru Island, and also resembles Ch. problepteryx from the Eulepidina-Operculina-horizon of Fiji Islands. These Miocene (to Pliocene ?) species so closely resemble one another, concerning their primary radioles only, that it might seem probable that they represent the same and single species or allopatric. But, until their identity would be proved in future by other characters, i. e., the secondary radioles, ambulacra, and the coronal plates, besides the primary radioles they must be practically regarded as three distinct species (or subspecies). It seems highly probable that there was a great development at the center of evolution of Chondrocidaris in the West Pacific Ocean of the Miocene time, and from one of which (viz., Ch. sundaica) the living species was directly derived in the younger geological age.

The genus *Chronocidaris*, although the ambulacral pores on peristome are in a single series, some what resembles, *Phyllacanthus* and is practically referred to the subfamily Rhabdocidarinae. This genus seems to be of a recent origin and the fossil representative is not known with certainty; it has probably developed in the very young geological age along the side or parallel line of development from that of *Phyllacanthus*.

The genus *Phyllacanthus*, which is well limited and comprises a natural group of species, dates back at least to the Miocene and is rather widely distributed in the Recent over the Indo-Pacific Oceans. One of the living species, *Ph. imperialis* is known to occur as fossil from the Miocene of Java and the Pliocene of Timor, Ceram, Java, and Fiji Islands, and is also found by the writer from the Pleistocene of Angaur Island, Palao Islands. *Ph. dubius*, which is known only living in the Bonin Islands, is reported to occur as fossil from the upper Miocene of Java; but, the exact identity of the primary radioles of the latter with those of the living species leaves an uncertainty. A fossil species *Ph. javanus*, is known from the Miocene of Java, New Guinea, and Madura Islands. Several imperfect primary radioles that are conferable to this fossil species are known in the Donney (*Eulepidina*-horizon) of Saipan Island. Although the origin is not certain in the present state of our knowledge, *Phyllacanthus* has flourished in the Malay region with a fair number of species of the Miocene and Pliocene ages. There is then no question that the living species of this. genus have probably migrated from the center of their development and distribution to the Japanese region during younger geological ages.

The genus *Psychocidaris*, which was erected on a single living species *ohshimai* from the Bonin Islands, is of great interest because of the non-crenulate and imperforates primary tubercles, which are an unique feature among the living Cidaridae. Ambulacral pores on the peristomial ambulacral plates are diploporous as in Phyllacanthus, and peculiar shape of the primary radioles and flask-shaped valves of the large globiferous pedicellariae are diagnostic. Due to these peculiarities manifested in the structure of the Cidarid, IKEDA (1936-b, p. 486) proposed a distinct family Psychocidaridae separated from the family Cidaridae. MORTENSEN (1951. p. 576) regarded Psychocidaris as a descendant of the Cretaceous Tylocidaris of the Stylocidarinae, and DURHAM and MELVILLE (1957, p. 252) suppressed the family Psychocidaridae as a subfamily of the Cidaridae. The genus Tylocidaris (POMEL, 1883, p. 109.—Type-species.—Cidaris clavigera KONIG: COTTEAU, 1861-67, p. 285, pls. 1069-1071— Senonian) is characterized by having non-conjugate ambulacral pores, imperforate and non-crenulate primary tubercles, and thick and club-shaped primary radioles, and dates back to the Cenomanian and ranges to Senonian with a moderate number of species confined to the Palaeo-Lusitanian and East American regions. The two genera, the Recent Psychocidaris and the Cretaceous Tylocidaris, have in common the characters of imperforate and non-crenulate primary tubercles, non-conjugate ambulacral pores, and the club-shaped adoral primary radioles. These features suggest that there might be a close relationship or genetic connexion between the two genera. As a matter of fact, however, it is difficult to ascertain whether the imperforate primary tubercles of the former are inherited directly from those of the Cretaceous genus or have developed independently by convergency without relation to the latter; moreover, the discontinuity of existence between the two genera, i.e., Recent and the Senonian, and the lacking of the representatives of Tylocidaris in Japan and the adjacent regions set forth the problem of derivation of the former from the latter more difficult. It is very curious that the imperforate character of primary radioles of the Cidaridae has developed only in Tylocidaris of the Cretaceous against the perforate character that is regarded as one of the normal features of the Cidaridae; and if it really occurred only on one occasion in *Tylocidaris* and never occurred again throughout their development of the Cidaridae from the Carboniferous to Recent, it would seem most probable that the Recent Psychocidaris has been descended, as stated by MORTENSEN, from the Cretaceous Tylocidaris, and some transitional forms might have existed, althogh such are not known at present. But, if the imperforate character were developed twice or thrice in different groups in different ages, the derivation of Psychocidaris would be explained in another way that Psychocidaris could be a more recent specialization from the Rhabdocidarid-stem, viz., from the Rhabdocidaris-Chondrocidaris or Phyllacanthus branch; that is to say, by specialization of imperforate from perforate and non-crenulate from crenulate primary tubercles, biserial arrangement of the peristomial ambulacral pores along the development of Phyllacanthus, and peculiar form of the primary radioles from simpler and normal form. The peculiar cidarid of the Recent *Psychocidaris*, at any rate, although it is not clear whether has descended directly from Tylocidaris or has been derived from

some form of the Rhabdocidarinae, has probably developed recently and authochthonously in the Japanese region.

In Japan and the adjacent regions the family Aspidodiadematidae are represented by a single genus *Aspidodiadema* of the Recent deep-sea. Although the origin of *Aspidodiadema* is not known with certainty in the present state of our knowledge, it seems probable that some related fossils would have existed in the Lias and Cretaceous of other regions outside the Japanese one. The living *Asp. tonsum*, the Malayan and Japanese species of deep-sea form, seems to have developed recently and migrated from the center of its development and distribution to the Japanese region.

The family Pedinidae of Japan and the adjacent regions are represented by a single living genus *Caenopedina*, which has close relations with the fossil genera *Hemipedina*, *Stereopedina*, and *Pedina*. The genus *Caenopedina* has probably descended from such ancestor these genera, but the transitional forms are not known with certainty. *Caen. mirabilis*, the typical Japanese species, is not known to occur as fossil. Although its origin is uncertain to the writer, the species has probably originated from unknown progenitor and developed autochthonously in the Japanese region. An Hawaiian species of the genus, *Caen. pulchella*, is reported to occur in the Sagami Sea, but there leaves a doubt on the matter, as the specimens came from Japan were brought from ALLAN OWSTON (MORTENSEN, 1940, p. 115); if the specimens truely came from Japan, it is one of very rare cases of common species between Hawaiian Islands and central Japan.

The large family Diadematidae of Japan and the adjacent regions are represented by the following recent genera, viz., Astropyga, Chaetodiadema, Diadema, and Echinothrix, and all of the recent forms are essentially warm water or tropical and shallow water ones. Owing to deficiency of fossil genera, such as Eodiadema, Pedinothuria, and Palaeodiadema, in the Japanese region, the history of the family in the region is very hard to establish. The genus Astropyga is represented by a single living species, Ast. radiata, but it is not known to occur as fossil. The species has probably developed recently in the tropical region and distributed from there to the Japanese region, as far north as Tanabe Bay in Kii Peninsula. MAYR (1954, pp. 3-4) regarded the three living species, viz., radiata, pulvinata, and magnifica, of this genus as The genus Chaetodiadema is represented in Japan by a living species, allopatric. *Ch. japonicum*, which has a close relation with the Malayan species *Ch. granulatum*, and the species seems to have descended from a common progenitor and the former has probably developed autochthonously in the Japanese region by taking a more or less different line of development from that of the latter. The genus Diadema is represented by two living species, D. setosum and D. savignvi, which are closely related with each other. They are now flourishing in the tropical and subtropical seas, but their fossils are not known with certainty from the Malay and Japanese regions. The two species seem to have originated in the tropical region and soon became vigour recently and distributed from the place of development to the Japanese region. MAYR (1954, pp. 8-9) stated that 5 out of 6 species recognized by MORTENSEN (1940, pp. 241-281) are allopatric, and most of them are so similar to each other that there is no reason that why they should not be considered subspecies. The genus Echinothrix is represented by two species, Ech. calamaris and diadema of the characteristics

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of the tropical or subtropical seas. The two species have probably originated in the tropical region along parallel lines of development from that of the species of *Diadema*. *Ech. calamaris* is known with certainty to occur as fossil in the Pleistocene Ryukyu Limestone of North Borodino Island, and this seems to suggest that the species at that time already had distributed as nearly widely as in the present time, and also that the two closely related species, *calamaris* and *diadema*, may have descended from a common progenitor and differentiated into the two distinct ones taking more or less different lines of development in the young geological age.

The family Saleniidae of Japan and the adjacent regions are represented by two Recent genera (with fossil species), Salenocidaris and Salenia. The genus Salenocidaris is represented by one fossil species, Sal. hakkaidoensis from the Neogene series of Hokkaido and two living species, Sal. pacifica and hastigera. The genus dates back to the Tertiary period, occurring obviously later than Salenia, and perisists to the Recent of the Pacific, East Indian, and Atlantic Oceans. It has relations, in the structures of ambulacra and apical system, to Salenidia on one hand and to Salenia on the other hand. It can, thus, be assumed that the genus may have descended either from Salenidia of the Cretaceous and older Cenozoic by specialization of oral ambulacra near the peristome or from Salenia of the Senonian and older Cenozoic by simplification of aboral ambulacra, but the conclusion cannot be given definitely in the present state of our knowledge. The interrelationship or the direct connexion between the fossil and living species from Japan is obscure; however, Sal. pacifica seems to have descended from such a progenitor of the Japanese region as Sal. hakkaidoensis, and probably developed autochthonously in the Japanese region. Another species, Sal. hastigera, of the Malayan and deep-sea form is known to occur from western Pacific, off Japan. It has probably distributed from the center of development to the Japanese region in the very young geological age. The genus Salenia is represented by two fossil species, Sal. novemprovincialis from the Oligocene formation of Kyushu and Sal. nipponica from the Miocene of central Japan, and two living species, Sal. cincta and unicolor. Although the Oligocene species from Japan resembles Sal. deleaui from the Eocene of France, the direct or genetic connexion between the two species is not definitely proved by sound evidence. Sal. nipponica of the Miocene seems to have some affinity with one of the two living species. The two living species, Sal. cincta and unicolor, differ from each other in the primary radioles and in the colouration; the former is at first found in the Japanese seas and now further known from the Malayan seas and the latter is known only from the Japanese seas. The two living species seem to have developed recently in the Japanese and Malay regions.

The family Hemicidaridae are represented in Japan and the adjacent regions by a single genus *Pseudocidaris*. *Ps. simulans* is known from the lower Cretaceous series of North Japan. It resembles *Ps. dourarensis* from the Neocomian of Mr-Abda and *Ps. cunifera* from the Neocomian of France. Presumably there are genetic connexions among these species.

The large family Phymosomatidae are represented in Japan and the adjacent regions by the two genera, *Eoglyptocidaris* and *Glyptocidaris*. It is now apparent that the center of development of the Phymosomatidae probably was in the European—

North African region of the Cretaceous seas, from which they radiated far away to South Africa and to Japan through the East Indian region. In the Japanese region a Porosomatid form evidently existed in the Senonian of Hokkaido and this seems to suggest that there is a genetic connexion between the East Indian and the Japanese species at that time. From this Porosomatid form the Oligocene *Eoglyptocidaris* of Hokkaido may be derived; and from the Oligocene *Eoglyptocidaris*, in turn, the Recent *Glyptocidaris* (with a fossil subspecies of Pliocene) may be directly derived. *Eoglyptocidaris* and *Glyptocidaris* of Japan, in general, seem to have developed mainly autochthonously during the Cenozoic time.

The family Stomechinidae are represented in Japan and the adjacent regions by a single genus Stomopneustes that comprises fossil and living species. PHILIP (1965, pp. 57, 61) separates the family Stomopneustidae MEISSNER, 1904 (possessing the echinoid ambulacral compounding) from the family Stomechinidae POMEL, 1883 (with generally the diadematoid ambulacral compounding). The structure of ambulacral plates of the genus Stomopneustes differs distinctly from the typical echinoid structure of the ambulacral plates of the Echinidae and Echinometridae, on one hand, and also from the typical diadematoid structure of the genus Stomechinus, the primitive member of the Stomechinidae, on the other hand. The oldest representative of the genus Stomopneustes is known from the Eocene of Bonin Islands; although the species (St. antiquus) has a larger number of the coronal plates and a narrower poriferous zone, it is safely referred to this genus by the characteristic features of the test. Another fossil species (St. pristinus) is known from the Oligocene of Mexico (Atlantic side). The source from which Stomopneustes is derived would seem to be found among the any known fossils in the present state of our knowledge is the Cretaceous Triadechinus of the West Indian region. The both genera, Stomopneustes and Triadechinus, have in common the characters of a conspicuously sunken, strongly undulating median line in the interambulacra on the aboral side and only alternating ambulacral plates with a primary tubercles, but the two genera are descriminated from each other by the feature of the primary tubercles on aboral side. By the complication of aboral primary tubercles and by the specialization of ambulacral structure the latter could give rise easily characters of the former and also the geological sequence of the two genera fits with the case. The Eocene species of the West Pacific and the Oligocene species of the West Indies were probably derived from the upper Cretaceous (or Eocene-Triadechinus multiporus in USNM) Triadechinus or its alliance of the West Indies, and the Eocene species, in turn, may give rise to a more specialized form (St. variolaris) from the upper Miocene of Java by widening of the poriferous zones, particularly on the aboral side, and by reduction but complication of the coronal plates, while the Oligocene species of the West Indies seems to have descended no species, because no species of Stomopneustes are known from the Miocene and later formations. This fact leads to the conclusion that the genus died out in the West Indian region about the end of the Oligocene, while it survived in the Indo-West Pacific region. The living species, St. variolaris, seems to originate in the Miocene of the Malay region, so far as the present state of our knowledge is concerned, and distributed from there to the present range of its distribution, and the fossil of this species is not known with certainty in Japan.

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The family Arbaciidae are regarded by MORTENSEN (1935, pp. 544, 546) as being in part derived from the Tiarechinidae of the Carnian and in part from the Hemicidaridae of the Lias and assigned to his suborder Phymosomina (the Arbacioina of the writer). The family is represented in Japan and the adjacent regions by a fossil genus *Goniopygus* and a living genus *Coelopleurus* (with a fossil species). *Goniopygus* ranges from the Portlandian to the Eocene, and the center of its evolution seems to have been in the European—North African region. An occurrence of this genus, *Gon. atavus*, from the lower Cretaceous of North Japan is noteworthy, as the place is so separated from the center of development that the intermediate place (i. e., East Indian region) has no fossil of the related species. The species resembles *Gon. delphinensis* from the Aptian of France and *Gon. major* from the Cenomanian of France. Although this and European species are widely separated in geographical situation, the resemblance may suggest the possibility of genetic connexion between the Japanese and European species of that time.

It is clear that the Recent genus Coelopleurs is not very closely connected with the other Recent forms, particularly to the Recent deep-sea forms, but it seems to have close relations to the fossil genera, such as Baueria, Heteropodia, and Codiopsis, in the feature of aboral interambulacra. Of the fossil genera Codiopsis (from the Sequanian to Eocene), as suggested by LAMBERT (1903-a, p. 90) and MORTENSEN (1935, p. 545), may be regarded as the source from which the Recent Coelopleurus has been derived. A fossil species, Coel. singularis, from the Miocene formation of central Japan resembles Coel. forbesi from the Miocene (the Gaj series) of western Sind. This occurrence seems to indicate continued connexion of the Japanese seas with the Indian Ocean and Malay seas, on one hand, and that the species could be regarded as an ancestral form of the Japanese living species, viz., Coel. maculatus and *undulatus*, on the other hand, namely by reduction of the interambulacral primary tubercles and by enlargement of the pore-zones this species leads easily to the features of the living. One of the living species, Coel. maculatus, is known to occur as fossil from the Pleistocene formation of Chiba Prefecture, central Japan, and also from the Pliocene of Ceram. The species seems to have been derived from the Miocene species of the East Indian or Malay-Japanese region and developed in the Malay and Japanese regions in the young geological age. Coel. undulatus is known only from the Japanese seas (with a subspecies *polymorphus*) but is not known to occur as fossil. This species has a close relation to Coel. maculatus, and the species seems to have been derived from the Miocene progenitor (such as Coel. singularis) of the Japanese region in the very young geological age.

The large and interesting family Temnopleuridae, one of the highly developed sea-urchins of the Recent age in the Malay region, are regarded by MORTENSEN (1940, p. 60) as a branch that seems to have arisen from the Pseudodiadematid stem associated with the Glyphocyphid branch, and this interpretation of MORTENSEN is accepted by DURHAM and MELVILLE (1957, p. 255) as the Temnopleuridae of a probable origin in the Pseudodiadematidae. The family Temnopleuridae contain various forms and they may be divided into three subfamilies, viz., the Temnopleurinae, Trigonocidarinae, and Genocidarinae. The subfamily Temnopleurinae of Japan and the adjacent regions are represented by the following genera, viz., *Temnopleurus*

(with a subgenus Toreumatica), Temnotrema, Mespilia, Microcyphus, Opechinus, Erbechinus, Salmacis, and Salmaciella. The genus Temnopleurus appeared at first in the upper Miocene of the Malay region and was probably derived from such a predecessor as Medocechinus or Trumechinus, or a common ancestor of them. Tem. toreumaticus, the widely distributed and oldest known species of the genus, is known to occur as fossil from localities of the Indo-West Pacific, and in Japan and the adjacent regions it occurs as fossil from the Pliocene of Formosa and the Pleistocene of western Japan. This species has probably originated in the Malay or East Indian region and has distributed from the center of its development to the present range of distribution throughout the Neogene and Quaternary ages. Tem. hardwickii seems to have descended from the related species of older occurrence, i. e., Tem. toreumaticus, by the specialization of pits of horizontal sutures on coronal plates, and to have developed autochthonously in the Japanese region in the young geological age. The subgenus Toreumatica is represented in Japan and the adjacent regions by two living species, Tem. (Tor.) reevesii and apodus, which are rather widely distributed over the Indo-West Pacific Oceans. The subgenus seems to have recently descended from the typical *Temnopleurus* taking a parallel line of development from that of *Salmacis* or Temnotrema in the specialization of ambulacral pore and pits on the oral side. Tem. (Tor.) reevesii is known to distribute as living species over the Indo-West Pacific and to occur as fossils only from the Pleistocene formation of central Japan; the species has probably originated in the East Indian or Malay region and has developed vigorously in the very young geological age. The origin of Tem. (Tor.) apodus is obscure in the present state of our knowledge and the species has a peculiar feature of buccal membrane consisting only of 5 distinct buccal plates and 5 buccal tube-feet.

The genus *Temnotrema*, the beautiful and small sea-urchins, appeared at first in the upper Miocene of the Malay region (JEANNET, 1935, p. 34) and Burma (CURRIE, 1939, p. 225), seems to have developed along a parallel line of development from that of Temnopleurus and is confined in the Recent to the Indo-West Pacific, but the record of Temnotrema from the Redonian stage (late Miocene) of Normandy is particularly noteworthy. The two species of Japan, Tem. sculptum and rubrum, are known to occur as fossils from the Pleistocene formation of central Japan, and seem to have probably developed along the parallel line of development from that of *Tem. macula*tum, which resembles to some extent the Japanese species and is known to occur as fossils from the Pliocene of Java (JEANNET, 1935, p. 48, pl. 1, fig. 6, pl. 4, fig. 15) and is living in the Malayan seas. On the other way, Dicoptella agassizi var. tenuis from the upper Miocene of Java has a close relation to the Japanese species, and it seems to suggest a probable way of origin of the Japanese species. The two Japanese species seem to have developed autochthonously in the Japanese region since the young geological age.

The Malayan and Japanese genus *Mespilia* comprises a well known and very diversified species, *Mes. globulus* (with some varieties). This genus seems to have developed recently along the parallel line of development from *Salmacis* or *Microcyphus* by specialization of the poriferous zones and median space of the interambulacral area, but there is no records of fossil. *Salmacis* is represented in Japan and the adjacent regions by a single species, *Sal. bicolor* which is rather widely distributed

over the Indo-West Pacific Oceans. This species is known to occur as fossil from the Pliocene of Java and Timor, but not known as fossil in the Japanese region; it may have originated together with other species of the genus (i. e., Sal. belli-JEAN-NET and MARTIN, 1937, p. 227.-Pliocene of Timor) in the Malay region and distributed recently from there to the Japanese region. The genus Salmaciella comprises only two species, Sal. dussumieri and oligopora, and has probably developed recently together with Salmacis, taking a more or less different line of development from that of Salmacis by the specialization of poriferous zones and the ambulacral structure. Sal. dussumieri is known to occur with some doubt as fossil from the Pliocene of Okinawa Island and seems to have originated in the Malay region and ditributed from there to the Japanese region. The genus Microcyphus comprises a considerable number of living species of the East Indian, Malay and Australian regions. The genus appeared at first in the Miocene of Java, as known from the two species, viz., Mic. javanus and melo, and seems to have flourished towards the modern seas from that time. The characteritic Japanese species, Mic. olivaceus, has probably descended recently from a Malayan or Japanese progenitor by the specialization of primary and secondary radioles and the interambulacral plates, and has developed autochthonously in the Japanese region.

The genus *Opechinus* appeared at first in the Oligocene of India with the simplest form, i. e., *Op. costatus* (D'ARCHIAC, 1853), remained with rather poorly representation during the Oligocene, but with the Miocene it became numerous and reached the climax in the Malay (with 4 species) and East Indian region (3 species), then it descreased in number in the Pliocene (1 species), and is represented in Recent seas only by one (and a doubtful) species, *Op. variabilis* of the Japanese and Malay (?) regions. This species seems to have descended from a progenitor of the Malay or the Japanese region and probably developed autochthonously in the Japanese region. The genus *Erbechinus* seems to have developed together with *Opechinus*, taking a more or less different line of development by the differentiation of tuberculation on the oral side in the Malay and Japanese regions. *Erb. gratus* from the Miocene formation of central Japan is the oldest known species, the Pliocene species, *Erb. erbi*, is known from Java, and a living species *Erb. spectabilis* from the Malayan seas; the three species seem to have a genetic connexion in their development since the Miocene epoch.

The subfamily Trigonocidarinae are represented in Japan and adjacent regions by the following genera, viz., *Printechinus*, *Brochopleurus*, *Prionechinus*, and *Lamprechinus*. The genus *Printechinus* dates back at least to the Pliocene, as is known from a fossil species, *Pr. javanus* (JEANNET, 1935, p. 23, pl. 1, figs. 35-36, pl. 4, figs. 9-10). Two living species, *Pr. impressus* and *viridis*, are known at present. The former is known from the Ryukyu Islands, and the species seems to have originated recently together with *Pr. viridis* or *javanus* in the East Indian or Malay region and distributed from there to the Japanese region.

The extinct genus *Brochopleurus* now comprises 8 fossil species, 2 from the Miocene of Egypt, 2 from the Miocene of India, 2 from the Miocene of Java (*Javanechinus*), 1 from the Miocene of Fiji Islands (*Graphipleurus*), and 1 from the Miocene of Japan. A Japanese fossil species, *Br. pulcherrimus* from the Miocene of central

Japan, has a close relation to *Br. stellulatus* and *gajensis* of India and Malay. It seems quite probable that there exists a genetic connexion among these species, and the Japanese species seems to have descended from the East Indian or Malayan progenitor, developed autochthonously, and then soon become extinct in the Japanese region. From a view-point of the speciation, these Miocene forms may be regarded as allopatric. Some Miocene species of *Brochopleurus* (together with *Javanechinus*) can be regarded, as MORTENSEN (1943, p. 341) stated, as ancestors of the Recent species of *Desmchinus* of more specialized form.

The Recent species of the genus *Prionechinus* are confined to the Indo-West Pacific, and no fossil species have been recorded from the Indian, Malay and the Japanese regions, while they are present in the Lusitanian (from the Miocene to Pliocene) together with fossil species of the genus *Arbacina* of the Genocidarinae. There is a possibility that the genus developed in the Lusitanian seas and, when it vanished there, found its way to the Indo-West Pacific to take the flourishing condition of Recent seas. The genus is represented in Japan and adjacent regions by two living species, *Pr. forbesianus* and *Pr. agassizii*; the two species are not known to occur as fossil and seem to have developed recently in the Malay and East Indian regions. They seem to have distributed from the center of their development to the Japanese region; however, if the specimens from Japan are correctly referred to *Pr. agassizii*, this is one of the rare cases of common species between Japan and the Indian deep-sea.

The living species of the genus *Lamprechinus* are confined to the Indo-West Pacific. As no fossil species have been recorded hitherto, the genus seems to have developed recently in the Indo-West Pacific. The genus is represented in Japan and adjacent regions by a single species, *Lam. sculptus* from southern Japan; the species seems to have developed recently along a parallel or more or less different line of development from that of the Malayan *Lam. nitidus* from a common progenitor.

The family Toxopneustidae range from the lower Tertiary (excepting a doubtful genus *Scoliechinus* of the Cretaceous (?)) to Recent, but the great number of the genera are recent forms, and the Toxopneustidae seem to have developed together with the Temnopleuridae either from a common ancestor or from the older Temnopleuridae themselves. The family in Japan and the adjacent regions comprises the following genera, viz., *Mirechinus, Tripneustes, Nudechinus, Toxopneustes, Pseudoboletia*, and *Pseudocentrotus*. The genus *Mirechinus* is represented by a single species, *Mir. mirabilis* from the upper Eocene of Bonin Islands. Although the origin of this species is obscure in the present state of our knowledge, it is very interesting that this primitive Toxopneustid has already existed in the Eocene of the West Pacific.

The genus *Tripneustes* dates back at least to the Oligocene, comprising 8 Miocene species, one Pliocene, and at least 3 living species. MAYR (1954, p. 4) claimed that these living species should be regarded as allopatric. A magnificent fossil species, *Tr. magnificus*, is known from the Miocene of Saipan Island. It has close relation to *Tr. provius* from the Gaj series of Sind and *Tr. schneideri* from the Miocene of Madura and Java Islands, and there may have existed a genetic connexion among the three species. A living species, *Tr. gratilla*, is widely distributed over the Indo-West Pacific and not known with certainty to occur as fossil. This species seems to

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have descended recently from the Indo-West Pacific progenitor and distributed from the center of its development to the Japanese region. Although the genus *Nudechinus* has rather primitive characters in the family Toxopneustidae, it seems to be of recent origin and a majority of recent species are confined to the Indo-Pacific region. A living species, *Nud. multicolor* of beautiful and small form, is known from the Japanese region, but the origin of this species is not certain. The species may have descended recently from the Malayan progenitor and developed rather autochthonously in the Japanese region.

The genus *Toxopneustes* seems to be of recent origin, as no species is known tooccur as fossil (regardless a very doubtful species, *Tox. fouquei*), and have developed together with *Tripneustes*. The living species are now flourishing in the Indo-West Pacific, tropical coast of North America, and in the Japanese region. A living species, *Tox. pileolus*, seems to have originated recently from a certain progenitor and probably distributed from the center of its development to the Japanese region. Another living species, *Tox. elegans*, is known only from Kagoshima Gulf and Amami-Ôshima. This species has probably developed recently taking a more or less different line of development from that of *pileolus* (with *chlorocanthus*) and authochthonously in the Japanese region.

The genus *Pseudoboletia* seems to be of recent origin, not recorded as fossil, and comprises three living species, of which two are known from the East Indian— Malay—southern Japanese region and one from the Atlantic Ocean. The specific validity of *Ps. maculata* was doubted by H. L. CLARK (1925, p. 132) who regarded it as a variety of *Ps. indiana*; it has probably originated in association with or from *indiana*-like form in the Malay region and distributed recently from there to the Japanese region. The genus *Pseudocentrotus* seems to be the most specialized of all the genera in the family Toxopneustidae and closely related to the Lusitanian genus *Sphaerechinus*. *Pseudocentrotus* is confined to the Japanese region in its. geological and geographical distribution and ranges from the Miocene to Recent. The fossil, *Ps. stenoporus*, and the living, *Ps. depressus*, are noticed by the writer in the preceding pages.

The family Echinidae range from the Palaeogene to Recent, and MORTENSEN (1943-a, p. 6) suggested that the Echinidae seem to have evolved from the primitive Stomechinidae, like *Echinotiara* and *Psephechinus*. The family is very poorly developed in Japan and the adjacent regions, represented by a living species of the genus *Echinus*, and no species is known to occur as fossil in the region. *Ech. lucidus*, an endemic species to the Japanese region, is an only representative of the Indo-West Pacific in contrast to the flourishing great majoirity of recent species (about 12) in the Atlantic Ocean. It seems probable that *Ech. lucidus* represents a descendant of the immigrant that has migrated from Arctic or North Atlantic when the northern part of northern hemisphere was warmer than the present seas, and then *Ech. lucidus* has probably developed autochthonously in the Japanese region. Another possibility is that *Ech. lucidus* could be a recent specialization from a certain predecessor that has already developed in the Japanese region, but the writer can by no means prove it because of the lack of fossil record.

The family Strongylocentrotidae are very highly developed in Japan and adjacent.

regions, represented by all of the genera, viz., Strongylocentrotus, Allocentrotus and *Hemicentrotus*, and some fossil species are also known to occur in the regions. The genus Strongylocentrotus, although its origin is obscure in the present state of our knowledge, is characteristic of cold and temperate water, as it is wide-spread in the Recent northern seas, particularly in the northern Pacific, where the great majority of living species are in their flourishing condition. Of fossil species of Japan and adjacent regions, Str. ? octoporus known from the Fukaura and Suenomatsuyama formations of northern Japan has been, although the features of pedicellariae and radioles are not discernible, referred with some doubt to the genus, and it is the oldest known species from Japan. The occurrence of this primitive form seems to indicate that some more specialized forms of the living species (such as Str. intermedius or Hem. pulcherrimus) may be derived from such a form, though not necessarily this form, by specialization of the ambulacral structure and the tuberculation of the coronal plates. Another species, Str. magistrus known from the Himi formation of Toyama Prefecture and Setana formation of southern Hokkaido, has already developed such specialized features in the ambulacral structure and the tuberculation on the coronal plates as those of the living species, St. polyacanthus and dorebachienssis; the species seems to have developed quickly and attained the specialized condition in the Japanese region, particulary in northern part, and vanished there leaving no descendants. As for Str. intermedius the writer has noticed in the preceding pages. Str. echinoides resembles other living species of northern Japan, viz., Str. sachalinicus, polyacanthus, and pulchellus, and they seem to constitute a species-group. These living species that are related with one another seem to have descended from a common progenitor in the North Pacific and developed along parallel lines of development and differentiated into several species (or subspecies) in the young geological age. The well developed and widely distributed species, Str. dorebachiensis, is not known with certainty to occur as fossil from Japan and the adjacent regions. Another living species of Japan, Str. nudus, seems to have developed along a different line of development from that of other species and autochthonously in the Japanese region.

The genus *Allocentrotus* comprises hitherto only a single species of very beautiful and delicate form of west coast of North America. An occurrence of the fossil species, *All. japonicus*, from the Pliocene series of central Japan is very interesting. The species so closely resembles the Californian living species *All. fragilis* that a close genetical connexion may exist between the Japanese Pliocene and the Californian living species. Another possibility is that the Californian living species could be derived by a more recent specialization from the Strongylocentrotid stem. The genus *Allocentrotus*, as a whole, seems to have developed along a more or less different line of development from that of *Strongylocentrotus* in the North Pacific.

The genus *Hemicentrotus* seems to be a recent type and not known with certainty as fossil. Its origin is uncertain, but it has a close relation with certainty to *Strongylocentrotus* and seems to have descended from that genus and reached the flourishing condition of the present seas of the Japanese region.

The small family Parasaleniidae have the very peculiar combination of the characters in the test. This causes much difficulty to know their real affinities and

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also about their ancestry. The family is represented in Japan and the adjacent regions by a single genus *Parasalenia*. The genus *Parasalenia* has appeared at first in the Miocene (*Spiroclypeus*-horizon) of Mariana Islands with the oldest form, *Par. marianae*. This species evidently has one large primary tubercle on each interambulacral plate (except the adapicalmost) and differs strikingly from *Diplosalenia*. Through the Pliocene and Pleistocene epochs of the Indo-Pacific and Lusitanian regions the Parasaleniidae are not known with certainty to occur as fossil, but in the Recent seas of the Indo-West Pacific region they seem to be rather highly developed with two living species (with a subspecies). One of the living species, *Par. gratiosa* (with a subspecies *boninensis*), seems to have descended from *Par. marianae* of the Miocene epoch and have developed in the Malay or East Indian region and distributed recently from the center of its development to the Japanese region.

The large family Echinometridae are represented in Japan and the adjacent regions by the following genera, viz., Echinostrephus, Anthocidaris, Echinometra, Heterocentrotus, and Colobocentrotus. As for the origin of the Echinometridae, MOR-TENSEN (1943-a, p. 255) assumed that the facts known to us point towards the Stomopneustidae or the Phymosomatidae as the source from which the Echinometridae evolved, while DURHAM and MELVILLE (1957, p. 255), in discussing the affinities of the families Echinidae, Strongylocentrotidae, Parasaleniidae, and Echinometridae, admit ignorance as to the phylogenetic background of these families and they donot claim that their arrangement is necessarily a natural one. The Echinometridae date back to the Miocene and range to the Recent, comprising characterically tropical or subtropical forms. The genus Echinostrephus appeared at first in the Miocene limestone of Saipan Island with the oldest form, Ech. saipanicum. This species seems to have more or less intermediate features, as suggested by COOKE (1957, p. 362),. of the two living species, and may be regarded as an ancestral form of the Recent. A living species with quadrigeminate ambulacra, Ech. aciculatum, is known to occur as fossil from the Pleistocene of Fiji and Ryukyu Islands; the fact that this species has already distributed in the Pleistocene seas as widely as in the Recent may indicates its origin in the Malay region, but the exact source from which the species. evolved cannot be pointed out definitely. Another living species with trigeminate ambulacra, Ech. molare, is not known with certainty to occur as fossil, and its relation to Ech. aciculatum is obscure. The two species seem to have probably derived from a common progenitor, such as Ech. saipanicum, and developed in the Malay or East Indian region.

The genus *Anthocidaris*, is characteristic of southern Japan and China Sea and comprises only a single living species, *Anth. crassispina*, which is not known with certainty as fossil (except a doubtful form from the Miocene series of Saipan Island), and about its ancestry we know nothing. The genus, however, seems to have descended from a certain progenitor in the China Sea or its neighbourhood, taking there the flourishing condition of Recent seas.

The genus *Echinometra* dates back at least to the Miocene, including, *Ech. prisca* (once referred to *Parasalenia*) of the Anguilla limestone in the island of Anguilla, *Ech. miocenica* from the Miocene series in south Europe, and *Ech. hondoana* from the Miocene formation of northern Japan. It is the oldest genus in the family Echinome-

tridae. That the genus occurs in the Miocene series of separated localities, such as the West Indian, Lusitanitan, Japanese, and Malay (Ellipsechinus sp., JEANNET, 1935, p. 55, text-figs. 74-75) regions, implies that the genus has already well developed and widely distributed over the tropical or warm temperate regions at that time. However, the true genetic connexion among these species and their ancestry or source from which they have been derived are uncertain in the present state of our knowledge. Ech. hondoana from the Miocene of Japan has well developed generic and specific characters and resembles Ech. mathaei in the tuberculation on the interambulacra, but this species cannot be regarded as an ancestral form from which the living Ech. mathaei has been derived. The living species of the Indo-Pacific region, Ech. mathaei, is known with certainty to occur as fossil from the Pleistocene of Farsan Islands, Ishigaki-jima, and Fiji Islands of the Indo-Pacific. The species mathaei seems to have probably descended from a Miocene ancestor, such as a species reported by JEANNET as Ellipsechinus sp. from the upper Miocene of Java in the Malay or East Indian region, and distributed from the center of its development to reach the great flourishing condition of the Recent seas. A much discussed and perplexing form, Echinometra oblonga, seems to have descended together with mathaei from a common ancestor or mathaei and slightly differentiated into a subspecies (or distinct species), particularly in the eastern Pacific.

About the ancestry of the genus *Heterocentrotus* the writer knows nothing, but the Neogene strata in Madagascar have yielded an unnamed species of *Heterocentrotus*, which is the oldest record known to the writer. A living species, *Het. mammillatus*, is known to occur as fossil in the Pleistocene of Farsan Islands in the Red Sea and Ceram in the Malay region. The species seems to have descended from such a Neogene form, as that from Madagascar, originated in the East Indian or Malay region, and distributed from the center of its development to the present distribution to take flourishing condition of the Recent tropical region. Another living species, *Het. trigonarius*, which is cited with *mammillatus* by MAYR (1954) as an instance of the sympatric occurrence of sibling species, is not known to occur as fossil. The species seems to have descended either in association with *mammillatus* from a common progenitor or from *mammillatus* itself. It may have differentiated into a distinct species by the specialization of ambulacral structure and taken a smaller area of present distribution.

The genus *Colobocentrotus* seems to have descended together with *Podophora* from Echinometrid-like ancestor by the specialization of aboral radioles, the ambulacral structure, and the tuberculation on interambulacra; the genus has probably developed along a somewhat different line of development from that of *Podophora* and autochthonously in the southern Japanese region.

The family Holectypidae are represented in Japan and the adjacent regions by a single genus *Caenoholectypus*, known from the lower Cretacoues of northern Japan. *Caen. peridoneus* shows much resemblance to the following fossil species, viz., *Caen. neocomiensis* from the Aptian of France, *Caen. cenomaniensis* from the Cenomanian of France, *Caen. adkinsi* from the Fredericksburg formation (Albian) of Texas, and it seems most likely that there some genetic relation among these fossil species from Europe, Japan, and North America. The perplexing family Echinoneidae of Japan and the adjacent regions are represented by a single genus *Echinoneus*. *Ech. cyclostomus*, a highly variable and wide-spread species of the genus, is noticed by the writer in the preceding pages. The family Clypeidae are represented in Japan and the adjacent regions by a single genus *Pygurus*. Although *Pyg. asiaticus* was reported from Torinosu, Kôchi Prefecture, and TOKUNAGA (1903, p. 17) presumed its occurrence from the Cretaceous strata, its exact horizon is still unknown. This species resembles *Pyg. blumenbachi* from the Rauracian or Corallian of France and England and *Pyg. montmollini* from the Neocomian of Switzerland and France. *Pyg. complanatus* is recorded from the presumed Neocomian Ishido formation of Nagano Prefecture, and resembles to some extent *Pyg. impar* from the upper Neocomian of Algeria. The resemblance among the two Japanese species and the European and Algerian species seems to indicate probable genetic connexion among them.

The family Cassidulidae are represented in Japan and the adjacent regions by a single genus *Cassidulus*, to which an Eocene species is presumedly referred. '*Cassidulus*' yoshiwarai is known from the Eocene series of Bonin Islands and provisionally referred by the writer to the genus *Procassidulus*. This species resembles *Rhynchopygus lapiscancri* in its general features, but the former has a monobasal apical system, while the latter tetrabasal one.

The family Echinolampadidae date back to the Cenomanian, in the Eocene they developed there explosively into a great number of species, continued with an almost equally great number through the Oligocene and Miocene, and then decrease rather considerably in number, while in the Recent seas they are rather poorly represented, no less than 10 species being known hitherto. Although the Echinolampadidae have been derived either from the Nucleolitidae, as suggested by MORTENSEN (1948-a, p. 269) and KIER (1962, pp. 18-19), or from the Cassidulidae, as shown by DURHAM and MELVILLE (1957, p. 266, text-fig. 9), they seem to represent a most highly specialized type of the Cassiduloida. The family is represented in Japan and the adjacent regions by a single genus Echinolampas. Echinolampas starts in the Eocene and comprises very numerous fossil forms (no less than 285 species) of world-wide distribution. Ech. bombos is known from the Eocene (Eorupertia-Alveolina zone) of Bonin Islands, the oldest known horizon for the occurrence of *Echinolampas* in Japan and the adjacent regions. This species resembles Ech. novae-hollandiae, from the Oligocene of Australia, and Ech. sphaeroidalis, from the Oligocene or Miocene of India. It is also superficially similar to Pseudopygaulus antecursor from the Ranikot series of western Sind. Although the true genetic connexion of this species with other fossil species is obscure in the present state of our knowledge, the occurrence from the Eocene of Bonin Islands seems to suggest that this species may represent the radical stock of of the Oligocene or Miocene species of the East Indian, Australian or Malay regions, as is mentioned above.

Ech. oviformis jacquemonti is reported from the Miocene Nanko formation of Formosa (Taiwan) and the occurrence of this subspecies indicates that Formosa had marine connexion with the Indian Ocean or with the Malayan waters at that time; the fossil subspecies seems to have given rise to the living *Ech. oviformis* of the East Indian and Malay regions. *Ech. yoshiwarai* (with *Ech. concavus*), the charac-

teristic Miocene species of Japan, occupies nearly the same geological horizon as or a little higher than, the *Miogypsina-Operculina* zone in Japan. The living species, *Ech. alexandri*, is known to occur as fossil from the Pliocene of Java and the Pleistocene of Tokuno-shima; this species closely resembles the fossil species, *Ech. subangulata* and *elevata* from the upper Miocene of the Malay region, and it can be assumed that the species has descended from the Malayan or East Indian Miocene species and distributed from the center of its development to the present areas since the Pliocene epoch. *Ech. koreana* is known only from the Sea of Japan, but not known with certainty to occur as fossil; the species closely resembles *Ech. yoshiwarai* and seems to have been derived from that species and have probably developed autochthonously in the Japanese region, particularly in the Sea of Japan. *Ech. sternopetala* is only known from the Japanese seas on the Pacific side and closely resembles *Ech. keiensis* from the Kei Islands. The two species seem to have developed from a certain progenitor along somewhat different lines of development and differentiated into distinct species (or subspecies), the allopatric.

The Pliolampadidae are represented in Japan and the adjacent regions by the three genera, *Gitolampas*, *Oligopodia*, and *Studeria*. *Git. sendaica* is known from the Miocene of northern Japan and seems to resemble the following species, viz.. *Git. scutella* of Europe, *Git. wrighti* of Europe, and Git. *intermedia* of western Sind, India. Thus, it is asumed that there was genetic relation among these fossil species of Europe, India, and Japan. The genus *Oligopodia* from Japan and the adjacent regions is represented by a living species *Olig. epigona* known from the Bonin Islands, but not known with certainty to occur as fossil. The species seems to be a recent type and has probably originated in the Malay region. *Studeria okinawa*, from the Pliocene and Miocene of Java, but the true genetic connexion of them is obscure.

The puzzling family Neolampadidae are represented in Japan and the adjacent regions by a single living genus *Anochanus*, which comprises only a single species, *An. sinensis*. This species is said to be known from the China Sea, but the genetic relation to other genera, such as *Aphanopora* of the Malay and *Tropholampas* of the South African region, is quite obscure in the present state of our knowledge.

The family Clypeasteridae of Japan and the adjacent regions are represented by a single genus *Clypeaster*. A fossil species, *Cl. saipanicus*, one of the oldest species, is known from the Miocene (*Eulepidina-Spiroclypeus* horizon) of Saipan Island. This species is closely relates to *Cl. pulvinatus* from the Gaj series of western Sind on one hand, and also to *Cl. reticulatus*, the living as well as fossil species of the Indo-West Pacifc, on the other hand. It seems probable that there would be a genetic relation among these species. *Cl. reticulatus* seems to have originated in the Malay or East Indian region, probably has descended from the Oligocene or Miocene ancestor, and distributed from the center of its development to the present area since at least the Pliocene. *Cl. humilis* seems to have originated in the Malay or East Indian region was probably derived from the Oligocene or lower Miocene progenitor, e.g., *Cl.* cf. *humilis* (JEANNET and MARTIN, 1937, p. 243), and distributed from the center of its distribution to the present area. *Cl. japonicus*, a characteristic species of the Japanese region, seems to be rather recent type and has more southward distribution in the Pleistocene than the present day. Another living species, *Cl. virescens*, although originally described from Japan, has a larger area of distribution than *Cl. japonicus*, seems to have genetic relation to some extent with the species of the East Indian and Malay region, e.g., *Cl. complanatus* and *Cl. sladeni*, and has probably descended from the Miocene ancestor in the Malay region and distributed from the center of its development to the present area. It is not certain whether the resemblance between the living *Cl. ohshimensis* of the western Pacific and the Oligocene *Cl. corvini* of the Lusitanian region, in the presence of the bourrelets-like warts indicate a genetic connexion of them or a parallel development by covergency, and about the ancestry of these species we know nothing.

The family Arachnoididae are represented in Japan and the adjacent regions by a single genus *Arachnoides*. *Ar. placenta* is known to occur as fossil from the Pliocene and Quaternary of Java and Billiton Island, but not known from Japan and the adjacent regions. The species seems to have descended from the Miocene ancestor, such as Monostychiid-like form, by specialization of the ambulacra on the ambulacra on the aboral side but rather retardation of the periproct, probably originated in the Malay region.

The family Fibulariidae are represented in Japan and the adjacent regions by the following genera, viz., Sismondia, Echinocyamus (with subgenus Mortonia), and Fibularia (with subgenus Fibulariella). Sis. convexa from the Miocene of the island of Pell, Bonin Islands, Sis. javana ladronensis from the Miocene (Eulepidina-horizon) of Mariana Island, and Sis. javana from the "Older Miocene" of west Mountains in Java, seem to be closely related and can be regarded even as conspecific with one another, but are discriminated from one another in minor differences. They may have flourished in the warm sea. Ech. crispus seems to be of the recent type and about its ancestry we have no definite knowledge at present. Ech. prostratus so closely resembles Ech. crispus that it seems to represent only a varietal form of that species and it has probably developed recently in association with Ech. cirspus or descended from that species in the North China Sea. Ech. provectus is not known with certainty as fossil, but its related species, Ech. scaber, is reported as fossil from the Pleistocene of Ceram; the two species have probably originated in the Malay region.

The systematic position of *Mortonia* has been much disputed. H. L. CLARK (1925, pp. 162-163) regarded it only as a synonym of *Fibularia*, MORTENSEN (1948-b, p. 196) assigned it as a subgenus of *Echinocyamus*, while DURHAM (1955, p. 134) separates it as a distinct genus from *Fibularia* and *Echinocyamus*. A living species, *Ech. (Mortonia) australis*, is widely distributed over the West Pacific, but not known with certainty as fossil; the species seems to be of very recent type, but about its ancestry we know nothing.

Fib. ovulum is known to occur as fossil from the Pleistocene of Farsan Islands, Red Sea (BRIGHTON, 1931, p. 326, text-fig. 1), but not known from Japan. Fib. ovulum trigona is known to distribute over the West Pacific, but not known with certainty as fossil. The subspecies seems to be of the recent type and have migrated from the center of its development to the present area. Fib. cribellum is distributed over the Malayan waters and also known to occur as fossil from the Pleistocene of Kikai-jima, northern Ryukyu Islands, and Ceram. This species seems to have originated in the Malay region and distributed more northwards in the Pleistocene than in the Recent. *Fib. (Fibulariella) acuta* seems to have evolved from a certain Fibulariid-ancestor of the Miocene epoch and has probably developed autochthonously in the Japanese region since the Pliocene.

The family Laganidae are represented in Japan and the adjacent regions by the following genera, viz., Laganum, Hupea, and Peronella. Lag. depressum is known to occur as fossil from various localities, viz., the Pliocene of Egypt, Zanzibar, east coast of Africa, Java, Fiji Islands, and the Pleistocene of Farsan Islands, Billiton Island, and in Japan and the adjacent regions it is known with certainty from the Pliocene formation of Formosa and the Pleistocene of Kikai-jima, Ryukyu Islands. The forms from the Pliocene formations, particularly the Formosan specimens, seem to be smaller in size than the living, and resemble Lag. multiforme from the Miocene series of Java and Borneo; the resemblance between the two species probably indicate the genetic connexion between them. Lag. depressum seems to have evolved from Lag. multiforme or its ally of the older geological age, originated in the Malay or East Indian region, and distributed from there to the present area since the lower Pliocene; it seems, however, evident that the species distributed more northwards in the Pliocene and Pleistocene than in the Recent. Lag. pachycraspedum is known from the Miocene formation of central Japan. The strong resemblance of this species to the two species, Lag. laganum and depressum, now inhabiting in the tropical or subtropical regions seems to indicate that the sea-water temperature of central Japan at that time was decidedly warmer than the present day, and to suggest that this species has genetic connexion with the two species, particularly with Lag. laganum, but has left no descendants. Laganum laganum is known to occur as fossil from the upper Miocene and Pliocene of Java and seems to have descended in association with Lag. depressum from common an ancestor (e.g., Lag. multiforme-like form) and differentiated into different species by parallel line of development, and then distributed from the center of its development to the present area since the upper Miocene. Hupea decagonalis is known to occur as fossil from the upper Miocene of Java and the Pliocene of Philippines; about its ancestry we have no definite knowledge, but the species seems to have originated in the Malay region and developed there since the upper Miocene. Lag. boninense is known only from the Bonin Islands and seems to be a recent type. It seems probable that this species has been derived recently from Lag. depressum or its ally of the older geological occurrence, the allopatric, and has developed in the southern part of the Japanese region.

Lag. fudsiyama seems to have descended from a certain ancestor of the older geological age and developed particularly in the southern part of the Japanese region. The two fossil subspecies, tokunagai from the Miocene of central Japan and untenensis from the Pliocene of Okinawa, strongly resemble the living species. This seems to indicate the genetic connexion among them, but about the ancestry of these fossils we have no definite knowledge. Lag. putnami is known only from Amami-Ôshima in Ryukyu Islands, but not known with certainty as fossil. It is very interesting to note that in this species the genital pores are far removed from the apical system. This peculiar feature is only found in certain species of separated genera, as in *Peronella peronii* besides *Lag. putnami* and the feature, most probably, does not imply a genetic connexion between them. *Lag. putnami* seems to be of a recent type and about its ancestry we know nothing.

Per. lesueuri, one of the most common species of the genus in the Malay region, is known to occur as fossil from the Malay region, viz., the upper Miocene of Java, Pliocene of Java, New Guinea, and the Philippines, and the Quaternary of Billiton Island, but not known with certainty from Japan and the adjacent regions. The species seems to have evolved from a certain progenitor of the lower Miocene in the Malay region and have developed there since the Miocene epoch. *Per. pellucida* is known with certainty from the Japanese Seas and also known to occur as fossil from the Pleistocene of Kikai-jima, northern Ryukyu Islands. This species seems to have developed in association with *Per. rubra* from common ancestor and differentiated into two distinct species (or subspecies) in the northwestern Pacific. *Per. japonica* is known with certainty only from the Japanese Seas and also known to occur as fossil from the Pleistocene of central Japan; the species has probably been derived from the Malayan *lesueuri*-like progenitor of the Miocene epoch and has developed autochthonously in the Japanese region.

Per. rubra is known with certainty also only from the Japanese Seas, but not known as fossil and seems to be a recent type; the species has probably developed in association with *Per. pellucida* and differentiated recently into a distinct species (or subspecies) in the Japanese region. *Per. orbicularis*, one of the distinctive species of the genus, seems to be a recent type, and is not known with certainty as fossil. About its ancestry we have no definite knowledge excepting that it has some resemblance with *Per. lesueuri* of the older geological occurrence. *Per. minuta* is known formerly from the Sulu Archipelago, but now a day from Tanabe Bay, Japan, and the Philippines; the species seems to be a recent type. *Per. (Peronellites) ovalis* is recorded from the Miocene Kanshirei formation of Formosa, and it is interesting to find that the same character of vaulted apical system as well as the proximal ends of petals occurs in two separated genera, *Peronella* (if this species were really referred to) and *Laganum*, in almost the same gelogical age.

The family Scutellidae are represented in Japan and the adjacent regions by a single subfamily Dendrasterinae; the subfamily of Japan comprises the following genera, viz., Kewia, Echinarachnius, Scaphechinus, Allaster, and Pseudoastrodapsis. The genus Kewia, although MORTENSEN (1948-b, p. 365) doubted its generic or sub-generic validity, is recognized by DURHAM (1955, p. 164) and the writer as a well-marked genus. The genus on the northwestern side of the Pacific is probably close to the ancestral radicle of the more specialized genera, e. i., Echinarachnius and Scaphechinus, and comprises at least four fossil species from Japan and the adjacent regions;— Kew. parva from the upper Oligocene of South Sakhalin, Kew. nipponica from the upper Oligocene of Kyushu, Kew. elongata from the Miocene of South Sakhalin, Kew. minoensis from the Miocene of Nagano, Aichi, Kyoto, Nara and Yamaguchi Prefectures, and Kew. ugoensis from the Miocene of Yamagata Prefecture. The probable relationships of these fossil species are briefly discussed by the writer in Chapter IV of this article, but about their ancestry we know nothing.

The genus Echinarachnius dates back to the Miocene and ranges to the Recent of,

in the main, the North Pacific, particulary Japan and its north region. The probable relationships of the fossil species, viz., microthyroides, subtumidus, naganoensis, humilis, ishioi, rumoensis, and laganolithinus, are briefly discussed by the writer in Chapter IV of this article. Ech. parma, the type-species of the genus, has a discontinuous distribution as a living form, while it is not known with certainty from Japan and the adjacent regions; but, fossil specimens conferable to this species are known from the Pliocene formations of Niigata and Toyama Prefectures. They are evidently and most closely related to the living species, but differ, in some degree, from the typical parma from the east coast of North America. By considering the wide range of variation in Ech. parma, the fossil specimens from Japan should be referred to the living species, though with some uncertainty. It is very interesting that Ech. parma or its close ally, that may be regarded as the direct progenitor of the living parma and parma obesus, flourished in the Pliocene of the Japanese region and then has vanished there, particularly in central Japan. Ech. parma obesus is distributed in the Recent from Kamtchatka to east the coast of northern Japan through the east coast of Sakhalin and Hokkaido, and the fossils that are conferable to it are known from the Pliocene of North Sakhalin. This form probably represents a descendant of the main *parma*-stem and is not a direct descendant of the Miocene *Ech. subtumidus*. a superficially related one. Ech. asiaticus, another living species of the Asiatic coast, seems to be a recent type and may have descended together with Ech. parma obesus from the same stock (the main *parma*-stem).

The genus *Scaphechinus* should be regarded as representing the ultimate stage in morphological development of the North Pacific *Echinarachnius*-stock, but not as the descendant of the European *Scutella*. MORTENSEN (1948-b, p. 374) and DURHAM (1955, p. 162) regarded it as a distinct genus separated from *Echinarachnius* or *Scutella*. It is a typical Japanese echinarachniid and ranges from the Mio-Pliocene or Pliocene to the Recent. The fossil species, viz., *raritalis, tsudai*, and the living species that are also known to occur as fossil, viz., *mirabilis* and *griseus*, are described and noticed by the writer in Chapters IV and V of this article. *Scaph. brevis* seems to have descended in association with *Scaph. griseus* from *mirabilis* of the older geological age along somewhat different line of development from that of *griseus* by specialization of the ramification of oral ambulacral furrows and the radioles. The difference of growth rate between *mirabilis* and *griseus*-brevis probably indicates the difference of stages in the evolutionary trend.

The genus Allaster may be regarded as more primitive than Pseudoastrodapsis in the depressed apical system and thick margin and form of the test, and from such a primitive form some species of Pseudoastrodapsis may have sprunfi off. It seems evident that the genus differs phylogenetically from the Californian genus Remondella that has some resemblance with Kewia and is regarded as a side branch of the stock that produced Astrodapsis of the Californian Neogene. The fossil genus Pseudoastrodapsis of Japan and the adjacent regions is described and noticed by the writer in the Chapters IV and V of this article.

The family Astriclypeidae are represented in Japan and the adjacent regions by a single subfamily Astriclypeinae. The subfamily is characterized by having lunules or slits in the ambulacra, at least in the postero-lateral ones, but none in the posterior interambulacrum, and three-valved pedicellariae. It comprises two genera Echinodiscus (with subgenus Amphiope) and Astriclypeus. The origin of Echinodiscus (Amphiope) is obscure. If a Scutella-like form of the late Tethys Sea, which has large, discoidal test, and branching oral ambulacral furrows, acquired two postero-lateral ambulacral lunules, it could approach the form of Echinodiscus (Amhiope). Unfortunately, however, as the genus Scutella has no living representatives, the pedicellariae of that genus are not known, and hence it is not certain whether it has three-valved pedicellariae as in Echinodiscus or has another kind of pedicellariae. Ech. tenuissimus is distributed from the Indian Ocean to Indo-China and also reported from southwestern Japan (MCZ 2372-Ousina, Japan); the species seems to be a recent type, probably derived from a fossil progenitor of the East Indian or Malay region and distributed from the center of its development to the present area during the young geological age. Ech. auritus siamensis is distributed, in the Recent from the Indian Ocean to the Malay region and to as far north as southwestern Japan, and is also known to occur as fossil from the Malay region, viz., the Pliocene of the island of Aru (CURRIE, 1924, p. 66) and the Pliocene and Pleistocene of Java (JEANNET and MARTIN, 1937, p. 266). The subspecies seems to have descended from a certain ancestor in the Malay region and migrated from the center of its development to the present area since the Pliocene epoch. Ech. (Amphiope) formosus, from the Miocene of Formosa and Ryukyu Islands, seems to have a genetic connexion with Ech. (Amphiope) placenta, from the Miocene of India, and probably differentiated into a distinct species during the early Miocene in the southern area of the Japanese region.

The genus Astriclypeus is described and its development is discussed by the writer in Chapters IV and V of this article. Ast. mannii, the living representative of the genus, is known with certainty to occur as fossil from the Pliocene of Formosa and Kôchi Prefecture and the Pleistocene of Ryukyu Islands. This species seems to have descended directly from a Miocene fossil progenitor by the specialization of characters and has developed autochthonously in the Japanese region and neighbuuring area since the Pliocene epoch.

The Holasteridae are represented in Japan and the adjacent regions by the following genera, viz., Holaster, Cardiaster, and Stereopneustes. Hol. clypeatulus, from the lower Cretaceous of Iwate Prefecture, northern Japan, is similar to Hol. laevis from the Albian of Europe and Hol. simplex from the Fort Worth formation of Texas; although the true genetic connexion of this species to the other species from Europe and North America is obscure, the occurrence of this species in northern Japan is noteworthy. Card. perorientalis, from the Senonian of Ehime Prefecture, Shikoku, is very similar to Card. orientalis from the Senonian of southern India; it seems probable that there existed a genetic connexion between the Japanese and the Indian species and the occurrence of this species from Japan offers data concerning the geographical distribution of the genus and geological correlation of the strata between the two regions. The genus Stereopneustes, one of the living genera of the Holasteridae, with a single representative Ster. relictus, is known from the Malay region and distributed as north as to southern Japan (off Kagoshima Gulf-MCZ no. 1023), but not known with certainty as fossil, and seems to be a recent type. Although the source of this species is uncertain, the species seems to have descended from a certain ancestor in the Malay region and distributed from there to the present area during the very young geological age.

The family Urechinidae, which comprise only recent forms, probably derived from the Holasteridae of the older geological occurrence, as stated by MORTENSEN (1950-a, p. 106) and demonstated by DURHAM and MELVILLE (1957, text-fig. 9 on p. 266). The family is represented in Japan and the adjacent regions by a single genus *Urechinus*. The two species of the genus, *Ur. loveni* and *naresianus*, the former with certainty and the latter with some doubt, are known from the northern Pacific (Bering Sea and Ochotsk Sea) in the deep sea; the former is also known to distribute from Lower California to Acapulco, and the latter is recorded from separated localities, viz., North Atlantic, Central Atlantic, Cape of Good Hope, South Indian Ocean, and off the coast of Chile. Although we must acknowledge that little is known of the ancestry of these species, their distribution and relation offer an interesting problem on the phylogeny of the echinoids, and future elucidation of their origin and development is expected.

The family Pourtalesiidae seem to include the most bizarre and the highly specialized sea-urchins and are little known to many echinologists owing to their occurrence in deep water and the great fragility of their tests. MORTENSEN offered his idea that the very unusual form of the Pourtalesiidae makes difficulty in seeing their source in the other Urechinoina but in the writer's opinion they have probably been derived from the Holasteridae. The family is represented in Japan and the adjacent regions by a single genus *Pourtalesia*; the species of the genus are known to have wide distribution and seem to be of recent type. *Pourt. laguncula* is distributed over the West Pacific, from the Malay region to the Philippines and as far north as to Sagami Sea, central Japan (MCZ no. 2776), but not known with certainty as fossil. About its ancestry we know nothing, but it seems to have originated recently in the Malay or the southern part of the Japanese region and has migrated from there to the present area.

The family Palaeopneustidae, one of the most primitive groups of the Spatangoina, the limitation of which seems to be unsatisfactory, range from the Senonian to Recent and comprise a large number of living as well as fossil genera of various forms. The family is represented in Japan and the adjacent regions by the following seven genera, viz., Niponaster, Palaeopneustes, Linopneustes, Argopatagus, Platybrissus, and Palaeotrema. Although Niponaster was it is formerly referred by LAMBERT and THIÉRY (1924, p. 426) and MORTENSEN (1950-a, p. 169) to the family Stenonasteridae, it is now clear that the genus should be referred to the Palaeopneustidae in the structure of plastron and general form. The genus is represented by two species from the Senonian of Japan, one is Nip. hokkaidensis from Hokkaido and Awaji Island and the other Nip. nakaminatoensis from the Nakaminato formation of Ibaraki Prefecture. Although about their ancestry we know little, the two species seem to have originated in the Japanese region at that time and differentiated from a stock into two distinct species. It is interesting to the writer that these rather specialized forms (excepting the apical system that shows ethmophractic character) appeared as old as the Senonian epoch.

The genus Palaeopneustes, with a single living representative Pal. cristatus which

is known only from the West Indian region, ranges from the Miocene to Pliocenein the northwestean Pacific and to Recent in the West Indies. So far as the fossil evidence is concerned we know little about the source from which the genus Palaeopneustes has been derived. However, one of the possible courses is that the genus may have descended from the Senonian Niponaster of Japan, although there lies a great hiatus of time between the geological occurrence of the two genera, by the specialization of the frontal ambulacrum from undifferentiated one, ethmolytic apical system from ethmophractic one, and the reduction of tubercles of the postero-lateral ambulacra on the oral surface from tuberculated areas. The genus originated in the northwestern Pacific and there was probably the center of its development, but the West Indian living species seems to be a descendant of immigrant from the Pacific side. The Japanese fossil species of the genus have closer relationships, in general features, to the West Indian living species than to any other known forms, but the fossil species, as a whole, differ from the type-species in possessing longer poriferous zones in the ambulacra and in the less elevated test. Four fossil species, viz., lepidus from the Miocene of Ishikawa Prefecture, periturus from the Pliocene or Mio-Pliocene of Chiba Prefecture, psoidoperiodus from the Pliocene of Fukushima and Niigata Prefectures, and Pal. (Oopneustes) priscus from the Miocene of Miyagi Prefecture, are described and discussed by the writer in Chapter IV of this article. It can scarcely be doubted that these fossil species are closely related to one another with a genetic connexion but their true interrelationships are obscure in the present state of our knowledge. Pharaonaster japonicus, known only from the Tertiary formation of Wakkanai in Hokkaido, is similar to, in its general features, *Phar. ammon* from the Eocene of Egypt, particularly in the feature of interporiferous zone, the apical system, and in the peripetalous fasciole. It is interesting to see a similarity between the two species of much separated areas.

The two living species of the genus *Linopneustes* are known from Japan and the adjacent regions; *Lin. murrayi* being distributed from the Japanese Seas to the Philippines and Malay region and *Lin. fragilis* from the Japanese Seas to the Philippines and Celebes. These two species together with *Lin. spectabilis* of the Malay region are not known with certainty as fossil, and it seems probable that these species have probably descended from a certain progenitor and differentiated rather recently into three species in the Malay and the Japanese regions.

The genus Argopatagus seems to be of recent type as it is not known with certainty as fossil. Two living species of the genus are known from Japan and the adjacent regions; Arg. vitreus is distributed from Arafura Sea and Banda Sea to as far north as central Japan and Arg. planus is known only from the southwestern Japan (off Kagoshima Gulf). The origin of these two species is obscure in the present state of our knowledge. The genus Platybrissus comprises a few number of species and is known to occur as fossil from the Fiji Islands. Plat. roemeri, one of the living species of the genus, is distributed from the Banda Sea to as north as the western Sea of Japan and not known to occur as fossil. This species in association with Plat. ellipticus of the South Sea region seem to have descended from a common ancestor in the South Sea or Malay region and differentiated into two species in these regions.

The genus *Palaeotrema*, a peculiar form of the Palaeopneustidae, comprises only
a few number of species and is not known as fossil. *Pal. loveni* is known to distribute from the Japanese Seas to the Philippines, but not known to occur as fossil. The species seems to have originated in the Malay or the southern part of the Japanese region, but about its ancestry we know nothing.

The family Palaeostomatidae are probably related to and derived from the family Toxasteridae, as suggested by MORTENSEN (1950-a, p. 311), and this idea of derivation is also demonstrated by DURHAM and MELVILLE (1957, text-fig. 9 on p. 266); the family dates back to the Senonian with fossil genera of some uncertainty and ranges to Recent, and comprises a small number of genera. The family is represented in Japan and the adjacent regions by a single genus *Palaeostoma*. The genus *Palaeostoma* is maintained for the single living species *Pal. mirabile*, whose extraordinary peristome excludes it from all other families. This species is known to be distributed from the Java Sea and the Philippines to as far north as Ryukyu Islands. At present we must confess our ignorance of its true genetic relations and derivation of this peculiar form.

The family Aeropsidae seem to represent, as suggested by MORTENSEN (1950-a, p. 326) and DURHAM and MELVILLE (1957, text-fig. 9 on p. 266), a special small branch of the Spatangoina of unknown origin, and date back to the upper Cretaceous and range to Recent, comprising a small number of fossil and living genera. The family is represented in Japan and the adjacent regions by the genera Aceste, and Cottreaucorys (with subgenus Cordastrum) as incertae sedis. The genus Aceste, one of the deep-sea forms, seems to be a recent type and not known with certainty as fossil. Ac. ovata is known to be distributed from the Hawaiian Islands to Sunda Sea and as far north as to southwestern Japan in rather deep-sea, but about its ancestry the writer knows nothing. Cottreaucorys (Cordastrum) sulcatus, from the Senonian of Ehime Prefecture in Shikoku, differs from Cott. blayaci, besides the characters of subgenus, in the shorter primordial interamblacral plate, the wider sternal plates, and in supramarginal position of the periproct. The resemblance between the two species, sulcatus and blayaci, in general appearance, suggests that there may be to some extent genetic connexion between them.

The family Toxasteridae are noticed generally by absence of fascioles. This enables us to regard the family as primitive forms of the Spatangoina, which accord with their occurrence in the oldest geological time. The family ranges from the upper Jurassic to the Recent, comprising a considerable number of fossil genera and a surviving genus *Isopatagus* of the Philippines. In Japan and the adjacent regions the family is represented by the following five genera, viz., *Toxaster, Aphelaster, Allotoxaster, Heteraster* (with *Enallaster*), and *Paraheteraster. Toxaster sanchuensis*, from the Neocomian of central Japan, resembles the Neocomian species from the circum-Mediterranean region, such as *Tox. peroni, gibbus*, and *collegnoi*, and seems to have to some extent a genetic connexion with those species. *Aphelaster serotinus*, a characteristic species from the Barremian of Nagano, Wakayama and Tokushima Prefectures, can be regarded as more specialized form than the type-species, *Aph. integer*, of the Hauterivian, as might be expected for a later representative of the genus.

Allotoxaster tosaensis, from the Torinosu Limestone of Kôchi Prefecture, is des-

cribed and discussed by the writer in Chapter IV of this article; this species may be separated both from Tox. retusus and Aphel. integer as a distinct form that maintains a distinct genus. No less than three species of the genus Heteraster are known to the Japanese Cretaceous system, viz., Het. nexilis from the Barremian or Neocomian of Tokushima, Wakayama, Nagano, and Gunma Prefectures, Het. yuasensis from the Barremian and Neocomian of Wakayama and Gunma Prefectures, Het. cf. obliquatus from the Barremian and Albian of Wakayama and Kumamoto Prefectures, and Het. cf. boehmi from the Barremian and Albian of Wakayama and Kumamoto Prefectures. Among them the two Albian or rather Aptian species, Het. obliquatus and boehmi (a doubtful species—COOKE, 1955, p. 106) originally known from North America and Honduras, occur also in the Barremian of Japan. If their identification is correct, it offers an interesting problem on the evolution, disperal, and migration of the echinoid fauna. The three species of the genus Paraheteraster, viz., macroholcus from the Barremian or Neocomian of Wakayama and Gunma Prefectures, barremicus from the Barremian of Wakayama Prefecture, and *japonicus* from the Albian of Kumamoto Prefecture, are described and discussed by the writer in Chapter IV of this article. The genus Paraheteraster, in its general features, seems to have closes relation, as claimed by TANAKA (1965, p. 133), to the genus Heteraster than to Washitaster of the American Albian genus. The superficial resemblance between Paraheteraster and Washitaster may not indicate the genetic relation but the 'parallelism'.

The family Hemiasteridae range from the lower Cretaceous (Aptian) to Recent and comprise a considerable number of fossil and a small number of living genera. The family is represented in Japan and the adjacent regions by a single genus *Hemiaster* which comprises both fossil and living species. *Hem. uwajimensis*, from the Senoian of Ehime Prefecture, resembles *Hem. similaris* from the Senonian of southern India, but the true genetic connexion between the two species is not certain. *Hem. expergitus gibbosus*, a subspecies of the Atlantic *expergitus*, is known to be distributed from the Malay region to the Japanese Seas, and seems to have differentiated from original species into distinct subspecies in the Malay region, but about its true ancestry the writer knows nothing. *Hem. clarki*, a northern form of the genus, is known only from the northern part of the Sea of Japan, but not known with certainty as fossil. The species seems to have descended from fossil ancestor of Japan, by specialization in the structure of the apical system and in the oral interambulacra, and have developed autochthonously in the Japanese region.

The family Spatangidae are represented in Japan and the adjacent regions by a single genus *Spatangus. Sp. pallidus* is known only from the Japanese Seas and also known to occur as fossil from the Pleistocene of Chiba Prefecture. This species seems to have descended from a fossil ancestor and developed in the Japanese region. An unnamed fossil species is known from the Pliocene Koshiba formation of Kanagawa Prefecture. Although the aboral features are more or less obscure, in its general characters this fossil seems to represent the radical stock that produced the living species of the Japanese region.

Sp. luetkeni is known only from northern Japan, but not known with certainty as fossil. The species seems to have probably descended in association with Sp. pallidus from the fossil ancestor of Japan and differentiated into a distinct species in the northern part of the Japanese region. *Sp. altus* is known only from the China Sea, but not known as fossil; about its ancestry the writer knows nothing, but it seems evident that this species has a close relation to the two Japanese species. *Sp. (Granopatagus) paucituberculatus* is known to be distributed over the Indo-West Pacific, but not known with certainty as fossil.

The family Maretiidae are regarded by MORTENSEN (1951, pp. 6, 21) as a subfamily of the family Spatangidae, while DURHAM and MELVILLE (1957, p. 266) entitle them as a distinct family without mentioning reason, but they demonstrate that the family is related with the Loveniidae and Spatangidae. The family is represented in Japan and the adjacent regions by the two genera Maretia and Pseudomaretia. Maretia planulata is known to live in the Indo-Pacific and also known to occur as fossil from the following localities and geological horizons, viz., the upper Miocene of Java, the Pliocene or Pleistocene of Farsan Islands in the Red Sea, East Africa, Zanzibar, Java, Borneo, and Angaur Island in Micronesia. The species seems to have originated in the Malay or East Indian region and distributed from the center of its development to the present area since the upper Miocene or lower Pliocene epoch. Mar. tuberculata is known only in the Korean Straits, but not known with certainty as fossil, and thus about its ancestry the writer has no evidence. Pseudomaretia *alta*, one of the Indo-West Pacific and the oldest known species, is known to be distributed from the Indian Ocean (Ceylon, Mauritius) to the Japanese Seas, as far north as Sagami Sea, but not known as fossil.

The family Loveniidae range from the Eocene to the Recent and comprise a small number of distinct genera, which in Japan and the adjacent regions are represented by the following genera, viz., Lovenia, Breynia, Pseudolovenia, and Echino-.cardium. Lovenia elongata, a widely distributed and common species of the genus, is known to distribute widely over the Indo-West Pacific, but not known with certainty as fossil. The species seems to have probably descended from a fossil ancestor (such as Lov. madurae from the upper Miocene of Madura Island) in the Malay or East Indian region and been distributed from the center of its development to the present area. Lov. gregalis is known to be distributed from the Indian Ocean (Bay of Bengal) to the Malay region and to southwestern Japan, but not known as fossil. Lov. subcarinata is known to be distributed from the east coast of Africa to Hongkong, particularly common in the Java Sea and also in the Gulf of Siam, but the occurrence from Kagoshima Gulf is doubtful, and not known to occur as fossil. Lov. triforis is distributed from the Bay of Bengal to Kei Islands and to western Japan (off Goto Islands), and must be supposed to have its center of distribution in the Malay region, but not known with certainty as fossil.

The genus *Breynia* dates from the Oligocene and comprises about ten fossils of the Indo-Malay region (one from the circum-Mediterranean countries) as well as the living species, which are known with about five species. *Br. carinata*, a characteristic and common Oligocene and lower Miocene species in India, is recorded from the Miocene Nankô formation of Formosa. It seems highly probable that this species represents a radical stock that has given rise to some of both the younger fossil and living species of the Indo-Malay region. *Br. cordata*, from the Pliocene of Formosa, has undoubtedly affinity with, in the general appearance and in the number of porepairs within the subanal fasciole, *Br. carinata*, on one hand, and with the undescribed living species of the Pacific Ocean (MORTENSEN, 1951, p. 131), on the other hand. *Br. testudinaria* is known from the Pliocene Byôritsu formation of Taiwan (Formosa) and seems to be distributed northwards as far as Kôchi Prefecture. This species. seems to represent a side-branch of the main *Br. carinata*-stem.

Echinocardium cordatum, a very variable and remarkably wide-spread species of the genus, is described and noticed by the writer in Chapters IV and V of this article. *Ech. lymani* is known only from the Japanese Seas (central and northern Japan) in moderate depths, but not known with certainty as fossil; the species seems to be a recent type and about its ancestry the writer knows nothing.

The family Pericosmidae date back with certainty to the Eocene and only a single genus *Pericosmus* can certainly be referred to them. *Per.* cf. *spatangoides*, conferred to the Eocene species of the Lusitanian region, is recorded from the Oligocene Taishu group of Tsushima. It is noteworthy that the Palaeogene Pericosmid that has some resemblance with the European Palaeogene as well as the Miocene species, i. e., *peltatus* of the Lusitanian, granulosus of the Malay, and magnificus of the Japanese region, has already existed in the Palaeogene of Japan. *Per. magnificus*, from the Miocene Ajiri formation of Miyagi Prefecture, resembles to some extent the living *Per. macronesius* and *tenuis* of the Indian Ocean, on one hand, and also has some relation to the Palaeogene form (*Per.* cf. *spatangoides*) from Tsushima, on the other hand. It seems probable that the species has to some extent a genetic connexion to one or two of these species. An indeterminable species from the Miocene formation of Formosa resembles *Per. maginificus*, and seems to have a relation to the Miocene species of Japan and also of the Malay region. This is noticeable, since Formosa is situated in the intermediate area between the two regions.

Per. cordatus is known only from western Japan (near Goto Islands), but not known with certainty as fossil. The species apparently bears some relation to the Miocene species (i.e., *Per. magnificus*) of Japan, has probably descended from that or allied form, and is developed autochthonously in the Japanese region. *Per. melano-stomus* is known to occur from Sunda Strait and Java Sea to China Sea (near Hong-kong), but not known as fossil. This species apparently bears no relation to any known fossil species of the Pericosmids from the Malay region, and it seems to be a recent type, but about its ancestry the writer knows nothing.

The family Schizasteridae date back to the Cenomanian and comprise a large number of Recent and a considerable number of fossil genera. The family is represented in Japan and the adjacent regions by the following genera, viz., Paraster, Prenaster, Linthia, Faorina, Brisaster, Cagaster, Schizaster, Aplospatangus, Hypselaster and Moira (with subgenus Moiropsis). Paraster nummuliticus, from the Eocene of Bonin Islands, resembles Par. gibberulus, a living species of the Indian Ocean and Red Sea, in the course of peripetalous fasciole and the position of peristome. Although LAMBERT and THIERY stated on this species, as "semble une souche des formes actuelles", about its relation to other fossil species the writer has nothing to explain. Prenaster boninensis, from the Eocene of Bonin Islands, has close relations to the following Eocene species, viz., alpinus of Lusitanian, arabicus of Arabia and oviformis of India, and there may be genetic connexions among them.

The genus Linthia ranges from the Senonian to Pliocene and comprises some 70 fossil species of various forms from widely separated localities. The Japanese Miocene and Pliocene species differ in the features of the petals and the fascioles from the typical Eocene species of the Lusitanian. A living species that seems actually to belong to this genus is recorded from the Japanese Seas. The fossil species from Japan and the adjacent regions, viz., praenipponica from the Oligocene of Kyushu, yessoensis from the Palaeogene of Hokkaido, boreasteria from the Oligocene of South Sakhalin, nipponica from the Pliocene of Nagano and Chiba Prefectures, tokunagai from the Pliocene and Miocene of Nagano, Yamagata, Akita and Fukushima Prefectures and Lin.? taiwanensis from the Miocene of Formosa, are described and noticed by the writer in Chapter IV of this article. Of these fossil species Lin. tokunagai has probably descended from older Lin. praenipponica and seems to indicate the older geological horizon (the lower Pliocene at the youngest) than Lin. nipponica. Lin. nipponica is a rather rare fossil in Japan and is known only from the Pliocene of Japan. A fragment of rather large Schizasterid that seems to belong to the genus Linthia is recorded by MORTENSEN (1951, p. 236) off the coast of Iki Island. This living species of *Linthia*, according to the inference of MORTENSEN, seems to be a descendant of the Pliocene Lin. nipponica or to have survived to the Recent seas since the Pliocene. It is very noticeable fact that this large and widely distributed genus, which was regarded as having been extinct in the Pliocene, has a single surviving representative in the Japanese region.

Faorina chinensis (with Sinaechinus kawaguchii), a characteristic and peculiar Schizasterid of the Malay region, is known to be distributed from south of Formosa and coast of China (Hongkong) to Indo-China and Sulu Sea, and also to Flores Sea, but not known with certainty as fossil. About its true relationship to other schizasterids the writer confesses his ignorance. The genus Brisaster dates back, according to LAMBERT and THIÉRY (1925, pp. 528-530), to the Eocene and ranges to the recent seas, where 7 species are known to occur from various zoogeographical regions. Br. owstoni is known with certainty only from the Japanese Seas, and also known to occur as fossil from the Pliocene and Pleistocene of Chiba Prefecture. Although about its ancestry the writer has no knowledge, it seems to have developed in the Japanese Seas since the Pliocene epoch. Br. latifrons appears to be distributed along the American west coast from Alaska to southern California and Gulf of California; it is also recorded from the Bering and Ochotsk Seas to the northern part of Hokkaido, but the specimens reported from north and central Japan need reexamination to inspect confusion with the Japanese species, Br. owstoni. This species seems to be a recent type and not known with certainty as fossil; although it has much resemblance, in general features, with Br. owstoni, its true relationships to other species are obscure in the present state of our knowledge.

Cagaster recticanalis, a characteristic and peculiar fossil Schizasterid of Japan, is known with certainty only from the Miocene formation of Ishikawa Prefecture, but about its ancestry and relation to other Schizasterids the writer has no knowledge. *Cagaster* species is known only from the Pliocene formation of Formosa. The assignment of the Formosan fossil species to this genus offers an interesting problem that this genus may stand at an intermediate systematic position between the genera Brisster and Faorina in the family Schizasteridae.

The genus Schizaster dates back to the Eocene and comprising some 200 fossil species of various forms, but the living species are unsatisfactorily known, at least three species being known from comparatively wide-spread regions. The two fossil species from Japan, viz., miyazakiensis from the Miocene of Miyazaki Prefecture and kinasaensis from the Miocene (or Pliocene) of Nagano Prefecture, are noticed by the writer in Chapter IV of this article. In the two species the course of a peripetalous and a latero-anal fasciole and the structure of frontal ambulacral pores are not soclearly discernible that the specific characters distinguishing these forms from other species are not well established. Sch. lacunosus has been sometimes, in its general appearance, confounded with Brisaster owstoni of the Japanese region and with Hypselaster jukesii of the Malay region. This species is known to be distributed from Japan to the Natal coast, East Africa and to Northeast Australia, but not recorded from Malay Archipelago; the species is also known to occur as fossil from the Pliocene formations of Shizuoka and Chiba Prefectures and the Pleistocene formation of Chiba Prefecture. The origin and the discontinuous distribution of this species need further elucidation.

The very ill-defined, fossil genus Aplospatangus ranges from the Eocene to Miocene and comprises a considerable number of species that are known from the circum-Mediterranean countries, India and Malay Archipelago. Apl. taiwanicus, from the Eocene Karisan formation of Formosa, resembles to some extent Apl. howa from the Eocene of Madagascar and Apl. acuminatus from the Oligocene of Germany. It is provisionally referred to this genus, on account of resemblance in general features. with these species of the genus. Probably it has to some extent a relation with those Eocene or Oligocene species. The genus Hypselaster seems to be a recent type and a majority of the living species are known from the Indo-West Pacific region. Hyp. fragilis is known with certainty only from southwest of Koshiki Island, Japan; but as quite insufficient knowledge is available, we must leave it as incertae sedis, and thus about its ancestry the writer knows nothing. Hyp. pacificus is known only from the Japanese Seas, but not known with certainty as fossil. It is impossible at present to give a definite opinion about the relation between this species and *fragilis* of the Japanese region. The genus Moira dates back to the Oligocene and comprises a small number fossil species from the circum-Mediterranean countries, India and Japan; the living species are known to occur from rather separated regions, viz., the West Indies, tropical coast of West America, East Indies and Malay, Japanese and the Australian regions. The five living species recognized by MORTENSEN are regarded by MAYR (1954, pp. 5-6) as allopatric. A fossil species Moi. obesa is known from the Miocene formations of Aomori, Akita, and Tottori Prefectures, and also of Formosa. This is a characteristic fossil echinoid of Japan and the adjacent regions in the Miocene epoch. Moi. lachesinella is known only from the Japanese Seas, from Tateyama Bay to Hakata Bay and to western Sea of Japan; the species seems to have descended from the Miocene fossil species and been developed autochthonously in the Japanese region. The subgenus Moiropsis was known only with a single living species Moi. (Moiropsis) claudicans, but the second species, Moi. (Moiropsis) depressa, has been discovered from the Miocene series of Formosa. It is known only from the Miocene Kaizan formation of Formosa, and seems to have descended from the Oligocene or Miocene fossil *Moira* along a somewhat different line of development. But, whether it has given rise to a living descendant or not is uncertain.

The family Brissidae date back to the Santonian and comprise a large number of Recent as well as a considerable number of fossil genera; the family is represented in Japan and the adjacent regions by the following genera, viz., *Plesiaster*, *Brissopsis*, *Anametalia*, *Gymnopatagus*, *Eupatagus*, *Rhinobrissus*, *Brissus*, and *Metalia*. The genus *Plesiaster* ranges from the Santonian to Campanian of Europe, North Africa and North America and 8 fossil species have been hitherto known. *Ples. peini*, the type-species of the genus, is reported from the upper Cretaceous of Koshiki-jima in Kagoshima Prefecture and Amakusa in Kumamoto Prefecture. This species is known from the Santonian of Algeria and Tunisia. The specimens from Japan are in deficient condition of preservation, but by the general features they appear to be referable to this species of North African Cretaceous.

The genus *Brissopsis* dates back to the Eocene and comprising some 70 fossil and 17 living species of the world-wide distribution. The fossil species and a subspecies from Japan and the adjacent regions, viz., *makiyamai* from the Miocene series of Aomori, Iwate, Miyagi, Toyama, Wakayama, Shimane and Yamaguchi Prefectures, *luzonica cosibensis* from the Pliocene series of Kanagawa Prefecture, *japonica* from the Pliocene series of Chiba Prefecture, are described and noticed by the writer in Chapters IV and V of this article. Of these species *Br. makiyamai* seems to guide a certain geological horizon (from the *Miogypsina* to *Desmostylus*-horizon) in the Japanese region. *Br. japonica* seems to be more similar to the southern species, i. e., *Br. oldhami* and *bengalensis*, rather than to *Br. luzonica*, but this resemblance seems to be superficial as judged from the associated fauna that indicates rather cooler climate than now in that region. This species seems to have descended from the Japanese Miocene species, i. e., *Br. makiyamai*.

Br. luzonica is widely distributed over the Indo-West Pacific, ranging from the Japanese Seas to New Zealand, and also known to occur as fossil from the upper Miocene of Java and the Pliocene of Shizuoka Prefecture, Japan. This species seems to have originated in the Malay region and distributed from the center of its development to the present area, but it is rather rare species in the recent seas around Philippines. Br. oldhami is distributed from southern Japan to the Philippines and from Bay of Bengal to Celebes, but not known with certainty as fossil. This species seems to be of recent type and related to some extent with the living Br. luzonica of the Indo-West Pacific region. Br. bengalensis is known to be distributed from the Japanese Seas to south of Ceylon and from Bay of Bengal to Celebes, but not known with certainty as fossil; this species also seems to be of recent type and has. some relation to the living Br. luzonica.

The genus Anametalia resembles Cionobrissus, but differs from the latter in the frontal ambulacrum which does not form a deep furrow on the oral side. Anam. sternaloides, the type-species of the genus, differs from Anam. grandis, from the coast of Indo-China, by a more produced posterior end of the test, low and round front, and by slightly sunken petals. The species is known from Hongkong, China and Gulf of Siam, but not known as fossil. The South China Sea seems to be the center of

development of these recent forms.

The genus Gymnopatagus seems to be of recent type and comprises a small number of the Indo-West Pacific species and some obscure fossils of the east coast of Central America (COOKE, 1959, pp. 90-91). Gym. magnus is known to be distributed from the Japanese Seas to the Indian Ocean, but not known with certainty as fossil; this species seems to be of recent type and has probably originated recently in the East Indian region and has been distributed from the center of its development to the present area. The genus Eupatagus dates back to the Eocene, comprising some 50 fossil species of the Indo-Pacific and circum-Mediterranean regions and a small number of living species of the Indo-West Pacific regions. Eup. nipponicus is known only from the Miocene series of Toyama Prefecture, but its true relation to other species of this genus is obscure in the present state of our knowledge owing to the insufficient awareness of its peripetalous and subanal fascioles and large aboral primary tubercles. Eup. marianensis, from the Miocene series of the island of Saipan, Micronesia, has close relations to the two Miocene species of Java, i. e., Eup. pulchellus and affinis, and these species seem to have developed along the parallel lines of development from a common progenitor of earlier geological age and have flourished in the Miocene seas of the West Pacific. Eup. micropetalus, one of the living species of the genus, is known only from the Japanese Seas and differs from the related Eup. lymani in the aboral large primary tubercles, but is not known with certainty as fossil. This species seems to be of recent type and has probably originated recently in the Japanese region.

The genus *Rhinobrissus* seems to be of recent type and comprises a small number of the Indo-West Pacific species and a species (*Rh. cuneus* COOKE, 1957, p. 10, pl. 1; 1959, p. 88, pl. 36, figs. 7-11) from North Carolina. *Rh. pyramidalis*, the type-species of the genus, is distributed from the China coast and Gulf of Siam to Bay of Bengal, but not known as fossil. This species seems to have a relation to the living *Rh. hemiasteroides* of the West Pacific Ocean.

The genus *Brissus* seems to date back to the Eocene, but it is richly developed in the Miocene and Pliocene epochs, comprising some 17 species of rather wide distribution. The six living species recognized by MORTENSEN (1951, pp. 505-523) are all regarded by MAYR (1954, p. 6) as apparently allopatric. *Br. latecarinatus* is widely distributed over the Indo-West Pacific and as fossil it goes back to the Miocene (JEANNET and MARTIN, 1937, p. 280). It certainly occur as fossil from the Pliocene of Fiji Islands and the Pleistocene of Farsan Islands, Billiton Island, Ryukyu Islands and Formosa (Taiwan). This species seems to have originated in the Malay or East Indian region and have been distributed from the center of its development to the present area. *Br. agassizii* is known only from the Japanese Seas, from Sanriku coast and Sagami Sea to Kyushu and Sea of Japan, but not known with certainty as fossil. This species seems to have originated recently in the Japanese region and developed autochthonously in that region.

The genus *Metalia* dates back to the Eocene, but it is very poorly developed in the Miocene and Pliocene epochs and comprises a small number of fossil species, and in the Recent it is confined generally to the tropical and subtropical regions and known to comprise 7 species. *Met. pelagica* is known only from the Miocene series (*Spiroclypeus*-horizon) of the island of Saipan, Micronesia. Because it greatly resembles the living *Met. spatangus* and *dicrana*, this fossil species is probably the direct progenitor of the two living species. *Met. sternalis* differs from the other living species in the feature of postero-lateral petals and in the absence of aboral primary tubercles in the posterior interambulacrum. This species is known to be distributed over the Indo-West Pacific and also known to occur as fossil from the Pliocene of Fiji Islands (H. L. CLARK, 1945, p. 324); the species seems to have descended from a certain ancestor of the Miocene or earlier age and have been distributed from the center of its development to the present area.

Met. spatangus, another living species of large-size, is distributed over the Indo-West Pacific, from the Red Sea and East African coast to the Hawaiian Islands, the Society Islands, and to Japan, and also known to occur as fossil from the Pleistocene of the islands of Angaur, Micronesia. This species seems to have descended from the Miocene ancestor in the Malay or East Indian region and have been distributed from there to the present area. Met. dicrana differs from Met. spatangus in the form of sternum and is distributed from the Ryukyu Islands and the Philippines to the Malay and to Samoa Islands, but not known with certainty as fossil. This species seems to be of recent type, has probably descended in association with Met. spatangus from a common progenitor or from that species itself and has been distributed recently from the center of its development to the present area.

The above description and discussion on the Echinoid fauna of Japan and the adjacent regions given by the writer, after all, are not content with the writer himself owing to some uncertainties and insufficiencies here and there. It is, however, expected that future researches on new material would verify and correct this outline of the faunae of the Echinoidea.

ADDENDA ET ERRATA AD "PART 1"

ADDENDA

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ERRATA (CORRECTA)

The suborder Pygasteroina (Part I, p. 31) of the Diadematoida must be abandoned. MEL-VILLE (1961, pp. 243-246) has discovered that *Pygaster* possesses keeled teeth as in *Holectypus*, which disproves the continued assumption that this genus has grooved teeth.

The generic name Cardisaster (Part I, p. 45, line 16) is emended to Cardiaster and Echinanthus (Part I, p. 45, line 28) to Gitolampas.

The genus *Hemiaster* (Part I, p. 45, line 31) is eliminated from the list of the Neogene Subperiod.

In the diagnosis of the Cidaroida (Part I, p. 153) "Base of corona persisting" (line 13) should be emended to "Base of corona not persisting".

The date of the family Strongylocentrotidae GREGORY, 1900 is emended to 1892.

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Plate 19

Explanation of Plate 19

(Size as stated)

Figs. 1-2. Palaeopneustes (Oopneustes) priscus NISIYAMA, n. sp. 1, aboral view of holotype, ×0.83 (IGPS coll. cat. no. 8098, from the Tsunaki formation of Sendai City, Miyagi Prefecture); 2, oral view of the same, ×0.83.



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Explanation of Plate 20

(Size as stated)

- Figs. 1, 4. Palaeopneustes lepidus NISIYAMA, n. sp. 1, aboral view of holotype, ×0.94 (IGPS coll. cat. no. 8076, from the Nanao formation (Nozaki mudstone member ?, according to MORISHITA, 1960, p. 61) of Nanao City, Ishikawa Prefecture); 4, side view of the same, ×0.94.
- Fig. 2. Cottreaucorys (Cordastrum) sulcatus NISIYAMA, n. sp. Side view of holotype, ×2 (IGPS coll. cat. no. 73746, from the Miyakura (Furushiroyama) formation of Ehime Prefecture).
- Fig. 3. Brissopsis species. Posterior view of the specimen in figures 6 and 7 on plate 26, ×1 (IGPS coll. cat. no. 73878, from the Karisan formation of Taihoku-shû, Formosa).





Explanation of Plate 21

(Size as stated)

- Fig. 1. Palaeopneustes lepidus NISIYAMA, n. sp. Oral view of holotype, ×1 (IGPS coll. cat. no. 8076, from the Nanao formation (Nozaki mudstone member ?, according to Morishita, 1960, p. 61) of Nanao City, Ishikawa Prefecture).
- Fig. 2. Spatangus species. Aboral view of a fossil, $\times 1$ (IGPS coll. cat. no. 22244, from the Koshiba formation of Yokohama City, Kanagawa Prefecture).
- Fig. 3. Paraheteraster macroholcus (NISIYAMA, 1950). Posterior view of holotype, ×1 (IGPS coll. cat. no. 72981, from the Arita formation of Wakayama Prefecture).
- Fig. 4. Palaeopneustes (Oopneustes) priscus NISHIYAMA, n. sp. Side view of holotype, ×0.83 (IGPS coll. cat. no. 7098, from the Tsunaki formation of Sendai City, Miyagi Prefecture).


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Plate 22 - . : .

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- Figs. 1-6. Spatangus pallidus H. L. CLARK, 1908. 1, aboral view of a fossil, ×1 (IGPS coll. cat. no. 7976-2, from the Jizôdô formation of Chiba Prefecture); 2, aboral view of another fossil, ×1 (IGPS coll. cat. no. 7976-1, from same formation and locality); 3, anterior view of the same, ×1; side view of specimen in figure 1, ×1; 5, posterior view of specimen in figure 2, ×1; 6, side of the same, ×1.
- Figs. 7-10. Echinocardium cordatum (PENNANT, 1777). 7, aboral view of a fossil, ×1 (IGPS coll. cat. no. 73769, from the Shibikawa formation of Oga Peninsula, Akita Prefecture); 8, aboral view of a Recent specimen, ×1 (for comparison) (IGPS coll. cat. no. 58334, off Iioka-machi, Chiba Prefecture, in 39 metres); 9, oral view of the fossil in figure 7, ×1; 10, oral view of the Recent specimen in figure 8, ×1 (for comparison).



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- Figs. 1-6. Echinocardium cordatum (PENNANT, 1777) (for comparison). 1, aboral view of a Recent specimen, ×1 (IGPS coll. cat. no. 58336-1, off the River Kuriyama, Chiba Prefecture); 2, oral view of the same, ×1; 3, side view of the same, ×1; 4, posterior view of the same, ×1; 5, side view of the specimen in figure 8 and 10 on plate 22, ×1 (IGPS coll. cat. no. 58334, off Iioka-machi, Chiba Prefecture); 6, posterior view of the same, ×1.
- Fig. 7. Paraster nummuliticus (TOKUNAGA, 1903). Aboral view of a part of test, showing an ethmolytic apical system, with four genital pores, $\times 3$ (IGPS coll. cat. no. 73791, from the Eocene of Bonin Islands).
- Fig. 8. Schizaster lacunosus (LINNAEUS, 1758) (for comparison). Aboral view of a part of test, showing an ethmolytic apical system, with two genital pores, ×3 (IGPS coll. cat. no. 78220, from the east coast of Hiroshima Bay, Hiroshima Prefecture).
- Figs. 9-11. Paraster saipanicus COOKE, 1957. 9, aboral view, $\times 2$ (IGPS coll. cat. no. 73734, from the Donney formation of Saipan Island, Mariana Islands); 10, oval view of the same, $\times 2$; 11, side view of the same, $\times 2$.











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- Fig. 1. Brisaster owstoni MORTENSEN, 1950. Aboral view of a fossil, $\times 1$ (IGPS coll. cat. no. 73778, from the Sanuki formation of Chiba Prefecture).
- Figs. 2, 4, 5. Cagaster recticanalis (YOSHIWARA, 1899). 2, aboral view of holotype, ×1 (IGPS coll. cat. no. 5235, from the Nozoki (Yokawa?) formation of Kanazawa City, Ishikawa Prefecture); 4, oral view of the same, ×1; 5, anterior view of the same, ×1.
- Figs. 3, 6. Linthia tokunagai LAMBERT, 1925. 3, aboral view of a specimen, ×1 (IGPS coll. cat. no. 7918, from the upper part (Takafu mudstone) of Ogawa formation of Nagano Prefecture); 6, posterior view of the same, ×1.







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- Figs. 1-3. Linthia tokunagai LAMBERT, 1925. 1, oral view of the specimen in figure 3 on plate 24, ×1; 2, anterior view of the same, ×1; 3, aboral view of another specimen, ×1 (IGPS coll. cat. no. 78632, from the Kuzusawa formation of Yamagata Prefecture).
- Fig. 4. Maretia planulata (Le.MARCK, 1816). Aboral view of a fossil, ×2 (IGPS coll. cat. no. 73826, from the Younger Angaur Limestone of Angaur Island, Palao Islands).
- Figs. 5-6. Brissopsis luzonica cosibensis NISIYAMA, n. subsp. 5, aboral view of holotype, ×2 (IGPS coll. cat. no. 73747, from the Koshiba formation of Yokohama City, Kanagawa Prefecture); 6, oral view of the same, ×2.
- Fig. 7. Brissopsis japonica NISIYAMA, n. sp. Aboral view of holotype, $\times 1$ (IGPS coll. cat. no. 73774, from the Kokumoto formation of Chiba Prefecture).













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- Figs. 1-3. Linthia tokunagai LAMBERT, 1925. 1, oral view of the specimen in figure 3 on plate 25, ×1 (IGPS coll. cat. no. 78632, from the Kuzusawa formation of Yamagata Prefecture);
 2, side view of the same, ×1; 3, side view of the specimen in figures 3 and 6 on plate 24, ×1 (IGPS coll. cat. no. 7918, from the upper part (Takafu mudstone) of Ogawa formation of Nagano Prefecture).
- Figs. 4-5. Brissopsis makiyamai MORISHITA, 1957. 4, aboral view of a specimen, ×1 (IGPS coll. cat. no. 73802, from the Hatatate formation of Sendai City, Miyagi Prefecture); 5, oral view of the same, ×1.
- Figs. 6-7. Brissopsis species. 6, aboral view of a specimen, ×1 (IGPS coll. cat. no. 73878, from the Karisan formation of Taihoku-shû, Formosa); 7, oral view of the same, ×1.
- Figs. 8-9. Brissopsis japonica NISIYAMA, n. sp. 8, oral view of holotype, in figure 7 on plate 25 (IGPS coll. cat. no. 73774, from the Kokumoto formation of Chiba Prefecture); 9, side view of the same, ×1.

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Plate 27

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- Figs. 1-5. Metalia pelagica NISIYAMA, n. sp. 1, aboral view of holotype, ×2 (IGPS coll. cat. no. 73735-1, from the Donney formation of Saipan Island, Mariana Islands); 2, oral view of the same, ×2; 3, aboral view of paratype, ×2 (IGPS coll. cat. no. 83735-a, from the Donney formation of Saipan Island, Mariana Islands); 4, oral view of the same, ×2; 5, side view of holotype, ×2.
- Fig. 6. Metalia spatangus (LINNAEUS, 1758). Side view of fossil in the figures 7 and 8 on plate 28, ×1 (IGPS coll. cat. no. 73788, from the Older Angaur Limestone of Angaur Island, Palao Islands).
- Figs. 7-8, 10-11. Eupatagus marianensis NISIYAMA, n. sp. 7, aboral view of holotype, ×2 (IGPS coll. cat. no. 73739-1, from the Nephrolepidina-horizon of Saipan Island, Mariana Islands);
 8, oral view of the same, ×2, 10, side view of the same, ×2; 11, side view of paratype, ×2 (IGPS coll. cat. no. 73739-2, from the Nephrolepidina-horizon of Saipan Island, Mariana Islands).
- Fig. 9. Brissus latecarinatus (LESKE, 1778). Oral view of a fossil, ×0.8 (IGPS coll. cat. no. 73826, from the Older Angaur Limestone of Angaur Island, Palao Islands).





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- Figs. 1-2. Pericosmus magnificus NISIYAMA, n. sp. 1, aboral view of Holotype (a cast specimen) ×1 (IGPS coll. cat. no. 73868-1, from the Ajiri (Hatatate) formation of Miyagi Prefecture); 2, aboral view of paratype (a mould specimen), ×1 (IGPS coll. cat. no. 73868-2, from same horizons and locality).
- Figs. 3-6. Moira lachesinella MORTENSEN, 1930 (for comparison). 3, aboral view of a Recent specimen, ×1 (IGPS coll. cat. no. 56984-1, from the south coast of Tateyama Bay, Chiba Prefecture); 4, oral view of the same, ×1; 5, side view of the same, ×1; 6, posterior view of the same, ×1.
- Figs. 7-8. Metalia spatangus (LINNAEUS, 1758). 7, aboral view of a fossil, ×0.93 (IGPS coll. cat. no. 73788, from the Older Angaur Limestone of Angaur Island, Mariana Islands); 8, oral view of the same, ×0.93.



- Figs. 1-3. Brissus latecarinatus (LESKE, 1778). 1, aboral view of a fossil, ×1 (IGPS coll. cat. no. 73777-1, from the Ryukyu Limestone of North Borodino Island (Kita-Daitô-jima); 2, oral view of the same, ×1; 3, side view of the same, ×1.
- Fig. 4. Metalia pelagica NISIYAMA, n. sp. Side view of paratype in figures 3 and 4 on plate 27, ×2 (IGPS coll. cat. no. 73735-2, from the Donney formation of Saipan Island, Mariana Islands).
- Fig. 5. Glyptocidaris (Eoglyptocidaris) arctina NISIYAMA, n. sp. Side view of holotype (depressed), ×2 (IGPS coll. cat. no. 73752, from the Poronai formation of Teshio Province, Hokkaido).
- Fig. 6. *Brissopsis* species. Side view of the specimen in figures 6 and 7 on plate 26, $\times 1$ (IGPS coll. cat. no. 73878, from the Karisan formation of Taihoku-shû, Formosa).



- Figs. 1-2. Firmacidaris neumayri NISIYAMA, n. sp. 1, side view of radiole (holotype), ×2 (IGPS coll. cat. no. 7152, from the Torinosu Limestone of Kôchi Prefecture); 2, apical view of the same, ×2.
- Figs. 3, 5-7. Gitolampas sendaica NISIYAMA, n. sp. 3, posterior view of holotype, ×1 (IGPS coll. cat. no. 35003-1, from the Moniwa formation of Sendai City, Miyagi Prefecture); 5, side view of the same, ×1; 6, aboral view of the same, ×1; 7, oral view of the same, ×1.
- Fig. 4. Brissus latecarinatus (LESKE, 1788). Oral view of a fossil, ×1 (IGPS coll. cat. no. 73778, from the Ryukyu Limestone of North Borodino Island (Kita-Daitô-jima), Ryukyu Islands).



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東京大学理学部地質学教室内 1968年3月11日印刷 1968年3月16日 発行。 - 日本古生物学会

者一松平古子童 郎 者。花。一井 郎 定価 5,000円 学術図書印刷株式会社 印 刷 者

富。一面 東京都練馬区豊玉北2/13 発売所 * 東東京大学一出版会

東京都女京区本鄉了丁目東京大学構内 表版替 東京 59964 電 (811)-8814