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PART I

By

Syozo NISIYAMA

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Part I

By

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I. INTRODUCTION AND GENERAL REVIEW

INTRODUCTION

The seas bordering Japan and the adjacent regions are diversified in biogeochemical conditions and the marine faunas therein, and have been known to zoologists for the rich yield of Echinoids and other marine invertebrates. The collections made by various surveying ships have given the evidence that the Japanese seas, particularly the Sagami Sea and the adjacent areas, are the richest in Echinoids in the world (and apparently also in the other classes of Echinoderms), as were the European seas in the Jurassic and Cretaceous periods, and the Timor Sea in the western part of Arafura Sea in the Permian Period, and that they may be called " The Treasure Islands of Echinoderms ".

The Echinoidea comprise a class of exclusively marine animals that are generally considered to have as vigorously flourished through the past geological ages down to the present time. Of the larger marine invertebrate fossils in Japan and the adjacent regions, the Echinoidea are ranked as a whole next to the Mollusca (the Pelecypoda, Gastropoda, and Cephalopoda) in scientific importance and stratigraphical significance. The paleontological importance of the Echinoids rests upon their rather frequent occurrence as fossils, especially aggregated in rather limited places and horizons, and their complex morphology, which permits a fine discrimination of species and genera that are believed to have relatively short geological ranges. Thus they seem to prove to be valuable guides in stratigraphy, indicating definite geological ages, exhibiting weighty evidence for correlation of geological formations; and they manifest valuable data of evolution, as they have recorded many and diversified evolutionary changes. Owing to their relatively sedentary habits, their aversion to fresh water, the brevity of a free-swimming larval life, and the usually small bathymetrical range, the Echinoids provide remains that are remarkably suitable as bases for studying paleoecological and paleogeographical conditions through geological times. From another point of view, the Echinoids are especially interesting to zoologists (neontologists); as (1) materials for anatomical and embryological studies of the Recent species and genera that throw much light on those of the past, as (2) the materials to study the morphogenesis of the coronal plates, including the ambulacra which are excellent examples of morphogenetic sequences; (3) besides, morphologically they are the most complex encountered in invertebrates; and (4) embryologically the material provides, in the research, data to work out some problems in general zoology.

In the present article the writer intends to deal with almost all known Echinoids hitherto reported from the Japan and the adjacent regions. The present work is not complete because certain species and genera hitherto reported from these regions have been unfortunately inaccessible to the writer for study. However, the knowledge on the Echinoid fauna from these regions to date is exhaustively summarized in the present work; and it is hoped that future workers would throw additional light by future discoveries of undescribed material and contribute to the progress of our knowledge by detailed studies along various lines. The writer has also given an almost equal space for the genera and species that are as yet not recognized in the fossil state in these regions, because there is a great probability that many Recent Echinoids of Japan and the adjacent regions might have their direct ancestors in the paleontological horizons of these same regions, or more or less remoted areas, and may be actually discovered by future collectors. There is no sharp taxonomical line between the Recent and fossil forms, a fact sometimes not fully considered by modern authors on neontology.

The purpose of the present work are, (1) to review (and sometimes to revise) the generic and other systematic nomenclature of the Echinoidea, (2) to make available a convenient catalogue of the known genera and species of the Echinoids from Japan and the adjacent regions, (3) to record some new forms, and (4) to redescribe by the new and more excellently preserved specimens the hitherto ill-defined or inaccurately described species.

The scope of the present work is to summarize our previous knowledge along all lines of research concerning the Echinoid fauna from Japan and the adjacent regions. It is also intended to give some remarks on morphological features which have hitherto been given but little attention, and to discuss the classification proposed in the present article. Discussions on some evolutionary trends and changes, periods of flourishing and of the maximum development, geographical-bathymetrical and geological distributions are also dealt with. Biostratigraphical and geological significance of the Echinoid fossil fauna from the present regions are touched upon with some remarks on the paleoecology and geology of their occurrences. And finally, as only to the descriptions of the forms concerned; but not as of a monographic style, on the Echinoid fauna from Japan and the adjacent regions, the present article is devoted.

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A BRIEF REVIEW ON THE SYSTEMATIC ARRANGEMENT OF THE ECHINOIDEA

In regard to the systematic arrangement of the Echinoidea, important studies have been done during the past one and half centuries by the following workers, namely, GRAY (1825-55), L. AGASSIZ (1836-42), DESOR (1855-58), A. AGASSIZ (1863-1904), COTTEAU (1865-1889), POMEL (1869-1883), LOVÉN (1867-1892), DUNCAN (1882-1889), and GREGORY (1892-1900). Among the monographic works together with the systematic arrangement of the genera and species made by various authors, the following ones are accounted for their importance, namely, D'ORBIGNY (1853-55), WRIGHT (1857-92), COTTEAU (1861-89), and A. AGASSIZ (1872-74, 1881). MEISSNER (1904) fully reviewed the outline of systematic arrangement of the Echinoidea hitherto published until then, up to the end of the ninteenth century, and he also proposed a more or less revised arrangement.

Up to the present time, after the publication of MEISSNER's paper (1904), the more important works have been established by many authors. LAMBERT and THIÉRY in their " Essai de nomenclature, (1909-1925)" enumerating a large number of species and genera, almost all of the known species at that time, and they arranged the Echinoidea of both Recent and fossil forms, as follows (only the ranks higher than taxa of the family-group cited).

LAMBERT and THIÉRY (1909-1925)

- Sous-Classe: Gnathostomata POMEL
  - Ordre: Plagiocysta LAMBERT
    - Sous-Ordre: Cystocidaroida ZITTEL
      - Famille: Palaeodiscidae GREGORY, 1897
      - Famille: Echinocystidae GREGORY, 1897
  - Ordre: Endocysta LAMBERT
    - Section: Homalostomata LAMBERT & THIÉRY
      - Sous-Ordre: Bothriocidaroida ZITTEL
        - Famille: Bothriocidaridae SCHMIDT, 1874
      - Sous-Ordre: Perischoechinoida M'COY
        - Famille: Melonechinidae LAMBERT, 1900
          - Sous-Famille: Palaechinidae M'COY, 1849
          - Sous-Famille: Melechidae LAMBERT, 1900
        - Famille: Lepidocentridae LOVÉN, 1874
          - Sous-Famille: Rhoechinidae LAMBERT & THIÉRY, 1910
          - Sous-Famille: Lepidesthidae LOVÉN, 1897
        - Famille: Archaeocidaridae M'COY 1844
      - Sous-Ordre: Cidaroida DUNCAN
        - Famille: Cidaridae GRAY, 1825

- Sous-Famille : Streptocidaridae LAMBERT, 1900
- Sous-Famille : Stereocidaridae LAMBERT, 1900
  - Tribu : Rhabdocidarinae LAMBERT, 1900
  - Tribu : Leiocidarinae LAMBERT, 1900
- Sous-Famille : Tetracidaridae LAMBERT, 1900

- Section : Glyphostomata POMEL
  - Sous-Ordre : Streptosomata DUNCAN
    - Famille : Echinothuridae W. THOMSON, 1874
  - Sous-Ordre : Stereostomata DUNCAN
    - Famille : Phymatresidae LAMBERT, 1900
      - Sous-Famille : Diadematidae GRAY, 1825
        - Tribu : Astropyginae LAMBERT, 1900
        - Tribu : Aspidodiademinae DUNCAN, 1889
      - Sous-Famille : Tiaridae LAMBERT, 1900
        - Tribu : Eosaleninae LAMBERT & THIÉRY, 1911
        - Tribu : Hemicidarinae WRIGHT, 1857
        - Tribu : Pseudosaleninae LAMBERT, 1900
        - Tribu : Pseudodiademinae LAMBERT, 1900
        - Tribu : Glyphocyphinae DUNCAN, 1889
      - Sous-Famille : Pedinidae LAMBERT, 1900
        - Tribu : Orthopsinae DUNCAN, 1889
        - Tribu : Orthocidarinae LAMBERT & THIÉRY, 1911
        - Tribu : Climaeodinae LAMBERT, 1900
    - Famille : Olophymidae LAMBERT & THIÉRY, 1911
      - Sous-Famille : Salenidae HAIME, 1849
      - Sous-Famille : Phymosomidae LAMBERT, 1900
        - Tribu : Salmacinae LAMBERT, 1900
        - Tribu : Coptosominae LAMBERT, 1900
      - Sous-Famille : Echinometridae GRAY, 1855
        - Division : Orthoporidae LAMBERT, 1900
        - Tribu : Prototiarinae LAMBERT, 1900
        - Tribu : Cotteaudinae LAMBERT, 1900
        - Tribu : Temnechinae LAMBERT, 1900
        - Division : Oligoporidae LAMBERT, 1900
        - Tribu : Mespilinae LAMBERT & THIÉRY, 1911
        - Tribu : Triplechinae A. AGASSIZ, 1872
        - Tribu : Noetlingasterinae LAMBERT, 1906
        - Tribu : Schizechinae LAMBERT, 1900
        - Division : Polyporidae DUNCAN, 1889
        - Tribu : Sphaerechinae LAMBERT, 1900
        - Tribu : Trochalosominae BATHER, 1898
        - Tribu : Holopneustinae LAMBERT & THIÉRY, 1914
        - Tribu : Heliocidarinae LAMBERT, 1900
        - Tribu : Ellipsechininae LAMBERT & THIÉRY, 1914
    - Famille : Habrocidaridae LAMBERT & THIÉRY, 1914
      - Sous-Famille : Tiarechinidae GREGORY, 1897
        - Tribu : Tiarechinae LAMBERT & THIÉRY, 1914
        - Tribu : Lysechinae GREGORY, 1897
      - Sous-Famille : Arbacidae GRAY, 1855
        - Tribu : Glypticinae LAMBERT & THIÉRY, 1914
        - Tribu : Acropeltinae LAMBERT & THIÉRY, 1914
        - Tribu : Eucosmechinae LAMBERT & THIÉRY, 1914

- Ordre : Exocysta LAMBERT
  - Sous-Ordre : Pileatoida LAMBERT

  - Famille: Pygasteridae LAMBERT, 1900
    - Sous-Famille: Holectypidae LAMBERT, 1900
    - Sous-Famille: Discoidesidae LAMBERT, 1900
  - Famille: Conulusidae LAMBERT, 1911
  - Famille: Conoclypeidae ZITTEL, 1879
- Sous-Ordre: Clypeastroida AGASSIZ
  - Famille: Eoscutidae LAMBERT, 1900
    - Sous-Famille: Echinocyamidae LAMBERT, 1900
    - Sous-Famille: Fibularidae GRAY, 1855
      - Tribu: Lenitinae LAMBERT, 1914
      - Tribu: Sismondinae LAMBERT, 1914
  - Famille: Clypeasteridae HAIME, 1849
  - Famille: Scutellidae GRAY, 1855
    - Sous-Famille: Laganidae DUNCAN, 1889
      - Tribu: Echinodiscinae LAMBERT, 1914
      - Tribu: Rumphinae LAMBERT, 1914
    - Sous-Famille: Echinarachnidae LAMBERT, 1914
    - Sous-Famille: Dendrasteridae LAMBERT, 1900
      - Tribu: Phelsumasterinae LAMBERT & THIÉRY, 1914
      - Tribu: Rotulinae GRAY, 1855
      - Tribu: Monophorinae LAHILLE, 1896

- Sous-Classe: Atelostomata POMEL
  - Ordre: Brachygnata LAMBERT
    - Sous-Ordre: Globatoroida LAMBERT
      - Famille: Echinoneidae AGASSIZ, 1847
        - Sous-Famille: Desorellidae LAMBERT, 1911
          - Tribu: Menopyginae LAMBERT, 1911
          - Tribu: Globatorinae LAMBERT, 1911
          - Tribu: Echinogalerinae LAMBERT, 1915
        - Sous-Famille: Echinoconidae WRIGHT, 1856
  - Ordre: Nodostomata LAMBERT
    - Sous-Ordre: Procassiduloida LAMBERT
      - Famille: Galeropygidae LAMBERT, 1911
      - Famille: Echinobrissidae WRIGHT, 1856
        - Sous-Famille: Pygaulidae LAMBERT, 1905
        - Sous-Famille: Nucleolidae LAMBERT, 1905
          - Tribu: Clypeinae LAMBERT, 1898
          - Tribu: Catopyginae LAMBERT, 1898
          - Tribu: Mepygurinae LAMBERT & THIÉRY, 1918
        - Sous-Famille: Archiacidae COTTEAU, 1869
        - Sous-Famille: Echinolampadidae BERNARD, 1895
          - Tribu: Rhynchopyginae LAMBERT, 1918
          - Tribu: Echinanthinae LAMBERT, 1895
          - Tribu: Faujasinae LAMBERT, 1905
          - Tribu: Plesiolampinae LAMBERT, 1905
      - Famille: Neolampadidae LAMBERT, 1918
      - Famille: Collyritidae D'ORBIGNY, 1853
        - Sous-Famille: Pygorhytidae LAMBERT, 1909
        - Sous-Famille: Disasteridae LAMBERT, 1909
    - Sous-Ordre: Spatangoida AGASSIZ
      - Famille: Ananchitidae A. GRAS, 1848
        - Sous-Famille: Holasteridae LAMBERT, 1917
          - Tribu: Cardiasterinae LAMBERT, 1917
          - Tribu: Offasterinae LAMBERT & THIÉRY, 1924

Tribu: Hemipneustinae LAMBERT, 1917
Tribu: Echinocorinae LAMBERT, 1917
Sous-Famille: Urechinidae LAMBERT, 1917
Famille: Pourtalesidae W. THOMSON, 1877
Famille: Aeropsidae LAMBERT, 1896
Sous-Famille: Stenonasteridae LAMBERT, 1922
Sous-Famille: Ovulasteridae LAMBERT, 1896
Tribu: Corasterinae LAMBERT & THIÉRY, 1924
Tribu: Neopneustinae LAMBERT, 1896
Tribu: Palaeotropinae LAMBERT, 1896
Famille: Prospatangidae LAMBERT, 1905
Sous-Famille: Toxasteridae LAMBERT, 1920
Sous-Famille: Asterostomidae POMEL, 1883
Tribu: Antillasterinae LAMBERT, 1924
Tribu: Megapneustinae FOURTAU, 1905
Tribu: Enichasterinae LAMBERT, 1920
Sous-Famille: Lovenidae LAMBERT, 1905
Tribu: Brissoidesinae LAMBERT, 1920
Tribu: Maretinae LAMBERT, 1905
Tribu: Breyninae LAMBERT, 1905
Famille: Brissidae COTTEAU, 1885
Sous-Famille: Palaeostomidae LOVÉN, 1867
Sous-Famille: Plesiasteridae LAMBERT, 1920
Tribu: Micrasterinae LAMBERT, 1920
Tribu: Brissopsinae LAMBERT, 1905
Tribu: Macropneustinae LAMBERT, 1895
Sous-Famille: Periasteridae LAMBERT, 1920
Tribu: Hemiasterinae LAMBERT, 1920
Tribu: Pericosminae LAMBERT, 1905
Tribu: Prenasterinae LAMBERT, 1905
Tribu: Schizasterinae LAMBERT, 1905

This systematic arrangement has been followed by various authors, especially by paleontologists on the fossil Echinoidea. Their classifactory scheme is evidently practical, as shown in the subclasses Gnathostomata (with dental apparatus in the adult, including Clypeastroida) and Atelostomata (without dental apparatus in the adult, including *Echinoneus* and its allies); however, this distinction by the presence and absence of dental apparatus is against the natural affinities. Their order Plagiocysta (comprising *Palaeodiscus* and *Echinocystites*) owing to supposed eccentric position of the periproct, was eliminated through the fine research of HAWKINS and HAMPTON (1927, pp. 574-603, 7 text-figs., pls. 44-46), and there is no reason for excluding them from the group of the Echinocystitoids (Lepidocentroids).

Also a practical purpose on the classifactory scheme of the so-called Regular Echinoidea by LAMBERT and THIÉRY was founded on the crenulation or non-crenulation of the tubercles. They distinguish the oligoporous and the polyporous forms of the Regular Echinoidea, the "Triplechinidae A. AGASSIZ" and "Echinometridae GRAY", which have been considered to play an important role in Echinoid classification of the previous authors, such as A. AGASSIZ, DUNCAN, and GREGORY; but it is unnatural to the systematic arrangement of the Echinoidea. In their "Subfamily" Phymosomidae (p. 213) LAMBERT and THIÉRY distinguish the two "Tribus" Salmacinae (p. 213) with oligoporous ambulacra, and Coptosominae (p. 218) with polyporuos ambulacra.

The latter tribus correctly comprises all the true polyporous Phymosomatids, but further includes the genus *Glyptocyphus* POMEL also, which is apparently a camarodont, thus this being placed together in the same family with *Echinocyphus* COTTEAU. In the former tribus they include all the Temnopleurids together with *Thylechinus* POMEL, *Pleurodiadema* LORIOL, and *Leptechinus* GAUTHIER of the Phymosomatids. This is due to the fact that they paid no attention to the character of the ambulacral structures, but based their classification mainly on the character of the tubercles. This is very easy, but goes decidedly against the natural affinities. It is unfortunate that we do not know the lantern structure in any of the more primitive Phymosomatids, but the character of the ambulacra is here very obviously diadematid structure, whereas it is as clearly echinoid in the Temnopleurids. To class them together is an evidently error, the Salmacinae belonging to the Camarodonta (Echinoida), and the Coptosominae to the Stirodonta (Arbacioida). Also *Echinostrephus molare* (BLAINVILLE) with trigeminate ambulacra (oligoporous) they made the type of a separate genus, *Rhaphidechinus* (p. 241) of the Oligoporidae, and *Echinostrephus*, restricted to comprise only the quadrigeminate (polyporous) species *aciculatum* A. AGASSIZ (p. 254), being referred to the Polyporidae. The two species are very closely related to each other, except in the number of pore-pairs in an ambulacral plate.

On the systematic arrangement of the so-called Irregular Echinoidea, LAMBERT and THIÉRY's classifactory scheme is too much in detail: they laid too great stress on the minute differences in the ambulacral and other structures. And at the same time they changed a number of the old familiar names (e. g., *Echinarachinus* used for *Arachnoides* for instance), the result being a great confusion. In the classification adopted by LAMBERT and THIÉRY their Lovenidae (p. 447) as one of the amphisternous Spatangoids) comprise a great number of genera among which are, besides *Breynia* DESOR and *Lovenia* DESOR, e. g., also *Prospatangus* LAMBERT (*Spatangus* of authors), *Gaultieria* DESOR, *Cionobrissus* A. AGASSIZ, *Maretia* GRAY, and *Brissoides* KLEIN (*Eupatagus* of authors), divided in the tribus Brissoidesinae (p. 447), Maretinae (p. 456), and Breyninae (p. 446), which together form a subfamily Lovenidae of their family Prospatangidae (p. 435).

JACKSON set forth in his monumental work "Phylogeny of the Echini, 1912" and "Echinoidea, in EASTMAN-ZITTEL, 1913" a new classifactory scheme, especially to devote to the systematic arrangement of the so-called Regular Echinoidea based on their dental apparatus. His systematic arrangement of the Echinoidea is as follows (the ranks higher than taxa of the family-group cited).

JACKSON (1912-1913)

Order 1: Bothriocidaroida DUNCAN
    Family 1: Bothriocidaridae KLEMING
Order 2: Cidaroida DUNCAN
    Family 1: Cidaridae GRAY
Order 3: Centrechinoida JACKSON
  Suborder A: Aulodonta JACKSON
    Family 1: Hemicidaridae WRIGHT
    Family 2: Aspidodiadematidae DUNCAN
    Family 3: Centrechinidae JACKSON (=Diadematidae PETERS)

- Family 4: Echinothuridae W. THOMSON
- Suborder B: Stirodonta JACKSON
  - Family 1: Saleniidae DESOR
  - Family 2: Phymosomatidae MEISSNER
  - Family 3: Stomopneustidae MORTENSEN
  - Family 4: Arbaciidae GRAY
- Suborder C: Camarodonta JACKSON
  - Family 1: Echinidae AGASSIZ
  - Family 2: Temnopleuridae DESOR
  - Family 3: Strongylocentrotidae GREGORY
  - Family 4: Echinometridae GRAY

Order 4: Exocycloida JACKSON
- Suborder A: Holectypina GREGORY
  - Family 1: Discoidiidae GREGORY
  - Family 2: Pygasteridae GREGORY
- Suborder B: Clypeasterina GREGORY
  - Family 1: Clypeasteridae AGASSIZ
  - Family 2: Fibulariidae GRAY
  - Family 3: Scutellidae AGASSIZ
- Suborder C: Spatangina JACKSON
  - Tribe A: Cassiduloidea DUNCAN
  - Family 1: Echinoneidae WRIGHT
    - Subfamily A: Echinoneinae DESOR
    - Subfamily B: Echinobrissinae DUNCAN
  - Family 2: Cassidulidae AGASSIZ
  - Family 3: Collyritidae D'ORBIGNY
  - Tribe B: Spatangoidea DUNCAN
  - Family 4: Ananchytidae DESOR
  - Family 5: Spatangidae WRIGHT
    - Section A: Adetes GREGORY
    - Section B: Prymnadetes GREGORY
    - Section C: Prymnodesmia GREGORY
    - Section D: Apetala GREGORY
  - Family 6: Palaeostomatidae MORTENSEN
  - Family 7: Pourtalesiidae LOVÉN

Order 5: Plesiocidaroida DUNCAN
- Family 1: Tiarechininae ZITTEL

Order 6: Echinocystoida JACKSON
- Family 1: Palaeodiscidae GREGORY
- Family 2: Echinocystidae GREGORY

Order 7: Perischoechinoida M'COY
- Family 1: Archaeocidaridae M'COY
- Family 2: Lepidocidaridae LOVÉN
- Family 3: Palaechinidae M'COY
- Family 4: Lepidesthidae JACKSON

JACKSON divided the order Centrechinoida JACKSON (=Diadematoida of DUNCAN) into three suborders; the first suborder Aulodonta JACKSON, which are characterized by the teeth being grooved or unkeeled, the epiphyses narrow and not joining above the teeth. In this suborder he included the four families, namely, the Hemicidaridae WRIGHT, Aspidodiadematidae DUNCAN, Centrechinidae JACKSON, and Echinothuridae W. THOMSON. The first family of these have proved that they really stirodont teeth (MORTENSEN, 1935, pp. 391, 396) and the allied forms, Pseudodiadematidae POMEL, also have stirodont teeth (MORTENSEN, 1935, p. 423). It is thus established beyond any doubt that the Hemicidarids and Pseudodiadematids must be excluded from the Aulodonta, and have no nearer relation to *Diadema* and the Diadematids, but they must belong to the order Stirodonta (Arbacioida). The fourth family, the Echinothuridae W. THOMSON, have similar aulodont teeth as in *Diadema*, and by reason of only the character of teeth, JACKSON considers that they must belong to the Aulodonta. But the imbrication of the plates in this family, the compound amblacral plates, the numerous peristomial ambulacral plates, the inner anatomy, and the STEWART's organs of the Echinothuriids, show the affinity is decidedly more close with the Pedinids than with the Diadematids, and the family of Echinothuriids must be excluded from the Aulodonta. The aulodont teeth, in the broad sense, actually exist in the Aulodonta (Diadematoids), Lepidocentroids (Echinocystitoids), Cidaroids. Echinothuriids, and perhaps in the Melonechinoids (Palaechinoids), and thus the character of teeth alone cannot decide the taxonomic position of their bearers. The second suborder, the Stirodonta, are characterized by the teeth being keeled or not grooved, and the epiphyses of lantern being narrow and not joining above the teeth. JACKSON, comprising four families in this suborder, namely, the Saleniidae DESOR, Phymosomatidae MEISSNER, Stomopneustidae MORTENSEN, and Arbaciidae GRAY, concludes that these families together form rather a natural group. The third suborder, the Camarodonta, named by JACKSON, are characterized by the fact that teeth are keeled and the epiphyses of lantern are large and join above the teeth so as to form a closed foramen. This character of the camarodont teeth is an unique feature in the Echinoid morphology, and forms a more or less distinct and natural group; JACKSON included the four families in this suborder, namely, the Echinidae AGASSIZ, Temnopleuridae DESOR, Strongylocentrotidae GREGORY, and Echinometridae GRAY.

As to the classifactory scheme of the so-called Irregular Echinoidea, JACKSON is only slightly concerned, except that he gave a new order name Exocycloida for all these Irregular Echinoidea, and also a new suborder name Spatangina for Cassiduloids and Spatangoids.

On account of an interesting sea-urchin, *Tiarechinus* NEUMAYR of the Triassic, JACKSON, followed DUNCAN (1889) and GREGORY (1900), to place it in a special order, the Plesiocidaroida DUNCAN; it is, however, an aberrant and primitive form of the Stirodonta (Arbacioida).

JACKSON made a great contribution to the systematic arrangement of the so-called Palaechinoids in his great work. The order Echinocystoida JACKSON (=Cystocidaroidea ZITTEL or Cystechinoida STEINMANN and DÖDERLEIN), comprising *Palaeodiscus* and *Echinocystites*, as described above, cannot stand as a separate order, but be united with the Echinocystitoids (Lepidocentroids). To the order Perischoechinoida M'COY, JACKSON referred to four families, namely, the Archaeocidaridae M'COY, Lepidocentridae LOVÉN, Palaechinidae M'COY, and Lepidesthidae JACKSON; and he considered that the pluriseriate condition of the interambulacra in these Echinoids may be more specialized than the biserial condition of interambulacral plates in the area. But there are now proofs that the 20-columnar (e.g., biserial condition of plates in each area) Echinoids pass through a pluriserial state in the embryological development. Further it is accepted that there is no sharp distinction between the pluriseriate Palaeozoic

Echinoids and the post-Palaeozoic 20-columnar Echinoids in the evolution and morphology. The first family Archaeocidaridae differ from the Cidaridae proper of the order Cidaroida only in having more than two columnar (series) of interambulacral plates, and thus to be placed in the order Perischoechinoida of the pluriseriate Palaeozoic Echinoids. However, the other characters, i. e., the ambulacra, the interambulacra, the primary spines, the apical system, and others, present a closer relation to the Cidaridae proper than to other Palaeozoic Echinoids. The natural course may be to regard the Archaeocidaridae as the older, more primitive forms, from which the Cidaridae proper developed by the gradual reduction of the columns of interambulacral plates to two, and by the gradual giving up of the imbrication of the coronal plates: thus the family Archaeocidaridae must be placed in the order Cidaroida.

The second family Lepidocentridae comprise forms of pluriseriate and imbricating plates, and chiefly biserial ambulacral plates that are imbricating adorally and bevelled strongly under the interambulacral plates. JACKSON also distinguished the Lepidesthidae from the Lepidocentrotidae chiefly by the multicolumnar ambulacral plates, otherwise the two families cannot be safely distinguished from each other by other characters. But in the simpler forms of the former family the ambulacra are as simple as those in the latter family, and there is no sound reason to distinguish them.

The third family Palaechidae also have bi- to pluriseriate ambulacral plates and pluriseriate interambulacral plates as in the other Palaeozoic Echinoids, and in this character they are placed in the order Perischoechinoida. The character of the peristome (the ambulacral plates continue over the peristome to the mouth and the interradial plates are present on the peristome) recalls of the Cidaridae proper, but otherwise it is evident that they cannot have any relation to the Cidarids. The thick, non-imbricate coronal plates distinguish them sharply from all other pluriseriate Palaeozoic Echinoids, and they seem to represent rather an isolated group of the Palaeozoic Echinoids. The Palaechinidae cannot be classified together with the Lepidocentroids (Echinocystitoids).

In the great monographic work on the " Hawaiian and other Pacific Echini " by A. AGASSIZ and H. L. CLARK (1907-1909) and succeeded by CLARK (1912-1917) are treated only the Recent species and genera in the systematic arrngement of the Echinoidea; the scheme followed in the main that of JACKSON.

HAWKINS in his studies in the interesting and primitive Irregular Echinoids, the Holectypoida and the allies (1909-1926), revised the systematic arrangement of the primitive Irregular Echinoidea, particularly in the Holectypoida, Cassiduloida, and Nucleolitoida (of his order, now united into the Cassiduloida). HAWKINS, in his most important work " The morphology and Evolution of the Ambulacrum in the Echinoidea Holectypoida, 1920 " is led to distinguish two orders by means of the ambulacral structure: namely, the Nucleolitoida (including Nucleolitidae, Catopygidae, and Collyritidae) and the Cassiduloidea) (comprising the families Cassidulidae, Echinolampadidae, and Eolampadidae). HAWKINS, in his great work of 1920 laid too much great stress on the minute differences in the ambulacral structures that he had found in these forms: the illustrations are very beautiful. This classifactory sheme of the Irregular Echinoidea is followed principally by H. L. CLARK (1925), his systematic arrangement of the Echinoidea on the Recent forms only, that combined with the scheme in the

Regular Echinoidea of JACKSON, is as follows (only the ranks higher than taxa of the family-group cited).

H. L. CLARK (1925)

Order 1: Cidaroida DUNCAN
  Family 1: Cidaridae J. MÜLLER
Order 2: Diadematoida DUNCAN
  Suborder A: Aulodonta JACKSON
    Family 1: Aspidodiadematidae DUNCAN
    Family 2: Diadematidae PETERS
    Family 3: Echinothuriidae WYVILLE THOMSON
  Suborder B: Stirodonta JACKSON
    Family 1: Saleniidae DESOR
    Family 2: Stomopneustidae MORTENSEN
    Family 3: Arbaciidae GRAY
  Suborder C: Camarodonta JACKSON
    Family 1: Temnopleuridae DESOR
    Family 2: Echinidae AGASSIZ
    Family 3: Strongylocentrotidae GREGORY
    Family 4: Echinometridae GRAY
Order 3: Exocycloida JACKSON
  Suborder A: Clypeastrina GREGORY
    Family 1: Clypeastridae AGASSIZ
    Family 2: Arachnoididae GREGORY
    Family 3: Laganidae A. AGASSIZ
    Family 4: Fibulariidae GRAY
    Family 5: Scutellidae AGASSIZ
  Suborder B: Echinoneina HAWKINS
    Family 1: Echinoneidae WRIGHT
  Suborder C: Nucleolitina HAWKINS
    Family 1: Nucleolitidae GREGORY
  Suborder D: Cassidulina HAWKINS
    Family 1: Cassidulidae AGASSIZ
  Suborder E: Urechinina H. L. CLARK
    Family 1: Urechinidae LAMBERT
    Family 2: Calymnidae MORTENSEN
    Family 3: Pourtalesiidae LOVÉN
  Suborder F: Spatangina JACKSON
    Family 1: Palaeostomatidae GREGORY
    Family 2: Aeropsidae H. L. CLARK
    Family 3: Palaeopneustidae A. AGASSIZ
    Family 4: Hemiasteridae H. L. CLARK
    Family 5: Spatangidae GRAY

Among them, the family Echinothuriidae cannot be classified with the Diadematids, as discussed above. Another major classification of the so-called Regular Echinoidea, as far as the Recent forms are concerned, may have not a strong contradiction, except for some details here and there. In the Aulodonta the genus *Caenopedina* A. AGASSIZ, CLARK included it into the family of the Diadematids, as none of the characters he described, have been found to warrant its being anything else. This dealing is contrary to the former assignment of it to the family of the Pedinids (H. L. CLARK, 1912-b, p. 213) by himself. The structure of the spines of the Pedinids, recalling that of the Cidarid spines, is so fundamentally different from that of the Diadematid spines, and the genus *Caenopedina,* the living representative of the Pedinids, cannot classified with the Diadematids.

H. L. CLARK strongly holds his view for the essential difference between the triporous (or oligoporous) and polyporous forms of the so-called Regular Echinoidea. He recognized three families, of which the least specialized is the Echinids, the intermediate, the Strongylocentrotids, and the most specialized, the Echinometrids, under the Camarodonta, excepting the sculptured Temnopleurids. The first family Echinidae, comprise the genera *Echinus, Toxopneustes,* and *Tripneustes,* with trigeminate ambulacra and circular ambitus. The second family Strongylocentrotidae, comprise the genera *Echinostrephus, Strongylocentrotus,* and *Heliocidaris,* with multigeminate ambulacra and circular ambitus. The third family Echinometridae, comprise the genera *Paraselenia, Echinometra,* and *Heterocentrotus,* with tri- to multigeminate ambulacra and elliptical ambitus. This treatment of classification met a strong opposition of MORTENSEN. MORTENSEN claims that the distinction between the oligoporous and the polyporous forms of the Regular Echinoidea is a mistake, and in various families there is a clear evidence of development from primitive, simple to compound ambulacral plates, trigeminate and, ultimately as the most specialized, polyporous plates. On the other hand, H. L. CLARK claims that the test structure is essential for the classification of these forms, but the appendages of the test, pedicellariae and spines, are subject to all environmental influences, and that Toxopneustid-like globiferous pedicellariae, which characterize MORTENSEN's Toxopneustids, have arisen independently three times is at least as equally likely as the alternative, that polyporous ambulacra have arisen independently. These two diverse courses of the authors present an interesting problem as to the systematic arrangement of the Echinoidea. At any rate, the true genetic relations of the so-called Regular Echinoidea with complex morphologies cannot be steadily determined on single independent characters.

In the systematic arrangement of the so-called Irregular Echinoidea (the order Exocycloida), H. L. CLARK subdivided them into six suborders as listed above; each of these, the Clypeastrina, Echinoneina, and Urechinina, forms a more or less natural and distinct group as a whole. But the Spatangina (emended by CLARK, 1925) itself comprise, diversified forms derived from different sources, and the grouping of genera and species made by him seem to be far from the natural affinities. CLARK included in his family Sptangidae the Brissids and the Loveniids also, besides an evident Palaeopneustid, *Linopneustes*: the presence of a subanal fasciole is taken as the main characteristic, regardless of all other characters. His classification is in the main the same as that of DUNCAN. This classification, as well as his family Hemiasteridae, cannot be accepted.

MORTENSEN, in his great and exhaustive work " A Monograph of the Echinoidea, 1928–1951 ", the greatest and most valuable monograph in the former half of the twentieth century, based on the very large amount of materials accumulated in a long time, the most experienced savant on the Echinoidea, with the deep and precise knowledge on the animals, describing the Recent forms to species, and fossil forms to genera, rearranged and reviewed the systematic arrangement of the Echinoidea and steadily made great strides in the science. MORTENSEN's classificatory scheme is as follows (only the ranks higher than taxa of the family-group cited).

Mortensen (1928-1951)

Order: Lepidocentroida Mortensen, 1934
Family: Lepidocentridae Lovén, 1874
Family: Echinothuridae Wyville Thomson, 1872
Subfamily: Phormosominae Mortensen, 1934
Subfamily: Kamptosominae Mortensen, 1934
Subfamily: Pelanechininae Groom, 1887
Subfamily: Asthenosominae Mortensen, 1937
Order: Melonechinoida Mortensen, 1934
Family: Palaechinidae M'Coy. 1849
Order: Cidaroidea Duncan, 1889
Family: Archaeocidaridae M'Coy, 1849
Family: Cidaridae Gray, 1825
Subfamily: Streptocidarinae Lambert, 1900
Subfamily: Stereocidarinae Lambert, 1900
Subfamily: Diplocidarinae Gregory, 1900
Order: Stirodonta Jackson, 1912
Suborder: Calycina Gregory, 1900
Family: Acrosaleniidae Gregory, 1900
Family: Saleniidae L. Agassiz, 1838
Subfamily: Hyposaleninae Mortensen, 1934
Subfamily: Saleninae Mortensen, 1934
Suborder: Phymosomina Mortensen, 1934
Family: Hemicidaridae Wright, 1857
Family: Pseudodiadematidae Pomel, 1883
Family: Phymosomatidae (Pomel) Meissner, 1904
Family: Stomopneustidae Mortensen, 1903
Family: Tiarechinidae Gregory, 1896
Family: Arbaciidae Gray, 1855
Order: Aulodonta Jackson, 1912
Suborder: Aspidodiademina Mortensen, 1939
Family: Aspidodiadematidae Duncan, 1889
Suborder: Pedinina Mortensen, 1939
Family: Pedinidae (Pomel) Gregory, 1900
Suborder: Diademina Gregory, 1900
Family: Micropygidae Mortensen, 1904
Family: Diadematidae Peters, 1855
Order: Camarodonta Jackson, 1912
Suborder: Orthopsina Mortensen, 1942
Family: Orthopsidae Duncan, 1889
Suborder: Temnopleurina Mortensen, 1942
Family: Glyphocyphidae (Duncan) Delage & Hérouard, 1903
Family: Temnopleuridae A. Agassiz, 1872
Subfamily: Temnopleurinae Duncan, 1889
Subfamily: Trigonocidarinae Mortensen, 1903
Subfamily: Genocidarinae Mortensen, 1942
Family: Toxopneustidae (Troschel) Mortensen, 1903
Suborder: Echinina Mortensen, 1942
Family: Echinidae Gray, 1825
Subfamily: Echininae Mortensen, 1903
Subfamily: Parechininae Mortensen, 1903

Family: Strongylocentrotidae GREGORY, 1900
Family: Parasaleniidae MORTENSEN, 1903
Family: Echinometridae GRAY, 1855
Order: Holectypoida DUNCAN, 1889
Suborder: Holectypina GREGORY, 1900
Family: Pygasteridae LAMBERT, 1900
Family: Holectypidae LAMBERT, 1900
Family: Conulidae HAWKINS, 1912
Family: Discoidiidae LAMBERT, 1900
Family: Galeritidae GRAY, 1825
Suborder: Echinoneina HAWKINS, 1925
Family: Echinoneidae WRIGHT, 1857
Order: Cassiduloida DUNCAN, 1889
Suborder: Cassidulina DELAGE & HÉROUARD, 1903
Family: Galeropygidae LAMBERT, 1911
Family: Echinobrissidae D'ORBIGNY, 1855
Family: Cassidulidae L. AGASSIZ, 1847
Family: Echinolampadidae GRAY, 1851
Family: Archiaciidae COTTEAU, 1869
Family: Neolampadidae LAMBERT, 1918
Suborder: Conoclypina DELAGE & HÉROUARD, 1903
Family: Conoclypidae ZITTEL, 1879
Order: Clypeastroida (AGASSIZ & DESOR) DUNCAN, 1889
Suborder: Clypeastrina GREGORY, 1900
Family: Clypeastridae DUNCAN, 1889
Family: Arachnoididae GREGORY, 1900
Suborder: Laganida DESOR, 1857
Family: Fibulariidae DUNCAN, 1889
Family: Laganidae A. AGASSIZ, 1872
Family: Scutellidae GRAY, 1825
Subfamily: Scutellinae LAHILLE, 1896
Subfamily: Astriclypeinae STEFANINI, 1911
Subfamily: Monophorinae LAHILLE, 1896
Subfamily: Rotulinae GRAY, 1855
Order: Spatangoida L. AGASSIZ, 1840
Suborder: Protosternata MORTENSEN, 1907
Family: Disasteridae A. GRAS, 1848
Subfamily: Pygorhytinae LAMBERT, 1909
Subfamily: Collyritinae BEURLEN, 1934
Subfamily: Disasterinae LAMBERT, 1909
Suborder: Meridosternata (LOVÉN) MORTENSEN, 1907
Family: Holasteridae ZITTEL, 1879
Subfamily: Holasterinae DELAGE & HÉROUARD, 1903
Subfamily: Stegasterinae LAMBERT, 1917
Family: Urechinidae MEISSNER, 1904
Family: Calymnidae MORTENSEN, 1907
Family: Pourtalesiidae LOVÉN, 1883
Family: Stenonasteridae LAMBERT, 1922
Suborder: Amphisternata (LOVÉN) MORTENSEN, 1907
Family: Palaeopneustidae A. AGASSIZ, 1904
Subfamily: Palaeopneustinae MORTENSEN, 1950
Subfamily: Palaeotropinae LAMBERT, 1896
Family: Asterostomidae POMEL, 1883
Family: Aeropsidae LAMBERT, 1896
Family: Toxasteridae LAMBERT, 1920

Family: Micrasteridae (LAMBERT) MORTENSEN, 1950
Family: Spatangidae GRAY, 1825
  Subfamily: Spatanginae MORTENSEN, 1950
  Subfamily: Maretiinae LAMBERT, 1905
Family: Loveniidae LAMBERT, 1905
  Subfamily: Loveniinae MORTENSEN, 1950
  Subfamily: Echinocardiinae WYTHE COOKE, 1942
Family: Pericosmidae LAMBERT, 1905
Family: Schizasteridae LAMBERT, 1905
Family: Brissidae GRAY, 1855

In MORTENSEN's systematic arrangement of the Echinoidea, as listed above, the following three points are important and noteworthy. 1. *Bothriocidaris* is neither an Echinoid as hitherto generally assumed nor the ancestor of all the Echinoids as had been considered by former writers. The monoserial interambulacral plates of *Bothriocidaris*, the so-called dental apparatus, and the anatomical position of the radial water-vessel, the nerve, and the blood-vessel show no affinity with the primitive Echinoids. He considered the primitive Echinoids should have a number of interambulacral plates which are more or less irregularly arranged and the radial water-vessels, nerves, etc. lay in an open furrow outside the ambulacral plates. The oldest and most primitive form, *Aulechinus* BATHER and SPENCER, gives the clue to the origin of the Echinoids; though it is doubted by many authors, as to the validity of the open ambulacral furrows, and the irregular interambulacral plates. On the derivation of the primitive Ordovician Echinoid, *Aulechinus*, he further sought for among the Edrioasteroids of the Cambrian Period.

2. MORTENSEN disregarded the sharp distinction between the multicolumnar Palaeozoic Echinoids and the post-Palaeozoic 20-column Echinoids, the Subclass Palaechinoidea and Euechinoidea, hitherto generally accepted. The family Archaeocidaridae he excluded from the Palaeozoic order Perischoechinoida and put them into the post-Palaeozoic order Cidaroida, and divided the Perischoechinoida of multicolumnar Palaeozoic Echinoids into two orders, the Lepidocentroida and Melonechinoida. The family Echinothuriidae, which have been hitherto classified into the Aulodonta, on account of the character of teeth, are regards as the surviving member of the older Lepidocentroids; but this procedure is open to later criticism.

3. MORTENSEN also pointed out a mistake of the sharp distinction between the oligoporous and the polyporous forms of the so-called Regular Echinoidea, the "Triplechinidae A. AGASSIZ" and "Echinometridae GRAY" which have prevailed in an Echinoid classification, as seen in A. AGASSIZ, DUNCAN, GREGORY, LAMBERT, and H. L. CLARK. In various families, i. e., the Pseudodiamatidae, Phymosomatidae, Stomechinidae (Stomopneustidae), Saleniidae, Echinidae, and the Echinometridae, there is a clear evidence for development from primitive, simple (cidaroid structure) to compound ambulacral plates, trigeminate (diadematoid, arbacioid, and echinoid structure) and, ultimately to the most specialized polyporous plates.

On the systematic arrangement of the so-called Regular Echinoidea MORTENSEN followed in the main that of JACKSON, excepting the families Echinothuriidae and Hemicidaridae, and JACKSON's three suborders he raised to ordinal level, respectively. The order Stirodonta were divided into two suborders, the Calycina GREGORY (with angular suranal plates) and the Phymosomina MORTENSEN (without angular suranal plates), the latter comprising six families; among them the Hemicidaridae WRIGHT and Pseudodiadematidae POMEL are removed from the Aulodonta, and placed in this order based on the stirodont character of teeth found in the members of these two families through the researches of MORTENSEN and others; the members of these two families represent rather primitive stage in the development of this order. The small and interesting family Tiarechinidae GREGORY were removed to this order from its special and separate order Plesiocidaroida; because their ambulacral structure bears a primitive character of primary plates throughout—in accordance with the fact that it is also the oldest among the order. The assignment of these families to the order seems to justify in their natural affinities.

By excluding the families, by MORTENSEN, of the Echinothuriids, the Hemicidarids, the Pseudodiadematids, and the Orthopsids from the order Aulodonts, in which they had been included by JACKSON and CLARK, the first family to the order of the Lepidocentroids, the second and third to the order of the Stirodonts, and the fourth to the order of the Camarodonts, the order of the Aulodonts have thus become clearly restricted and approached more closely to the nature. MORTENSEN divided the order into three suborders on account of the difference of structures of the primary spines. After the discovery of the remarkable structure of the spines of the Aspidodiadematids, so entirely different from the simple structure of the Diadematid spines, he maintains that the Aspidodiadematids probably originated from some Palaeozoic Lepidocentroids, and may represent a separate branch of or without direct connexion with, the Diadematids: -the Aspidodiadematids form a separate suborder, the Aspidodiademina MORTENSEN. The structure of the spines (the solid axis) of the Pedinids clearly disprove the derivation of them from the Diadematids, the spines of which are charcterized by their hollow axis: MORTENSEN agrees with BATHER's and MERCIER's view that the Pedinids were derived from the primitive Cidarids, such as *Triadocidaris*. Pedinids themselves form a special suborder, the Pedinina MORTENSEN. The hollow spines of the Micropygids and the Diadematids are fundamentally different from those of the Aspidodiadematids and the Pedinids. MORTENSEN also suggested that the Micropygids—Diadematids must be derived from the Lepidocentroids. Accordingly the Aulodonta are not a natural order as described above, but comprise three quite different groups (suborders), each of the independent origin. This classifactory scheme of this order is practical, and shows clear distinction of each group.

The discovery of the camarodont character of teeth (masticatory apparatus) in *Orthopsis* by SERRA (1934, p. 51) and the general resemblance of the Glyphocyphids to the Temnopleurids make the origin of the order of the Camarodonts not from single source, but along two or three separate lineages. The perforate, non-crenulate tubercles of *Orthopsis*, combined with the primitive character of the ambulacra, point towards the more primitive forms of the Pedinids as the source from which it evolved; this procedure, however, is open to later criticism. The family of the Glyphocyphids stand apart from other families of the Camarodonts, excepting for the Orthopsids, by their diadematoid ambulacra and their perforate, crenulate tubercles. The lantern is not known of any Glyphocyphids, so that there is no proof whether the Glyphocyphids really belong to either of the Camarodonts, the Stirodonts or to the Aulodonts.

But their general resemblance to the Temnopleurids makes it very probable that they are actually related to the Temnopleurids, representing the more primitive forms from which the latter evolved. The Temnopleurids are very closely connected with the Toxopneustids, and it seems then that, as MORTENSEN maintains, in the Glyphocyphids—Temnopleurids—Toxopneustids a separate branch must have evolved from the Pseudodiadematids. The other families, which are much diverse in the systematic arrangement of the genera and species of MORTENSEN and of H. L. CLARK, the Echinids, Strongylocentrotids, Parasaleniids, and the Echinometrids, adopted from MORTENSEN'S, do not seem to have any close relations to the Temnopleurids—Toxopneutids stem. MORTENSEN suggested that the Echinids—Strongylocentrotids—Parasaleniids—Echinometrids derived from the Stomopneustids of the Stirodonts, and he also claims that the three groups, the Orthopsids, the Glyphocyphids—Temnopleurids—Toxopneustids, and the Echinids—Strongylocentrotids—Parasaleniids—Echinometrids, would naturally be regarded as three suborders, the Orthopsina, the Temnopleurina, and the Echinina. This classifactory procedure seems to be natural, except for dubious Orthopsids, and plausible at the present state of our knowledge. The name Echinina of MORTENSEN (1942, p. 225), however, is a junior homonym of the suborder Echinina of GREGORY (1900-b, p. 311), a fact is not touched by MORTENSEN.

The members of the Holectypoids, MORTENSEN claims, seem to have originated from different sources, the Pygasterids from the Pedinids of the Aulodonts :—DURHAM and MELVILLE (1957, pp. 246, 253) associated the Pygasterids with the Aulodonts, Holectypids from the Diadematids, Conulids, on account of their carinate teeth, suggest their derivation from the Stirodonts, and the Discoidiids also have stirodont character of teeth that prove their affinity with the Stirodonts. On the systematic arrangement of the families and genera within the order, there is no great difference between that of MORTENSEN and of HAWKINS. It is rather by practical reasons, MORTENSEN stated, but not because of true relationship, that MORTENSEN placed those families in the same order. The Echinoneids are difficult to find place convincingly; the discovery of a stirodont character of masticatory apparatus in the young proves their connexion with the Holectypoids (especially to the Conulids or Discoidiids). But in view of the many points of differences from the typical Holectypoids, and accordingly, MORTENSEN thought that it is reasonable to distinguish them, as a separate suborder, the Echinoneina, as HAWKINS and CLARK have already done.

The subdivision of the order Cassiduloida into families offers great difficulties, and there are hardly any unanimous opinions. MORTENSEN abandoned the order Nucleolitoida HAWINS (in which HAWKINS includes the families, the Nucleolitidae, Clypeidae, Catopygidae, and the Collyritidae), and united in the Cassiduloida. As to the minute differences in the ambulacal structure found by HAWKINS in these forms, MORTENSEN declares that they afford excellent generic, but not family characters, just as the ambulacral structure of the Cassiduloids does in the so-called Regular Echinoidea. MORTENSEN uses the difference in the character of the apical system, either " tetrabasal " or " monobasal ", have a character of primary importance which may be used for distinction of the families. Accordingly, MORTENSEN recognized the following seven families within the order, i. e., the Galeropygidae LAMBERT, Echinobrissidae D'ORBIGNY, Cassidulidae AGASSIZ, Echinolampadidae GRAY, Archiaciidae COTTEAU, Neolampadidae LAMBERT, and the Conoclypidae ZITTEL. A contradictional expression, however, stated by MORTENSEN himself on the classifactory value of the apical system in the same great work—" Here again it is the question of the classifactory value of the apical system, tetrabasal or monobasal, that decides whether it is a convergency or actual relation " (1948-a, p. 121). The Galeropygids are evidently primitive forms and stand in the early relation to the primitive Aulodonts. The large family of the Echinobrissidae, comprising about thirty genera, seem beyond doubt that they are the direct descendants of the Galeropygids. The family of the Cassidulids, in the sense of MORTENSEN's limitation, comprising a large number of genera and species, represent a further development from the Echinobrissids, and there may be a number of different lines connecting the two families. The Echinolampadids are so closely related to the Cassidulids, that they might almost equally well be included in the same family. It is for a practical reason, in the main, that, as MORTENSEN maintains, who keeps the Echinolampadids as a separate family, and the Cassidulids on the other hand from such a very large group (with over thirty genera) that a subdivision is desirable. MORTENSEN also considered that the Echinolampadids are derived from the tetrabasal Echinobrissids, but not from the monobasal Cassidulids. On the whole, there can be no doubt that there is close relation between the Echinolampadids and the Galeropygids—Echinobrissids—Cassidulids line, but the classification and the systematic arrangement of this group are at present more or less apart from the natural relation than the practical.

The reduction of the pores of the frontal ambulacrum, the essential characteristic of the family of the Archiaciids, as MORTENSEN claims, may have developed along different lines, for instance from the Echinobrissids or Cassidulids, but it gives a very practical distinction from the order Cassiduloids, and it may be kept as a family, though not represent a true relationship. The question arises here as to the classificatory value of the simple ambulacra. Particularly the single pores and the more or less rudimentary condition of the aboral part of the ambulacra in the family of the Neolampadids; is it a primitive character derived as a direct inheritance from the primitive ancestors among the so-called Regular Echinoidea, or is it rather a highly specialized feature ? Through the researches of STEFANINI (1913) and MORTENSEN (1948-a), it is concluded that it has nothing to do with a direct inheritance from the primitive ancestors among the so-called Regular Echinoidea, but all the other characters showing these forms appear to be closely allied to the Cassiduloids. It is also quite possible that family of the Neolampadids, as comprised by LAMBERT and THIÉRY, and MORTENSEN, are not a natural family; but that the Neolampadids, as a whole, as MORTENSEN claims, represent a specialization from the Echinobrissids or the Cassiduloids seems beyond doubt.

The discoveries of the presence of a lantern in the young Cassiduloids (*Apatopygus*, *Echinolampas*, and *Conolampas*) lead to the conclusion that a lantern must be typically in all (young) Cassiduloids, and thus the presence of a lantern in *Conoclypus* (adult) cannot mean such a profound difference between *Conoclypus* and the Cassiduloids as hitherto thought. Very probably, as HAWKINS (1912-b, p. 494) and MORTENSEN (1948-a, p. 349) suggest, the Conoclypids are derived from the Discoidiids of the Holectypoids, the radiating internal walls (buttresses) of *Conoclypus* strongly recall *Discoidea*, and in no other Cassiduloid do we find anything comparable. Thus the Conoclypids are markedly different from the other Cassiduloids in the structure and in the source.

The order of the Clypeastroids is subdivided into two suborders, the Clypeastrina and the Laganina, by MORNENSEN, owing to the differences in the ambulacral plates of petals, the position and mode of auricles, and in the aboral miliary spines; the probable diphyletic or polyphyletic origin of the order has been already noticed by H. L. CLARK (1914, p. 123) and the writer. The families of the Clypeastrids and the Arachnoidids are assumed to have been derived probably from the Conoclypids of the Cassiduloids, and systematic arrangement of the genera and subgenera given by MORTENSEN, i. e., the Clypeastrids with a single genus, *Clypeaster*, and the Arachnoididae with three genera, seems to be justify at present state of our knowledge. The characteristics, e. g., the four genital pores, the ambulacral furrows, the "combed" areas, the lantern, and the larvae, distinguished the family Arachnoididae so sharply from the Clypeastridae that their value is beyond doubt. The second suborder, the Laganina DESOR, comprising three families of the Fibulariids, the Laganids, and the Scutellids, and they have probably been derived from the Discoidiids of the Holectypoids, thus differing from the Clypeastrina in their source: and it appears that the three families have evolved as three or more parallel stems from this root. The systematic arrangement of genera and subgenera in the family of the Fibulariids (including a rather large number of extinct forms) adopted by MORTENSEN, seems to more or less close to natural sequence. The only two genera (*Peronella* GRAY and *Laganum* (KLEIN) LINK) are referred to the family Laganidae, as already done by H. L. CLARK (1914-1946) and the writer; but MORTENSEN considered the former genus (*Peronella*) is more primitive than the latter, which is treated reversely by CLARK as rather a more primitive form. According to MORTENSEN the family Scutellidae fall into four subfamilies as listed above, i. e., the Scutellinae (including three living and twelve extinct genera) having the test without lunules or indentations, the Astriclypeinae (including three living and an extinct genera) having the test with at most two long narrow slits in the posterior ambulacra, the Monophorinae (including two living and an extinct genera) having the test with at least a lunule in the posterior interambulacrum, and the Rotulinae (including a living and an extinct genera) with the posterior edge of test with numerous, more or less deep indentations.

MORTENSEN subdivided the order Spatangoida into three suborders chiefly according to the difference of the structure of the plastron. The first suborder, which MORTENSEN named the Protosternata, are characterized by the primitive structure of the plastron, comprise only a single family of the Disasterids (Collyritids). As to the origin and the systematic arrangement of the genera and subgenera of the Collyritids, MORTENSEN almost fully followed BURLEN's view (BURLEN, 1934). The origin of the Collyritids, which BURLEN and MORTENSEN quite agree, can only be found among the Galeropygids of the primitive Cassiduloids. The two authors also have a view that the primitive meridosternous Spatangoids, the Holasteroids, are derived from the Collyritids through *Proholaster*, and the amphisternous Spatangoids have also evolved from the Collyritids through *Metaporinus*. Thus MORTENSEN and BEURLEN considered that the Collyritids would represent the ancestors of both the Holasterids and of the mighty group of the amphisternous Spatangoids.

The second suborder, which MORTENSEN named the Meridosternata, are characterized by the meridosternous plastron (the labrum abutting against a single sternal plate) and comprising five families, the Holasterids, the Urechinids, the Pourtalesiids, the Stenonasterids, and the Calymnids, the last two being small as families. The Holasterids, the primitive member of the suborder, have their flourishing age in the Cretaceous Period with about thirty genera, but continue sparingly into the Recent seas, only represented by the two genera, *Sternopneustes* MEIJERE and *Sternopatagus* MEIJERE. The Urechinids are direct descendants of the Holasterids. The small family of the Calymnids also comprise only Recent forms and it seems that the Calymnids are a small branch of the Urechinids. The Pourtalesiids are in an acmaic state in the Recent seas; they seem to have been derived directly from the Disasterids (Collyritids). The Stenonasterids, with their double ambulacral pores and the ethmophract apical system, as well as their primitively meridosternous plastron, are decidedly more primitive than the Urechinids; the Stenonasterids comprise only extinct genera, and form more or less an artificial family, they seem to represent a separate line from the Disasterids (Collyritids).

The third suborder, which MORTENSEN named the Amphisternata, are characterized by the amphisternous plastron (the labrum abutting against two usually equal-sized plates), comprising a large number of families that might probably have been derived from various sources. The classification and the systematic arrangement of the amphisternous Spatangoids must, as MORTENSEN considered, be based in the main on the fascioles, although the function and use of these organs are not certainly assured; this idea has been suggested by LAMBERT and THIÉRY. In that way, grouping after the fascioles, a clear distinction of the various groups becomes possible and practical, as it is at once clear to which family some form is referable. The primitive amphisternous Spatangoids, the family of the Toxasterids, are characterized by the total absence of fasciole, and it is accordance with their Cretaceous (MORTENSEN's view; ascertained to be Jurassic by the writer) age and they are richly developed in the Cretaceous, including about ten genera, but have survived till Recent seas with the single genus *Isopatagus* MORTENSEN. From the Toxasterids, probably the main families, the Micrasterids, Hemiasterids, Spatangids, Schizasterids, and the Brissids seem to have been derived. The Micrasterids are characterized by having only a subanal fasciole; they are thus a further specialization from the Toxasterids. This is in accordance with the fact that they are somewhat younger than the Toxasterids, and are confined to the Upper Cretaceous (four genera) and the Eocene. The Hemiasterids characterized by having a well developed peripetalous fasciole are in the main fossil richly developed in the Upper Cretaceous (nearly twelve genera), but surviving till the Recent seas by species of the genera *Hemiaster* DESOR and *Sarsiaster* MORTENSEN. The Spantagids characterized by having only a subanal fasciole, as in the family of the Micrasterids, but they have an ethmolytic apical system against the ethmophract apical system of the Micrasterids. They are mostly Recent forms, and may represent a further specialization from the Micrasterids. The Schizasterids characterized by having both a peripetalous and a latero-anal fasciole are chiefly Recent forms comprising a large number (about twenty-five) of genera. The origin of the Schizasterids is not very clear, but the marked difference of the origin of the peripetalous fasciole in the Hemiasterids and in the Schizasterids, as MORTENSEN claims, speak against the direct derivation of the Schizasterids from the Hemiasterids; it might be natural to seek for the source of the Schizasterids in the Toxasterids. The Brissids defined by MORTENSEN are characterized by having both a peripetalous and a subanal fasciole; they are also mostly Recent forms comprising about thirty genera. The great and very important family of the Palaeopneustids would seem to have been derived from the Conoclypids of the Cassiduloids, thus being very different from other amphisternous Spantagoids in their source; there are over twenty genera of Recent and fossil forms. From the Palaeopneustids again the families of the Loveniids and the Pericosmids seem to have developed. The Loveniids are characterized by having an inner (or internal) fasciole, and they seem to have provided consist the origin of two different genera, the *Lovenia—Breynia* and the *Echinocardium*. The Pericosmids are characterized by having both a peripetalous and a marginal fasciole, and also by the peculiar character of the petals, with the distalmost plates occluded. They comprise only a single genus *Pericosmus* AGASSIZ and two doubtful fossil genera. The Palaeostomatids, among the Recent Spantagoids, have an unique character of their peristome, and the well developed peripetalous fasciole. MORTENSEN suggests that the Palaeostomatids have their source in the Palaeopneustids, but we must confess our ignorance as to the actual genetic relations of these peculiar forms. The affinity of the Aeropsids with the Schizasterids in the peripetalous fasciole may be superficial instead of a true relation. MORTENSEN suggests that either they have their source in the Palaeopneustids, or are a special small branch of the amphisternous Spatangoids of unknown origin.

An important work on the major classification of Echinoids was published by DURHAM and MELVILLE (1957, pp. 242-272) after a large monograph of MORTENSEN had been completed. They critically reviewed and revised the classification of the class Echinoidea by MORTENSEN (1928-1951). Their systematic arrangement of the Echinoidea is as follows (only the ranks higher than taxa of the family-group cited).

DURHAM and MELVILLE (1957)

Subclass: Perischoechinoidea McCOY, 1849
    Order: Bothriocidaroida ZITTEL, 1879
        Family: Bothriocidaridae KLEM, 1904
    Order: Echinocystitoida JACKSON, 1912
        Family: Echinocystitidae GREGORY, 1897
    Order: Palaechinoida HAECKEL, 1886
        Family: Palaechinidae McCOY, 1849
        Family: Cravenechinidae HAWKINS, 1946
    Order: Cidaroida CLAUS, 1880
        Family: Archaeocidaridae McCOY, 1849
        Family: Miocidaridae DURHAM & MELVILLE, 1957
        Family: Cidaridae GRAY, 1825
            Subfamily: Histocidarinae MORTENSEN, 1928
            Subfamily: Cidarinae GRAY, 1825
            Subfamily: Stylocidarinae MORTENSEN, 1928
            Subfamily: Rhabdocidarinae MORTENSEN, 1928
            Subfamily: Goniocidarinae MORTENSEN, 1928

Subfamily: Ctenocidarinae Mortensen, 1928
Subfamily: Stereocidarinae Lambert, 1900
Subfamily: Psychocidarinae Ikeda, 1936
Subfamily: Diplocidarinae Gregory, 1900

Subclass: Euechinoidea Bronn, 1860
Superorder: Diadematacea Duncan, 1889
Order: Diadematoida Duncan, 1889
Family: Micropygidae Mortensen, 1904
Family: Diadematidae Gray, 1855
Family: Aspidodiadematidae Duncan, 1889
Order: Echinothurioida Claus, 1880
Family: Pedinidae Pomel, 1883
Family: Echinothuriidae Wyville Thomson, 1872
Order: Pygasterida Durham & Melville, 1957
Family: Pygasteridae Lambert, 1900

Superorder: Echinacea Claus, 1886
Order: Hemicidaroida Beurlen, 1937
Family: Acrosaleniidae Gregory, 1900
Family: Saleniidae Agassiz, 1838
Family: Hemicidaridae Wright, 1957
Family: Orthopsidae Duncan, 1889
Order: Phymosomatoida Mortensen, 1904
Family: Pseudodiadematidae Pomel, 1883
Family: Phymosomatidae Pomel, 1883
Family: Stomechinidae Pomel, 1883
Order: Arbacioida Gregory, 1900
Family: Arbaciidae Gray, 1855
Order: Temnopleuroida Mortensen, 1942
Family: Glyphocyphidae Duncan, 1889
Family: Temnopleuridae A. Agassiz, 1872
Family: Toxopneustidae Troschel, 1872
Order: Echinoida Claus, 1876
Family: Echinidae Gray, 1825
Family: Parasaleniidae Mortensen, 1903
Family: Strongylocentrotidae Gregory, 1900
Family: Echinometridae Gray, 1855

Superorder: Gnathostomata Zittel, 1879
Order: Holectypoida Duncan, 1889
Suborder: Holectypina Duncan, 1889
Family: Holectypidae Lambert, 1900
Suborder: Echinoneina H. L. Clark, 1925
Family: Discoidiidae Lambert, 1900
Family: Conulidae Lambert, 1911
Family: Echinoneidae Wright, 1857
Family: Galeritidae Gray, 1825
Suborder: Conoclypina Zittel, 1879
Family: Conoclypidae Zittel, 1879
Family: Oligopygidae Duncan, 1889
Order: Clypeasteroida A. Agassiz, 1873
Suborder: Clypeasterina A. Agassiz, 1873
Family: Clypeasteridae L. Agassiz, 1835
Family: Arachnoididae Duncan, 1889
Suborder: Laganina Mortensen, 1948
Family: Laganidae Desor, 1858

Family: Fibulariidae A. AGASSIZ, 1873
Family: Neolaganidae DURHAM, 1954
Suborder: Scutellina HAECKEL, 1896
Family: Scutellidae GRAY, 1825
Family: Protoscutellidae DURHAM, 1955
Family: Eoscutellidae DURHAM, 1955
Family: Dendrasteridae LAMBERT, 1900
Family: Echinarachniidae LAMBERT, 1914
Family: Monophorasteridae LAHILLE, 1896
Family: Mellitidae STEFANINI, 1911
Family: Astriclypeidae STEFANINI, 1911
Family: Abertellidae DURHAM, 1955
Family: Scutasteridae DURHAM, 1955
Suborder: Rotulina DURHAM, 1955
Family: Rotulidae GRAY, 1855
Superorder: Atelostomata ZITTEL, 1879
Order: Nucleolitoida HAWKINS, 1920
Family: Nucleolitidae AGASSIZ & DESOR, 1847
Family: Galeropydidae LAMBERT, 1911
Family: Neolampadidae LAMBERT, 1911
Order: Cassiduloida CLAUS, 1880
Family: Cassidulidae AGASSIZ & DESOR, 1847
Family: Echinolampadidae GRAY, 1851
Order: Holasteroida DURHAM & MELVILLE, 1957
Family: Collyritidae D'ORBIGNY, 1853
Family: Disasteridae A. GRAS, 1848
Family: Holasteridae PICTET, 1857
Family: Urechinidae DUNCAN, 1889
Family: Calymnidae MORTENSEN, 1907
Family: Pourtalesiidae A. AGASSIZ, 1881
Family: Stenonasteridae LAMBERT, 1922
Order: Spatangoida CLAUS, 1876
Family: Asterostomatidae PICTET, 1857
Family: Palaeostomatidae LOVÉN, 1867
Family: Palaeopneustidae A. AGASSIZ, 1904
Family: Aeropsidae LAMBERT, 1896
Family: Toxasteridae LAMBERT, 1920
Family: Micrasteridae LAMBERT, 1920
Family: Hemiasteridae H. L. CLARK, 1917
Family: Spatangidae GRAY, 1825
Family: Loveniidae LAMBERT, 1905
Family: Pericosmidae LAMBERT, 1905
Family: Schizasteridae LAMBERT, 1905
Family: Brissidae GRAY, 1855
Family: Maretiidae LAMBERT, 1905

Incertae sedis

Family: Archiaciidae COTTEAU & TRIGER, 1869
Family: Heterocidaridae MORTENSEN, 1934
Family: Tiarechinidae GREGORY, 1896

In their major classification they recognized, as listed above, two subclasses of the Echinoidea, the Perischoechinoidea and the Euechinoidea. The first subclass include all the Palaeozoic Echinoids and the post-Palaeozoic Cidaroids. The remaining Echinoids are placed in the second subclass Euechinoidea. They divided the second into four superorders, as follows: -the Diadematacea (corresponding to the order Aulodonta as used by MORTENSEN, as well as families Echinothuriidae and Pygasteridae); the Echinacea (for the orders Stirodonta and Camarodonta as used by MORTENSEN); the Gnathostomata (for the order Holectypoida of MORTENSEN, excluding the Pygasteridae, and including his Clypeastroida and certain genera of the Cassiduloida); and the Atelostomata (for the remainder of MORTENSEN's Cassiduloida and his Spatangoida). They also made some rearrangement on the ordinal level, but the families are left as used by MORTENSEN.

In their systematic arrangement of the Echidoidea, the following results are important and noteworthy. 1. As for the position of *Bothriocidaris* they conceded, with three sound reasons, to the view that the genus, if it is ancestral or not, is a true Echinoid, contrasting to MORTENSEN's view that *Bothriocidaris* is not a true Echinoid, and that it has no genetic connexion with the class. 2. They are lumping together numerous and diverse forms of the Palaeozoic Lepidocentroids into a single family, and prefer to accept the family Echinocystitidae (Lepidocentridae as a senior subjective synonym) in the wide sence of MORTENSEN; for example, they regarded that the family of the Palaeodiscids, established for genera with an open ambulacral furrow (*Aulechinus, Ectinechinus, Palaeodiscus*, etc.) is of questionable value since it is by no means certain that a true ambulacral furrow is present in all these genera, and they can find no satisfactory basis for separating from the family of the Echinocystitids (Lepidocentrids). 3. They expressively claim that the family of the Echinothuriids, which are regarded by MORTENSEN as the surviving member of the Palaeozoic Lepidocentroids, originated from some other contemporary and closely similar Pedinid stock than the Echinocystitids (Lepidocentrids); the association of these families appears unreasonable and unnatural, and the authors classified the Echinothuriids (Lepidocentrids) with the Pedinids, by the evidence from the Jurassic *Pelanechinus*, the earliest Echinothuriid, or from certain Recent forms. 4. Although MORTENSEN (1948-a, pp. 9-26) admitted that the Pygasterids and the Holectypids have originated from different sources, the former from the Pedinids and the latter from the Diadematids, and have evolved along different lines, he classified them together in the order of the Holectypoids after their more important structural resemblances. DURHAM and MELVILLE (1957, pp. 246-247, 253), however, rightly regarded that the Pygasterids, which are referred by MORTENSEN to the primitive forms of the Holectypoids, should be regarded as a sterile offshoot of the Pedinids, associating the Pygasterids with the Diadematoids on the evidence derived from the general resemblance of the Pygasterids to the Pedinid genera. The Holectypids, which are characterized by having the perforate and crenulate tubercles and the ancestral family of the remaining Holectypoids, are perhaps near the root of certain other irregular stocks as well: and they were in turn derived from the stirodont regular ancestor, in spite of earlier opinions that the Holectypids were of the Pygasterid derivation (LAMBERT and THÉRY, 1914, p. 277;—HAWKINS, 1920, p. 453;—HAWKINS, 1943, p. 69). 5. The division of the Cassiduloids into two orders, the Cassiduloida and Nucleolitoida, as proposed by HAWKINS, and followed by DURHAM and MELVILLE (1957, pp. 259-260), is opposed by later writers, such as KIER (1962) and PHILIP (1963), because it was judged impractical since it necessitated separating only several genera that are very similar and related. They held a view that the orderof the Clypeastroids, as understood by MORTENSEN (1948-c) and DURHAM (1955), to be a homogenous group of Holectypoid ancestry; and by the characters of the adapical termination of the interambulacra, this is, the continuity or not of the interambulacra on the oral surface, and the position of the auricles, they divided this order into four well marked suborders; as did the senior (DURHAM, 1955) of the two authors. 6. DURHAM and MELVILLE (1957, pp. 259, 260, 266) proposed the new order Holasteroida to embrace two suborders Protosternata and Meridosternata of MORTENSEN's usage on the reason that the characters of their apical system are of sufficient importance to unite them in an order than to divide into two suborders.

This brief review should give an impression of how the systematic arrangement and the classification of the Echinoidea differ in various authors, and how different nomenclatures are devised for a group of different ranks. Among the classifications established hitherto, that of MORTENSEN with an emendation of DURHAM and MELVILLE seems to be most reliable, although he stated in his great work (MORTENSEN, 1951, p. 573) that—" It was only clear to me that I could not accept any of the classification hitherto given in the literature, and my own classification was still in the making ". His material included the whole of Recent and fossil genera and subgenera, and his classification is not based on a few, simple characters, but on nearly all the exceedingly numerous, diversified and complex skeletal structures, as well as the larvae and the internal spicules. But the fact that so a large number of the genera and subgenera are fossil (in which the paleontologist has disadvantage of the neontologist in that pedicellariae, internal spicules, well preserved microstructure of spines, as well as the fact that the occurrence of such structures in place on the test in fossil is uncommon), and thus only incompletely known, and there are so many gaps, beside lack of materials, naturally causes some uncertainties here and there. Future fortunate finds of necessary fossils, which clear up the uncertainties, and future embryological researches, which may prove the true genetic relations, may be expected to consolidate the classification and the systematic arrangement of the great class of the Echinoidea.

A NOTE ON TAXA OF THE ORDER-GROUP AND THEIR NAMES

As listed above, so many different nomenclatures have been tried for a rank (group), particularly to a ordinal rank, of the Echinoidea by various authors, e. g., LAMBERT's Pileatoida LAMBERT (suborder) corresponds to MORTENSEN's Holectypina GREGORY, and LAMBERT's both of Brachygnatha (order) and Globatoroida approximately correspond to MORTENSEN's Echinoneina HAWKINS (suborder), that for the use of these nomenclatures must be paid much caution. The International Code of Zoological Nomenclature have no codification on the nomenclature of ranks higher than the ordinal group. In considering the name to be used for order-group DURHAM and MELVILLE (1957, pp. 262-270), bearing in mind the recommondations published in " Copenhagen Decision on Zoological Nomenclature ", have approved to use uniform terminations for ordinal and subordinal names. They have used " -oida ", by addition to the stem (base) of the name of the type-genus, for ordinal and " -ina " for subordinal terminations, and systematically adjusted the ordinal names. The same format is already being used by the writer (NISIYAMA, 1954) since several years.

The termination " -oida ", by addition to the stem of the name of the type-genus, for ordinal rank has used, for many of the ordinal ranks of the Echinoidea, by DUNCAN, GREGORY, H. L. CLARK, and MORTENSEN (e. g., Diadematoida DUNCAN, 1889-a, p. 24: Lepidocentroida MORTENSEN, 1934, p. 162; 1935, p. 42); DURHAM and MELVILLE and the writer, however, have used the uniform termination for all the oridinal ranks, as they have seen that names formed from morphological characters are particularly liable to cause inconvenience on account of the taxa they represent are so frequently considered, with advances in taxonomic theory, to include unrelated forms. A difficulty, however, lies in the name of the order Echinoida, the taxon of the writer (1954, p. 326) is an emended name from the suborder Echinina GREGORY (1900-b, p. 311), and that of DURHAM and MELVILLE from MORTENSEN (after CLAUS, 1876). In forming the suborder Echinina GREGORY simply ignored the characters of masticatory apparatus and of pedicellariae, but he comprised the following families, e. g., Temnopleuridae, Triplechinidae, Strongylocentrotidae, and the Echinometridae; these families, with a few exceptions of some genera, are characterized by having the camarodont teeth in the masticatory apparatus, and with the echinoid-type or its specialized structure in ambulacral plates. Of these families, the Temnopleuridae are referred to his suborder Temnopleurina by MORTENSEN in 1942. The Echinoida is a good ordinal name for it stands in its proper position as the type-order of the class Echinoidea, and likewise it has the type-family Echinidae GRAY of the inferior rank as erected from the stem of the name of the type-genus *Echinus*.

The termination " -ina ", by addition to the stem (base) of the name of the type-genus, for taxa of the family-group was already used in the Cidaroida by MORTENSEN (i. e., Histocidarina MORTENSEN, 1928, p. 69). This use of termination nomenclature already appeared a century ago in GRAY's Catalogue (1955-a); in this work GRAY used the following names, e. g., Clypeastrina, Rotulina and Fibularina (Fistularina, p. 27) under the family Scutellidae, Echinoneina under the family Galeritidae, Cassidulina and Echinobrissa under the family Echinolampadidae (Echinolampasidae), and Spatangina and Brissina under the family Spatangidae. Although the rank of these names in modern usage must be raised to subfamily, family, or even to suborder; the same names were adopted by H. L. CLARK (1925-46), MORTENSEN (1928-51), DURHAM (1955) and DURHAM and MELVILLE (1957) as the names of the suborders, e. g., Clypeastrina GREGORY, 1900 (Clypeasterina A. AGASSIZ, 1873), Echinoneina HAWKINS, 1925, Cassidulina DELAGE and HÉROUARD, 1903—HAWKINS, 1925 (the name itself becomes a junior homonym of *Cassidulina* D'ORBIGNY, 1826), and Spatangina JACKSON, 1912, become junior homonyms of GRAY's names, respectively.

The writer has felt it appropriate to use termination " -oina ", by addition to the stem (base) of the name of the type-genus, for subordinal rank, in accordance with the termination of ordinal rank as well as to show the inferior, not as in the termination " -ina " as used by former authors, such as H. L. CLARK, MORTENSEN, and DURHAM and MELVILLE. This format, thus, naturally causes the clear distinction between taxa of the order-group and of the family-group or of the genus-group (e. g., Arbacioina GREGORY, 1900, emended here—from Arbacina GREGORY, 1900-b, p. 307, which was once rejected for a junior homonym of *Arbacina* POMEL, 1883; Cassiduloina CLAUS, 1880—Cassidulina CLAUS, 1880 (DELAGE and HÉROUARD, 1903), non D'ORBIGNY, 1826; Scutelloina HAECKEL, 1896—Scutellina HAECKEL, 1896 (DURHAM, 1955), non L. AGASSIZ, 1841). The application of this format almost of the names of important suborders used in the works of H. L. CLARK, MORTENSEN, and DURHAM and MELVILLE must be emended as follows.—

Original names	Names emended
Diademina GREGORY, 1900	Diadematoina
Holectypina GREGORY, 1900	Holectypoina
Echinoneina HAWKINS, 1925	Echinoneoina
Cassidulina CLAUS, 1880	Cassiduloina
Conoclypina ZITTEL, 1879	Conoclypoina
Clypeasterina A. AGASSIZ, 1873	Clypeasteroina
Laganina MORTENSEN, 1948	Laganoina
Scutellina HAECKEL, 1896	Scutelloina
Rotulina DURHAM, 1955	Rotuloina
Urechinina H. L. CLARK, 1925	Urechinoina
Spatangina JACKSON, 1912	Spatangoina

The writer also does not prefer the following names of suborders used in the great monograph of MORTENSEN, e. g., the Calycina GREGORY, 1900 (1935, p. 301), the Protosternata MORTENSEN, 1907 (1950-a, p. 6), the Meridosternata (LOVÉN) MORTENSEN, (1950-a, p. 37), and the Amphisternata (LOVÉN) MORTENSEN, 1907 (1950-a, p. 174), because these names are formed from morphological characters in adjective noun, although they represent good characters for their groups, respectively.

ON THE KEY TO THE ORDERS AND SUBORDERS OF THE CLASS ECHINOIDEA

On the entering into the review on the outline of classification and on the systematic arrangement of the Echinoidea in the foregoing paragraphs and giving a key to the higher ranks of the class, the writer has been perplexed by the fact that it is not clear to him what would be the natural classification of the whole of this class, as he had not been able to accept some points of the classifications hitherto given in literature, and as his own classification being still in the going. But the writer has been urged to give a brief survey and a short outline of the classification of the whole class for the forthcoming description of the fossils, and the discussion on the fauna in this work. The following key to the orders and suborders given by the writer, of course, is not satisfactory to the writer himself because there are some uncertainties here and there. But future researches on the fossils, and young stages of Echinoids may be useful for verify and correcting errors to be discovered here and there in this sketch of the system of the great class of the Echinoidea.

In his comprehensive and exhaustive survey of the whole class, MORTENSEN recognized ten orders as listed above (except the Megalopoda MACBRIDE and SPENCER), grouped into two subclasses. MORTENSEN gave the excellent key to the orders of the class Echinoidea, through his sound judgement and his extensive knowledge of the class, three times in his great monograph; the first in the second volume (1935, p. 26) he made a survey of key to all the orders so far as he thought it possible at that time, before he had studied all of them throughly; the second, in volume 4, part 1 (1948-a, p. 8) a key to the orders of his Irregularia; and the third, at the end of the Monograph (1951, p. 573) he gave a survey of the whole class. His key to the ten orders and to the suborders and furthermore to the families and the genera is excellent and sound, and shows considerable elaboration to guard against the perplexing groups. MORTENSEN, however, hesitates the separation of forms with open ambulacral furrows (i. e., *Aulechinus* BATHER and SPENCER) from the Lepidocentroids (Echinocystitids) with closed ambulacral furrows (i. e., *Meekechinus* JACKSON, 1912) as distinct orders or suborders, or even distinct families. He described (1951, p. 574, foot-note) as follows—" It might have been preferable to regard the forms with open ambulacral furrows as a separate order. But the long delay in the publication of SPENCER's (and MACBRIDE's) researches on these forms made it too awkward now to introduce this division of the primitive Lepidocentroids (Echinocystitoids)." DURHAM and MELVILLE (1957, pp. 249, 250) agree MORTENSEN in this view that they can find no satisfactory basis for subdividing the former from the latter as distinct groups; they stated that (1957, p. 244) the open radial groove said by MORTENSEN to be present in *Myriastiches* (and in ?*Aulechinus*) does not exist. The great family of the Echinothuriids, which are regarded by MORTENSEN as the surviving member of the Palaeozoic Lepidocentroids, with two columns of plates in the interambulacra and well developed auricles are clearly a separate stem from the Palaeozoic Lepidocentrids (Echinocystitids) with usually pluriseriate plates in the interambulacra and without distinct auricles, although the skeletal plates of the Echinothuriids are only loosely connected, easily explains that finds of these forms are so rare; but the Jurassic *Pelanechinus* KEEPING and the Cretaceous *Echinothuria* WOODWARD show the characters that they clearly belong to the family of the Echinothuriids but not to the the Lepidocentroids, as pointed out by DURHAM and MELVILLE (1957, pp. 250-251).

In their " A Classification of Echinoids " DURHAM and MELVILLE (1957) recognized seventeen orders (excepting the Bothriocidaroida and Megalopoda, but including two new) in the class Echinoidea; they gave no key to the orders and suborders, but from their excellent diagnoses given to each rank, the ordinal and subordinal characters are clearly discriminated. They have elevated each of three suborders of the order Stirodonta as used by MORTENSEN and two suborders of the Camarodonta to ordinal rank by the reason that they might have been attained independently in diverse stocks.

In comparing the classification of the class Echinoidea with that of other classes of higher invertebrates of highly diverse and specialized forms (excepting the Insecta of Arthropoda), e. g., Crustacea (from the Cambrian to Recent) of Arthropoda, Cephalopoda (Cambrian to Recent) and Gastropoda (Cambrian to Recent) of Mollusca, and Ophiuroidea (Ordovician to Recent) of Echinodermata, and with considering the temporary span of main development, since the Jurassic Period, and main morphogenetic branches of the Echinoidea, the writer has come to infer that the number of ordinal ranks in the Echinoidea may be less than twenty, or even less. The writer feels that the minor differences in the primitive Echinoids can not be so small as hitherto thought, but considering their long geological range (e. g., the family of the Echinocystitids range from the Lower Silurian to the Permian, almost three times as long as the range of the family of the Glyphocyphids, and also ten times as long as that of the family of the Echinometrids of the specialized forms), and comparing the minor differences to those of the short-lived and specialized forms, morphological change in the primitive forms should be of a slow rate, because it can be assumed that the differences in the primitive forms must have a significance in the morphogenetic development and in the classification of the class. But, unfortunately, as new material of very rare forms of the primitive Echinoids has not been accessible to the writer, the solution of this problem appears to be easily inaccessible to the writer himself.

A key to the orders and suborders of the class Echinoidea, in the writer's mind, is as follows (emended from MORTENSEN's, DURHAM and MELVILLE's, and others).

1. Regular Echinoids with interambulacra of 1-14 columns; ambulacra of 2-20 column's, without compound plates; periproct within apical system; perignathic girdle only of apophyses, or none; teeth grooved; no branchial slits, no sphaerida, no ophicephalous pedicellariae 2

Echinoids with interambulacra and ambulacra of two columns each; corona generally rigid, rarely imbricating; periproct within or outside the apical system; perignathic girdle of auricles, with or without apophyses, or absent in adult; lantern with grooved or keeled teeth, or absent in adult; branchial slits present, or absent in adult; sphaeridia present; ophicephalous pedicellariae generally present 4

2. Interambulacra of one or more than two, ambulacra of two or more; corona rigid, but ambulacra level over interambulacra along adradial suture; base of corona resorbed; genital plates present; tubercles imperforate; tubercles and spines all small, of uniform size; peristome with ambulacral and some interradial plates; lantern inclined; no perignathic girdle .... Palaechinoida. (Melonechinoida)

Twenty or more columns of plates; if more than 20, the coronal plates are always imbricate, or not; tubercles and spines usually of various sizes, primaries and secondaries; ambulacra continuing over the peristome, there being series of plates between mouth and edge of peristome 3

3. Corona imbricating, ambulacral plates imbricating adorally, interambulacral plates adapically and over the ambulacrals along the adradial suture; primordial ambulacral and interambulacral plates in basicoronal row; genital plates present; no perignathic girdle; primary radioles slender, without cortex layer; lantern inclined .... Echinocystitoida (Lepidocentroida)

Interambulacra of two or four columns, and ambulacra of two; ambulacra narrow; corona rigid, or imbricating as in the Echinocystitoids; base of corona resorbed; genital plates present; one large primary tubercle on each interambulacral plate; peristome with both ambulacral and interradial series of plates; perignathic girdle only of apophyses, or none; primary radioles with a cortex layer; lantern generally erect .... Cidaroida

4. Lantern and perignathic girdle present in adult; periproct within or outside apical system 5

Lantern, perignathic girdle, and branchial slits absent in adult; periproct outside apical system 15

5. Teeth grooved or unkeeled; lantern erect; epiphyses not joining above the teeth 6

Teeth keeled 8

6. Corona rigid or imbricating; periproct within or outside apical system; tubecles perforate; perignathic girdle complete in adult; branchial slits in adult; compound plates of diadematoid structure ordinarily present; symmetry of corona approaching radial, never markedly bilateral .... Diadematoida

Periproct within apical system; ambulacra with compound plates 7

Periproct outside apical system; ambulacra without compound plates; corona rigid; tubercles smooth; genital pores four; axis of primary radioles solid (?) .... Pygasteroina

7. Corona rigid or imbricating; axis of primary radioles (usually) hollow; primary tubercles crenulate; five genital pores .... Diadematoina

Corona rigid or flexible; axis of primary radioles solid when corona is rigid, hollow when corona is flexible; tubercles smooth; genital pores five .... Echinothurioina

8. Corona regular, periproct with apical system; ambulacra (generally) with compound plates 9

Corona irregular, periproct outside apical system; ambulacra (generally) without compound plates 12

9. Epiphyses not joining over the teeth; foramen open; lantern erect 10

Epiphyses joining over the teeth; foramen closed; lantern erect 11

10. Corona rigid; branchial slits present in adult; perignathic girdle complete in adult .... Arbacioida

Interambulacral plates with a single large tubercle, which is sometimes reduced in size above the ambitus; ambulacra with compound plates of diadematoid structure, often only in adoral region; primary radioles with solid axis and a cortex layer; apical system with or without suranal plates .... Salenioina (Hemicidaroina)

Interambulacral plates generally with more than one smooth tubercle, but one only in some forms; compound ambulacral plates of diadematoid structure; primary radioles usually with solid axis, with or without a cortex layer; no suranal plate .... Phymosomatoina

Compound ambulacral plates of arbacioid structure; primary tubercles imperforate, smooth; periproct (always ?) covered by four or five large plates; primary radioles with solid axis, cortex layer more or less developed; surface of corona usually covered with an "epistroma" .... Arbacioina

11. Corona rigid; compound ambulacral plates of diadematoid or echinoid structure; primordial interambulacral plates not persisting; primary radioles with solid

axis .... Echinoida

Compound ambulacral plates of diadematoid or echinoid structure; test sculptured or not, if not then branchial slits sharp, more or less deep; primary radioles with solid axis .... Temnopleuroina

Compound ambulacral plates of echinoid structure; corona not sculptured; primary tubercles imperforate, smooth; primary radioles with solid axis, without a cortex layer .... Echinoina

12\. Lantern and perignathic girdle usually present in adult; apical system and peristome usually approximately opposite; primary tubercles usually perforate and crenulate; radioles hollow; branchial slits usually absent in adult.... 13

Lantern, perignathic girdle, and branchial slits absent in adult; apical system and peristome rarely opposite; primary tubercles usually perforate, crenulate; primary radioles hollows; floscelle present or not; interambulacra always wider than ambulacra on oral surface................................. 15

13\. Corona inflated; ambulacra not forming petals adapically, or phyllodes adorally, with reduced plates; interambulacral ornament orderly; ambulacra narrow on oral surface; lantern usually inclined; teeth with lateral flanges..Holectypoida

Auricles radial in position; reduced plates in ambulacra; ornament orderly...... .... Holectypoina

Auricles interradial in position, or radial only when present in juveniles; reduced plates in ambulacra; ornament orderly .... Echinoneoina

Corona inflated or depressed; ambulacra petaloid adapically; no phyllodes or bourrelets; lantern strongly developed and persistent in adult 14

14\. Corona usually with internal supports; apical system monobasal; ambulacra wider than interambulacra on adoral surface; secondary tube-feet often extending outside ambulacra; lantern inclined, without compass; keeled teeth lacking lateral flanges.. Clypeasteroida

Auricles separate, radial in position; petals with complex structure and reduced plates; interambulacra discontinuous on adoral surface, teminated by a pair of plates .... Clypeasteroina

Auricles fused, interradial in position; petals with or without reduced plates; interambulacra continuous on adoral surface, terminated adapically by a single plate or a series of single plates .... Laganoina

Auricle fused, interradial in position; corona depressed; no reduced plates in ambulacra; interambulacra continuous or discontinuous on adoral surface, terminated adapically by a pair of plates; ambulacral food-grooves present.. .... Scutelloina

Auricles fused, interradial in position; corona depressed, posteriorly slightly to strongly dentate or digitate; no reduced plates in ambulacra; posterior interambulacrum (5) continuous on adoral surface, others variable, all terminating adapically in a series of single plates .... Rotuloina

15\. Plastron undifferentiated; floscelle more or less developed 16

Plastron feebly differentiated or highly specialized; no distinct floscelle 17

16\. Ambulacra petaloid adapically, with petals usually all similar; floscelle usually developed; apical system disparate or compact; apical system and peristome sometimes opposite; genital pores four; no fasciole .... Cassiduloida

Lantern present in the juveniles, but resorbed completely before the adult stage is reached; ambulacra petaloid adapically .... Cassiduloina

Lantern present even in adult stages; ambulacra petaloid adapically; auricles interradial in position .... Conoclypoina

Lantern absent in adult stages; petals lacking, and adapical ambulacral plates with single pores .... Neolampadoina

17. Ambulacra more or less petaloid adapically or quite rudimentary; apical system never to opposite peristome or sometimes opposite; no branchial slits; no bourrelets; fascioles often present.............................. Spatangoida

Plastron of primary, simple, primitive structure, very small not differentiated labrum meeting at its posterior end joining two not specialized sternal plates; apical system elongate or disjunct; no distinct fasciole.......... Collyritoina

Plastron meridosternous (labrum joining at its posterior end only a single plate no. 2); fasciole of irregular occurrence; apical system generally elongate or disjunct; petals, when present, not impressed .... Urechinoina

Plastron amphisternous (labrum joining at its posterior end two large sternal plates, equally, or nearly equally, developed); apical system compact, never opposite to peristome; petals usually impressed, not all similar; fascioles usually present .... Spatangoina

It seems to the writer that no clear-cut division into two subclasses (the Regularia (Endocycloida)—the periproct within the apical system and the Irregularia (Endocycloidea)—the periproct outside the apical system in the posterior interambulacrum (5)), in the class Echinoidea, is possible. The distinction between the two subclasses is somewhat arbitrary and practical, because in some Regularia (i. e., *Acrosalenia* AGASSIZ and *Pygaster* AGASSIZ) the periproct is just barely within or outside the ring, and in some primitive Irregularia (i. e., *Galeropygus* COTTEAU) it lies scarcely outside. From such a difference in the features to erect the higher rank like subclass superior to order appears peculiar and is inacceptable to the writer. It also follows that the division of the so-called Irregularia into two superorders, viz, Gnathostomata (roughly corresponding to the Holectypoida and Clypeasteroida) and Atelostomata (Cassiduloida and Spatangoida) is unnecessary.

TYPES IN THE GENUS-GROUP

The kinds and their names of type-species (ICZN, 1961, p. 63), which the writer intends to use here, are followed, chiefly what have been used by the writer himself (1937, pp. 47-60) and IREDALE (1939, pp. 209-425): they are—

Orthotype: (ICZN, 1961, Article 68 (a))—(Type by original designation).

Example: Genus *Hemicentrotus* MORTENSEN, 1942

Hemicentrotus MORTENSEN, 1942, p. 231.

Orthotype.—Psammechinus pulcherrimus A. AGASSIZ, 1863-a, p. 357 (Hakodate Bay, Japan).

Haplotype: (ICZN, 1961, Article 68 (c))—(Type by monotypy at the time).

Example: Genus *Scaphechinus* A. AGASSIZ, 1863

Scaphechinus A. AGASSIZ, 1863-a, p. 359.

Haplotype.—Scaphechinus mirabilis A. AGASSIZ, 1863-a, p. 359 (Hakodate Bay, Japan).

Tautotype: (ICZN, 1961, Article 68 (d))—(Type by absolute tautonomy).

Example: Genus *Laganum* (KLEIN) LINK, 1807

Laganum LINK, 1807, p. 161.

Tautotype.—Laganum petaloides LINK, 1807, p. 161.=*Echinodiscus laganum* LESKE, 1778, p. 140, pl. 22, fig. C (Indian Ocean).

Logotype: (ICZN, 1961, Article 69 (a))—(Type by subsequent designation—the designator is enclosed in brackets after the citation of type-species).

Example: Genus *Holaster* L. AGASSIZ, 1836

Holaster L. AGASSIZ, 1836, p. 16 (183).

Logotype.—Spatangus nodulosus GOLDFUSS, 1829, p. 149, pl. 45, fig. 6 (Cenomanian of Germany). [Savin, 1905, p. 37 (173)].

HISTORICAL SKETCH OF THE FOSSIL ECHINOIDS FROM JAPAN AND ADJACENT REGIONS

Although the number of fossil Echinoids hitherto described and illustrated from Japan and the adjacent regions is small, yet there are several interesting and important forms amongst them. Paleontological studies on the fossils from those regions are considerably backward from the studies of the Recent forms, and it was probably not later than the later half of the nineteenth century that the fossils from these regions began to communicated by the scientists.

The species which have been described and illustrated from Japan and the adjacent regions as fossil are given in the following list in the order of dates of publication, together with their respective localities, geological ages, and original names.

1. The first work to make its appearance was a notice of Cidarid spines in the description of the geology of Japan by two German authors: NAUMANN and NEUMAYR (1890, pp. 1-45).

Cidaris cf. *grandifera* GOLDF.	Tosa, Cretaceous
Cidaris (new species)	Tosa, Cretaceous

2. Several years later JIMBO (1894) described a Spatangoid from Hokkaido.

Ananchytidium sp.	Hokkaido, Cretaceous

3. The important works of TOKUNAGA (formerly YOSHIWARA) began to appear somewhat later, and the first paper on the fossil was entitled "On some Fossil Echinoids of Japan" (1899).

Astriclypeus integris, n. sp.	Kai, Miocene
Linthia nipponica, n. sp.	Shinano, probably Pliocene
Schizaster recticanalis, n. sp.	Kaga, Pliocene

4. DE LORIOL described six fossil species from Japan in 1902.

Salenia (*Pleurosalenia*) *hakkaidoensis*, n. sp.	Hokkaido, Tertiary
Ilarionia yoshiwarai, n. sp.	Bonin Islands, Eocene
Echinolampas yoshiwarai, n. sp.	Kazusa, Pliocene

Toxaster tosaensis, n. sp.	Tosa, Cretaceous
Prenaster boninensis, n. sp.	Bonin Islands, Eocene
Hypsospatangus japonicus, n. sp.	Hokkaido, Neogene

5. The most important work on the fossil Echihoids from Japan by Tokunaga appeared in 1903.

Salenia (Pleurosalenia) hakkaidoensis Loriol	Yûbari coal-field, probably Pliocene
Coptosoma crenulare (A. Agassiz)	Sagami, Pliocene
Temnopleurus toreumaticus (Klein)	Tokyo, Diluvium
Fibularia acuta Yoshiwara	Tokyo, Diluvium
Clypeaster testitudinarius (Gray)	Okinawa, Diluvium
Laganum decagonalis (Lesson)	Tokyo and Shimôsa, Diluvium
Laganum fudsiyama Döderlein	Sagami, Pliocene
Echinarachnius mirabilis (Barn)	Hitachi, Tokyo, and Shimôsa, Diluvium
Echinarachnius parma (Lamarck)	Etchû, Echigo, and Sado Island, Neogene Tertiary
Echinodiscus formosus Yoshiwara	Formosa, Miocene
Astriclypeus integer Yoshiwara	Kai, Formosa, and Ryûkyû Islands, Miocene
Pygurus asiaticus Tokunaga	Tosa, probably Cretaceous
Echinolampas yoshiwarai Loriol	Kazusa, Pliocene
Toxaster tosaensis Loriol	Tosa, Cretaceous
Linthia nipponica Yoshiwara	Kaga, Shinano, Hitachi, Uzen, and Ugo, probably Pliocene
Schizaster nummuliticus Tokunaga	Bonin Islands, Eocene
Prenaster boninensis Loriol	Bonin Islands, Eocene
Hypospatangus japonicus Loriol	Hokkaido, Neogene Tertiary
Brissopsis luzonica (Gray)	Iwaki, Neogene Tertiary
Cidaris sp.	Tosa, probably Cretaceous
Pseudocidaris sp.	Tosa, probably Cretaceous
Pseudocidaris sp.	Tosa, probably Cretaceous
Cidaris sp.	Musashi, Jurassic or Cretaceous
Cidaris sp.	Musashi, Jurassic or Cretaceous
Cidaris sp.	Tosa, probably Cretaceous

6. Tokunaga reported the following species from the Pleistocene of Tokyo in 1906.

Temnopleurus toreumaticus (Klein)	Tokyo, Diluvium
Fibularia acuta Yoshiwara	Tokyo, Diluvium
Laganum decagonalis (Lesson)	Tokyo, Diluvium
Echinarachnius mirabilis (Barn)	Tokyo, Diluvium

7. Lambert and Thiéry in their " Essai de nomenclature raisonnée des Echinides, fasc. 1-9, 1909-1925) enumerated a large number of genera and species known to the science at that time, and reviewed (sometimes revised) genera and even species, but at the same time they changed a number of the old familiar names to those that are not acceptable by many authors. The fossil species from Japan and the adjacent regions in their literature is as follows.

Salenia hakkaidoensis de Loriol	Eocene
Lobophora formosa (Yoshiwara)	Miocene
Astriclypeus integer Yoshiwara	Pliocene
Echinopygus asiaticus (Tokunaga)	Cenomanian
Ilarionia yoshiwarai de Loriol	Eocene
Echinolampas yoshiwarai de Loriol	Miocene
Niponaster hokkaidensis Lambert, n. sp.	Cretaceous
Nordenskjoldaster tosaensis (de Loriol)	Cretaceous

Aphelaster tosaensis (DE LORIOL) (same the above)
Pharaonaster japonicus (DE LORIOL) Tertiary
Prenaster boniensis DE LORIOL Eocene
Linthia nipponica YOSHIWARA Pliocene
Linthia tokunagai LAMBERT, n. sp. Pliocene
Schizaster (*Brachybrissus*) *recticanalis* YOSHIWARA Miocene
Schizaster (*Brisaster*) *nummuliticus* TOKUNAGA Eocene

8. NAGAO (1928) described three species of fossil Echinoids derived from the coal-fields in Kyûshû, describing together a large number of other invertebrate fossils in his great work " Palaeogene Fossils of the Island of Kyushu ".

Scutella nipponica, n. sp. Chikuzen, Oligocene
Echinodiscus chikuzenensis, n. sp. Chikuzen, Oligocene
Linthia praenipponica, n. sp. Chikuzen, Oligocene

9. NISIYAMA (formerly AOKI) (1935) described three species of fossil Echinoids derived from the Miocene formation of Northeast Japan, with addition of a synopsis of the Scutellids.

Astriclypeus manni ambigenus, subsp. nov. Tsugaru, Miocene
Echinolampas yoshiwarai DE LORIOL, var. Tsugaru, Miocene
Moira obesa, sp. nov. Tsugaru, Miocene

10. NISIYAMA (1936) reported the occurrence of an interesting and rare Echinoid in the Pleistocene of Yokohama City.

Temnotrema rubrum (DÖDERLEIN, 1885) Tsurumi, Pleistocene

11. NISIYAMA (1937-a) described a new species of *Sismondia* from the Oilgocene of the islands of Bonin.

Sismondia convexa, sp. nov. Bonin Islands, Oligocene

12. OTUKA (1938) described a subspecies of Echinoid from the Miocene of Shizuoka Prefecture, describing together with other fossils.

Laganum fudsiyama tokunagai, subsp. nov. Kanbara, Miocene

13. NISIYAMA (1940) in his " On the Japanese species of *Echinarachnius* ", discriminated the following species occurred as fossil in Japan and the adjacent regions.

Echinarachnius (*Kewia*) *nipponicus* (NAGAO, 1928) Chikuzen, Oligocene
Echinarachnius (*Kewia*) *parvus*, n. sp. Sakhalin, Oligocene
Echinarachnius (*Kewia*) *elongatus*, n. sp. Sakhalin, Miocene
Echinarachnius (*Echinarachnius*) *microthyroides*, n. sp. Mutsu, Mio-Plioocene
Echinarachnius (*Echinarachnius*) *laganolithinus*, n. sp. Ugo, Pliocene
Echinarachnius (*Scaphechinus*) *mirabilis* (A. AGASSIZ, 1863) Tokyo, Shimôsa, Kazusa, and Hitachi, Pleistocene ; Formosa, Pliocene
Echinarachnius (*Scaphechinus*) *griseus* MORTENSEN, 1927 Kazusa, Pleistocene

14. HAYASAKA and MORISHITA (1947) reported fossil species of *Clypeaster* from Taiwan (Formosa) as the first Note of " Notes on some Fossil Echinoids of Taiwan " in their " Fossil Species of *Clypeaster* from Taiwan ".

Clypeaster japonicus DÖDL. Formosa and Tokuno-shima. Pleistocene
Clypeaster japonicus DÖDL. subsp. *plana*, nov. Formosa, Pleistocene
Clypeaster japonicus DÖDL. subsp. *alta*, nov. Formosa, Pleistocene
Clypeaster cf. *deserti* KEW Formosa, Pliocene

Clypeaster colloti LAMBERT Formosa, Pliocene
Clypeaster cf. *reticulatus* (LINNÉ) Tokuno-shima, Pleistocene

15. HAYASAKA and MORISHITA (1947-a) reported the following species from Formosa.

Echinarachnius (*Scaphechinus*) *mirabilis* (A. AGASSIZ) Formosa, Pliocene
Laganum aff. *boschi* (R. MARTIN) Tokuno-shima, Pleistocene
Peronella cf. *decagonalis* A. AGASSIZ Formosa, Pliocene
Peronella (*Peronellites*) *ovalis*, sp. nov. Formosa, Miocene
Echinolampas sp. indet. Formosa, Miocene
Echinolampas (*Miolampas*) *depressus* GRAY Tokuno-shima, Pleistocene

16. HAYASAKA (1947) in his "Notes on Some fossil Echinoids of Taiwan", enumerating the following species from Formosa.

Clypeaster aff. *humilis* (LESKE) Formosa, Pliocene
Astriclypeus integer YOSHIWARA Formosa, Miocene
Astriclypeus manni VERRILL Formosa, Pliocene
Breynia cordata, sp. nov. Formosa, Pliocene
Breynia testudinaria, sp. nov. Formosa, Pliocene

17. NISIYAMA (1948) described an interesting fossil Echinoid from the Mio-Pliocene (Suenomatsuyama) formation of Mutsu Province, Northeast Japan.

Astrodapsis nipponicus, n. sp. Mutsu, Mio-Pliocene

18. HAYASAKA (1948-a) described and enumerating the following species from Formosa.

Porosoma sp. indet. Formosa, Pliocene
Echinolampas jackemonti D'ARCHIAC et HAIME Formosa, Miocene
Echinolampas concavus, sp. nov. Formosa, Miocene
Linthia taiwanensis, sp. nov. Formosa, Miocene
Sinaechinus kawaguchii, sp. nov. Formosa, Miocene
Schizaster (?*Paraster*) *taiwanicus*, sp. nov. Formosa, Eocene
Schizaster (?*Paraster*) sp. indet. Formosa, Eocene
Moira obesa NISIYAMA Formosa, Miocene
?*Moira* sp. Formosa, Miocene
Moiropsis depressa, sp. nov. Formosa, Miocene
Brissus sp. indet. α Formosa, Pleistocene
Brissus sp. indet. β Formosa, Pleistocene
Breynia carinata D'ARCHIAC et HAIME Formosa, Miocene

19. MORISHITA (1950) reported fossil Echinoids derived from the Neogene deposits developed in Ishikawa and Toyama Prefectures.

Astriclypeus manni VERRILL Toyama and Ishikawa, Miocene
Echinarachnius parma (LAMARCK) Toyama, Pliocene
Echinarachnius (*Scaphechinus*) *mirabilis* (AGASSIZ) Ishikawa and Toyama, Pliocene
Echinarachnius (*Scaphechinus*) *mirabilis tenuis* YOSHIWARA Ishikawa, Pliocene
Echinarachnius (*Echinarachnius*) *microthyroides* NISIYAMA Toyama, Pliocene
Echinarachnius tsudai, sp. nov. Ishikawa, Pliocene
Echinarachnius ishioi, sp. nov. Toyama, Pliocene
Clypeaster virescens DÖDERLEIN Ishikawa, Pliocene
Clypeaster sp. indet. Toyama, Pliocene
Echinolampas yoshiwarai LORIOL Ishikawa, Pliocene
Linthia nipponica YOSHIWARA Toyama, Pliocene

Schizaster sp. indet. Toyama, Miocene
Schizaster recticanalis Yoshiwara Ishikawa and Toyama, Miocene
Eupatagus (*Brissoides*) sp. Toyama, Miocene
Cidaris sp. a Toyama, Pliocene
Cidaris sp. b Ishikawa, Pliocene

20. Nisiyama (1950) described two species of the Toxasteridae, one of the families of the Spatangoids, from the Cretaceous of Japan.

Heteraster nexilis Nisiyama, n. sp. Shikoku, Cretaceous
Washitaster (?) *macroholcus* Nisiyama, n. sp. Kii, Cretaceous

21. Nisiyama (1950-a) described four species of Cretaceous Echinoids from Miyako district, Northeast Japan.

Pseudocidaris simulans Nisiyama, n. sp. Miyako, Cretaceous
Goniopygus atavus Nisiyama, n. sp. Miyako, Cretaceous
Holectypus (*Caenholectypus*) *peridoneus* Nisiyama, n. sp. Miyako, Cretaceous
Holaster clypeatulus Nisiyama, n. sp. Miyako, Cretaceous

22. Minato (1950) described a fossil species of *Linthia* from the Palaeogene deposits of Hokkaido.

Linthia yessoensis Minato, n. sp. Northeastern part of Ishikari coal-field, Hokkaido, Palaeogene

23. Nisiyama and Hashimoto (1950) described a species of *Echinarachinus* from the Tertiary of Hokkaido.

Echinarachnius subtumidus Nisiyama and Hashimoto, n. sp. Teshio, Hokkaido, Miocene

24. Nisiyama (1951) described a fossil species of *Scaphechinus* from the Miocene formation of Northeast Japan.

Echinarachnius (*Scaphechinus*) *raritalis* Nisiyama, n. sp. East of Akita City, Miocene

25. Mortensen, in his great monographic work " A Monograph of the Echinoidea, vols. 1-5, 1928-51 ", discussed and reviewed the following species occurred as fossil from Japan and the adjacent regions.

Cidarid spine (*Pseudocidaris* sp. of Tokunaga) Tosa, probably Cretaceous
Temnotrema rubrum (Döderlein) Tsurumi, Pleistocene
Clypeaster japonicus clypeus Döderlein (*Clypeaster japonicus plana* Hayasaka & Morishita) Formosa, Pleistocene
Clypeaster japonicus excelsior Döderlein (*Clypeaster japonicus alta* Hayasaka & Morishita) Formosa, Pleistocene
Echinarachnius elongatus Nisiyama Sakhalin, Miocene
Echinarachnius nipponicus (Nagao) Chikuzen, Oligocene
Echinarachnius laganolithinus Nisiyama Ugo, Pliocene
Scaphechinus griseus (Mortensen) Kazusa, Pleistocene
Niponaster hokkaidensis Lambert Hokkaido, Cretaceous
Pharaonaster japonicus (de Loriol) Hokkaido, Tertiary
Aphelaster? *tosaensis* (de Loriol) Tosa, probably Cretaceous
Breynia cordata Hayasaka Formosa, Pliocene
Breynia testudinaria Hayasaka Formosa, Pliocene
Linthia nipponica Yoshiwara Shinano, Pliocene
Linthia tokunagai Lambert Shinano, Pliocene
Sismondia convexa Nisiyama Bonin Islands, Oligocene

Peronella (*Peronellites*) *ovalis* HAYASAKA & MORISHITA? Formosa, Miocene
Astrodapsis nipponicus NISIYAMA Mutsu, Mio-Pliocene
Heteraster nexillis NISIYAMA Shikoku, Cretaceous
Washitaster? *macroholcus* NISIYAMA Kii, Cretaceous
Goniopigus atavus NISIYAMA Miyako, Cretaceous
Pseudocidaris simulans NISIYAMA Miyako, Cretaceous
Caenholectypus peridoneus (NISIYAMA) Miyako, Cretaceous
Holaster clypeatulus NISIYAMA Miyako, Cretaceous

26. DURHAM (1952-b) re-examined and redescribed a species formerly assigned to *Astrodapsis* from Japan.

Nipponaster nipponicus (NISIYAMA) Mutsu, Mio-Pliocene

27. HAYASAKA and SHIBATA (1952) described a species of *Echinarachnius* from the Miocene deposits of Hokkaido.

Echinarachnius rumoensis HAYASAKA & SHIBATA, n. sp. Teshio, Hokkaido, Miocene

28. MORISHITA (1952) described a new subspecies of *Astriclypeus manni* VERRILL from the Miocene deposits of Central Japan.

Astriclypeus manni minoensis MORISHITA, subsp. nov. Gifu, Miocene

29. HAYASAKA (1953) reported an occurrence of an interesting Echinoid from the Pliocene of Formosa.

Faorina chinensis GRAY? Formosa, Pliocene

30. MORISHITA (1953) reported the occurrence of the Palaeopneustid Echinoids in Japan.

Palaeopneustes cf. *cristatus* A. AGASSIZ Niigata, Pliocene
Archaeopneustes cf. *hystrix* (A. AGASSIZ) Shizuoka and Miyazaki, Pliocene

31. MORISHITA (1953-a) reported the following fossil Echinoids from Nagano Prefecture, Central Japan.

Sismondia naganoensis, sp. nov. Nagano, Miocene
Echinarachnius microthyroides NISIYAMA Nagano, Pliocene
Echinarachnius naganoensis, sp. nov. Nagano, Pliocene
Linthia nipponica YOSHIWARA Nagano, Pliocene
Schizaster kinasaensis, sp. nov. Nagano, Pliocene
Schizaster sp. indet. Nagano, Miocene

32. MORISHITA (1953-b) reported four fossil Echinoids from Gifu Prefecture, Central Japan.

Echinocyamus crispus MAZZETTI Gifu, Miocene
Astriclypeus manni VERRILL Gifu, Miocene
Astriclypeus manni minoensis MORISHITA Gifu, Miocene
Schizaster sp. indet. Gifu, Miocene

33. MORISHITA (1954) reported a fossil *Brissus* from the Pleistocene of Ryûkyû Islands.

Brissus latecarinatus LESKE Ishigaki-jima, Pleistocene

34. MORISHITA (1954-a) reported the Tertiary Echinoids from the Environs of the Ise-Bay, Central Japan.

Echinocyamus crispus MAZZETTI Gifu Pref., Miocene
Echinarachnius brevis IKEDA Gifu and Aichi Pref., Miocene
Astriclypeus manni VERRILL Gifu Pref., Miocene
Astriclypeus manni minoensis MORISHITA Gifu Pref., Miocene
Linthia nipponica YOSHIWARA Mie, Aichi and Gifu Pref., Miocene
Schizaster sp. Gifu Pref., Miocene

35. TANAKA and OKUBO (1954) described the following fossil Echinoids from the Palaeo-Cretaceous formations of Japan.

Washitaster barremicus, sp. nov. Kii, Barremian
Washitaster japonicus, sp. nov. Yatsushiro, Albian
Washitaster macroholcus NISIYAMA Kii, Barremian
Enallaster cf. *obliquatus* CLARK Yatsushiro and Kii, Albian and Barremian
Enallaster yuasensis, sp. nov. Kii, Barremian
Enallaster cf. *böhmi* LORIOL Kii and Yatsushiro, Albian and Barremian
Enallaster cf. *nexillis* (NISIYAMA) Kii, Barremian

36. COOKE (1954) described the Pliocene Echinoids from the lower part of the Ryukyu limestone developed in the Islands of Okinawa.

Cidaris metularia (LAMARCK) Uza, Pliocene
Cidaris sp. Maeta, Pliocene
Temnopleurus toreumaticus (LESKE) varieties Unten, Pliocene
Temnotrema sculptum A. AGASSIZ Naha, Pliocene
Lytechinus okinawa COOKE, n. sp. Shima-unten, Pliocene
Echinoneus cyclostomus LESKE Naha-kô, Pliocene
Clypeaster okinawa COOKE, n. sp. Ishikawa, Pliocene
Clypeaster japonicus DÖDERLEIN Naha, Pliocene
Peronella pellucida DÖDERLEIN Quarry south of Highway 5, Pliocene
Peronella kamimura COOKE, n. sp. Naha, Pliocene
Peronella motobu COOKE, n. sp. Quarry east of Route 124, Pliocene
Peronella merrilli ISRAELSKY Kerabaru, Pliocene
Laganum fudsiyama untenensis COOKE, n. subsp. Unten, Pliocene
Astriclypeus sp. Geochi, Pliocene
Oligopodia okinawa COOKE, n. sp. Gushichan, Pliocene
Schizaster excavatus R. MARTIN Imatomari, Pliocene
Brissus sp. Yonamine, Pliocene
Breynia carinata D'ARCHIAC & HAIME Nakaosu and Unten-kô, Pliocene

37. MORISHITA (1955) discriminated the following species of *Echinarachnius* occur as fossil in Japan.

Echinarachnius nipponicus (NAGAO) Fukuoka Pref., Oligocene
Echinarachnius microthyroides NISIYAMA Iwate and Toyama Pref., Miocene; Nagano Pref., Pliocene
Echinarachnins subtumidus NISIYAMA & HASHIMOTO Rumoe City, Hokkaido, Miocene
Echinarachnius rumoensis HAYASAKA & SHIBATA Rumoe City, Hokkaido, Miocene
Echinarachnius minoensis (MORISHITA) Nagano, Gifu, Aichi, Kyoto, Yamaguchi and Nara Pref., Miocene
Echinarachnius parma (LAMARCK) Toyama and Niigata Pref., Pliocene
Echinarachnius mirabilis (A. AGASSIZ) Ishikawa and Toyama Pref., Pliocene; Chiba, Kanagawa, and Ibaragi Pref., and Tokyo City, Pleistocene
Echinarachnius laganolithinus NISIYAMA Akita Pref., Pliocene
Echinarachnius tsudai MORISHITA Ishikawa Pref., Pliocene
Echinarachnius ishioi MORISHITA Toyama Pref., Pliocene
Echinarachnius naganoensis MORISHITA Nagano and Niigata Pref., Pliocene

Echinarachnius mirabilis tenuis YOSHIWARA Ishikawa Pref., Pliocene
Echinarachnius griseus MORTENSEN Chiba Pref., Pleistocene

38. MORISHITA (1955-a) reported an occurrence of the Cretaceous Echinoid from the Island of Awaji.

Niponaster hokkaidensis LAMBERT Awaji, Cretaceous

39. DURHAM (1955), in his "Classification of Clypeastroid Echinoids", discussed and illustrated the following fossil Clypeastroids from Japan, Sakhalin, and Formosa.

Peronellites ovalis (HAYASAKA & MORISHITA) Formosa, Miocene
Echinarachnius microthyroides NISIYAMA Japan, Mio-Pliocene
Echinarachnius laganolithinus NISIYAMA Japan, Pliocene
Echinarachnius parma sakhalinensis ARGAMAKOVA Sakhalin, Pliocene
Echinarachnius subtumidus NISIYAMA & HASHIMOTO Japan, Miocene
Kewia parva (NISIYAMA) Sakhalin, Oligocene
Kewia elongata (NISIYAMA) Sakhalin, Miocene
Kewia nipponica (NAGAO) Japan, Oligocene
Pseudoastrodapsis nipponicus (NISIYAMA) Japan, Mio-Pliocene
Astriclypeus manni ambigenus NISIYAMA Japan, Miocene

40. MORISHITA (1956) described six fossil Echinoids from the Tertiary formations of Kyushu.

Echinodiscus chikuzenensis NAGAO Miyazaki and Fukuoka Pref., Oligocene
Palmeraster joponicus, n. sp. Fukuoka Pref., Oligocene
Nudobrissus sp. Fukuoka Pref., Oligocene
Pericosmus cf. *spatangoides* LORIOL Nagasaki Pref., Oligocene
Linthia praenipponica NAGAO Nagasaki Pref., Oligocene
Schizaster miyazakiensis, n. sp. Miyazaki Pref., Miocene

41. MORISHITA (1957) described fossil species of the genera *Brissopsis* and *Eupatagus* from Japan.

Brissopsis makiyamai, n. sp. Aomori, Toyama, Wakayama, and Yamaguchi Pref., Miocene
Eupatagus nipponicus, n. sp. Toyama Pref., Miocene

42. COOKE (1957) described the following species from the Miocene Tagpochau limestone development in the Islands of Saipan, Mariana Islands.

Parasalenia marianae COOKE, n. sp. Northwest-central Saipan, Miocene
Echinostrephus saipanicum COOKE, n. sp. Northeast-central Saipan, Miocene
Acanthocidaris sp. East-central Saipan, Miocene
Heterocentrotus sp. East-central Saipan, Miocene
Echinoneus sp. Northeast-central Saipan, Miocene
Clypeaster saipanicus COOKE, n. sp. East-central Saipan, Miocene
Sismondia polymorpha DUNCAN & SLADEN? Northwest-central Saipan, Miocene
Paraster saipanicus COOKE, n. sp. Northwest-central Saipan, Miocene
Echinolampas sp. South-central Saipan, Miocene

43. OZAKI (1958) reported two species of the Echinoids from the Neogene formations of the Tyôsi (Chôsi) district, Central Japan, in association with a number of other fossils.

Brisaster owstoni MORTENSEN, 1950 Iioka formation, Pliocene
Strongylocentrotus? octoporus NISIYAMA (MS) Na-arai formation, Pliocene

44. SAITO (1959) described a new species of *Niponaster* from the Cretaceous

formation of Nakaminato City, Central Japan.

Niponaster nakaminatoensis, n. sp. Nakaminato formation, Cretaceous

45. Morishita (1960), in his "Check List of the Japanese Tertiary Echinoids", enumerated the Japanese Tertiary Echinoids, published and unpublished, with their localities and geological horizons; they are—

Salenocidaris hokkaidoensis (Loriol) Hokkaido, Miocene
Salenocidaris sp. Yamagata Pref., Miocene
Salenia novemprovincialis Nisiyama (MS) Nagasaki Pref., Oligocene
Salenia (Pleurosalenia) hokkaidoensis Loriol Hokkaido, Pliocene
Coelopleurus sp. (Nisiyama) Shizuoka Pref., Miocene
Brochopleurus sp. (Nisiyama) Chiba Pref., Miocene
Erbechinus sp. (Nisiyama) Shizuoka Pref., Miocene
Pseudocentrotus stenoporus Nisiyama (MS) Shizuoka Pref., Miocene
Allocentrotus japonicus Nisiyama (MS) Chiba Pref., Pliocene
Echinometra sp. (Nisiyama) Miyagi Pref., Miocene
Echinoneus cyclostomus Leske Wakayama Pref., Miocene
Echinanthus sp. (Nisiyama) Miyagi Pref., Miocene
Echinolampas yoshiwarai Loriol Hokkaido; Aomori, Akita, Yamagata, Miyagi, Niigata, Ishikawa, and Chiba Pref., Miocene and Pliocene
Clypeaster virescens Döderlein Ishikawa Pref., Pliocene
Echinocyamus crispus Mazzetti Gifu Pref., Miocene
Laganum fudsiyama Döderlein Kanagawa Pref., Pliocene
Laganum fudsiyama tokunagai Otuka Shizuoka Pref., Miocene
Echinarachnius ishioi Morishita Toyama Pref., Pliocene
Echinarachnius laganolithinus Nisiyama Akita and Toyama Pref., Pliocene
Echinarachnius microthyroides Nisiyama Iwate, Toyama, Nagano, and Aichi Pref., Miocene
Echinarachnius minoensis Morishita Iwate, Toyama, Nagano, Aichi, Gifu, Kyoto, Nara, and Yamaguchi Pref., Miocene
Echinarachnius mirabilis (A. Agassiz) Aomori, Toyama, Ishikawa, and Ibaraki Pref., Pliocene
Echinarachnius mirabilis tenuis Yoshiwara Ishikawa Pref., Pliocene
Echinarachnius naganoensis Morishita Niigata and Nagano Pref., Pliocene
Echinarachnius nipponicus (Nagao) Fukuoka Pref., Oligocene
Echinarachnius parma (Lamarck) Akita, Ibaraki, Niigata, and Toyama Pref., Pliocene
Echinarachnius raritalis Nisiyama Akita Pref., Miocene
Echinarachnius rumoensis Hayasaka & Shibata Hokkaido, Miocene
Echinarachnius subtumidus Nisiyama & Hashimoto Hokkaido, Miocene
Echinarachnius tsudai Morishita Ishikawa Pref., Pliocene
Echinarachnius sp. Hokkaido, Oligocene
Echinarachnius sp. Yamagata Pref., Miocene
Echinarachnius sp. Shizuoka Pref., Pliocene
Pseudoastrodapsis nipponicus (Nisiyama) Iwate Pref., Miocene
Echinodiscus chikuzenensis Nagao Miyazaki and Fukuoka Pref., Oligocene
Astriclypeus integer Yoshiwara Yamanashi and Shizuoka Pref., Miocene
Astriclypeus manni Verrill Hokkaido; Iwate, Miyagi, Gifu, Niigata, Toyama, Ishikawa, Fukui, Wakayama, Shimane, Okayama, and Hiroshima Pref., Miocene
Astriclypeus manni ambigenus Nisiyama Aomori and Akita Pref., Miocene
Astriclypeus manni minoensis Morishita Gifu Pref., Miocene
Palaeopneustes cf. *cristatus* A. Agassiz Niigata Pref., Pliocene
Palaeopneustes cf. *fragilis* de Meijere Chiba Pref., Pliocene
Palaeopneustes periturus Nisiyama (MS) Chiba Pref., Pliocene
Palaeopneustes psoidoperiodus Nisiyama (MS) Fukushima Pref., Pliocene

Palaeopneustes splendus Nisiyama (MS) Ishikawa Pref., Pliocene
Archaeopneustes cf. *hystrix* (A. Agassiz) Shizuoka and Miyazaki Pref., Pliocene
Pharaonaster japonicus (Loriol) Hokkaido, Neogene
Palmeraster japonicus Morishita Fukuoka Pref., Oligocene
Hypsopatagus japonicus Loriol Hokkaido, Neogene
Nudobrissus sp. Fukuoka Pref., Oligocene
Pericosmus elegans Nisiyama (MS) Miyagi Pref., Miocene
Pericosmus cf. *spatangoides* Loriol Nagasaki Pref., Oligocene
Linthia nipponica Yoshiwara Yamagata, Miyagi, Niigata, Toyama, Chiba, Aichi, Gifu, Nagano, Mie,·Okayama, and Yamaguchi Pref., Miocene and Pliocene
Linthia praenipponica Nagao Nagasaki Pref., and Hokkaido, Oligocene
Linthia yessoensis Minato Hokkaido, Oligocene
Linthia sp. Hokkaido, Miocene
Linthia? sp. Yamagata Pref., Miocene
Schizaster kinasaensis Morishita Niigata and Nagano Pref., Miocene
Schizaster miyazakiensis Morishita Miyazaki Pref., Miocene
Schizaster recticanalis Yoshiwara Ishikawa Pref., Miocene?
Schizaster sp. Gifu Pref., Miocene
Schizaster sp. Nagasaki Pref., Miocene
Schizaster n. sp. Toyama and Ishikawa Pref., Miocene
Schizaster? sp. Nara Pref., Miocene
Schizaster? sp. Wakayama Pref., Miocene?
Moira obesa Nisiyama Aomori, Akita, and Yamaguchi Pref., Miocene
Brissopsis luzonica (Gray) Fukushima Pref., Miocene
Brissopsis makiyamai Morishita Aomori, Toyama, Wakayama, and Yamaguchi, Pref., Miocene
Brissopsis sp. Yamagata Pref., Miocene
Eupatagus nipponicus Morishita Toyama Pref., Miocene

46. Tanaka and Shibata (1961) described a new species of *Aphelaster* from the Cretaceous formations of Wakayama, Kumamoto, and Tokushima Prefectures.

Aphelaster serotinus Tanaka & Shibata, n. sp. Wakayama, Kumamoto, and Tokushima Pref., Cretaceous

47. Morishita (1962) described a fossil species of *Hemiaster* from the Cretaceous formation of Shikoku.

Hemiaster uwajimensis, sp. nov. Shikoku, Upper Cretaceous

48. Morishita (1963), in his " On the lunuled Scutellidae (Key-hole sea urchins)", discussed and illustrated the following fossil lunuled Scutellids from Japan and Formosa.

Echinodiscus chikuzenensis Nagao Japan, Oligocene
Astriclypeus integer Yoshiwara Japan, Miocene
Astriclypeus? sp. Formosa, Miocene
Amphiope formosus (Yoshiwara) Formosa, Miocene

49. Morishita (1964) enumerated four fossil Echinoids stored in the Museum of Seto Marine Biological Laboratory, Wakayama Prefecture.

Balanocidaris sp. Wakayama Pref., Jurassic
Enallaster yuasensis Tanaka & Okubo Wakayama Pref., Cretaceous
Enallaster sp. Wakayama Pref., Cretaceous
Echinoneus cyclostomus Leske Wakayama Pref., Miocene

From the above lists of authors and the species which have been reported from various localities and geological horizons in Japan and the adjacent regions, it may be noticed that many of the generic and specific names used by previous authors are very diverse and are in need of various changes, and they are made in the part of this article dealing with the description of the species.

Besides above mentioned literatures on the fossil Echinoids from Japan and the adjacent regions there are many other literatures concerning the fossils, but they are either the only mention of manuscript names, only the presenting of figures without description, only the citation of Echinoids names, or the report on the occurrence of fossil Echinoids; these remain out of consideration for the time being.

Available literature shows that a large number of genera and species have been reported from Japan and the adjacent regions. By refined methods of H. L. CLARK, MORTENSEN, DURHAM, and others, however, the number of species and genera have increased in some cases and have decreased in others. Particularly because some have proved to be synonyms of others, certain cases or found to be mere local variation or mutations unworthy of new names in the others, and in still other cases some have been taken as type-species of new genera and subgenera. And, in future, even in present, it is expected that the number of generic and specific names will be increased, simultaneously the number of synonyms and homonyms may also be increased on the one hand, and be found to be valid on the other. In the present article, the writer gives many localities and geological horizons for the fossil Echinoids, with the hope that future workers can add more to those here enumerated.

MATERIAL

The material studied by the writer is probably one of the largest collections of fossil Echinoids known from Japan and the adjacent regions. The collections studied include the large number of specimens now stored in the Institute of Geology and Paleontology, Tohoku University, Sendai, the collection of the Department of the Saito Ho-on Kai Museum, Sendai, the collection of the Paleontological Branch of the National Science Museum, Tokyo, and the specimens now stored in the Geological Department of the Shimane University, Matsue. Dr. COOKE's specimens in the collection of the United States National Museum, Washington, D. C., and the part of A. AGASSIZ's and H. L. CLARK's collections in the Museum of Comparative Zoology at Harvard University, Cambridge, may be added to the material examined, as the writer had an opportunity to examine them though for a short time. The specimens in the Institute of Geology and Paleontology, Tohoku University were collected mostly by early members of the Institute, having been increased in kinds and number by some later members, as well. The fossil specimens are from nearly every part of Japan and the adjacent regions where fossils of Echinoids are known to occur, no exact Triassic occurrence has been on record until now. Covering nearly the whole regions of Japan and the adjacent areas, and ranging in time from the Permian to the Pleistocene Epoch, excepting the Triassic, the large collection studied by the writer, has afforded the writer the opportunity to work out many interesting problems.

In the course of this work it was necessary to ascertain, as far as possible, the precise localities and stratigraphical positions from which the specimens of fossil

Echinoids described in the literature were collected, as well as of those newly added to the material. Because there are many names of the stratigraphical units in Japan, especially of the Tertiary, a glossary describing these units which concern the fossil Echinoids seems to be necessary here, but it is not referred to this article. In this chapter the writer only lists the genera and subgenera of the fossil Echinoids treated in this work, arranged according to the geological age.

Permian Period

Miocidaris

Triassic Period

Cidarid spines are reported to occur by authors, they are not accessible to the writer. Some of them seem to represent primary spines of the Hemicidarids or the Pseudodiadematids.

Jurassic Period

Balanocidaris, Firmacidaris, Pygurus (*Echinopygus*), and *Allotoxaster.*

Cretaceous Period

Pseudocidaris, Goniopygus, Caenholectypus, Holaster, Cardisaster, Cottreaucorys (*Cordastrum*), *Niponaster, Aphelaster, Hemiaster, Heteraster* (*Enallaster*), and *Paraheteraster.*

Tertiary Period

Palaeogene Subperiod

Chondrocidaris, Phyllacanthus, Salenia, Eoglyptocidaris, Stomopneustes, Tripneustes, Mirechinus, Parasalenia, Procassidulus, Echinolampas, Sismondia, Kewia, Allaster, Echinodiscus, Paraster, Palmeraster, Linthia, Schizaster, Nudobrissus Aplospatangus, Brissopsis, and *Metalia.*

Neogene Subperiod

Stereocidaris, Stereocidaris (*Phalacrocidaris*), *Salenocidaris, Glyptocidaris, Coelopleurus, Temnopleurus, Temnotrema, Erbechinus, Brochopleurus, Salmaciella, Pseudocentrotus, Stronglocentrotus, Allocentrotus, Echinometra, Echinanthus, Oligopodia, Echinolampas, Clypeaster, Peronella* (*Peronellites*)?, *Laganum, Kewia, Echinarachnius, Scaphechinus, Pseudoastrodapsis, Echinodiscus* (*Amphiope*), *Astriclypeus, Palaeopneustes, Palaeopneustes* (*Oopneustes*), *Echinoneus, Hemiaster, Spatangus, Breynia, Echinocardium, Pericosmus, Linthia, Cagaster, Brisaster, Moira, Moira* (*Moiropsis*), *Brissopsis,* and *Eupatagus.*

Quaternary Period

Pleistocene Epoch

Prionocidaris, Phyllacanthus, Glyptocidaris, Coelopleurus, Echinothrix, Temnopleurus, Temnopleurus (*Toreumatica*), *Temnotrema, Echinostrephus, Echinometra, Echinoneus, Echinolampas, Clypeaster, Echinocyamus, Fibularia, Fibularia* (*Fibullariella*), *Peronella, Laganum, Scaphechinus, Astriclypeus, Spatangus, Maretia, Lovenia, Brisaster, Metalia,* and *Brissus.*

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III. SYSTEMATIC DESCRIPTION

(1—CIDAROIDA, DIADEMATOIDA, ARBACIOIDA, ECHINOIDA, HOLECTYPOIDA)

Order CIDAROIDA CLAUS, 1880

Cidarideae CLAUS, 1880, p. 355.—*Cidaroida* DUNCAN, 1889-a, p. 24.—GREGORY, 1900-b, p. 301.—JACKSON, 1912, p. 201.—H. L. CLARK, 1925, p. 1.—*Cidaroidea* DUNCAN: MORTENSEN, 1928-b, p. 9.—H. L. CLARK, 1946, p. 279.—TERMIER and TERMIER, 1953, p. 887.—*Cidaroida* CLAUS: DURHAM and MELVILLE, 1957, p. 251.

Type-family.—*Cidaridae* GRAY, 1825

Test regular, usually of spherical form, with well develop masticatory apparatus. Corona rigid, or ambulacral plates imbricating adorally, interambulacral plates adapically and over the ambulacrals along the adradial suture; interambulacra of two or four columns and ambulacra of two. Interambulacral plates with a single, large primary tubercle (spine) each, usually surrounded by a circle of smaller, secondary tubercles (spines); primary spines provided with a specially differentiated outer or cortex layer, except on the basal part, the collar. Tubercles, with very few exceptions, perforate, often crenulate, surrounded by a large areole. Ambulacra narrow, simple, pore-pairs usually in single, regular series, the cidaroid structure, more rarely in alternating double series. Apical system regular, anal opening placed in center of periproct; none of the periproctal plates specially developed. Peristome wholly covered with series of imbricating ambulacral and interradial plates. Base of corona persisting. No external gills, and no gill-slits at edge of peristome. No sphaeridia. Pedicellariae of two main sorts only, tridentate and globiferous; the latter, which occur in a large and a small form, have an internal poison gland, situated in the interior of the valves. In masticatory apparatus upper surface of pyramids is smooth, not grooved; epiphyses small, not joining above the foramen magnum. Teeth grooved, generally erect. Edge of test usually with interradial apophyses for attachment of muscle of masticatory apparatus, or sometimes none. From upper edge of masticatory apparatus proceed five bush-shaped organs, the STEWART's organs (from MORTENSEN, 1928, and DURHAM and MELVILLE, 1957). From the Devonian Period to Recent.

This is the mighty group among the Echinoids, continuing uninterruptedly, and in full vigour, from the Devonian ancestor till the Recent forms. It comprises three families, e. g., the Archaeocidaridae MACCOY, 1849, Miocidaridae DURHAM and MELVILLE, 1957, and Cidaridae GRAY, 1825; and the fossils of the Miocidarids and the Cidarids are represented in our collection.

Family MIOCIDARIDAE DURHAM and MELVILLE, 1957

Streptocidarinae LAMBERT, 1900, p. 49.—LAMBERT and THIÉRY, 1910, p. 127.—MORTENSEN, 1928-b, p. 61.

Miocidaridae DURHAM and MELVILLE, 1957, pp. 251, 252.

Type-genus.—*Miocidaris* DÖDERLEIN, 1887

Coronal plates more or less distinctly bevelled, ambulacral plates being covered by adjoining interambulacral plates; in some, very minute, forms (i. e., *Mikrocidaris* DÖDERLEIN, 1887, p. 39) the bevelling has apparently disappeared. Interambulacral plates more or less imbricating adorally (excepting in the minute forms). Pores non-conjngate, arranged in simple series. Primary tubercles crenulate or non-crenulate. Primary spines may be developed into large shields, or thorny. Pedicellariae known in a single species only.

Forms of moderate or very small size, ranging from the Lower Carboniferous to the Lias of Europe, North America, and the Far East.

The term "Streptocidarinae", with imbricate corona, is, as pointed out by DURHAM and MELVILLE (1957, p. 252), not acceptable as the name of a subfamily or family name a no nominal genus is included in the family. They proposed the new term Miocidaridae in substitution and gave family rank because of the distinctive character of the imbrication and on account of their restriction in geological time. This family differs from the Archaeocidaridae only in having two series of interambulacral plates, but the coronal plates imbricating also as in the Archaeocidaridae. The natural course must be to regard the Archaeocidarids as the older, more primitive type of the same order, from which the Miocidarids and the Cidarids proper developed by the gradual reduction of the columns of interambulacral plates to two, and by the gradual giving up of the imbrication of the coronal plates. The fact that the Miocidarids with two columns of interambulacral plates still preserve the imbrication and bevelling of the coronal plate is a very important indication of the fact that this is really the way along which the Miocidarids and the Cidarids proper evolved from the Archaeocidarids. DURHAM and MELVILLE (1957, p. 252) claimed that the Liassic species referred formerly to *Miocidaris* and some genera of the family may represent more than one lineage running from Archaeocidaridae to Cidaridae.

To this family LAMBERT and THIÉRY (1910, pp. 127-129) refer the genera *Eotiaris* LAMBERT (1899, p. 82), *Miocidaris* DÖDERLEIN (1887, p. 40), and *Triadocidaris* DÖRDERLEIN (1887, p. 39). While there is no disagreement about the generic value of the two latter, *Eotiaris* must, according to BATHER (1909, pp. 57-62, and 1909-a, pp. 83-86) be dropped as a junior synonym of *Miocidaris*. The very detailed and precise discussion of the whole qustion given by BATHER seems to the writer quite convincing. Besides the two genera above mentioned, MORTENSEN (1928-b, pp. 62-67) referred the following genera to this family, i. e., *Mikrocidaris* DÖDERLEIN (1887, p. 39), *Aplocidaris* LAMBERT and THIÉRY (1909, p. 31.—1910, p. 140), and *Anaulocidaris* ZITTEL (1879, p. 486). Fossils of the genus *Miocidaris* are represented in our collection.

Genus *Miocidaris* DÖDERLEIN, 1887

Miocidaris DÖDERLEIN, 1887, p. 40.—BATHER, 1909-a, p. 83.—LAMBERT and THIÉRY, 1910, p. 128.—JACKSON, 1912, p. 378.—MORTENSEN, 1928-b, p. 62.

Haplotype.—Cidaris amalthei QUENSTEDT, 1875, p. 198, pl. 2, fig. 44 (Charmouthian of Germany).

Eotiaris LAMBERT, 1899, p. 82.—LAMBERT and THIÉRY 1910, p. 127.

Orthotype.—Cidaris keyserlingi GEINITZ, 1843, p. 16, pl. 17, figs. 1-2 (Permian of Germany).

Moderate-sized and bevelled Cidarid, having the bevelled edge usually (? always) denticulate. Primary tubercles perforate and crenulate. Areoles usually confluent. Primary spines slender, not shield-shaped. Pores non-conjugate. From the Lower Carboniferous to Trias.

Three Palaeozoic species, i. e., *M. keyserlingi* (GEINITZ, 1843), from the Permian of Europe, *M. cannoni* JACKSON, 1912, from the Lower Carboniferous of North America, and *M. permica* WANNER, 1948, from the Permian of Timor Island, are the only certain Palaeozoic representatives of the genus. The occurrence of two species of this genus in the Permian of Japan is very noteworthy and describe herein.

Miocidaris spinulifera NISIYAMA, n. sp.

(Pl. 1, figs. 1-2)

Holotype.—IGPS coll. cat. no. 6442, in the collection of the Institute of Geology and Paleontology, Tohoku University, Sendai, Japan.

Locality and geological horizon (the format after HATAI and NISIYAMA, 1952).—IGPS loc. no.-Gi-1.-North of Kinshô-zan, Akasaka-machi, Fuha-gun, Gifu Prefecture (tm Ôgaki, Lat. 36°23′40″ N., Long. 136°34′40″ E.), Akasaka Limestone, Permian (Basleonian Stage ?; Middle Permian—SAITO, 1960, p. 12).

Known only from several primary spines and some fragments of coronal plates (preserved in the National Science Museum (NSM nos. 1476, 3580)). The largest one measures about 50 mm in length and 6 mm in the greatest diameter of shaft. Primary spines long, more or less curved near the base, thickened at about the middle of shaft, more or less tapering distally, slightly compressed, or nearly in section; collar low, about 2 mm high, oblique, with milled ring; shaft smooth proximally, beyond which they are armed with strong, sharp lateral spinules directly and obliquely distally, not in regular series but irregularly dispersed around. Edge of plates denticulate.

Distinction.—These primary spines appear to be quite unique among the accessible materials of the genus *Miocidaris.* The primary spines of this new species, however, superficially resemble those of *Archaeocidaris mucronata* MEEK and WORTHEN (MEEK and WORTHEN, 1860, p. 396.—MEEK and WORTHEN, 1866, p. 295, pl. 23, figs. 3a-3c.—JACKSON, 1912, p. 271, pl. 14, figs. 3a, 3b, 4) from the Chester group (Lower Carboniferous) of Illinois, U.S.A., but are distinguished from the latter by the thickened middle part of the shaft.

Miocidaris platyacantha NISIYAMA, n. sp.

(Pl. 1, fig. 3)

Holotype.—A specimen in the collection of the Institute of Geology and Paleontology, Tohoku University, Sendai, Japan.

Locality and geological horizon.—IGPS loc. no.-Gi-1.-North of Kinshô-zan, Akasaka-machi, Fuha-gun, Gifu Prefecture (tm Ôgaki, Lat. 35°23′40″N., Long. 136°34′40″E.), Akasaka Limestone, Permian (Basleonian Stage ?; Middle Permian—SAITO, 1961, p. 12).

There are several primary spines of this new species at hand, the largest one measures 40 mm in length in preserved part and 8 mm in the greatest diameter.

Primary spines rather stout, moderately long, and a little narrowed near the base, where they are nearly circular in section. Farther up the shaft they are compressed laterally, elliptical in section, the lateral margins being sharp and regularly serrated, the small scale-like projections inclined outward, and toward the apex of shaft. On the both surfaces of flattened shaft are six longitudinal series of similar serrations more or less smaller than those of the laterals. Number of serrations is counted eight to ten in the space of one millimeter. Collar low with milled ring; base concave, not oblique.

The primary spines of this species are very characteristic and there are no comparable spines among the genus *Miocidaris*. There arises a question that the spines of the preceding species (*M. spinulifera*) and those of this (*M. platyacantha*) may be belong to one and the same species, as the spines of the former represent the aboral or ambital ones and those of the latter the oral spines of a species, as seen in the case of the Recent species of the genus *Histocidaris*, especially in *H. magnifica* MORTENSEN (MORTENSEN, 1927, p. 245, pls. 48-49, pl. 76, figs. 1-3, text-figs. 1-3). In *H. magnifica*, the aboral spines long, taper to point, perfectly smooth, shining, without any serrations, but the oral primaries are curved, flattened, strongly serrate, and ending abruptly as if worn off. The primaries of *M. platyacantha*, however, are not curved and the primaries of *M. spinulifera* have spinules being not smooth as in *H. magnifica*, and the two types of the primaries did not occur together, but found separately. There is no positive proof that they belong to one and the same species, so the writer here treated them as two distinct species.

Family CIDARIDAE GRAY, 1825

Cidaridae GRAY, 1825, p. 426.—*Cidaridae* MÜLLER: A. AGASSIZ, 1872-74, p. 96.—DUNCAN, 1889-a, p. 25 (pro parte).—GREGORY, 1900-b, p. 302.—H. L. CLARK, 1907, p. 172.—JACKSON, 1912, p. 202.—H. L. CLARK, 1925, p. 1.—*Cidaridae* GRAY: MORTENSEN, 1928-b, p. 61.—*Cidaridae* MÜLLER: GRANT and HERTLEIN, 1938, p. 4.—*Cidaridae* GRAY: DURHAM and MELVILLE, 1957, pp. 251, 252.
Type-genus.—*Cidaris* LESKE, 1778

Stereocidarinae LAMBERT, 1900, p. 49.—LAMBERT and THIÉRY, 1910, p. 129.—MORTENSEN, 1928-b, p. 68.
Type-genus.—*Stereocidaris* POMEL, 1883

Interambulacra with only two columns of usually solid plates, in one case, *Tetracidaris* COTTEAU (1873-a, p. 163) there are four columns of interambulacrals, but only at the ambitus, not in the adoral part of test; rigid sutures. Primary spines very diverse, though in the main cylindrical or club-shaped, sometimes (*Goniocidaris* AGASSIZ and DESOR, 1846, p. 337) the upper ones shield-shaped. Pores non-conjugate or conjugate, arranged in simple series. 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.

Moderate, to large forms, more rarely small, ranging from the Jurassic Period to the Recent seas.

DURHAM and MELVILLE (1957, p. 252) restricted the family Cidaridae to those having 20 columns of plates (with the exception of *Tetracidaris*) in a rigid corona and are equivalent to "Stereocidarinae" as used by MORTENSEN (1928-b).

This family is the main stem of the order of the Cidaroids, and comprises a large number of the Recent and fossil genera. MORTENSEN (1928-b) subdivided the family into seven genus-groups, i. e., Histocidarina, Cidarina, Stylocidarina, Rhabdocidarina, Goniocidarina, Ctenocidarina, and Stereocidarina, based on the main the character of the pedicellariae and on the neontological features; it is regrettable, however, that this procedure of discrimination cannot be safely applied to the fossil forms. DURHAM and MELVILLE (1957, p. 252) proposed to treat the "genus-groups" of MORTENSEN's Stereocidarinae as subfamilies, respectively.

Fossils of the Stereocidarinae, Stylocidarinae, and Rhabdocidarinae are represented in our collection.

Subfamily STEREOCIDARINAE LAMBERT, 1900

Stereocidarinae LAMBERT, 1900, p. 49 (pro parte).—LAMBERT and THIÉRY, 1910, p. 129 (pro parte).—MORTENSEN, 1928-b, p. 68 (pro parte).

Stereocidarina MORTENSEN, 1928-b, pp. 69, 225.—*Stereocidarinae* DURHAM and MELVILLE, 1957, p. 252.

Type-genus.—*Stereocicaris* Pomel, 1883

This subfamily is characterized by its 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 spines and tubercles more or less rudimentary or atrophied. Usually there are more or less distinct grooves in the upper horizontal sutures of interambulacra, more rarely on plates or in ambulacra. Secondary spines flattened, more or less appressed (after MORTENSEN, 1928-b).

To this subfamily belongs only the genus *Stereocidaris* of Recent forms, and of the fossil genera, *Temnocidaris* COTTEAU (1863, p. 355) evidently belongs here also.

Genus *Stereocidaris* POMEL, 1883

Stereocidaris POMEL, 1883, p. 110.—DÖDERLEIN, 1887, p. 42.—MORTENSEN, 1903-b, p. 29.—DÖDERLEIN, 1906, pp. 96, 102.—H. L. CLARK, 1907, pp. 177, 216.—MORTENSEN, 1909. p. 55.—LAMBERT and THIÉRY, 1910, p. 152.—MORTENSEN, 1928-b, p. 225.—H. L. CLARK, 1946, p. 225.—COOKE, 1955, p. 88.

Logotype.—Cidaris cretosa MANTELL, 1822, p. 194, pl. 17, fig. 13 (PARKINSON, 1811, p. 13, pl. 1, fig. 11; Upper Chalk of Kent, Sussex).—COTTEAU, 1861-67 (62). p. 276, pl. 1067 (Senonian of France).=*Cidaris subvesiculosa* D'ORBIGNY: WRIGHT, 1864-82 (64), p. 57, pl. 8 figs. 4, 5, 6 (Upper Chalk of Kent, Sussex). [H. L. CLARK, 1907, p. 177—but of Recent species *grandis* DÖDERLEIN:—LAMBERT and THIÉRY, 1909, p. 31].

Test solid, usually very closely tuberculate. Rarely more than 7 interambulacral plates in a column, 1-3 of the upper interambulacral plates with areole and primary tubercle (spine) usually rudimentary or atrophied. Areoles deep, generally well separated, even those on the oral side; especially the upper interambulacral plates usually very high, there being thus a broad space covered with small miliaries between neighbouring areoles. Tubercles often with fairly distinct traces of crenulation. Usually one or several more or less distinct grooves or impressions in the upper horizontal sutures of interambulacra, and usually a small but fairly distinct groove at the admedian end of ambital horizontal sutures of interambulacra. Ambulacra in general conspicuously sinuate; pores non-conjugate, the wall usually forming a low, rounded crest. Madreporite not distinctly enlarged. Pores on peristome in a single, regular series. Primary spines often conspicuously flaring at the tip; the shaft usually with a spongy coat of hairs, more rarely with simple, unbranched hairs; collar short, neck very conspicuous, about twice as long as the collar. Scrobicular spines form a close mail round the base of primaries; miliary spines scale-like, appressed, or spiniform, erect. Large globiferous pedicellariae without end-tooth and without a limb on the stalk; small globiferous pedicellariae usually without end-tooth, but sometimes with a distinct, though small end-tooth; they may be very elongate and slender, resembling tridentate pedicellariae, and in this case true tridentate pedicellariae are lacking. Spicules of tube-feet may be transformed into larger fenestrated plates; spicules of intestinal wall numerous, small, triradiate, or reduced to very small rods, simple or slightly branched, in which case they are exceedingly scarce.

Moderate to usually large forms, ranging from the Cenomanian to the Recent seas (from MORTENSEN, 1928-b).

This is the poorly defined and perplexing genus in the family, usually recognized by the absence of primaries on the uppermost coronal plates, but this is not marked in small specimens. The resemblance to *Cidaris* LESKE, 1778, on the one hand, and to *Austrocidaris* H. L. CLARK, 1907, and to *Goniocidaris* AGASSIZ and DESOR, 1846, on the other hand, is great. Often the primary spines carry ridges or 'rings' on the basal part, and usually they are flaring at the tip, but they may be cylindrical or terete. The apical system is large, often convex, and noticeably thick and stout, and usually thickly and uniformly covered with tubercles of approximately equal size. This and the primary spines are the best characteristic for separating the genus from *Austrocidaris*, besides the character of the pedicellariae. Recent forms of *Stereocidaris*, essentially an Indo-Pacific, ranging from South Africa to Japan and eastwards to the Hawaiian Islands. But one isolated species (*ingolfiana* MORTENSEN) occurs in the North Atlantic from Iceland to Nervis in 165-665 fathoms. As to the distribution and history of species of this genus, MORTENSEN (1928-b, p. 230) suggested a possibility that the genus originated in the European seas of the Cretaceous and, when it was about to vanish there, found its way to the Indo-Pacific to reach there the flourishing condition of Recent days. This is a very interesting suggestion and may be near the truth, but a number of fossil species (about 20) from the Cretaceous System (from the Cenomanian to Senonian) are referred to this genus, and the interrelationships of them to the Recent species are somewhat dubious, and moreover, there is a trace of occurrence of species in the Cretaceous system of Japan. All the Recent species usually occur in depth of 70 metres or over.

The existence of more or less distinct grooves at the median end of the horizontal interambulacral sutures is very interesting, and suggests *Goniocidaris* affinities of *Stereocidaris*. Also the structure of the pedicellariae and the character of the spicules in the intestinal wall suggest affinities with the *Goniocidaris*. The suggestion, therefore, is at hand that the Goniocidarids may have been derived from Stereocidarid ancestors. The fact that *Goniocidaris* is a very Recent type, not known with certainty as fossil, is in good accordance with such suggestion.

Three species and three subspecies of the living *Stereocidaris* are reported from

Japan.

There is a fossil subspecies from Central Japan at the writer's disposal and described herein.

Stereocidaris grandis fusana NISIYAMA, n. subsp.

(Pl. 1, fig. 4)

Compared with:

Dorocidaris grandis DÖDERLEIN, 1885, p. 77.—*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, pl. 5, figs. 18-20 (partim, pl. 36, *St. grandis hyatorina* MORTENSEN, 1928, non pl. 33).—H. L. CLARK, 1925, p. 26 (partim ; Challenger St. 210,= *St. indica philippinensis* MORTENSEN, 1928).—MORTENSEN, 1927, p. 299.—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).

Holotype.—IGPS coll. cat. no. 73741.

Locality and *geological horizon.*—IGPS loc. no.-Ch-12.-Tuffaceous sandstone of sea cliff below shrine at Tômiya, Takeoka-mura, Kimitsu-gun, Chiba Prefecture. (tm Futtu, Lat. 35°12′52″N., Long. 139°51′E.), Kurotaki formation (Tômiya tuffaceous sandstone), Lower Pliocene. (Collected by K. HATAI, S. NISIYAMA, T. KOTAKA, and K. HATORI, 1950).

There is only a part of corona of this subspecies at the writer's disposal: it is finely preserved, and well shows its subspecific characters.

Coronal plates rather thick, about 1 mm in upper coronal plate. Ambulacra distinctly sinuate; interporiferous area much broader than a poriferous one, about three times as broad as the poriferous area; marginal series of tubercles very regular, and the tubercles somewhat contiguous; inside the marginal tubercles, each plate carries a secondary tubercle nearly as large as, or somewhat smaller than those of marginal one adapically and adorally, or large secondary tubercles accompanying a small tubercle below the secondary one; farther inside of the secondary tubercle, each plate carries usually two small tubercles, about a half in size of large secondary tubercle, situated at upper and lower corners of the plate; these large secondary tubercles and small tubercles form four of very regular longitudinal series within the series of marginal tubercles, and the whole interporiferous area so narrow that it is quite filled up by those six series, no naked median space being left. Poriferous area narrow, about 1 mm wide at the broadest point, somewhat depressed; pores about equal in size, and separated by a more or less broad, slightly elevated wall, whereas the ridge separating pore-pairs is rather high, pores being fairly deep lying.

In interambulacra, areoles fairly deep and well separated, those on oral side slightly transverse-oval; the uppermost areole rudimentary and without a primary spine, as is usual in the *Stereocidaris*; but areole and its tubercle not so very small, about 1.5 mm wide and 2 mm high in a plate about 6 mm wide and 5 mm high; scrobicular ring very regular, rather conspicuous, and somewhat raised, the tubercles being more than twice as large as the marginal ambulacral ones, almost contiguous, number of tubercles in a ring being 14-16; ring 7 mm in diameter in a plate about 12 mm wide and 11 mm high.; outside a scrobicular ring, the plates covered with small miliary tubercles of rather uniform size, or slightly decrease the sizes outwardly, where almost no naked median line is recognized. There is an indication of fine horizontal transverse furrows, especially on midzone.

Ambulacral plates rather high, the height at midzone, or on the third interambulacral plate from the apical system, corresponds to 17-20 ambulacral plates. 6 or 7 interambulacral plates in a column.

Distinction.—This subspecies very closely resembles *St. grandis* (DÖDERLEIN, 1885) (DÖDERLEIN, 1887, p. 3, pl. 1, figs. 1-6, pl. 2, figs. 1-11, pl. 8, figs. 2a-m.—MORTENSEN, 1928-b, p. 233, pl. 18, figs. 4-6, pl. 19, figs. 1-3, pl. 70, figs. 1-2, pl. 80, fig. 35), a Recent species from Japan, in the tuberculation of ambulacra, but is distinguished from the typical species by having broader interporiferous areas in the ambulacra, higher ambulacral plates, and larger scrobicular rings. The typical species is reported from Sagami Bay, Western Japan, and the Philippine Islands, from 70 to 220 metres in depths.

Subgenus *Phalacrocidaris* LAMBERT, 1902

Phalacrocidaris LAMBERT, 1902, p. 26.—LAMBERT and THIÉRY, 1910, p. 149.—MORTENSEN, 1928-b, p. 280.

Orthotype.—Dorocidaris japonica DÖDERLEIN, 1885, p. 76 (Sagami Bay, Japan).—*Stereocidaris japonica* (DÖDERLEIN) DÖDERLEIN, 1887, pp. 6, 42 pl. 3, figs. 1-20, pl. 8, figs. la-h.

Anomocidaris A. AGASSIZ and H. L. CLARK, 1907, p. 30.—H. L. CLARK, 1907, p. 221.

Haplotype.—Cidaris (*Stereocidaris*) *tenuispina* YOSHIWARA, 1898, p. 57 (Japan).—*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 (Japan, Recent).

Test rather flat, vertical diameter about a half of test-length, but sometimes, through elevation of apical system, conspicuously rounded-conical; vertical diameter from center of anal system in some cases being about 0.6 of test-length; coronal plates 7-9 in a column; areoles aborally small, very shallow and indistinct, on the uppermost plates practically wanting, but at the ambitus and below they are deeply sunken and merging together near the peristome; median interambulacral area covered with small tubercles, not at all bare or sunken, but sutural lines distinct; ambulacra about one third of interambulacra; poriferous zones not deeply sunken; median ambulacral area with two or three series of tubercles on each side, the inner much smaller and more or less incomplete; vertical sutural line usually distinct; pores nearly horizontal; distance between the two not quite to diameter of pore. Apical system moderate, about less than a half the test-length; anal system small, less than 0.4 of the apical system and composed of only about 20 plates and granules; oculars rather small and genitals very widely in contact with one another. Whole aboral surface more or less densely covered with very small secondaries, miliaries, and pedicellariae. Peristome small, only about three-fourths of the apical system. Primary spines slender, one to one and a half times as long as test-length; cylindrical, with longitudinal series of minute granules, sometime nearly smooth, often flattened and widened at the tip; oral primaries very variable, sometimes flattened, curved, and entire, slightly notched or even serrate, but frequently thick, straight, and more or less smooth; secondaries flat, those on ambulacra quite narrow. Large globiferous pedicellariae sometimes, and tridentate ones always, wanting; small globiferous pedicellariae sometimes with, more often without, a small end-tooth on valves.

There is an agreement among zoologists and paleontologists, or at least little doubt about the question of the identify of DÖDERLEIN's *japonica* and YOSHIWARA's *tenuispina*; and some of the peculiarities are given by those authors in their original description of only a single species, which they regarded to be a *Stereocidaris*. It can be distinguished from all other Cidarids by the sharp, deep sutures separating the plates of the apical system, and of the interambulacral areas, and the deep median vertical sutures of the ambulacral areas; towards the peristomial system the sutures tend to be obscured, at the angles of both ambulacral and interambulacral plates; the upper interambulacral plates have no well developed primary tubercles as in *Stereocidaris*. and the primary tubercles begin only at the equatorial zone and extend from there to the peristomial system. While its nearest relatives are probably to be found in the genus *Stereocidaris*, it is distinct from them, and is well entitled to subgeneric rank of that genus. This may be considered as a *Stereocidaris* in which the generic characters reach their extreme.

There is a fossil subspecies from Central Japan at the writer's disposal, and described herein.

Stereocidaris (*Phalacrocidaris*) *japonica multipora* NISIYAMA, n. sp.

(Pl. 1, figs. 5, 6)

Compared with:

Dorocidaris japonica DÖDERLEIN, 1885, p. 76 (4).—*Stereocidaris japonica* (DÖDERLEIN) DÖDERLEIN, 1887, pp. 6, 42, pl. 3, figs. 1-20, pl. 8, figs. la-h.—*Anomocidaris japonica* (DÖDERLEIN) A. AGASSIZ and H. L. CLARK, 1907-b, p. 112.—H. L. CLARK, 1907, p. 222.—*Stereocidaris japonica* (DÖDERLEIN) H. L. CLARK, 1925, p. 27.—*Stereocidaris* (*Phalacrocidaris*) *japonica* (DÖDERLEIN) MORTENSEN, 1928-b, p. 280, pl. 28, figs. 1-10, pl. 70, fig. 9, pl. 82, figs. 11-17.—NISIYAMA, 1937, p. 48.—UTINOMI, 1954, p. 341.

Cidaris (*Stereocidaris*) *tenuispina* YOSHIWARA, 1898, p. 57.—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.

Non *Stereocidaris japonica* TOKUNAGA, 1904, pl. 1, figs. 4, 5 (non DÖDERLEIN, 1885; *St. sceptriferoides* DÖDERLEIN, 1887).

Holotype.—IGPS coll. cat. no. 73742.

Locality and geological horizon.—IGPS loc. no.-Kn-21.-Sea cliff of Shiba, Minato Ward, Yokohama City, Kanagawa Prefecture. (tm Yokohama, Lat. 35°20′N., Long. 139°58′E.), Koshiba formation, Pleistocene (or Pliocene). *Hypotype.*—IGPS coll. cat. no. 73743.

There are several fragmentary specimens of this new subspecies at hand; they are rather well preserved.

Test small, about 20 mm in horizontal diameter and about 11 mm in height, rather stout, about 1 mm thick at midzone; interambulacral plates 6-7 in each column; apical system wanting. Ambulacra moderately broad, about 0.3 of interambulacra, moderately sinuate; interporiferous area narrow, nearly equal or somewhat wider than poriferous one; marginal series of tubercles regular, rather large, not contiguous; within the marginal tubercles, each plate carries a somewhat smaller tubercle at lower edge; these secondary tubercles form a pair of very regular longitudinal series within the marginal series, and whole interporiferous area is so narrow that it is quite filled up by those four series, no naked median space being left; vertical sutural line usually distinct; poriferous area not deeply sunken, pores nearly horizontal; distance between the two not quite equal to diameter of pore, ridge separating pore-pairs rather high; ambulacral plates rather low, 10-11 plates correspond to interambulacral third plate from the apical system.

In interambulacra, areoles fairly deep and well separated, and those on oral side distinctly transverse-oval; areole on first or second plate from the apical system rudimentary and without a primary spine, but the areole and its tubercle rather large, about 2.5 mm high and 2 mm wide in a plate 4 mm high and wide; from the ambitus to peristomial system, areoles well developed; scrobicular ring very regular, rather conspicuous, and raised, the tubercles being nearly twice as large as, or more or less larger than, the marginal ambulacral ones, almost contiguous, ring about 4 mm in diameter in a plate about 5 mm high and 5.5 mm wide, number of tubercles in a ring being 12-14; outside a scrobicular ring, the plates covered with one or rarely two rows of smaller tubercles. Sutures of interambulacral areas sharp and deep, and there is an indication of fine horizontal transverse furrows especially on adambulacral and aboral sutures.

Distinction.—This subspecies very closely resembles *St.* (*Ph.*) *japonica* (DÖDERLEIN, 1885) (DÖDERLEIN, 1887, p. 6, pl. 3, figs. 1-20, pl. 8, figs. 1a-h.-MORTENSEN, 1928-b, p. 280, pl. 28, figs. 1-10, pl. 70, fig. 9, pl. 82, figs. 11-17), a Recent species from Sagami Bay, Japan, in the outline of test and the tuberculation of ambulacra, but is distinguished from the typical species by having lower ambulacral plates. In examining the Recent specimens with 8 mm to 35 mm in test-diameter from Central Japan and stored in the Institute of Geology and Paleontology, Tohoku University, Sendai (IGPS coll. cat. nos, 788, 58302), the writer found that 8-9 ambulacral plates corresponding to an interambulacral plates at midzone (but in a specimen 8 mm in test-diameter, 7 ambulacral plates seem to correspond to an interambulacral plate), as in the original description of DÖDERLEIN (op. cit.); whereas in this subspecies, although the specimen is 20 mm in test-diameter, 10-11 ambulacral plates correspond to an interambulacral plate at midzone or above the ambitus.

Stereocidaris (*Phalacrocidaris*) *japonica* (DÖDERLEIN) is reported from the Tsugaru Straight, Sea of Japan, Tango, Pacific coast of Boso Peninsula, Gulf of Tokyo, Sagami Bay, Shimizu Harbour, and Eastern Channel, from 70-700 metres in depths.

Subfamily STYLOCIDARINAE MORTENSEN, 1928

Stylocidarina MORTENSEN, 1928-b, pp. 69, 320.—*Stylocidarinae* MORTENSEN: DURHAM and MELVILLE, 1957, p. 252.

Type-genus.—*Stylocidaris* MORTENSEN, 1909

This subfamily is characterized by its large globiferous pedicellariae having a well formed terminal opening, generally bordered by a fairly regular lip with teeth-like serrations. The stalk usually has a beautiful limb of freely projection rods. Small globiferous pedicellariae as a rule with a distinct end-tooth; tridentate pedicellariae on the whole well developed. Pores non-conjugate or conjugate. Primary tubercles crenulate or non-crenulate. Secondary spines flattened, usually not appressed or scale-like (after MORTENSEN, 1928-b).

This is a large group of the family comprising the Recent genera, i. e., *Acantho-*

cidaris MORTENSEN, 1903, *Compsocidaris* IKEDA, 1939, '*Eucidaris*' POMEL, 1883, *Stylocidaris* MORTENSEN, 1909, *Actinocidaris* MORTENSEN, 1928, *Hesperocidaris* MORTENSEN, 1928, *Centrocidaris* A. AGASSIZ, 1904, *Plococidaris* MORTENSEN, 1909, and *Prionocidaris* A. AGASSIZ, 1863. This subfamily is chiefly confined to the tropical and subtropical regions of the Indo-Pacific; in the Atlantic it is represented by only two species of *Stylocidaris* and two species of '*Eucidaris*', while hitherto no representative has been reported from the Antarctic seas.

As there are no very striking peculiarities in the structure of the test or the spines, it is not possible to decide with certainty which of the fossil forms belong to which of these subfamilies. But it seems reasonable at least to regard *Balanocidaris* LAMBERT, 1910, is closely related to '*Eucidaris*'. Anyhow, it may be practical, not strictly systematic, to deal with the fossil genera, so far as they cannot be definitely decided that referred it does not belong to any other subfamily, other than the present subfamily.

There are fossil representatives of the genera *Prionocidaris*, *Balanocidaris*, and others are in our collection, and they are describe herein.

Genus *Prionocidaris* A. AGASSIZ, 1863

Prionocidaris A. AGASSIZ, 1863, p. 18.—MORTENSEN, 1909, p. 50.—DÖDERLEIN, 1911, p. 242.—MORTENSEN, 1918, p. 7.—H. L. CLARK, 1916, p. 99.—H. L. CLARK, 1925, pp. 2, 12.—MORTENSEN, 1928-b, p. 434.—H. L. CLARK, 1946, p. 284.

Haplotype.—Cidarites pistillaris LAMARCK, 1816, p. 55 (de l'Ile-de France).—*Prionocidaris pistillaris* (LAMARCK) MORTENSEN, 1928-b, p. 452, pls. 49-51, pl. 73, fig. 18, pl. 86, figs. 20-21, text-fig. 139 (Mauritius, Seychelles, Madagascar, Dar es Salaam to Natal.—From littoral to 60 metres in depths).

Stephanocidaris A. AGASSIZ, 1872-74, pp. 160, 393 (non *Stephanocidaris* A. AGASSIZ, 1863, p. 18).—POMEL, 1883, p. 111.—DUNCAN, 1889-a, p. 31.—A. AGASSIZ and H. L. CLARK, 1907, p. 17.—H. L. CLARK, 1907, pp. 177, 192.

Logotype.—Cidarites bispinosa LAMARCK, 1816, p. 37 (Nouvelle-Hollande).—*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 (Pacific Ocean). [H. L. Clark, 1907, p. 177].

Schleinitzia STUDER, 1876, p. 463.—STUDER, 1880-a, p. 862.

Haplotype.—Schleinitzia crenularis STUDER, 1876, p. 463 (Papua). This species is identical with *Prionocidaris bispinosa* (LAMARCK, 1816), and includes *Pr. baculosa annulifera* (LAMARCK, 1816), also.

Test rather thin and fragile. Apical system usually ca. 0.4-0.5 of horizontal diameter of test; oculars nearly always all broadly insert; madreporite not noticeably larger than other genitals; whole area more or less closely covered by small tubercles (spines). Periproct generally with numerous small plates, often conically raised. Primary tubercles non-crenulate, or at most with an indication of crenulation on the uppermost tubercles. Pores usually distinctly conjugate by a shallow groove, horizontal and usually distant. Peristome generally slightly smaller than apical system. Primary spines rather slender, mostly tapering, often widened in the point, more simply cylindrical; they are as a rule rather coarsely thorny; the thorns forming more or less distinctly longitudinal series, sometimes arranged in more or less distinct whorls. Surface of the spines otherwise covered by a spongy coat of more or less anastomosing, fine hairs; collar as a rule not very long, usually provided with very characteristic purplish or white spots. Oral primaries more or less distinctly "capped". Secondary spines flattened, not tightly appressed, the smaller ones spiniform, not scale-like. Large globiferous pedicellariae, which are often very scarce or even totally lacking, without an end-tooth and with a beautiful limb on the stalk; small globiferous pedicellariae with an end-tooth, often very numerous; tridentate pedicellariae with very slender, simple valves. Spicules of intestinal wall, small, round bodies with few holes, lying so close as to be more or less imbricated (from MORTENSEN, 1928-b).

From the geological and geographical distributions of the fossil species that can be referred to this genus, it would appear that the genus was formerly, in the Cretaceous (Senonian), Eocene, and in the Miocene, rather richly represented in the European seas, as in the case of the *Stereocidaris*, and also had at least one representative in the American Eocene seas (*Cidaris mitchelli* EMMONS: CLARK and TWICHELL, 1915, p. 9, pl. 1, fig. 7), whereas in Recent times it entirely disappeared from these seas, being now confined to the Indo-Pacific.

The much discussed genus *Stephanocidaris* A. AGASSIZ, as used by A. AGASSIZ (1872-74, pp. 160, 393) and H. L. CLARK (1907, pp. 177, 192), is undoubtedly the same as *Prionocidaris*, as in the synonymy listed above, because both names include the congeneric species, but the name itself is a junior synonym of *Goniocidaris* AGASSIZ and DESOR (1846, p. 337).

This is an Indo-Pacific genus in the living, ranging from Mauritius to the Hawaii and from Japan to Southwest Australia.

Prionocidaris baculosa annulifera (LAMARCK, 1816)

Cidarites annulifera LAMARCK, 1816, p. 55.—*Cidaris annulifera* LAMARCK: DE LORIOL, 1873, p. 25, pl. 3.

Cidaris (*Cidaris*) *baculosa* LAMARCK: DE MEIJERE, 1904, p. 9, pl. 2, figs. 9-12.—*Cidaris* (*Leiocidaris*) *baculosa* LAMARCK: TOKUNAGA, 1904, pl. 1, figs. 6, 11, pl. 2, fig. 1.—*Phyllacanthus baculosa* (LAMARCK) A. AGASSIZ and H. L. CLARK, 1907. p. 15.—*Prionocidaris baculosa* (LAMARCK) H. L. CLARK, 1946, p. 285.

Leiocidaris pistillaris annulifera LAMARCK: DÖDERLEIN, 1903, p. 692, pl. 59, figs. 1-5.—*Prionocidaris baculosa annulifera* (LAMARCK): MORTENSEN, 1927, p. 257, pls. 53, 54.—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, fig. 5, text-fig. 137.—JEANNET, 1935, p. 11, pl. 1, figs. 10, 11.—JEANNET and MARTIN, 1937, p. 221.—UTINOMI, 1954, p. 341.

Non *Prionocidaris baculosa* ROXAS, 1928, p. 249, pl. 1, fig. 2 (non LAMARCK, 1816; '*Eucidaris*' *metularia* (LAMARCK, 1816)).—HAYASAKA, 1948, p. 14, pl. 3, fig. 1 (non LAMARCK, 1816; '*Eucidaris*' *metularia* LAMARCK, 1816)).

Locality and geological horizon.—Plateau above Kami-Katetsu, Kikai-jima, Ôshima-gun, Kagoshima Prefecture. Ryukyu Limestone, Pleistocene. IGPS coll. cat. no. 73727-A.

There are six primary spines referred to this subspecies at the writer's disposal, but all of them are partly broken.

The colour of the spines are well retained in its original nature, the deep red or purplish spots on the collar of the primaries; the collars are usually less than 3 mm in height; these are obvious characters of the species that are almost always recognized. The ground colour of the spines are almost brownish, and the distal half is more or less clearly banded with reddish-purple; there are several (five in the longest spine, the top of which is broken off) of these bands on the spines. They almost have wing-like thorns at least near the base.

Fig. 1. A primary spine of *Prionocidaris baculosa annulifera* (LAMARCK, 1816) (for comparison).
(Pliocene of Ceram ; after JEANNET, 1935).

These spines fairly well agree with the figures of MORTENSEN (1927, pls. 53, 54) ; they are fusiform and strongly spinous in the basal portion, and the general appearance is very characteristic, and may belong within the variational range of the polymorphous subspecies *annulifera* of the highly polymorphous species *Prionocidaris baculosa.* The largest primary spine measures about 30 mm in length and about 6 mm in the greatest breadth.

This subspecies dates from the Pliocene of Ceram, and still are living in Java, Moluccan seas, the Philippines and Japan, in the depth less than 250 metres.

Prionocidaris bispinosa (LAMARCK, 1816)

(Pl. 1, figs. 7-14)

Cidarites bispinosa LAMARCK, 1816, p. 57.—*Rhabdocidaris bispinosa* (LAMARCK) DE LORIOL, 1873, p. 33, pl. 5.—*Leiocidaris bispinosa* (LAMARCK) DÖDERLEIN, 1903, p. 695, pl. 58, figs. 5-11.—*Stephanocidaris bispinosa* (LAMARCK) MORTENSEN, 1904, p. 6, pl. 2, figs. 3, 17, 18, pl. 4, fig. 30, pl. 5, figs. 20, 25, (non *Stephanocidaris bispinosa* A. AGASSIZ, 1872-74, pp. 160, 393).—*Cidaris (Stephanocidaris) bispinopa* LAMARCK : DE MEIJERE, 1904, p. 4, pl. 1, fig. 4, pl. 2, fig. 14.—DÖDERLEIN, 1906, p. 92, pl. 44 (36), figs. 4a-i.—*Prionocidaris bispinosa* (LAMARCK) DÖDERLEIN, 1911, p. 240, pl. 9, figs. 1, 2.—MORTENSEN, 1918, p. 6, pl. 3, fig. 1, pl. 4, fig. 3.—MORTENSEN, 1927, p. 258, pl. 52, fig. 3.—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.—JEANNET, 1935, p. 12, pl. 1, fig. 4.—H. L. CLARK, 1946, p. 286.

Phyllacanthus annulifera A. AGASSIZ, 1872-74, p. 387 (non LAMARCK, 1816).

Cidaris luetkeni DE LORIOL, 1873, p. 29, pl. 4.

Locality and geological horizon.—Plateau above Kami-Katetsu, Kikai-jima, Ôshima-gun, Kagoshima Prefecture. Ryukyu Limestone, Pleistocene. *Hypotype.*—IGPS coll. cat. no. 73727.

There are four primary spines referred to this species at hand, but all of them are partly broken.

The primary spines are cross-banded with purplish and greenish tints and are distinctly flattened in the distal part, just as in the case of large primary spines of *Prionocidaris baculosa annulifera* (LAMARCK, 1816) (op. cit.), and quite thorny. The collar low, about 3 mm high in the longest primary, and unspotted or unlined, not as in *Pr. baculosa annulifera.*

These spines well agree with the figures of DÖDERLEIN (1903, pl. 58), and can be referred to this species. The largest spine measures 30 mm in length. Also, these primary spines are quite identical with those of *Pr. bispinosa* from the Straight of Makassar, in 22-28 fathoms depth, now stored in the Museum of Comparative Zoology at Harvard University (cat. no. 748) ; they are very spinous and the collar without spots. In other specimens from Australia (MCZ cat. no. 77) the primary spines are banded as in the Ryukyu specimens, but the collar without spots.

The confusion between this species and *Pr. baculosa annulifera* has caused much trouble to zoologists, but through the researches of DÖDERLEIN and MORTENSEN, in examination of LAMARCK's type-specimens in Paris, it has been settled which species is meant by the *Cidarites bispinosa* LAMARCK, 1816 (op. cit.), and *Cid. annulifera* LAMARCK, 1816 (op. cit.) has been shown to be either merely a subspecies of *Pr. baculosa* or a species very closely related to it.

This species dates from the Pliocene of Ceram and distributed alive in Ceylon, Java, Moluccan seas, the Philippines, and Southwest Australia, in less than 50 meters depths.

Genus *Balanocidaris* LAMBERT, 1910

Balanocidaris LAMBERT, 1910-c, p. 4.—LAMBERT and THIÉRY, 1910, p. 146.—MORTENSEN, 1928-b, p. 483.

Orthotype.—Cidarites glandifera MÜNSTER in GOLDFUSS, 1826-33 (29), p. 120, pl. 40, figs. 3a-d.—COTTEAU, 1875-80(77), p. 191, pl. 195, figs. 7-13, pl. 196, figs. 1-9 (Rauracian of France and Tithonian of Suisse).

Pores non-conjugate. Primary tubercles perforate, non-crenulate. Primary spines very thickened, glandiform, with rather coarse spinules or granules, serially arranged.

This genus is characterized by its primary spines which are usually glandiform in outline and ornamented with granules, spinules, or striae, and the articular facet is usually non-crenulate or slightly crenulate. This genus dates from the Carnian and ranges to the Senonian, and five species, besides the type-species, are assigned to it hitherto. There are primary spines of a species which are assigned to this genus in our collection and described herein.

Balanocidaris japonica NISIYAMA, n. sp.

(Pl. 1, figs. 15-18)

Cidaris cf. *glandifera* GOLDFUSS: NAUMANN and NEUMAYR, 1890, p. 31.
Pseudocidaris sp. TOKUNAGA, 1903, p. 26, pl. 2, fig. 12.

Holotype.—IGPS coll. cat. no. 73767.

Locality and geological horizon.—IGPS loc. no.-Eh-11.—A point below Shôhôji temple, Uonashi-mura, Higashi-Uwa-gun, Ehime Prefecture. (tm Unomachi, Lat. 36°22′N., Long. 132°42′27″E.), Torinosu Limestone, Upper Jurassic (probably from the Callovian to Tithonian).

Locality and geological horizon.—IGPS loc. no.-Ko-21.—Limestone masses east of Torinosu, Sakawa-machi, Takaoka-gun, Kôchi Prefecture. (tm Susaki, Lat. 33°29′N., Long. 133°17′35″E.), Torinosu Limestone, Upper Jurassic (probably from the Callovian to Tithonian).

There are several primary spines referred to those of this species at the writer's disposal, but many of them largely or partly broken and rather not well preserved.

The large one measures over 35 mm in length and about 15 mm in the greatest diameter, rather club-shaped, acuminated near the apex and narrowed near the base; longitudinally closely striated, the number of striae at the greatest diameter being about 40, and each stria being very closely granulated; granules more than 40 on each stria, and the granules become larger and coarser near the distal than proximal part.

Distinction.—The primary spines of this new species resemble those of *Bal.*

glandifera (MÜNSTER, 1829) (COTTEAU, 1875-80(77), p. 191, pl. 196, figs. 1-9), from the Rauracian of France and Tithonian of Suisse, but are distinguished from them by having the broader base and by the finer granulation on the shaft. The primary spines of *Bal. japonica* are also related to those of *Bal. meandrina* (AGASSIZ, 1839) (some authors assigned it to the genus *Sphaerotiaris* LAMBERT and THIÉRY, 1910) (COTTEAU, 1875-80(75), p. 79, pl. 163, figs. 1-10), from the Bathonian of France, but differ from them in the slender shaft and in the broader base. The primary spines of this species have superficial resemblance to those of *Pseudocidaris zitteli* DE LORIOL, 1901 (DE LORIOL, 1901, p. 11, pl. 1, figs. 18-20), from the Tithonian of Moravia, where he reported its occurrence associated with *Bal. glandifera*, but is easily distinguished from that species by the granulation near the distal portion. From *Bal. californica* (CLARK, 1893) (CLARK, 1893, p. 36, pl. 6, figs. 1a-b.—CLARK and TWITCHELL, 1915, p. 30, pl. 4, figs. 1a-c), from the Mormon sandstone (Middle Jurassic) of California, it differs in the finer granulation on the shaft. As to "*Pseudocidaris* sp." of TOKUNAGA (1903, p. 26, pl. 2, fig. 12) MORTENSEN (1935, p. 402) stated that "It is true, TOKUNAGA records *Pseudocidaris* sp. from Japan, viz. two fragmentary egg-shaped spines. There is, however, not the slightest proof these spines belong to *Pseudocidaris*; there is no reason whatever, why they should not be Cidarid spines." As for the statement the writer quite agrees with him, and considers the fossil represents a new species of the genus *Balanocidaris* as described above.

Genus *Firmacidaris* LAMBERT, 1937

Firmacidaris LAMBERT, 1937, p. 45.

Orthotype.—Sphaerotiaris precincta LAMBERT, 1933-b, p. 36, pl. 3, fig. 9 (Domerian of Morocco).—*Firmacidaris precincta* (LAMBERT) LAMBERT, 1937, p. 47, pl. 1, fig. 8, pl. 4, figs. 1-4.

Test circular, moderately inflated; apical system solid, dicyclic, genitals hexagonal, madreporite slightly larger than the other genitals, genitals covered with small tubercles, oculars subtrigonal; periproct central, round. Ambulacra narrow, sinuate; pores not closely approach, and separated by a small ridge, non-conjugate. Primary tubercles non-crenulate; the uppermost tubercle usually atrophied. Peristome small, circular. Articular facet of primary spines non-crenulate, and ornamentation of shaft very characteristic. Primary spines baculiform or glandiform, ornamented with concentric circles of round granules (tubercles) and the circles separated by a small depression of very minute granules, appear finely reticulate-undulating; collar indistinct.

As the primary spines of the type-species are club-shaped having more or less a finely reticulate-undulate surface recall those of the genus *Sphaerotiaris* LAMBERT and THIÉRY (1911, p. 169), a Hemicidarid genus, and it seems probable that this species may be a true *Sphaerotiaris*. The characteristic spines of the type-species were found together with Cidarid test (though not attached to the test), but not with Hemicidarid (or Sphaerotiarid) test; and the writer uses this generic name as a Cidarid genus as originally proposed till it becomes positively proved that it belongs to the Hemicidarids.

The occurrence of this genus in the Upper Jurassic of Japan is very noteworthy and described herein.

Firmacidaris neumayri NISIYAMA, n. sp.

(Pl. 30, figs. 1-2)

Cidaris n. sp., NAUMANN and NEUMAYR, 1890, p. 32.
Cidaris sp., TOKUNAGA, 1903, p. 27, pl. 2, fig. 9.

Holotype.—IGPS coll. cat. no. 7152.

Locality and geological horizon.—IGPS loc. no. Ko-22.-A point near Hanabatake, Togano-mura, Takaoka-gun, Kôchi Prefecture. (tm Susaki, Lat. 33°28′48″N., Long. 133°16′42″E.), Torinosu Limestone, Upper Jurassic (probably from the Callovian to Tithonian).

There is only a single specimen of primary spine referred to this new species in the collection, but it is broken near the base.

The preserved part measures about 30 mm in length and about 33 mm in the greatest diameter which lies at middle of shaft; club-shaped in outline, abruptly narrowed both distally and proximally; longitudinal striae made up of fine granules limited from the narrowed part to distal point of shaft, very numerous, over 50 near the narrowed part, granules in the lower part of longitudinal striae crenulated at their upper margin; lower two-thirds of shaft preserved ornamented with regularly undulating horizontal striae, numbering about 20, being crenulated upper margin of these upper at the upper margin. This feature of horizontal striation (granulation) is very characteristic among the spines of allied species.

Distinction.—The primary spine of this new species resembles those of *Fir. precincta* (LAMBERT, 1933) (LAMBERT, 1933-b p. 36, pl, 3, fig. 9.—LAMBERT, 1937, p. 47, pl. 1, fig. 8, pl. 4, figs. 1-4), from the Domerian of Morocco, but is distinguished from those of the latter by having longitudinal striae made up of fine granules on distal part of shaft. The spine of this species has also superficial resemblance to those of *Sphaerotiaris meandrina* (AGASSIZ, 1839) (COTTEAU, 1875-80(75), p. 79, pl. 163, figs. 1-10), from the Bathonian of France, but is easily distinguished from those of the latter by having the horizontal striation (made up of fine granules) on the shaft.

Genus *Eucidaris* POMEL, 1883

Eucidaris POMEL, 1883, p. 109.—H. L. CLARK, 1925, pp. 3, 8, 20.—MORTENSEN, 1928-b, p. 384.—H. L. CLARK, 1946, p. 288.

Logotype.—Cidarites monilifera GOLDFUSS, 1826: COTTEAU, 1875-80, p. 163, pls. 185, 186 (Jurassic). [COOKE, 1959, p. 8].

Type-species.—Cidarites metularia LAMARCK, 1816, p. 56. [H. L. CLARK and BATHER, 1909, p. 88.—This species was not one of the six species that POMEL referred to by name, fide COOKE, 1959, p. 8].

Primary spines short, usually nearly equal to test-diameter and rather stout, often very short and even swollen, rarely slender and elongate, blunt, not thorny. Areoles little or not sunken. Peristome generally larger than the apical system. Apical system sharply defined. Ambulacral pores close together, more or less oblique. Large globiferous pedicellariae with the valves curved, with a large terminal opening, and without an end-tooth.

This is an interesting little genus, but it is difficult to define satisfactorily, as it is near *Stylocidaris* MORTENSEN, 1909, in one point, and as likely to be distinguished in another point, namely by the development of short and stout spines in majority of the living species. The genus is wide-spread in the tropics. Neither *Eucidaris* nor *Cidaris* can be used for the name of this Cidarid-group, as it is regarded as a distinct group of a generic level on account of the neontological feature observed; it is necessary to a new name substituting them.

'*Eucidaris*' *metularia* (LAMARCK, 1816)

Cidarites metularia LAMARCK, 1816, p. 56.—*Cidaris metularia* (LAMARCK) A. AGASSIZ, 1872-74, pp. 98, 254, 385, pl. lc, figs. 23-24, pl. lg, fig. 1, pl. 35, fig. 3.—*Eucidaris metularia* (LAMARCK) DÖDERLEIN, 1887, p. 42, pl. 9, fig. 1.—*Cidaris* (*Dorocidaris*) *metularia* (LAMARCK) TOKUNAGA, 1904, pl. 1, fig. 1.—*Cidaris metularia* (LAMARCK) A. AGASSIZ and H. L. CLARK, 1907, p. 5, pl. 1, figs. 3-7.—*Eucidaris metularia* (Lamarck) MORTENSEN, 1928-b, p. 386, pl. 41, figs. 1-8, pl. 73, fig. 6, pl. 86, figs. 11-14, text-figs. 113a-b, 114, 115, 116.—JEANNET, 1935, p. 9, pl. 1, figs. 8-9.—NISIYAMA, 1942, p. 15, text-figs. la-b.—COOKE, 1954, p. 45, pl. 9, fig. 1.

Prionocidaris baculosa ROXAS, 1928, p. 249, pl. 1, fig. 2 (non LAMARCK, 1816).—HAYASAKA, 1948, p. 14, pl. 3, fig. 1 (non LAMARCK, 1816).

Although there are no fossil specimens referred to this species at the writer's disposal, COOKE (1954, p. 45) reported an occurrence of the species based on a specimen (corona) obtained from the Ryukyu Limestone (Pliocene) of Uza, Okinawa. Although *Eu. metularia* has so wide a geographical range, it seems to be not a variable species, and is characterized by having the cross-banded primary spines, and by the wide and bare median ambulacral areas. MAYR (1954, p. 3) claims that all six described forms (*metularia*, *galapagensis*, *thouarsii*, *tribuloides*, *africana*, and *clavata*) under this genus are allopatric, and the genus would become monotypic.

This species dates from the Pliocene of Ceram and Okinawa, and is found from the seas around Japanese seas extending to Ryukyu Islands and Formosa, and, widely distributed over the Indo-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; and from littoral zones to 20 metres in depths.

The following Cidarid genera, i. e., *Chondrocidaris* A. AGASSIZ, 1863, *Rhabdocidaris* DESOR, 1855, together with doubtful *Phyllacanthus* BRANDT, 1835, and probably *Porocidaris* DESOR, 1855, seem to make up a subfamily-group under the family Cidaridae.

Subfamily RHABDOCIDARINAE MORTENSEN, 1928

Rhabdocidarina MORTENSEN, 1928-b, pp. 69, 489.—*Rhabdocidarinae* MORTENSEN: DURHAM and MELVILLE, 1957, p. 252.

Type-genus.—*Rhabdocidaris* DESOR, 1855

Large forms. Pores conjugate; they may be arranged in double series on the peristome. Tubercles crenulate or non-crenulate. Primary spines on the whole large and coarse, cylindrical, smooth, or with more or less coarse thorns. Sometimes very conspicuously widened. Large globiferous pedicellariae with a rather larger subterminal opening, without an end-tooth; stalk without a distinct limb; small globiferous pedicellariae with or without an end-tooth (after MORTENSEN, 1928-b).

This subfamily does not seem to be very well defined, and perhaps the genus *Phyllacanthus* does not rightly belong here. It is assigned, however, to the subfamily, on account of the apparent similarity to the *Chondrocidaris*. The fossil genus *Rhabdocidaris* may well be regarded as the main genus of the subfamily, and to this the Recent genus *Chondrocidaris* appears to be related.

There are fossil representatives of the genera *Chondrocidaris* and *Phyllacanthus* in our collection; they are describe herein.

Genus *Chondrocidaris* A. AGASSIZ, 1863

Chondrocidaris A. AGASSIZ, 1863, p. 18.—MORTENSEN, 1903-b, p. 29.—DÖDERLEIN, 1906, p. 102.—H. L. CLARK, 1907, p. 190.—H. L. CLARK, 1925, pp. 2, 10.—MORTENSEN, 1928-b, p. p. 491.—H. L. CLARK, 1946, p. 284.

Haplotype.—Chondrocidaris gigantea A. AGASSIZ, 1863, p. 18 (Sandwich Islands).—*Phyllacanthus giganteus* (A. AGASSIZ) A. AGASSIZ, 1872-74, pp. 150, 390, pl. la, pl. lf, figs. 27-31.—*Chondrocidaris gigantea* AGASSIZ: MORTENSEN, 1928-b, p. 492, pl. 64, figs. 1-2, pls. 65-66, pl. 74, figs. 3-4, text-figs. 157-158 (Hawaiian Islands, in ca. 125-385 metres depths).

Test thick, with a wide median interambulacral space closely covered with small tubercles (spines) of uniform size, of the shape of elevated, glassy, more or less spiny warts, without a mamelon; they carry very small, conical, appressed spines, which are attached to the side, not to the top of the tubercle. Some sort of spines on apical system and in the median ambulacral area. Apical system ca. 0.36-0.45 of horizontal diameter of test, very compact and closely covered with tubercles (spines) of uniform size; the system dicyclic, oculars widely exsert; madreporite scarcely larger than the other genital plates. Pores conjugate. Primary tubercles smooth, non-crenulate, the areoles not much sunken, not confluent; primary spines thick, with very coarse thorns, arranged without any distinct order. Surface of shaft otherwise with delicate, not branched hairs. Collar fairly long, indistinctly or not at all striate. Peristome as large as, or even distinctly exceeding the apical system; peristomial ambulacral pores in single series. Large globiferous pedicellariae without end-tooth, small globiferous pedicellariae with it; no limb on the stalk; tridendate pedicellariae simple (from MORTENSEN, 1928-b).

This genus, although apparently allied to *Phyllacanthus*, has such remarkable primary spines and such characteristic features of test, which show the peculiarity bare appearance of both ambulacra and interambulacra, and the pedicellariae that there can be little question as to the validity of the genus. The characters, moreover, of the small secondary spines and tubercles distinguish this genus from all other Recent Cidarids, thus, these features, together with the others, raise the generic value of this form beyond doubt. Since both MORTENSEN (1903-b, p. 29.—1928-b, p. 491) and H. L. CLARK (1907, p. 190.—1925, p. 10) have acknowledged the generic validity, against the former idea mixing it up with *Phyllacanthus*, there is no need for a further discussion of this matter.

This is an old, rare, and widespread genus known Recent forms from Mauritius to Hawaii. In various places (Madagascar, India, Java, Fiji, and Australia) spines of fossil Cidarids have been found that more or less resemble those of *Ch. gigantea*.

Chondrocidaris marianica NISIYAMA, n. sp.

(Pl. 1, figs. 19-20)

Holotype.—IGPS coll. cat. no. 73740.

Locality and geological horizon.—Near Laulau, Saipan Island, Mariana (Ladrone) Islands, Micronesia, South Sea Islands. Donney formation (*Eulepidina*—horizon), Lower Miocene (Oligocene of authors).

There is only a single primary spine of this new species accessible; the distal half of it is broken off. It is slightly curved.

Preserved part 26 mm in length, somewhat widened distally, and much flattened more distally than proximally; collar low, about 3 mm high, smooth, not widened outward; above the collar, shaft provided with stout, pointed or blunt, thorny projections, and their size gradually increases to distal part; thorny projections confined to the compressed side of the concave surface of the flattened shaft, projecting more or less upwardly and inwardly, distal ones widen their base and very blunt at their tips; lateral convex surface of the shaft without any projection, and provided with longitudinal series of small granules. Thorny projections seem to make irregular longitudinal series of four or five.

Distinction.—This primary spine closely resembles that of *Ch. sundaica* (MARTIN, 1885) (*Cidaris sundaica* MARTIN, 1883-87 (85), pl. 15, fig. 293a), from the Miocene of Ngembak in Java, but differs from it by the flattened laterally flattened pattern, which shows convex and concave surfaces, and in the number of thorny projections. The spines of *Ch. sundaica* much resemble those of the living *gigantea* A. AGASSIZ, 1863 (MORTENSEN, 1928-b, p. 492, pl. figs. 1-2, pls. 65-66, pl, 74, figs. 3-4, text-figs. 157-158), in which the primary spines are stout, blunt, thorny projections, and often with longitudinal lamellae near the tip. The spines reported as *Phyllacanthus* sp. by COTTREAU (1908-a, p. 183(39), pl. 5, figs. 7-7a) from the Miocene (*Lepidocyclina*—horizon) of Madagascar should be referred to *Chondrocidaris*. The spine of *Ch. marianica* also resembles that of *Ch. problepteryx* H. L. CLARK, 1945 (H. L. CLARK, 1945, p. 314, pl. 41, fig. E), from the *Eulepidina-Operculina*—horizon of Fiji Islands, but differs from it in having more slender and numerous thorn-like projections on the shaft.

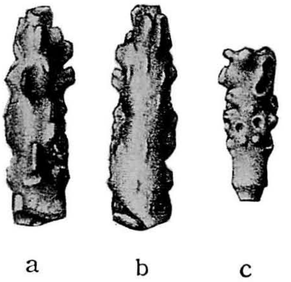


Fig. 2. Primary spines of *Chondrocidaris sundaica* (MARTIN, 1885) (for comparison). (Miocene of Ngembak, Java; after MARTIN, 1885).

At any rate, the spine from the Lower Miocene (or Oligocene) of Saipan Island is more or less related to those of the fossil and Recent species in the Indo-Pacific regions, i. e., *Ch. sundaica* from the Miocene of Java, *Ch. problepteryx* from the Miocene of Fiji Islands, *Ch.* sp. from the Miocene of Madagascar, *Ch. clarkii* CHAPMAN and CUDMORE, 1934 (CHAPMAN and CUDMORE, 1934, p. 141, pl. 13, figs. 15-17, pl. 15, fig. 3) from the Miocene of Australia, and farther has some resemblance to those of the living *Ch. gigantea* A. AGASSIZ, 1863.

From a view-point on the speciation of the Cidarids, these forms, particularly the Miocene forms, may be regarded as an allopatric, and, in turn, the living form has descended from the Miocene ancestor.

Genus *Phyllacanthus* BRANDT, 1835

Phyllacanthus BRANDT, 1835, p. 267 (in separate p. 67).—A. AGASSIZ, 1872-74, pp. 149, 388 (pro prate).—POMEL, 1883, p. 111.—DUNCAN, 1889-a, p. 32.—MORTENSEN, 1903-b, p. 30.—DÖDERLEIN, 1906, p. 103.—H. L. CLARK, 1907, p. 172.—H. L. CLARK, 1925, pp. 2, 9.—MORTENSEN, 1928-b, p. 500, text-figs. 160-162.—COOKE, 1941, p. 3.—H. L. CLARK, 1946, p. 281.—COOKE, 1959, p. 10.

Haplotype.—Cidarites (Phyllacanthus) dubia BRANDT, 1835, p. 268 (68) (Bonin Islands).—*Phyllacanthus dubius* (BRANDT) A. AGASSIZ, 1872-74, pp. 150, 389, pl. 1f, figs. 6, 7.—MORTENSEN, 1928-b, p. 510, pl. 55, fig. 1, pl. 56, figs. 1-2, pl. figs. 4-6, pl. 74, fig. 7, pl. 88, figs. 13-17, text-figs. 164-166 (Bonin Islands, littoral).

Leiocidaris DESOR, 1855-57 (56), p. 48.—DE LORIOL, 1873, p. 63.—POMEL, 1883, p. 111.—DUNCAN, 1889-a, p. 31.—LAMBERT and THIÉRY, 1910, p. 153.

Logotype.—Cidarites imperialis LAMARCK, 1816, p. 54.—*Phyllacanthus imperialis* (LAMARCK) A. AGASSIZ, 1872-74, pp. 151, 391, pl. 1, fig. 2.—MORTENSEN, 1928-b, p. 504, pl. 54, fig. 4, pl. 57, fig. 3, pl. 74, fig. 6, pl. 88, figs. 4-10, text-fig. 163 (Red Sea—Zanzibar—Ryukyu Islands, in 0-73 metres depts). [DE LORIOL, 1873, p. 63].

Test thick, with prominent, non-crenulate primary tubercles. Apical system small, rarely exceeding 0.4 of horizontal diameter of test, very compact and closely covered with tubercles (spines); dicyclic, oculars generally widely exsert; madreporite conspicuously larger than the other genital plates, encroaching upon the small anal area. Scrobicular tubercles conspicuous, usually with a well limited elevation on the side towards the areole. Ambulacra sinuate; the space inside the marginal tubercles usually very narrow, filled up by small tubercles. Pores conjugate, but upper part of wall somewhat raised. Peristome large, usually 0.4-0.5 of horizontal diameter of test. Ambulacral series on peristome biseriate or pluriseriate. Primary spines thick and stout, cylindrical or fusiform, with fine granules more or less distinctly serially arranged, the surface otherwise covered by a spongy structure of branching outgrowths; spines smooth, never prominent thorns. Secondary spines broad, flat, closely appressed, the minor ones more or less scale-like; at most some larger spines along the inner edge of genital plates and around anal and genital openings, forming prominent tufts. Both large and small globiferous pedicellariae without an end-tooth; no limb on the stalk; tridentate pedicellariae with serrate, longitudinal crests in the blade, basal part often thorny on outer side (after MORTENSEN, 1928-b).

The elimination of *Prionocidaris baculosa* (LAMARCK, 1816) and its allies, in which the primary spines with more or less numerous projecting thorns or ridges, at least near base, or with the spotted collar, leave this as a natural group of *Ph. imperialis* (LAMARCK, 1816) and its allies, in which the primary spines are cylindrical or terete, sometimes with longitudinal series of small serrations but never thorns or projecting ridges or spotted collar, as are usually known in the large Indo-Pacific Cidarids. This genus dates back at least to the Miocene, and rather widely distributed in the Indo-Pacific Oceans.

The peculiar feature of the scrobicular tubercles and of the inner structure of the primary spines, as has been pointed out by MORTENSEN (1928-b, pp. 501, 502) seems to be rather unique among the Recent Cidarids. The scrobicular tubercles are semilunular in shape and have a well limited elevated area in the side towards the areole and another, not sharply limited elevation on the outer side is an adaptation serving for strongly appressing the spines around the base of the primary spines. In the inner structure of the primary spines, the rays projected from the central core show a fan-like arrangement around the rays of the central part, and then gradually assuming the usual regular radiating arrangement. MORTENSEN claims (1928-b, p. 502) that this character is found in all the species of the genus, and it is thus a valuable generic character. The biserial arrangement of the ambulacral pores on the peristome is one of the characteristic features of the genus. However, a similar arrangement of the pores is found, though less pronouncedly, in '*Eucidaris*', and more pronouncedly in *Psychocidaris* of the Recent Cidarids.

Phyllacanthus imperialis (LAMARCK, 1816)

(Pl. 2, figs. 1-3)

Cidarites imperialis LAMARCK, 1816, p. 54.—*Phyllacanthus imperialis* (LAMARCK) A. AGASSIZ, 1872-74, pp. 151, 391, pl. 1, fig. 2.—*Rhabdocidaris imperialis* (LAMARCK) DE LORIOL, 1883-a, p. 11, pl. 1, fig 2.—*Leiocidaris imperialis* (LAMARCK) DÖDERLEIN, 1887, p. 25, pl. 9, figs. 7a-f.—DÖDERLEIN, 1903, p. 690, pl. 58, figs. 1-4.—*Phyllacanthus imperialis* (LAMARCK) H. L. CLARK, 1925, p. 10.—MORTENSEN, 1928-b, p. 504, pl. 54, fig. 4, pl. 57, fig. 3, pl. 74, fig. 6, pl. 88, figs. 4-10, text-fig. 163.—JEANNET, 1935, p. 13, pl. 1, figs. 13-14 (pars).—JEANNET and MARTIN, 1937, p. 222.—H. L. CLARK, 1945, p. 313, pl. 41, fig. C.—H. L. CLARK, 1946, p. 282.

Locality and geological horizon.—Angaur, Palao Islands, Micronesia, South Sea Islands. Peliliu Limestone, Pleistocene. *Hypotype.*—IGPS coll. cat. no. 78201.

There are four primary spines of this species at hand, the almost all of them are partly broken off, but they show characters of the specific nature.

The largest spine preserved measures about 65 mm in length and about 9 mm in the greatest diameter. The spines are stout and rather short, collar very low and gradually passes to the shaft; shaft cylindrical in outline and the greatest diameter lies in the middle; from this point the shaft gradually narrows proximally and distally. The shaft with numerous, close, indistinct longitudinal series of granules, and only near the distal end, fourteen very narrow and low ridges of granules are placed longitudinally. The spines closely resemble those of the Recent *Ph. imperialis* (LAMARCK, 1816), and somewhat differ from those of the Recent *Ph. dubius* (BRANDT, 1835), in the stout, short, and indistinct longitudinal series of granules on the shaft.

Phyllacanthus cf. *javanus* MARTIN, 1885

(Pl. 2, figs. 4-5)

Compared with:

Phyllacanthus javanus MARTIN, 1883-87(85), p. 289, pl. 15, fig. 294.—GERTH, 1922, p. 517.—JEANNET, 1935, p. 13 (pars), pl. 1, fig. 15.—JEANNET and MARTIN, 1937, p. 222, text-fig. 4.

Locality and geological horizon.—Near Laulau, Saipan Islnad, Mariana (Ladrone) Islands, Micronesia, South Sea Islands. Donney formation (*Eulepidina*—horizon), Lower Miocene (Oligocene of authors). *Hypotype.*—IGPS coll. cat. no. 78202.

Several primary spines, usually fragmentary and often badly weathered, of a large Cidarid are present in our collection. Most of them are difficult to identify specificially, but there seems no reason to doubt that they all represent a single species. The proximal part of shaft of the best preserved sample agrees well with that of the figure of Martin (1885, pl. 15, fig. 294d), and the shaft of spines longitudinally striated. But owing to the fragmentary condition of specimens the precise identification with that species is quite difficult, if not impossible. *Ph. javanus* was first reported from the Lower Miocene of Ngembak in Java, and distributed to the Miocene of New Guinea and Madura Islands, and the occurrence of this species in Mariana Islands seems to be probable. Jeannet's *Ph. imperialis* from the Miocene of Tji Sande in Java (1935, pl. 1, fig. 15) was identified with this species by later writers (Jeannet and Martin, 1937, p. 222).

Order Diadematoida Duncan, 1889

Diadematoida Duncan, 1889-a, p. 24 (pro prate).—*Diademoida* Duncan: Gregory, 1900-b, p. 305 (pro prate).—*Diadematoidea* Duncan: Beurlen, 1937-a, p. 19.—*Diadematoida* Duncan: Nisiyama, 1954, p. 325 (in Japanese).—*Diadematacea* Duncan: Durham and Melville, 1957, p. 252 (superorder).

Aulodonta Jackson, 1912, p. 202 (suborder).—H. L. Clark, 1925, p. 38 (suborder).—Mortensen, 1927-b, p. 276.—Mortensen, 1940, p. 3.

Type-family.—*Diadematidae* Gray, 1855

Corona imbricating or rigid, of usually hemispherical form, with well developed masticatory apparatus, and with interambulacra and ambulacra of two columns each. Tubercles perforate, crenulate or non-crenulate. Primordial interambulacral plates usually not persisting, or rarely persisting. Compound ambulacral plates of the generally diadematoid structure when present. Apical system endocyclic or exocyclic; when endocyclic the system dicyclic, or monocyclic, or with oculars partly insert; or the apical system is more or less dissolved in adult; no suranal plates. Peristome rarely with the ambulacral series of plates; usually with a single pair of ambulacral plates, i. e., the buccal plates, otherwise only with small, irregular non-ambulacral plates. Gills generally present, gill-slits usually distinct. Spines solid or hollow; no outer layer. Lantern generally erect; epiphyses narrow and not joining above the teeth; pyramids usually pitted under the epiphyses. Teeth grooved or unkeeled. Perignathic girdle consisting of radial auricles, which may or may not join with their upper ends over each ambulacrum, connected by an apophysis (interradial wall) or none. Pedicellariae richly developed, of the tridentate, ophicephalous, and triphyllous, in some forms also of the globiferous and dactylous types. Sphaeridia present. Spicules usually irregular rods, more or less fenestrated, or elegantly anchor-shaped.

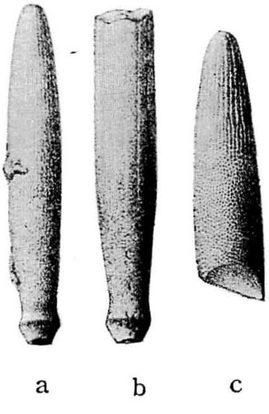


Fig. 3. Primary spines of *Phyllacanthus javanus* (Martin, 1885) (for comparison). (Miocene of Java; after Martin, 1885).

From the Rhaetian to Recent.

This order has originally and customarily included in various and uncertain forms, but by removing of the families of the Hemicidarids and Pseudodiadematids from this order by MORTENSEN (1935, pp. 384, 417) and DURHAM and MELVILLE (1957, pp. 253, 254) to the order of the Arbacioids, the order of the Diadematoids becomes much more natural in the classification and affinities of the Echinoidea.

MORTENSEN believed (1935, p. 5) that the families of the order Diadematoida (with the exclusion of the Echinothuriids) appear to represent three different stems, mainly founded on the structural characters of their spines, and on their probable sources, and that these three parallel, but separate stems, each originating from its own source. On recognizing the three separate stems, MORTENSEN claimed the necessity to separate them into three suborders, i. e., the Aspidodiademina, Diademina, and Pedinina; he believed that his suborders Diademina and Pedinina are of independent origin, the former having been derived from the Palaeozoic Echinocystitids, and the latter from the Cidarids. DURHAM and MELVILLE (1957, p. 253) disregarding, MORTENSEN's derivation of the Diademina from the Echinocystitids, believe a Cidaroid ancestry for Diademina and Pedinina; they proposed the elevation of each to ordinal rank. They associated also the Aspidodiadematidae with the Diadematidae and Micropygidae in their order Diadematoida.

The Echinothuriids, the much discussed and disputed forms, which are regarded by MORTENSEN (1934, 1935) as the survivors of the Palaeozoic Echinocystitids, may be associated, as claimed by DURHAM and MELVILLE (1957, pp. 250-251), with the Pedinids. DURHAM and MELVILLE (1957, pp. 246-247, 253) have separated the Pygasterids, which, are formerly classified with the Holectypids, from the true Holectypoids, and erected a new Order Pygasteroida (p. 253), for the Pygasterids have a close affinity the Diadematoids, and would be ascribed to a Pedinoid ancestry; this belief had already been stated by MORTENSEN (1948-b, p. 10).

Only a fossil representative of the suborder Diadematoina is in our collection.

Suborder DIADEMATOINA DUNCAN, 1889

Diadematoida DUNCAN, 1889-a, p. 24 (pro parte).—*Diademina* GREGORY, 1900-b, p. 308.—MORTENSEN, 1904, p. 55 (tribus).—MORTENSEN, 1939, p. 547.—MORTENSEN, 1940, p. 136.—*Diadematina* GREGORY: NISIYAMA, 1954, p. 325 (in Japanese).—*Diadematoida* DUNCAN: DURHAM and MELVILLE, 1957, p. 253 (order).

Type-family.—*Diadematidae* GRAY, 1855

Regular Echinoids with aulodont teeth and ambulacra consisting of generally compound plates of the diadematoid structure; coronal plates generally imbricating or rarely rigid; radioles (spines) hollow, only exceptionally the axis is filled by a loose meshwork. Primary tubercles perforate and crenulate or rarely non-crenulate.

From the Lower Jurassic (Lias) to Recent.

This suborder comprises three families, and they are distinguished from each other by the following key (after MORTENSEN, 1940).

Key to the families of the suborder Diadematoina.

1. Primary spines with the axis divided into compartment, separated by fenestrated transverse plates (dissepiments), connected by long, thin threads. Tubercles strongly crenulate. Ambulacra consisting of simple or compound plates of

diadematoid structure. Apical system large, monocyclic, oculars large and all insert. Periproct leathery, only partially plated........ Aspidodiadematidae

Primary spines (usually) with hollow axis; tubercles crenulate or non-crenulate .. 2

2. Tubercles non-crenulate. Tube-feet of the outer series transformed into large, umbrella-shaped organs, containing anchor-shaped spicules. Pore-pairs arranged in double series .... Micropygidae

Tubercles (usually) crenulate. Tube-feet of the outer series not transformed into large, umbrella-shaped organs. No anchor-shaped spicules. Pore-pairs not arranged in double series .... Diadematidae.

The distinction of the diadematids from the Micropygids by the character of tube- feet, as described above, does not apply to the fossil forms, as the tube-feet are not preserved in a fossil state, but the distinction by the character of tubercles (crenulate and non-crenulate) and arrangement of pore-pairs safely guarantee the families of the fossil forms.

The family Micropygidae MORTENSEN (MORTENSEN, 1904, p. 45.—DÖDERLEIN, 1906, pp. 86, 169.—MORTENSEN, 1940, p. 136) related to the Diadematidae in the structural character of the spines. The family of the Micropygids may be regarded as a side-branch from the Diadematids, or perhaps it has arose directly from the Cidarids as a small separate, specialized stem parallel with the Diadematids. There is nothing of our knowing, however, of any fossil forms linking the Micropygids with the Cidarids. The small family Aspidodiadematidae DUNCAN, 1889 (DUNCAN, 1889-a, p. 56.—A. AGASSIZ and H. L. CLARK, 1908, p. 59.—MORTENSEN, 1940, p. 6), which differ more or less in the structural character of spines from that of the Diadematids, may represent a separate branch, originating separately from some unknown form of the Cidaroids.

Only a fossil of a genus of the Diadematidae is represented in our collection.

Family DIADEMATIDAE GRAY, 1855

Diademadae GRAY, 1855, p. 35.—*Diadematidae* PETERS, 1855, p. 106.—*Diadematidae* GRAY: WRIGHT, 1857-78(57), pp. 18, 106.—*Diadematidae* PETERS: COTTEAU, 1861-67(61), p. 78.—DESOR and DE LORIOL, 1867-72(69), p. 88.—DE LORIOL, 1873, p. 67.—A. AGASSIZ, 1872-74, p. 407.—ZITTEL, 1879, p. 500.—COTTEAU, 1880-85(80), p. 1.—*Les Diadematiens* POMEL, 1883, p. 106.—*Diadematidae* PETERS: DUNCAN, 1889-a, pp. 57, 58.—GREGORY, 1900-b, p. 309.—DELAGE and HÉROUARD, 1903, p. 230.—MEISSNER, 1904, p. 1356.—MORTENSEN, 1904, p. 40.—A. AGASSIZ and H. L. CLARK, 1908, p. 103.—LAMBERT and THIÉRY, 1910, p. 162.—H. L. CLARK, 1925, p. 40.—MORTENSEN, 1940, p. 158.—TERMIER and TERMIER, 1953, p. 894.

Centrechinidae JACKSON, 1912, p. 202.—GRANT and HERTLEIN, 1938, p. 11.—H. L. CLARK, 1946, p. 296.

Type-genus.—*Diadema* (HUMPHREYS, 1797) GRAY, 1825

Test of moderate to large size, usually more or less flattened; plates may be rather strongly imbricating, the test then being more or less flexible. Ambulacra consisting of simple or trigeminate compound plates of the diadematoid structure. Apical system generally monocyclic, or the oculars partly insert; periproct more or less plated, to nearly leathery, sometimes with anal tube. Peristome of moderate to large size; gill-slits distinct. Primary ambulacral and interambulacral tubercles perforate and crenulate, exceptionally non-crenulate. Spines typically hollow, mostly distinctly verticillate. Pedicellariae of the tridentate, ophicephalous, and triphyllous pedicellariae occur in two forms; stalk of pedicellariae may be reduced to a single calcareous threads; globiferous pedicellariae without specially developed end-tooth, with or without glands on the stalk. Sphaeridia placed at the tube-feet of the lower component of each compound plate, continuing to the apical system. Spicules of tube-feet triradiate or more irregular rods. Rudimentary STEWART's organs may be present (from MORTENSEN, 1940).

From the Lias to Recent.

From the fossil evidence of this family, it may be assumed that the Diadematids start in the Lower Jurassic (Lias) with the genus *Eodiadema* DUNCAN, 1889, and pass through the Jurassic *Pedinothuria* GREGORY, 1897, and the Cretaceous *Palaeodiadema* POMEL, 1887, into the richly developed Recent Diadematids. Among the eight or nine Recent genera of the family, of the genera *Diadema*, *Echinothrix* PETERS, 1853, and *Centrostephanus* PETERS, 1855, as claimed by MORTENSEN (1940, p. 173), on one side, and *Astropyga* GRAY, 1925, *Eremopyga* A. AGASSIZ and H. L. CLARK, 1908, and *Chaetodiadema* MORTENSEN, 1903, on the other side seem to be more nearly related, and may form two groups. All are shallow-water genera and most of them occur along near the shore. The following Recent genera are known to occur in the Japanese seas, i. e., *Astropyga*, *Chaetodiadema*, *Diadema*, and *Echinothrix*, and they are discriminated from one another according to the following key.

Key to the Japanese genera of the family Diadematidae.

1. Test low, more or less flexible. Tubercles crenulate 2
   Test generally sub-hemispherical and round in the ambital outline. Pore-zones not uniserial adorally. Tubercles crenulate 3
2. Pore-pairs on the oral side arranged in a single series. Primary spines slender, rough, more or less solid. Adoral surface with tubercles tending to become small and densely crowded near the peristome .... *Chaetodiadema*
   Pore-pairs on the oral side arranged in distinct arcs of three. Pore-zones more or less widened adorally. Normal primary spines relatively short, rough, with central cavity filled by a calacreous network and appear solid in cross-section. Oral surface with normal primary tubercles; aboral side not very naked .. .. *Astropyga*
3. Primary ambulacral tubercles very small, not forming two regular series. Aboral ambulacral spines very fine, setiform, retrorsely barbed at point. Ambulacra with numerous secondary tubercles aborally and distinctly wider there than at the ambitus. Primary spines rough, hollow. No globiferous pedicellariae .. .. *Echinothrix*
   Primary ambulacral tubercles conspicuous, in two regular series. Ambulacral spines not essentially different from those of interambulacra. Ambulacra with few or no secondary tubercles aborally and narrower there than at the ambitus. Interambulacral primary spines rough with minute teeth and hollow. No spines on buccal plates. No globiferous pedicellariae .... *Diadema*

There is a fossil representaive of the genus *Echinothrix* in our collection.

Genus *Echinothrix* PETERS, 1853

Echinothrix PETERS, 1853, p. 484.—PETERS, 1855, p. 114.—A. AGASSIZ, 1863, p. 19.—BÖLSCHE, 1865, p. 328.—A. AGASSIZ, 1872–74, pp. 119, 413.—POMEL, 1883, p. 106.—DUNCAN, 1885, p. 191.—DUNCAN, 1889-a, p. 78.—DELAGE and HÉROUARD, 1903, p. 232.—MEISSNER, 1904, p. 1358.—A. AGASSIZ and H. L. CLARK, 1908, p. 115.—LAMBERT and THIÉRY, 1810, p. 164.—H. L. CLARK, 1925, p. 44.—MORTENSEN, 1940, p. 282.—H. L. CLARK, 1946, p. 299.

Logotype.—Echinus calamaris PALLAS, 1774, p. 31, pl. 2, figs. 4–7, 8a, 8b, 8A, 8B (Indiae Orientalis).—*Echinothrix calamaris* (PALLAS) A. AGASSIZ, 1872–74, pp. 119, 413, pl. 3a, figs. 1–2, pl. 35, figs. 10–15 (East Indian Islands, Society Islands, and Philippine Islands).—MORTENSEN, 1940, p. 285, pl. 39, fig. 1, pl 40, figs. 1–2, pl. 42, figs. 1–5, pl. 43, fig. 3, pl. 44, figs. 2–10, pl. 46, fig. 1, pl. 47, figs. 1–3, 5, pl. 48, fig. 3, pl. 71, figs. 5, 7, text-figs. 94d, 95a, 147–149 (Indo-Pacific Oceans, from Red Sea to Hawaii and to southern Japan; a littoral form). [A. AGASSIZ and H. L. CLARK, 1908, p. 115].

Garelia GRAY, 1855, pp. 36, 38.

Type-species.—Garelia aequalis GRAY, 1855, p. 38.=*Echinus calamaris* PALLAS, 1774, p. 31.

Savignyia DESOR, 1855–57 (56), p. 82.—MICHELIN, 1862, p. 4.

Type-species.—Echinus calamaris PALLAS, 1774, p. 31.

Diadema (SCHYNVOET) LAMBERT, 1907-b, p. 27 (after SCHYNVOET, 1711, Thesaurus imaginum Priscium testaceorum, p. 2-pre-Linnean).—LAMBERT and THIÉRY, 1911, p. 164.—LAMBERT and THIÉRY, 1925, p. 561.

Type-species.—Diadema turcarum SCHYNVOET, 1711, p. 2.—*Echinothrix turcarum* (SCHYNVOET) A. AGASSIZ, 1872–74, pp. 120, 416, pl. 2a, figs. 34–48, pl. 3a, fig. 3, pl. 24, figs. 33–36.= *Echinus diadema* LINNAEUS, 1758, p. 664 (Habitat in M. Indico).

Test of large size, flattened above and below, ambulacra sometimes raised adapically, and then the median area of interambulacra correspondingly sunken. Test not very fragile, not flexible; but as seen from the inside the interambulacra imbricate adorally along the median suture; the ambulacra bevel slightly under the interambulacra; in the ambulacra midline there is hardly any distinct overlap. Ambulacral plates trigeminate of the diadematoid structure throughout, the component plates all being primaries reaching from the midline to the interradial edge; only adorally they are partly reduced to demi-plate components. Pore-pairs form very regular oblique arcs of three; pore-zones not widened at the peristome, and hardly any crowing of the pores occur there. Ambulacral primary tubercles, though distinctly crenulate and perforate, remain quite small, at most increasing slightly at the ambitus, and there is very regularly one primary tubercle to each compound plate. Interporiferous zone quite narrow on oral side, leaving hardly room for more than primary tubercles, but on aboral side it widens very conspicuously adapically, being usually covered here by a great number of small tubercles, among which the primary tubercles are hardly distinguishable. Primary interambulacral tubercles numerous, 3–6 to each plate at the ambitus, arranged in regular longitudinal and transverse series, the latter oblique, admedially turning upwards, in correspondance with sutures of plates. Apical system usually dicyclic; periproct more or less naked, may be raised (in *calamaris*) into a conspicuous, flaring anal tube, covered with small, thick, round, white plates. Peristome larger than apical system. Buccal plates small, not quite contiguous, and the pairs widely separated from each other; buccal membrane with as a rule numerous plates imbedded in the skin, several of them bearing pedicellariae or even small spines. Gill-slits rather wide, not very deep, but there is a fairly long tag along the underside of gills, in continuation of gill-slits. Interambulacral spines (in *calamaris*) finely, but distinctly verticillate, with wide axial cavity, in young specimens even flaring, or (in *diadema*) only finely longitudinally striated, with very narrow axial cavity, and not flaring in the young. Ambulacral spines long, very thin, smooth setae, distinctly barbed. Pedicellariae of the tridentate, ophicephalous, and triphyllous types, but no globiferous pedicellariae; tridentate pedicellariae occur in two forms; ophicephalous pedicellariae of claviform type. Spicules of tube-feet triradiate, or more irregular, usually arranged in longitudinal series. Colour exceedingly varied, but more generally the primary spines banded; no blue spots. STEWART'S organs fairly well developed. Auricles united at their upper end; pits of pyramids distinct (after MORTENSEN, 1940).

From the Pleistocene to Recent.

In the living or dried specimens of the genus, the characteristic ambulacra, with the small primary tubercles, and their marked aboral widening, together with the numerous slender, setiform, aboral ambulacral spines, which often glitter like gold, make this genus easily recogniable, amog the genera of the family, particularly from the related genus *Diadema*.

The nomenclatorial confusion between this genus and the genus *Diadema* seems to require consideration in some legalistic senses. MORTENSEN (1932-e, pp. 360-365) has discussed the use of the generic names, *Diadema*, *Centrechinus*, *Echinothrix*, and *Centrostephanus*, in opposition to the uncustomary uses of JACKSON (1912, foot-note on pp. 27-28), LAMBERT (1907-b, p. 27), and LAMBERT and THIÉRY (1911, p. 164). MORTENSEN and several other authors are in favour of making the generic name *Diadema* with the type-species *Echinometra setosa* LESKE, 1778 (LESKE, 1778, p. 100, pl. 37, figs. 1-2), a nomen conservandum. LESKE'S "*Echinometra setosa*", which he himself misidentified with "*Echinus diadima* LINNEI", as clearly shown and pointed out by GRANT and HERTLEIN (1938, pp. 13-14, text-fig. 2), does not mean that species, but the figure (copied from KNORR, 1766) shows no secondary tubercles above the ambitus. In establishing his "*Echinus diadema*", LINNAEUS (1758, p. 664) based his species upon a figure in RUMPHIUS (1741, pl. 14, fig. B), which clearly shows the secondary tubercles above the ambitus. The identify, however, of RUMPHIUS' figure with SCHYNVOET'S *Diadema turcarum* is not certain. It may seem strange that the species *diadema* LINNAEUS, 1758, belongs to *Echinothrix* rather than to the genus *Diadema*. LESKE'S figure of *diadema* (based on KNORR'S figure) is the true *setosa*, and "*Echinus*" *diadema* of LINNAEUS (bassed on RUMPHIUS'S figure) must be clearly separated from LESKE'S *diadema* ("*Echinometra setosa*"), and LINNAEUS'S species also must be classified with *Echinus calamaris* PALLAS, 1774, into the genus *Echinothrix* in the sense as diagnosed above.

There are apparently only two living species which are constantly recognized in this genus, i. e., *Ech. calamaris* (PALLAS, 1774) and *Ech. diadema* (LINNAEUS, 1758) (*Echinus diadema* LINNAEUS, 1758, p. 664.—*Echinothrix diadema* (LINNAEUS) 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), both are littoral forms and ranging throughout the Indo-Pacific regions from Zanzibar to the Society and Hawaiian Islands and as far north as to southern Japan. Typical examples of the two are relatively easily distinguished, but full-grown adults are sometimes perplexing.

MORTENSEN (1940, p. 295) claims the two species to be "very distinct", and even suggests that they might be placed in different genera. They may be distinguishable from each other by the following key.

Key to the species of the genus *Echinothrix*

1. Ambulacra usually conspicuously raised aborally, or naked, sunken median area aborally in the interambulacra. Ambulacral tubercles not enlarged at the ambitus. Interambulacral primary spines fragile, diameter of inner cavity (lumen) large, more than half diameter of spines; distinctly verticillate, minute teeth covering arranged in distinctly separated whorls. In young specimens primary spines are conspicuously flaring. Interambulacral tubercles in adult specimens 4-6 to each plate at the ambitus. Anal tube large, swollen, with numerous small, round, thick, white plates. Colour usually black and white (large spines) and yellow green (ambulacral spines), very handsome, but old individuals may become dull and lose their distinctive appearance. Colour of test aborally usually green. Blade of valves of tridentate pedicellariae widest at or near tip .... *calamaris*
2. Ambulacra not raised aborally, no naked median area in the interambulacra. Ambital ambulacral tubercles enlarged. Intermbulacral primary spines rather solid, inner cavity (lumen) very small, much less than half diameter of spines; the spines not verticillate, minute teeth covering arranged in crowded longitudinal series and not in distinct whorls. Spines of young specimens not distinctly flaring. Interambulacral tubercles in adult specimens usually not more than three to each plate at ambitus. Anal tube large, swollen, without small, round, white plates. Colour mostly black, with ambulacral spines often rusty-red or brown; no green colour on test aborally. Blade of valves of tridentate pedicellariae widest near middle .... *diadema*

There is a fossil specimen of *Echinothrix calamaris* (PALLAS, 1774) in our collection.

Echinothrix calamaris (PALLAS, 1774)

(Pl. 3, figs. 6-9)

Echinus calamaris PALLAS, 1774, p. 31, pl. 2, figs. 4-7, 8a, 8b, 8A, 8B.

Cidaris calamaris (PALLAS) LESKE, 1778, p. 115, pl. 45, figs. 1-4.—BLAINVILLE, 1834, p. 231.—*Cidarites calamaris* (PALLAS) LAMARCK, 1816, p. 58.

Diadema calamaris (PALLAS) GRAY, 1825, p. 426.—*Diadema calamarium* (PALLAS) DESMOULINS, 1835-37 (37), p. 154.—*Diadema calamare* (PALLAS) VON MARTENS, 1866, p. 150.—LAMBERT and THIÉRY, 1911, p. 164,—LAMBERT and THIÉRY, 1925, p. 561.

Astropyga calamaris (PALLAS) AGASSIZ and DESOR, 1846, p. 345.

Astropay desori AGASSIZ in AGASSIZ and DESOR, 1846, p. 345.

Echinothrix calamaris (PALLAS) PETERS, 1853, p. 488.—PETERS, 1855, p. 116.—A. AGASSIZ, 1872-74, pp. 119, 413, pl. 3a. figs. 1-2, pl. 35, figs. 10-15.—STUDER, 1880-a, p. 868.—A. AGASSIZ, 1881-a, p. 67.—TENISON-WOODS, 1881-a, p. 195.—DÖDERLEIN, 1903, p. 698, pl. 59, fig. 9, pl. 63, fig. 6.—DE MEIJERE, 1904, p. 51.—MORTENSEN, 1904, p. 30, pl. 3, figs. 5, 13, 17, 21, pl. 4, fig. 7, pl. 5, figs. 3, 11.—TOKUNAGA, 1905, pl. 5, figs. 6-7.—A. AGASSIZ and H. L. CLARK, 1907-b, p. 236.—A. AGASSIZ and H. L. CLARK, 1908, p. 117.—JACKSON, 1912, p. 155.—H. L. CLARK, 1921, p. 146.—H. L. CLARK, 1923, p. 373.— H. L. CLARK, 1925,

p. 44.—BONNET, 1926-a, p. 250, text-figs. 6-7.—KOEHLER, 1927, p. 47.—ROXAS, 1928, p. 252, pl. 2, figs. 5-6, pl. 5, fig. 23.—H. L. CLARK, 1932, p. 212.—MORTENSEN, 1940, p. 285, pl. 39, fig. 1, pl. 40, pl. 41, figs. 1-2, pl. 42, figs. 1-5, pl. 43, fig. 3. pl. 44, figs. 2-10, pl. 46. fig. 1, pl. 47, figs. 1-3, 5, pl. 48, fig. 3, pl. 71, figs. 5, 8, text-figs. 94d, 95a, 147-149.—NISIYAMA, 1942, p. 16, text-fig. 2.—H. L. CLARK, 1946, p. 300.—UTINOMI, 1954, p. 345.

Echinothrix desorii (AGASSIZ) PETERS, 1853, p. 488.—PETERS, 1855, p. 117.—BÖLSCHE, 1865, p. 333.—A. AGASSIZ, 1872-74, pp. 120, 415.—GRAY, 1872, p. 120.—GIEBEL, 1877, p. 319.—DE LORIOL, 1883-a, p. 14.—DUNCAN, 1885-b, p. 101, pl. 5, figs. 5-8; p. 202.—KOEHLER, 1895, p. 411.—*Echinothrix calamaris var. desori* (AGASSIZ) DÖDERLEIN, 1903, p. 699, pl. 63, fig. 6.—*Echinothrix desori* (AGASSIZ) LAMBERT and THIÉRY, 1911, p. 164.

Echinothrix annellata PETERS, 1853, p. 588.—PETERS, 1855, p. 117.—A. AGASSIZ, 1863, p. 19.

Garelia aequalis GRAY, 1855, p. 38.

Savignya frappieri MICHELIN. 1862, p. 4, pl. 15.

Echinothrix aperta A. AGASSIZ, 1863, p. 19.—BÖLSCHE, 1865, p. 333.

Echinothrix aequalis (GRAY) BÖLSCHE, 1865, p. 333.

Echinothrix turcarum (SCHYNVOET) BÖLSCHE, 1865, p. 336 (pro parte).

Diadema frappieri (MICHELIN) LAMBERT, 1921-a, p. 24.—LAMBERT and THIÉRY, 1925, p. 562.

Locality and geological horizon.—A point on Kita-Daitô-jima (North Borodino Islands), Ryukyu Islands. Ryukyu Limestone, Pleistocene. *Hypotype.*—IGPS coll. cat. no. 73776.

There is only a single specimen of internal mold referred to this species at the writer's disposal. Test rather large, about 71 mm in diameter and about 35 mm in height. Apical system large, 18 mm in diameter, more or less sunken; genital plates large and projecting into interambulacral spaces. Ambulacra narrow, about 8 mm wide at the ambitus, raised, with numerous secondary tubercles above the ambitus aborally, and wider aborally, about 10 mm wide at zone 10 mm from the apical system, the ambitus than at; ambulacral plates very low, composed of three components of the diadematoid structure as usual; pairs of pores large, in close arcs. Interambulacra very broad, about 33 mm wide at the ambitus, with a bare median space, sunken; seven vertical series of rather small primary tubercles at the ambitus, crenulated and perforated, diminishing in number aborally. Peristome very large, about 37 mm in diameter, gill-slits deep and large.

Comparing this specimen with that of *Ech. diadema* (LINNAEUS, 1758) (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, fig. 4, 6-7, pl. 48, fig. 4, pl. 71, figs. 1, 3, text-figs. 150-152), the writer found that it has smaller primary tubercles and larger number of longitudinal series than those of the latter and it may be safely referred to *Ech. calamaris.*

Distinction between this species and *Ech. diadema* is somewhat perplexing, particularly when the species lack the spines, but as regards the tuberculation on the test, *Ech. diadema* rarely has more than three series of primary tubercles on an interambulacral column, while *Ech. calamaris* may usually have five or even six series. This species is widely distributed in the Indo-Pacific Oceans ranging from Zanzibar to the Society and Hawaiian Islands, reaching as far north as to Seto, Wakayama Prefecture, Japan (Utinomi, 1954, p. 345); in littoral zone, rarely down to 70 metres depth.

Order ARBACIOIDA GREGORY, 1900

Arbacina GREGORY, 1900-b, p. 307 (suborder; non *Arbacina* POMEL, 1883).—*Arbacioidea*

BEURLEN, 1937-a, p. 40.—*Arbacioida* BEURLEN: NISIYAMA, 1954, p. 325 (in Japanese).
Stirodonta JACKSON, 1912, p. 203 (suborder).—H. L. CLARK, 1925, p. 65 (suborder).—MORTENSEN, 1927-b, p. 288.—MORTENSEN, 1935, p. 229.
Type-family.—*Arbaciidae* GRAY, 1855

Corona rigid, or usually spherical form, with well developed masticatory apparatus, and with interambulacra and ambulacra of two columns each. Ambulacra consisting of trigeminate compound plates, often only in adoral region, of the diadematoid or arbacioid structure. Primordial plates persisting or not. Apical system endocyclic, compact, with or without a polygonal suranal plate. Spines solid, with or without an outer layer. Peristome with a single pair of ambulacral (buccal) plates, otherwise with small irregular non-ambulacral plates. External gills present, gill-slits usually distinct in adult. Lantern erect; epiphyses short and narrow, not joining above the teeth; pyramids pitted on the upper surface, under the epiphyses; teeth keeled. Perignathic girdle complete in adult, consisting of radial auricles connected by an apophysis. Tridentate, triphyllous, and ophicephalous pedicellariae present, in some forms also claviform or globiferous pedicellariae. No STEWART's organs; sphaeridia present (from MORTENSEN, 1935).

From the Lower Jurassic (Lias) to Recent.

The primitive member of this order, particularly the Hemicidarids and Pseudodiadematids, although little is as yet known of early stirodont type of them, have some resemblances to the members of the order Cidaroida, in the structure of the primary spines and ambulacral plates, as for the origin of them the writer does not see any other possibility than that they may have been derived from the Cidaroid stem. However, the characters of the teeth, the perignathic girdle, the existence of external gills and gill-slits, and the ambulacra not continuing over the peristome in the members of this order are distinctly differ from those in the Cidaroids, and scarcely transitional form being known here. DURHAM and MELVILLE (1957, p. 253) pointed out the early origin of the stirodont condition is indicated by the occurrence in the English Lias (Lower Pliensbachian) of Echinoids with the external characters of the Diadematids and keeled teeth. On the other hand, the specialized members of this order have some affinities with some members of the order Echinoida, in the structure of the primary spines, apical system, ambulacral plates, and the tubercles; and latter member would rather seem to have evolved from the former, less specialized member.

Owing to the diversified forms of the families included into this order, it seems necessary to separate them into three suborders (DURHAM and MELVILLE'S ordinal ranks), the Salenioina, Phymosomatoina, and the Arbacioina, as diagnosed in the preceding pages.

There are fossil representatives of these three suborders in our collection.

Suborder SALENIOINA MORTENSEN, 1903

Salenina MORTENSEN, in DELAGE and HÉROUARD, 1903, p. 235.—MORTENSEN, 1904, p. 56.—*Saleniina* MORTENSEN: NISIYAMA, 1954, p. 326 (in Japanese).
Calycina GREGORY, 1900-b, p. 306.—MORTENSEN, 1935, pp. 300, 301.
Type-family.—*Saleniidae* AGASSIZ, 1838
Hemicidarina BEURLEN, 1937-a, p. 41.—*Hemicidaroida* BEURLEN: DURHAM and MELVILLE,

1957, p. 254 (order).
Type-family.—*Hemicidaridae* WRIGHT, 1857

Regular Echinoids with stirodont teeth; interambulacral plates with a single large tubercle, which is sometimes reduced above the ambitus. Ambulacra simple, or with compound plates of the diadematoid structure, often only in adoral region. Apical system with or without any number of polygonal suranal plates. Primary spines with solid axis, a collar, and a cortex layer; secondary spines setaceous or flattened. Pedicellariae of the tridentate, triphyllous, and ophicephalous types; globiferous pedicellariae absent; claviform pedicellariae may be present (from DURHAM and MELVILLE, 1957, and MORTENSEN, 1935).

From the Lower Jurassic (Lias) to Recent.

To his Calycina MORTENSEN (1935, p. 302) comprised only two families, the Acrosaleniidae and Saleniidae, and he discriminated the two from each other, in the main, by the characters of the primary tubercles. DURHAM and MELVILLE (1957, p. 254) adopted BEURLEN's suggestion (1937-a, p. 41) of grouping the Hemicidaridae, which are classified, by MORTENSEN, with the Pseudodiadematidae in other suborder, with the Acrosaleniidae and Saleniidae in their order Hemicidaroida. These three families are in common with some important characters. MORTENSEN (1935, p. 390) reported that the apical system of *Hemicidaris luciensis* recalls the condition in *Acrosalenia*, and also claimed that it indicates that *Acrosalenia* and *Hemscidaris* must have developed from the same source. The three families are discriminated from one another as shown by the following key.

Key to the families of the suborder Salenioina.

1. Primary tubercles perforate and crenulate 2
   Primary tubercles imperforate, usually crenulate. Apical system with a single large suranal plate .... Saleniidae
2. Ambulacral primary tubercles large on the ambitus. Apical system with a single large or several smaller suranal plates .... Acrosaleniidae
   Ambulacral primary tubercles large on the oral side, rather abruptly becoming smaller above the ambitus. Apical system without no special development of the periproctal plates .... Hemicidaridae

There are fossil representatives of two families, the Saleniidae and Hemicidaridae, in our collection.

Family SALENIIDAE AGASSIZ, 1838

Des Salénies AGASSIZ, 1838, p. 3.—*Salenidae* AGASSIZ in AGASSIZ and DESOR, 1846, p. 341.—*Salenidae* DESOR, 1855-57 (56), p. 138.—WRIGHT, 1857-78 (57), pp. 19, 226.—COTTEAU, 1861-67 (61), p. 82.—COTTEAU and TRIGER, 1855-69 (69), p. 407.—WRIGHT, 1864-82 (71), p. 144.—A. AGASSIZ, 1872-74, p. 398.—COTTEAU, 1875-80 (78), p. 344.—ZITTEL, 1879, p. 497.—POMEL, 1883, p. 92.—DUNCAN and SLADEN, 1887, p. 136.—DUNCAN, 1889-a, p. 45.—GREGORY, 1900-b, p. 361.—DELAGE and HÉROUARD, 1903, p. 235.—MEISSNER, 1904, p. 1356.—A. AGASSIZ, 1904, p. 34.—A. AGASSIZ and H. L. CLARK, 1908, p. 49.—LAMBERT and THIÉRY, 1911, p. 208.—JACKSON, 1912, p. 203.—H. L. CLARK, 1925, p. 65.—MORTENSEN 1935, p. 320.—H. L. CLARK, 1946, p. 304.—TERMIER and TERMIER, 1953, p. 896.
Type-genus.— *Salenia* GRAY, 1835.

Test usually spheroidal, more or less flattened below, of small to moderate size. Ambulacra generally with pore-pairs monoserial, only rarely widened at the peristome; ambulacral plates simple, bigeminate of salenioid or trigeminate of diadematoid structures, exceptionally polyporous; each ambulacrum with a regular double series of small, imperforate, smooth, or exceptionally slightly crenulate, primary tubercles. Interambulacral primary tubercles large, imperforate, but usually crenulate; their areoles generally large, often joined throughout the interambulacrum so as to confine the secondary tubercles to the median area and to the adradial side of areoles. Apical system with a single large suranal plate; periproct situated either directly posteriorly or pushed out to the right side. Peristome with usually well marked gill-slits. Primary spines usually long and slender, of the Cidarid type. Pedicellariae, in the living, of the tridentate, ophicephalous, and triphyllous types; no globiferous pedicellariae, but claviform pedicellariae may occur. Sphaeridia near peristome in the midline of the ambulacra, or along the pores at the ambitus, free or in pits (from Mortensen, 1935).

From the Upper Jurassic (Malm) to Recent.

This is an interesting family being made up of the larger part of extinct forms. It first appears in the Upper Jurassic, reaches its maximum development in the Cretaceous, and then rapidly dies out so that only about a dozen or more species are known to the living now, all in rather deep waters of the Pacific, Indian, and Atlantic Oceans. The character of the primary tubercles, perforate and imperforate, is regarded to show the only differences of importance between the Acrosaleniidae and Saleniidae. The classificatory value, however, of the primary tubercles seems to be questioned, as it is known that within the family of the Cidarids two forms (*Tylocidaris* Pomel, 1883, and *Psychocidaris* Ikeda, 1935) are undoubtedly imperforate, whilst all other Cidarids have perforate primary tubercles, it seems plausible to assume the possibility of the occurrence of the same case among the Saleniids. It appears evident that perforate condition, as the whole, is the more primitive, the imperforate the more specialized among the so-called Regular Echinoids, and this is in good accordance with the fact that the Acrosaleniids are the older forms, the Saleniids the younger. There is no strong objection to assuming that the specialized Saleniian group is an offshoot of the primitive Acrosaleniian stem.

As the main character necessary for grouping the genera in the Saleniids, Mortensen (1934, p. 165.—1945, p. 341) claimed that it is found in the apical system, that is to say, in the position of the anal area, and the grouped them into two subfamilies. In the first subfamily, Hyposaleninae, the anal area is placed on the longitudinal axis, ocular (III)—genital (5), while in the second, Saleniinae, the anal area is pushed out to the right, against ocular (I), thus not placed on the longitudinal axis. This procedure is generally adopted by later authors.

The fossil representatives of the subfamily Saleniinae are in our collection.

Subfamily Saleniinae Agassiz, 1838

Saleninae Mortensen, 1934, p. 165.—Mortensen, 1935, p. 347.

Periproct eccentric, pushed to the right, against the ocular (I), not on the longitudinal axis ocular (III)—genital (5) (Mortensen, 1935).

It would seem that this subfamily represents the more specialized forms of the two in the family, and comprises the following Recent and fossil genera, e. g., *Salenidia* POMEL, 1883, *Valsalenia* MORTENSEN, 1934, *Salenocidaris* A. AGASSIZ, 1869, *Salenia* GRAY, 1835, *Trisalenia* LAMBERT, 1895, and *Polysalenia* MORTENSEN, 1934.

The fossil representatives of two genera, *Salenocidaris* and *Salenia*, are known from the geological formations of Japan.

Genus *Salenocidaris* A. AGASSIZ, 1869

Salenocidaris A. AGASSIZ, 1869, p. 254.—A. AGASSIZ and H. L. CLARK, 1908, p. 54.—LAMBERT and THIÉRY, 1911, p. 212.—H. L. CLARK, 1925, p. 66.—MORTENSEN, 1935, p. 348.

Haplotype.—Salenocidaris varispina A. AGASSIZ, 1869, p. 254.—*Salenia varispina* (A. AGASSIZ) A. AGASSIZ, 1872-74, pp. 155, 261, pl. 3, figs. 8-14.—*Salenocidaris varispina* A. AGASSIZ: MORTENSEN, 1935, p. 350, pl. 66, fig. 9, pl. 84, fig. 4, pl. 85, figs. 3-4, 8, 16-17, 37, text-fig. 193a (West Indies, in 620-1820 metres depths).

Pleurosalenia POMEL, 1883, p. 94.

Haplotype.—Salenia profundi DUNCAN, 1877-a, p. 70.—*Salenia hastigera* A. AGASSIZ, 1881-a, p. 54, pl. 4, figs. 3-17 (South Atlantic Ocean, in more than 1,000 metres depths).

Small forms scarcely exceeding 17 mm in horizontal diameter of test. Amblacra consisting of single plates, except for one to three near the peristome, which are bigeminate; and pore-zones not much widened at the peristome; large proximal ambulacral tubercles crenulate. Apical system closely covered with small rough papillae, with or without pits on the sutures, and the plates not clearly separated from one another; genital pores in the center of the plates. Primary spines long, slender, usually thorny, more or less distinctly verticillate. A pair of sphaeridia on the ambulacral midline at the peristomial edge; from the 4th or 5th plate they occur at the abradial side of the ambulacral spines (after MORTENSEN, 1935).

This genus is characterized, as diagnosed above, by its imperforate primary tubercles. ambulacral plates with simple primaries only, except for one or three near the peristome; apical system with plates not distinctly separated by grooves or pits and closely covered with small papillae, and by small number of ambulacral primary tubercles. This genus is distinguished from *Salenidia* POMEL, 1883 (1883, p. 94.—Type-species—*Salenia gibba* AGASSIZ, 1838, pl. 2, figs. 9-16.—COTTEAU, 1861-67 (61), p. 151, pl. 1035, figs. 13-20) by the apical system which is not distinctly separated by grooves or pits and covered with small and a few papillae, smaller number of ambulacral primary tubercles, and by having the bigeminate ambulacral plates near the peristome.

Among the Recent species of this genus five are now generally recognized as valid, although they are closely related one another and said to be that the specimens under 9 mm in test-diameter cannot be distinguished in all cases with certainty. They are rather widely distributed in the Atlantic, East Indian, and the Pacific Oceans, from 270 to 2,950 metres in depth, though most commonly below 720 metres.

Salenocidaris hakkaidoensis (LORIOL, 1902)

Salenia (*Pleurosalenia*) *hakkaidoensis* DE LORIOL, 1902-a, p. 29, pl. 3, figs. 1, 1a-1c.—TOKUNAGA, 1903, p. 4, pl. 2, fig. 1.—MORISHITA, 1960, p. 54.

Salenia hakkaidoensis LORIOL: LAMBERT and THIÉRY, 1911, p. 212.—ZULLO et al., 1964, p.

337.

Salenocidaris hokkaidoensis (LORIOL) MORISHITA, 1960, p. 54 (after NISIYAMA).

Locality and geological horizon.—Yûbari Coal-field (DE LORIOL, p. 31), Ekimoma-anoro, a branch of the Anoro river in Yûbari Coal-field, Province of Ishikari, Hokkaido (TOKUNAGA, 1903, p. 4) (Exact locality unknwon to the writer, but the locality of two authors seems to be the same) (tm Yûbari-Tanzan (Yûbari Coal-field), ca. Lat. 43° 35′ N., Long. 141° 55′ E.), probably Neogene. Formation unknown.

There is no authentic specimen of this species at the writer's disposal. Judging from the original description and figures of DE LORIOL and TOKUNAGA, however, the species would be assigned to the genus *Salenocidaris*. As to the ambulacral structure, DE LORIOL (loc. cit.) described "Les plaques ambulacraires sont simple, rectangularies; chacune porte paire de pores", but the figure (pl. 3, fig. lb) is more or less inaccurate and hardly shows the nature of plate-structure; the figure of TOKUNAGA of the ambulacra is also inaccurate but the ambulacral plates on the aboral surface seem to be made up of a primary component (plate) only. In the apical system, the plates are not separated by grooves or pits and covered with small, rough (6-9 on the genital and 4-5 on the ocular plates) tubercles (papillae). The number of ambulacral primary tubercles in each column may be over 20; thus, it is rather numerous comparing with that of the living species, except for *Sal. miliaris* (A. AGASSIZ, 1898) (A. AGASSIZ, 1898, p. 74.—A. AGASSIZ and H. L. CLARK, 1908, p. 60, pl. 45, figs. 1-8). Ocular (I) insert in the adult specimen (26 mm in test-diameter) as in *Sal. pacifica* (DÖDERLEIN, 1885) (DÖDERLEIN, 1885, p. 84 (12).—DÖDERLEIN, 1887, p. 52, pl. 11, figs. 9-28.—MORTENSEN, 1935, p. 364, pl. 84, fig. 2, pl. 85, figs. 22-23), from Japan, in 200 metres depth.

Genus *Salenia* GRAY, 1835

Salenia GRAY, 1835, p. 58.—AGASSIZ, 1838, p. 5.—COTTEAU, 1861-67 (61), p. 148.—A. AGASSIZ, 1872-74, pp. 153, 258.—DUNCAN, 1877-a-b, pp. 70, 245.—DUNCAN, 1889-a, p. 68.—A. AGASSIZ and H. L. CLARK, 1908, p. 53.—LAMBERT and THIÉRY, 1911, p. 210.—H. L. CLARK 1925, p. 65.—MORTENSEN, 1953, p. 367.—COOKE, 1959, p. 13.—ZULLO et al., 1964, p. 337.

Haplotype.—*Cidarites scutigera* MÜNSTER in GOLDFUSS, 1826-33 (29), p. 120, pl. 49, figs. 4a-b (Cretaceous of Dresden).—*Salenia scutigera* (MÜNSTER) AGASSIZ, 1838, p. 12, pl. 2, figs. 1-8 (Cretaceous of France).—COTTEAU, 1861-67(61), p. 154, pl. 1037, figs. 1-10 (Cenomanian of France, Germany, England, and Spain).

Very small to moderately sized, usually of spheroidal form. Ambulacra narrow, straight, or sometimes slightly flexuous. Ambulacral plates bigeminate of the salenioid structure throughout, there being one primary tubercle to two components of a plate; pore-zones only slightly widened at the peristomial edge; none of the ambulacral tubercles crenulate. Primary interambulacral tubercles large, crenulate. Apical system with or without suranal impressions, usually with various decorations or verrucae or papillae (but without spines) on the plates. Primary spines thorny or verticillate, usually slightly curved, sometimes (in fossil forms) with a spade-shaped terminal widening. Sphaeridia (in the Recent forms) not ocurring at the peristome, but only on the ambulacral plates which are either the 4th or 5th from the peristome (from MORTENSEN, 1935).

This genus is characterized, as diagnosed above, by its non-axial suranal plate, the imperforate interambulacral primary tubercles, and by the compound ambulacral plates of the salenioid structure throughout, which are made up of two primary components. This genus is distinguished from its allies, *Trisalenia* LAMBERT, 1895 (1895, p. 262.—Type-species—*Tr. loveni* (COTTEAU) MORTENSEN, 1932-d, p. 485, pl. 4, figs. 4-10, pl. 4, figs. 4-10, pl. 5, figs. 13-14, text-figs. 10-11, 14-16), and *Polysalenia* MORTENSEN, 1932 (1932-d, p. 490.—Type-species—*Pol. notabilis* MORTENSEN, 1932-d, p. 491, pl. 4, figs. 1-3, text-figs. 17-22), by the structure of the ambulacral plates at the ambitus.

The genus *Salenia* dates back to the Neocomian and ranges down to the Recent, but flourished in the Senonian Epoch, and a very few number survived in the Recent seas.

There is a fossil species of this genus in our collection, as described herein.

Salenia novemprovincialis NISIYAMA, n. sp.

(Pl. 2, figs. 6-9)

Holotype and paratypes.—IGPS coll. cat. no. 73750.

Locality and geological horizon.—IGPS loc. no.—Ns—11.—Southern sea-cliff of Otoko-jima, Sakito-mura, Nishi-Sonogi-gun, Nagasaki Prefecture. (tm Kakino-ura, Lat. 33°00′16″N., Long. 129°32′30″E.), Kakinoura formation, Oligocene (or Lower Miocene). NAGAO, 1927.

There are six specimens of this new species at hand; they are more or less broken and crushed by subsequent crustal deformation; the best preserved one is selected as the holotype.

Test of rather small size, about 24 mm in horizontal diameter, and rather low, nearly a half of the horizontal diameter or a little more; both oral and aboral sides flattened, apical system slightly elevated; oral side simply flattened, scarcely sunken at the peristomial edge.

Ambulacra slightly sinuate, aborally narrowed, about 3 mm wide at the ambitus, but suddenly widening at some distance from the peristome. Primary ambulacral tubercles form two very regular series in the ambulacra, conspicuously distinct in spite of their small size, on account of interporiferous area being somewhat raised; at the ambitus the tubercles increase a little in size, then become smaller below the ambitus, and again become larger towards the peristome, and finally decrease in size as to become very small on approaching to the peristomial edge; tubercles mamillate, no trace of crenulation, and not quite contiguous; primary series very close to the poriferous zone so that there is scarcely room for a distinct double series of secondary tubercles between them, especially on the aboral side. Pores rather large, and arranged in a single, regular series, as usual in the Saleniids, and there are very regularly two pore-pairs par tubercle; ambulacral plates rather low; at least 30 in a column.

Interambulacra broad, about 11 mm wide at the ambitus, at least 11 plates in each column, each plate with a large primary tubercle, excepting the uppermost one or two in each series, which are covered with small secondary tubercles only; large tubercles distinctly crenulate; areoles of large ambital primary tubercles comparatively large, rather deep, 5.5 mm wide and 4.5 mm high in a plate 7 mm wide and 5 mm high; large scrobicular tubercles make a complete circle around the uppermost areoles, they become continuous around; secondary tubercles form only a longitudinal series to each side of areoles, particularly distinct along the adradial side; median space of interambulacra at the ambitus covered with secondary tubercles, but the median line distinct on the aboral surface.

Apical system large, but more or less affected by subsequent deformation, about 0.5 of horizontal diameter of the test; periproct pushed out to right, ocular (I) being widely insert; suranal plate large, pentagonal in outline, about 5 mm long and wide, and in contact with all five genital plates; oculo-genital plates seem to be rather smooth, excepting a few small tubercles, generally 2 or 3 on the genital plates and usually one on the ocular plates.

Peristome rather small, nearly as large as the apical system; gill-slits appear to have been broad and deep.

Distinction.—This new species resembles *Sal. deleaui* COTTEAU (COTTEAU, 1889-94 (92), p. 480, pl. 296, figs. 11-16) from the Eocene of France, but distinguished from it by having much more numerous ambulacral and interambulacral plates in nearly equal-sized specimens. This species is also superficially related to *Salenidia blanfordi* (DUNCAN and SLADEN, 1882) (*Salenia blanfordi* DUNCAN and SLADEN, 1882-a, p. 29, pl. 6, figs. 1-8), from the Ranikot Series (Eocene) of India, with respect to the numerous coronal plates of the test, but differs from it in the structure of ambulacral plates, and in the suture of the apical system.

Family HEMICIDARIDAE WRIGHT, 1857

Hemicidaridae WRIGHT, 1857-78 (57), p. 68.—DUNCAN, 1889-a, p. 48.—GREGORY, 1900-b, p. 307.—LAMBERT and THIÉRY, 1911, p. 167.—JACKSON, 1912, p. 202.—MORTENSEN, 1935, p. 384.—BEURLEN, 1937-a, p. 41.—TERMIER and TERMIER, 1953, p. 896.

Test of usually moderate size, usually flattened below, often rather high. Ambulacra with compound plates of the salenioid or diadematoid structure, and large perforate, crenulate tubercles on the oral side, rather abruptly narrowing at the ambitus; the plates being then simple primaries or indistinctly compound, with tubercles much smaller than those at or below the ambitus. Each of the interambulacral plates with a large, perforate, crenulate, only very exceptionally smooth, tubercle; the surrounding large areoles usually broadly contiguous; sometimes the primary tubercles reduced in size the upper part of interambulacrum. Apical system simple, with no special development of the periproctal plates. Peristome usually large, with conspicuous gill-slits. Primary spines of the Cidarid type, with a distinct collar and an outer layer on the shaft; secondary spines flattened. Pedicellariae and sphaeridia unknown (from MORTENSEN, 1935).

From the Lower Lias (Hettangian) to the Middle Cretaceous (Cenomanian).

Most of the former authors have regarded the Hemicidarids as related to the Diadematoids; even such author as JACKSON (1912, p. 202) also classified them with Diadematids. However, after the more recent observations, made by MORTENSEN (1935) on the dental character of the Hemicidarids, e.g., the teeth being keeled and the foramen of dental pyramid open but rather deep (1935, text-figs. 206b-e on p.

391) in *Hemicidaris intermedia* and *H. luciensis*, it is proved beyond any doubt that the Hemicidarids belong to the order of the Arbacioids. Accordingly, the Hemicidarids have no nearer relation to the Diadematoids, but their relationship should be to the Acrosaleniids, as well as to the Pseudodiadematids (they have also strongly keeled teeth and the foramen of dental pyramid is open—MORTENSEN, 1932-c, p. 435, text-fig. 2.—1935, p. 423, pl. 73, fig. 1).

MORTENSEN (1935, p. 424) was strongly impressed by the great general resemblance existing between some Hemicidarids and Pseudodiadematids in the dental apparatus, but in recognizing the difference in the character of the spines; e.g., in the former the spines are with an outer layer, whereas in the latter the spines are without outer layer, he classified the Hemicidarids with the Pseudodiadematids in his suborder Phymosomatina. His point is that the writer adopts the view, almost unanimously profounded by BEURLEN, DURHAM and MELVILLE, that the Hemicidarids are closely related to the Acrosaleniids, and should be classified together in suborder Salenioina (Hemicidarina).

There is a single species of the genus *Pseudocidaris* in our collection.

Genus *Pseudocidaris* ETALLON, 1859

Pseudocidaris ETALLON, 1859-61 (59), p. 4.—DESOR and DE LORIOL, 1868-72 (69), p. 88.—ZITTEL, 1879, p. 501.—COTTEAU, 1880-85 (80), p. 13.—POMEL, 1883, p. 95.—DUNCAN, 1889-a, p. 51.—LAMBERT, 1900-a, p. 482.—LAMBERT and THIÉRY, 1911, p. 167.—MORTENSEN, 1935, p. 401, text-figs. 211-212.

Logotype.—Hemicidaris thurmanni AGASSIZ, 1840-a, p. 8.—*Pseudocidaris thurmanni* (AGASSIZ) COTTEAU, 1880-85 (80), p. 32, pl. 269, figs. 6-15, pl. 217, figs. 1-9 (Rauracian of France). [LAMBERT and THIÉRY, 1911, p. 167].

Test small to moderate in size, more or less swollen. Ambulacra narrow, rather strongly sinuate; ambulacral plates above th ambitus all simple primaries, each with a smooth, imperforate tubercle, all equally developed; at and below the ambitus the ambulacral tubercles are large, perforate, crenulate, as typical in Hemicidarids. Apical system dicyclic; peristome large, with distinct gill-slits. Primary spines short, thick, egg-shaped.

This Hemicidarid genus ranges from the Bathonian to the Cenomanian, and distributed in Europe, North America, Central Asia, and India. Its primary spines are large, massive, cylindrical and fusiform, or pear-shaped, usually striated longitudinally, or rarely granular, and superficially resemble those of *Balanocidaris*, a Cidarid.

This genus differs from its ally, *Plesiocidaris* POMEL, 1883, only in the character of the spines; i.e., in the latter the primary spines are long and cylindrical, but the ambulacral structure is in common with each other with the simple primary plates above the ambitus and only oligoporous compound plates at and below the ambitus; it is regarded as the most primitive of the Hemicidarids.

Pseudocidaris simulans NISIYAMA, 1950

Pseudocidaris simulans NISIYAMA, 1950-a, p. 29, pl. 4, figs. 1-2.

Holotype.—IGPS coll. cat. no. 66504.

Locality and geological horizon.—IGPS. loc. no. It-4.—Sea cliff northeast of Hiraiga, Tanohata-mura, Shimohei-gun, Iwate Prefecture. (tm Iwaizumi, Lat. 39° 55′ 53″ N., Long. 141° 56′ 39″ E.). Hiraiga sandstone (*Orbitolina*-horizon), Lower Cretaceous (probably Aptian or Albian). YABE and YEHARA, 1913.

The egg-shaped primary spines, which were reported by TOKUNAGA (1903, p. 25, pl. 2, figs. 11-12) as *Pseudocidaris* sp. from Japan, are not of that genus, as pointed out by MORTENSEN (1935, p. 402), but should be referred to the genus *Balanocidaris*, a Cidarid. That an occurrence, in the Lower Cretaceous of Japan, of a Pseudocidarid that resemble the Lower (or Middle) Cretaceous species of North America and Europe, is noteworthy.

Suborder PHYMOSOMATOINA MORTENSEN, 1904

Phymosomina MORTENSEN, 1904, p. 56, (tribus).—MORTENSEN 1935, p. 382.—*Phymosomatina* MORTENSEN: NISIYAMA, 1954, p. 326 (in Japanese).—*Phymosomatoida* MORTENSEN: DURHAM and MELVILLE, 1957, p. 255 (order).

Type-family.—*Phymosomatidae* POMEL, 1883

Echinoids with stirodont teeth, of varied appearance; interambulacral plates generally with more than one smooth or crenulate tubercle, but one only in some forms. Ambulacral plates usually compound, of the diadematoid structure, trigeminate or polyporous, extending above the ambitus. Apical system without angular suranal plate; periproctal central or pushed out towards the posterior interambulacrum (5). Primary spines usually with solid axis, with or without a cortex layer; secondary spines usually setaceous or rarely flattened. Pedicellariae, in the Recent forms, of the tridentate, triphyllous, and ophicephalous types; in some forms globiferous pedicellariae also present (from DURHAM and MELVILLE, 1957, and MORTENSEN, 1935).

From the Lower Jurassic (Lias) to Recent.

The families of the Hemicidarids and of the Arbaciids, which are assigned by MORTENSEN (1935) to his suborder Phymosomina, are excluded by DURHAM and MELVILLE (1957, p. 254) from the suborder on the reason that they are possibly not constituting a natural assemblage in it. They grouped the Hemicidarids with the Acrosaleniids and Saleniids in their order Hemicidaroida, and they proposed to separate the Arbaciids in an order Arbacioida. Accordingly, MORTENSEN's remaining families, i.e., the Pseudodiadematidae POMEL, 1883, Phymosomatidae POMEL, 1883, and Stomechinidae POMEL, 1883, seem to be in all probability, naturally related; they are discriminated from one another as shown by the following key.

Key to the families of the suborder Phymosomatoina.

1. Primary tubercles perforate and crenulate; usually large one on each interambulacral plate. Ambulacral primary tubercles generally continue throughout the area. Primary spines usually without a collar .... Pseudodiadematidae

Primary tubercles imperforate, crenulate or non-crenulate 2

2. Primary tubercles crenulate. Primary spines simple, with a thin cortex layer and a distinct collar .... Phymosomatidae

Primary tubercles non-crenulate. Primary spines simple, no outer layer, and accordingly no collar .... Stomechinidae

The fossil representatives of the two families, the Phymosomatidae and Stomechinidae are represented in our collection.

Family PHYMOSOMATIDAE POMEL, 1883

Les Phymosomiens POMEL, 1883, p. 90.—*Phymosominae* LAMBERT, 1900, p. 54 (pro parte).—*Phymosomatidae* (POMEL) MEISSNER, 1904, p. 1359.—*Phymosomidae* LAMBERT: LAMBERT and THIÉRY, 1911, p. 213.—*Phymosomatidae* (POMEL) MEISSNER: H. L. CLARK, 1912-b, p. 225.—DJAKONOV, 1923, p. 227.—MORTENSEN, 1935, p. 456.—TERMIER and TERMIER, 1953, p. 898.

Cyphosomatidae DUNCAN, 1889-a, p. 85.—LAMBERT, 1897, p. 498.—GREGORY, 1900-b, 310 (pro parte).—*Cyphosominae* DUNCAN: DELAGE and HÉROUARD 1903, p. 238.

Type-genus.—*Phymosoma* HAIME in D'ARCHIAC and HAIME, 1853.

Test of small to moderate size, usually low hemispherical, sometimes more or less flattened above. Ambulacra with simple to compound plates of generally diadematoid structure, in the more specialized forms polyporous and diplopodous. Primary tubercles crenulate, but imperforate; usually they form two regular series in each area, the interambulacral and ambulacral ones of about equal size. Apical system dicyclic or monocyclic, often somewhat extending into the posterior interambulacrum (5). Periproct sometimes covered with large, polygonal plates. Peristome generally rather large, with distinct gill-slits. Primary spines simple, with a thin cortex layer and accordingly a distinct collar; secondary spines setaceous. Pedicellariae, in the Recent forms, of the ophicephalous, tridentate, triphyllous, and globiferous types. Sphaeridia placed along the tube-feet, not in pits (after MORTENSEN, 1935).

From the Lias (Charmouthian) to Recent.

It is generally considered now that the family Phymosomatidae started in the Charmouthian of North Africa—Europe with the appearance of the simplest form, *Leptechinus* (*Protiara*) GAUTHIER, 1889, whereas the Phymosomatids were rather poorly represented throughout the Jurassic Period. But with opening of the Cretaceous they started to become vigorous, and in the Senonian they reached the climax with large number of the genera; however, they are scarcely represented in the Cretaceous System of Japan. In the Eocene Epoch, the genera *Tylechinus* POMEL, 1883, and *Porosoma* COTTEAU, 1856, still remained in a more or less flourishing condition, and some new specialized forms, such as *Eurypneustes* DUNCAN and SLADEN, 1882, and *Acanthechinus* DUNCAN and SLADEN, 1882, appeared in India, but then they rapidly decreased in number and in form, to be represented in the Recent seas by only one genus and species, *Glyptocidaris crenularis* A. AGASSIZ, 1863, of Northern Japan. The structure of the ambulacra and tubercles of this species are very similar to those found in a number of fossil Phymosomatids.

The center of evolution of the Phymosomatids probably was in the European—North African region, from where they radiated as far as to South Africa and Japan through India; also a fair number of species is known from North and South America. As for the source of the primitive Phymosomatids, founded on the structurs of their masticatory apparatus, ambulacral plates and spines, as pointed out by MORTENSEN, there should be some side-branch form to be sought for among the primitive Pseudodiadematids.

Among the fifteen genera and three subgenera of the family Phymosomatidae, only one genus, *Glyptocidaris*, is known to occur as fossil from Japan.

Genus *Glyptocidaris* A. AGASSIZ, 1863

Glyptocidaris A. AGASSIZ, 1863-a, p. 356.—POMEL, 1883, p. 91.—LAMBERT, 1897, p. 499.—MORTENSEN, 1903-b, p. 130.—DELAGE and HÉROUARD, 1903, p. 238.—MEISSNER, 1904, p. 1359.—H. L. CLARK, 1912-b, p. 228.—DJAKONOV, 1923, p. 228.—MORTENSEN, 1935, p. 480, text-figs. 280-282.

Haplotype.—*Glyptocidaris crenularis* A. AGASSIZ, 1863-a, p. 356.—H. L. CLARK, 1912-b, p. 228, pl. 90, figs. 5-10, pl. 92, figs. 1-11, pl. 105, figs. 1-2 (Hakodate Bay and Northern Japan).

Phymosoma HAIME in D'ARCHIAC and HAIME, 1853-54 (53), p. 197 (pro *Cyphosoma* AGASSIZ, 1838, non MANNERHEIM, 1837).—A. AGASSIZ, 1872-74, p. 487 (*Glyptocidaris crenularis* is referred to this genus).

Haplotype.—*Cidaris koenigi* MONTELL: FORBES et al., 1849-53 (50), p. 340, pl. 25, figs. 26-27 (Senonian of Sussex).

Coptosoma DESOR, 1855-57 (55), p. 91 (non LAPORTE, 1832).—DUNCAN, 1889-a, p. 87 (*Glyptocidaris crenularis* is referred to this genus).—LAMBERT, 1897, p. 498.—LAMBERT and THIÉRY, 1911, p. 219 (*Gl. crenularis* is referred to this genus).

Haplotype.—*Cidaris cribrum* AGASSIZ: SISMONDA, 1843, p. 62, figs. 14-16 (Eocene).

Porosoma COTTEAU, 1856-a, p. 648 (pro *Coptosoma* DESOR, 1855, non LAPORTE, 1832).—LAMBERT and THIÉRY, 1914, p. 274 (*Gl. crenularis* is referred to this genus).

Type-species.—*Cidaris cribrum* AGASSIZ.

Test rather low, hemispherical, of rather large in size. Ambulacra with polyporous plates throughout, there being five pore-pairs to each compound plate, arranged in alternating arcs of three and two; in large specimens there is a distinct diploporous arrangement in the distal part of the aboral side, whereas the pore-pairs are arranged in a single series adapically. A regular series of primary tubercles, which are imperforate and crenulate, in each ambulacrum and interambulacrum, but larger specimens sometimes have besides, on the oral side, a series of almost equally larger tubercles on each side of the primary series. Apical system usually with ocular (I) insert. Spines simple, slightly flattened, with very thin cortex layer. Pedicellariae of the globiferous, tridentate, ophicephalous, and triphyllous types. Sphaeridia along the tube-feet, not in pits. Aboral tube-feet with well developed sucking disk. Spicules slender rods with a few small holes in the middle. Auricles united above (after MORTENSEN, 1935).

The ambulacral structure of this genus is very characteristic, as such: generally, each plate is made up of five components (text-fig. 4), the adoral primary being followed by a demi-plate, a middle primary (as in echinoid structure), an upper demi-plate, and an aboral primary. Near the ambitus the pore-pairs of the aboral primary, the upper demi-plate and the middle primary form an oblique arc of three, which is followed by an arc of two made up of the pore-pairs of the lower demi-plate, and the adoral primary components; this alternation is marked by the fact that the outermost pore-pair of each plate is that of the middle component, while the pore-pair of the aboral primary is further in than that of the upper demi-plate; that of the lower demi-plate is directly below that of the aboral primary, while that of the adoral primary is further out. As following the ambulacrum adapically,

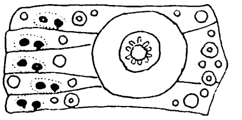


Fig. 4. Ambulacral structure of *Glyptocidaris crenularis* A. AGASSIZ, 1863. ×1.8

there can be found the pore-pairs to come to lie more and more in a single vertical series, and are never form double series (diplopodous) as in the genus *Phymosoma* (text-fig. 5) and the allied genera. In the genus *Porosoma*, the pore-pairs of a plate are not arranged simply in an arc, but some of the pores are pushed inwards of the pores, resulting in a distinct diplopodous arrangement in the distal part of the aboral side, whereas in the adapical part the pore-pairs are arranged in a single line, not in double series of the genus *Phymosoma*.

MORTENSEN (1935, p. 481) pointed out that the fossil genus *Heteractechinus* LAMBERT and THIÉRY, 1914 (1914, p. 274.—pro *Heteractis* LAMBERT, 1897 p. 500 (non EDWARDS and HAIME, 1851).—*Orthotype—Actinopsis* (*Heteractis*) *heteroporus* LAMBERT, 1897, p. 507, pl. 18, figs. 1-4, textfigs. 8a-c (Eocene of Aude)) must become a synonym of the Recent genus *Glyptocidaris* on account of the same arrangement of pore-pairs in the both genera. But the plate-structure of the genus *Heteractechiuns* does not appear as an alternation of three and two components as in the genus *Glyptocidaris*, and is not of quinquegeminate ambulacral plates but of septemgeminate plates in the ambitus. Accordingly, the genus *Heteractechinus* may be a separate genus from the *Glyptocidaris* and the true relationship of the former is not known to us untill the more and detailed material and the knowledge of fossils will have been obtained.

This genus, in the strict sense, appears to be living in the confined of the coast of Northern Japan and Sikhota alin, and to date in the Pliocene in geological age.

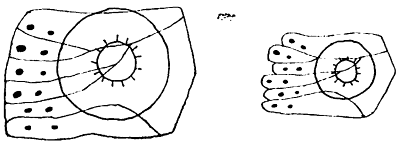
Glyptocidaris crenularis A. AGASSIZ, 1863

Glyptocidaris crenularis A. AGASSIZ, 1863-a, p. 356.—COTTEAU, 1861-67 (67), p. 817.—*Phymosoma crenulare* (A. AGASSIZ) A. AGASSIZ, 1872-74, p. 115, 487, pl. 6, figs. 2-3, pl. 7a, figs. 6, 8-9, pl. 25, figs. 3-5, pl. 36, figs. 10-11, pl. 38, figs. 18-19.—MACKINTOSH, 1883, p. 255, pl. 8, fig. 32.—*Coptosoma crenulare* (A. AGASSIZ) DUNCAN, 1889-a, p. 87.—LAMBERT, 1897, p. 499.—TOKUNAGA, 1905, pl. 7. figs. 1-6.—*Glyptocidaris crenularis* A. AGASSIZ: DÖDERLEIN, 1906-a, p. 520.—*Phymosoma crenulare* (A. AGASSIZ) A. AGASSIZ and H. L. CLARK, 1907-b, p. 127.—*Coptosoma crenulare* (A. AGASSIZ) LAMBERT and THIÉRY, 1911, p. 220.—*Glyptocidaris crenularis* A. AGASSIZ: H. L. CLARK, 1912-b, p. 228, pl. 90, figs, 5-10, pl. 92, figs. 1-11, pl. 105, figs. 1-2.—*Porosoma crenulare* (A. AGASSIZ) LAMBERT and THIÉRY, 1914, p. 274.—*Glyptocidaris crenularis* A. AGASSIZ: DJAKONOV, 1923, p. 231, text-figs. 85-88.—MORTENSEN, 1929, p. 473, pl. 19, fig. 1, text-fig. 4.—MORTENSEN, 1935, p. 482, pl. 71, figs. 1-2, pl. 89, figs. 1-15.—NISIYAMA, 1937, p. 51.—CHANG and WOO, 1954, p. 128, pl. 1, fig. 1, pl. 2, fig. 1.—UTINOMI, 1960, p. 239, pl. 38, figs. 3-4.

Locality and geological horizon.—IGPS loc. no. Ch-15.—In loose sands on small cliff of Shimo-Shinden, Ochi, Shitô-mura, Ichihara-gun, Chiba Prefecture. (tm Chiba, Lat. 35°31′35″N., Long. 140°13′47″E.). Narita formation, Pleistocene. *Hypotype.*—IGPS coll. cat. no. 73753.

There are fragmentary specimens referred to this species at the writer's disposal. The crenulate large tubercles and the structure of ambulacral plates of these specimens are characteristics of this species.

On the preserved specimen, ambulacra narrow, about 14 mm wide below the



a b

Fig. 5. Structure of an ambulacral plate of *Phymosoma koenigi* (MANTELL, 1822) (after DUNCAN, 1885).

a. A plate at the mid-zone.

b. A plate at the adapical region.

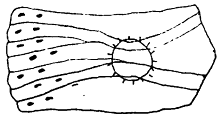


Fig. 6. Ambulacral structure of *Heteractechinus heteroporus* (LAMBERT, 1897). 7th plate from the apical system (from LAMBERT, 1897).

ambitus; ambulacral plates rather high, about 7 mm wide and 4.5 mm high below the ambitus, composed of five components as usual; pore-pairs of aboral primary, upper demi-plate and middle primary components form an oblique arc of three, which is followed by an arc of two pore-pairs of lower demi-plate and adoral primary components. Primary tubercles large, distinctly crenulated, number of crenulation from 10 to 12, imperforate, placed almost centrally and cover sutures of from aboral primary to lower demi-plate components; somewhat large secondary tubercels cover adoral primary sutures; small secondary and miliary tubercles make a circle close to base of primary tubercles.

Interambulacra broad, 24 mm wide below the ambitus; interambulacral plates broad, 12 mm and 5 mm high, below the ambitus; primary tubercles large, distinctly crenulated, number of crenulation 10-12, imperforate, as large as, or slightly larger than, those on ambulacra, and placed centrally; they make vertical series; large secondary tubercles, also distinctly crenulated, also make vertical series inside and the other outside the primary series, inner secondary series usually continue to the peristomial region; small secondary and miliary tubercles, not crenulated, make circles around the large crenulated tubercles.

This species seems to be confined to Northern Japan and Sikhotan alin coast in its geographical distribution, and reported from the Onahama Bay, Sendai Bay, off Kinkasan Light house, Mutsu Bay, Tsugaru Strait, Hakodate Bay, coasts of Hokkaido, and Victoria Bay; found in littoral to moderate depths (in 10-40 metres depths, rarely down to 159 metres). The occurrence of this species as fossil from Chiba Prefecture (ca. 35°30′N.) indicates that it seems to show that it was somewhat cooler than the present day at that time.

Glyptocidaris crenularis stenozona NISIYAMA, n. subsp.

(Pl. 2, figs. 10-11)

Coptosoma crenulare (A. AGASSIZ) TOKUNAGA, 1903, p. 4 (pro parte).

Holotype.—IGPS coll. cat. no. 73754.

Locality and geological horizon.—IGPS loc. no. Ch-12.—Tuffaceous sandstone at sea cliff below shrine at Tômiya, Takeoka-mura, Kimitsu-gun, Chiba Prefecure. (tm Futtsu, Lat. 35°12′52″N., Long. 139°51′E.). Kurotaki formation (Tômiya tuffaceous sandstone), Lower Pliocene. Coll. K. HATAI, S. NISIYAMA, T. KOTAKA, and K. HATORI, 1950.

There is a fragmentary specimen attached to mother rock referred to this subspecies in the collection, represented by fragmentary, ambulacrum around the peristome and a part of interambulacrum.

Ambulacrum near the peristomial edge made up of six ambulacral plates on left column and five ambulacral plates on right column, 5 mm wide at the peristomial edge and 8 mm wide at fifth plate from the peristome; third plate on both columns from the peristome made up of five components as usual type of the species, pore-pairs of aboral primary, upper demi-plate and middle primary components form an arc of three, which is followed by an arc of two pore-pairs of lower demi-plate and aboral primary components; the innermost is that of the lower demi-plate and placed nearly in a row inside the pore-pairs of middle primary, and that of adoral primary component is directly below that of lower demi- plate: this arrangement of pore-pairs more or less differs from that of plates near the ambital region: this ambulacrum seems to be narrower than that of the living specimen, the breadth of ambulacrum at fifth plate from the peristome is 11 mm, and height from the first plate to fifth from the peristome is equal in both the fossil and the living specimens, is 12 mm. Tuberculation on ambulacrum is similar to that of the living specimens, but large crenulated tubercles seem to be more smaller,

Interambulacral plates near the ambitus more or less fractured; primary tubercles distinctly crenulated, number of crenulation is 11, imperforate, with relatively small base; outer and inner large secondary tubercles besides the primaries are as in those of the living specimens, but the other small secondary and miliary tubercles seem to be larger and more numerous than those of the living.

Owing to the poor preserved condition of this specimen, it is presumely referred to the living species, *Gly. crenularis* A. AGASSIZ, as a subspecies, but it is more or less different from the living in the ambulacrum and in the tuberculation on coronal plates; to determine whether this difference signifies a mere variation of the living species, or they have to be separated as a distinct species from the living, more and new materials are necessary.

Subgenus ***Eoglyptocidaris*** NISIYAMA n. subgen.

Type-species.—Glyptocidaris (*Eoglyptocidaris*) *arctina* NISIYAMA, n. sp.

Test low and thin; ambulacral plates high, composed of five components, and divided into upper three components and lower two components; poriferous areas narrow and arcs of pore-pairs nearly erect; interambulacral plates high; primary tubercles imperforate, crenulate; secondary tubercles small and form vertical series on each side of the primary series. Apical system unkown. Peristome rather small, with broad and shallow gill-slits. Spines and pedicellariae unknown. Teeth strongly keeled.

This subgenus is very closely related to the typical genus *Glyptocidaris* A. AGASSIZ, 1863, in general features, but it differs from the typical genus by the structure of ambulacral plates and by the tuberculation on the interambulacral columns. This subgenus also resembles the genus *Porosoma* COTTEAU, 1856 (op. cit.), in having single series of the ambulacral pores adapically, but is easily distinguished from it by the structure of ambulacral plates and also by the tuberculation on both ambulacra and interambulacra.

Glyptocidaris (*Eoglyptocidaris*) *arctina* NISIYAMA, n. sp.

(Pl. 3, figs. 5-7, text-fig. 7)

Holotype.—IGPS coll. cat. no. 73752.

Locality and geological horizon.—IGPS loc. no. Te-24.—A point of Sukenebetsu, on the upper course of the River Obirashibe, Obirashibe-mura, Rumoe-gun, Teshio Province, Hokkaido. (tm Neiraku, ca. 44°03′N., Long. 141°55′E.). Poronai formation, Oligocene (or Eocene).

There is a single specimen referred to this new species at the writer's disposal, but the aboral surface is damaged; the test measures about 60 mm in horizontal diameter and about 30 mm in height.

Test low and coronal plates very thin, less than 0.5 mm thick at the ambitus. Ambulacra narrow, about 14 mm wide at the ambitus and narrowed gradually towards the peristomial edge, where breadth is 5 mm; ambulacral plates high, about 7 mm wide and 6 mm high at the ambital region, 10 or 11 plates on each ambulacral column from the ambitus to the peristomial edge; compound plates of peculiar mode of five components; these five components are divided into upper (aboral) three and lower (adoral) two; upper three are composed of aboral primary, upper demi-plate and middle primary components (as in the echinoid structure); lower two composed of lower demi-plate and adoral primary components (text-fig. 7). Poriferous zones narrow, about 2 mm wide at the ambitus, arcs of pore-pairs not so oblique but nearly erect near the ambital region; upper three pore-pairs of aboral primary, upper demi-plate and middle primary components form a nearly vertical arc, the slightly outermost is that of the upper demi-plate and the slightly innermost is that of the middle components; in arc of lower two components, pore-pair of lower demi-plate directly below that of middle primary component and pore-pair of adoral primary component further slightly inside than that of lower demi-plate; pore-pairs become a single series adapaically. Primary tubercles on ambulacrum large, distinctly crenulate, imperforate, number of crenulation is 10, placed somewhat aborally on plates and cover sutures of aboral primary and of upper demi-plate components, but not of middle primary component, thus lower (adoral) two components are free from the large primary tubercles even in the ambital region; small secondary and miliary tubercles placed inside the pore-pairs and irregularly around the primary tubercles; primary tubercles form vertical series on each side of ambulacral median line, and continue to the peristomial region, and gradually decrease in size; lower (adoral) two components of ambulacral plates on oral surface are always distinct from upper (aboral) three components, and with large secondary tubercles below, which are placed somewhat outside the primary tubercles.

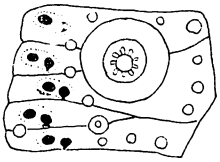


Fig. 7. Ambulacral structure of *Eoglyptocidaris arctina* NISIYAMA. ×3

Interambulacra broad, about 22 mm wide at the ambitus; interambulacral plates rather high, about 11 mm wide and 7 mm high at the ambitus, 8 or 9 plates in each interambulacral column from the ambitus to the peristomial edge; primary tubercles large, as large as or more or less larger than those on ambulacra, distinctly crenulate, number of crenulation 10, imperforate, placed centrally on plates and form distinct vertical series in each column; large secondary tubercles, which are much smaller than primary tubercles and also crenulate, also form vertical series one inside and the other outside of the primary series; large secondary tubercles on outside arranged in a series composed of two tubercles on a plate; the inside and outside series of large secondary tubercles seem to continue to the peristomial region; small secondary and miliary tubercles form circles around close to base of larger tubercles. Oral surface more or less concave to the peristome. Peristome rather small, about 18 mm in diameter, with broad and shallow, but distinct, gill-slits. Teeth strongly keeled, and moderately curved, over 12 mm in length.

Distinction.—This new species resembles *Glyptocidaris crenularis* A. AGASSIZ, 1863, the living species of Northern Japan, in the form of test and the manner of tuberculation on coronal plates, but is easily distinguished from that species by the structure of ambulacral plates and smaller secondary tubercles on the interambulacra. It is a very interesting fact that the structure of ambulacral plates on the ambital region and the tuberculation on oral surface of this species somewhat resemble those on the adapical surface of *Gly. crenularis;* and if the primary ambulacral tubercles on the upper arc of three components in this species were more developed further and were fully united the lower arc of two components (the lower demi-plate and adoral primary components), the structures of ambulacral plates of both species (*Gly. arctina* and *Gly. crenularis*) approach quite closely; that is to say, an ephebic stage of ambulacral plates in this fossil species corresponds to the neanic stage of ambulacral plates in the living species; thus it is very evident that the ambulacral structure of this fossil species in an archetypal form of the living species, and may stand intermediate between the older and primitive genus *Porosoma*-like (Porosomatid) ancestor and the younger and specialized genus *Glyptocidaris*. A *Porosoma*-like (Porosomatid) form really existed (an available specimen is so imcomplete that it is hardly described herein, and it is attached to a mother rock with a molluscan specimen) during the Senonian of Hokkaido. From this Porosomatid form (but not necessarily this form) the *Eoglyptocidaris* probably lead to the Recent form, the living *Gyptocidaris*, in the course of development. As the general character of the test of the *Eoglyptocidaris* is so closely related to the *Glyptocidaris* that the former may be treated as a subgenus, or dropped into the latter genus, the writer here separates it as a subgenus of the latter genus founded on the difference of the ambulacral structure and the tuberculation on the interambulacra.

Family STOMECHINIDAE POMEL, 1883

Les Stomechinidae POMEL, 1883, p. 81.—*Stomechinidae* POMEL: DURHAM and MELVILLE, 1957, p. 254.

Type-genus.—*Stomechinus* DESOR, 1856.

Stompneustidae MORTENSEN, 1903-b, p. 133.—JACKSON, 1912, p. 203.—H. L. CLARK, 1912-b, p. 212.—H. L. CLARK, 1925, p. 67.—MORTENSEN, 1935, p. 492.—H. L. CLARK, 1946, p. 305.

Type-genus.—*Stomopneustes* AGASSIZ, 1841.

Test small to very large in size, usually hemispherical, but it may be either more flattened or higher, almost egg-shaped. Ambulacra with compound, trigeminate, of generally diadematoid structure, or polyporous plates, rarely with simple plates adapically; a diplopodous arrangement may occur adapically or throughout the ambulacra. Primary tubercles imperforate, non-crenulate. Apical system usually small, dicyclic, or monocyclic, rarely slightly extending into the posterior interambulacrum (5), or oculars becoming insert in the sequence I, V, IV. Peristome generally rather large; gill-slits may be rather large and deep. Pedicellariae, in the Recent form, of the ophicephalous, tridentate, triphyllous and globiferous types. Sphaeridia placed along the tube-feet, not in pits (from MORTENSEN, 1935).

From the Lias (Domerian) to Recent.

The relations of *Stomechinus* and allied forms have been the object of puzzling among authors on the Echinoids, until MORTENSEN (1935, pp. 496, 504) clearly showed their relationship to the living *Stomopneustes* founded on their typically stirodont teeth and on the character of the test. Accordingly, it now becomes clear that the affinity of *Stomechinus* and allied genera in with the Phymosomatids, and with *Stomopneustes* among the Recent sea-urchins, the latter genus being the only living representative of the once flourished group (with about fifteen genera) during the Jurassic and Cretaceous Periods. Just like *Glyptocidlaris* (loc. cit.) is, the only Recent representative of that group of fossil Echinoids, the Phymosomatids (with nearly twenty genera and subgenera). A direct comparison between *Stomechinus* (*St. bigranularis* (LAMARCK, 1816) is in IGPS coll. cat. no. 5202) and the living *Stomopneustes* shows them to be so very alike in all the main characters that they should be classified into one group.

By their imperforate, non-crenulated tubercles, together with the structure of ambulacral plates (particularly in the *Stomopneustes*), and the complete reduction of the cortex layer on the spines, the Stomechinids (Stomopneustids) are regarded as the most specialized forms of all the Phymosomatoina.

There is only a fossil species of the genus *Stomopneustes* in our collection, as described herein.

Genus *Stomopneustes* AGASSIZ, 1841

Stomopneustes AGASSIZ, 1841, p. 7.—AGASSIZ, 1841-a, p. x.—A. AGASSIZ, 1872-74, pp. 161, 436.—TENISON-WOODS, 1878, p. 150.—ZITTEL, 1879, p. 509.—STEWART, 1880, p. 911.—BELL, 1881-a, p. 424.—POMEL, 1883, p. 79.—DUNCAN, 1889-a, p. 119.—MORTENSEN, 1903-b, p. 133.—DELAGE and HÉROUARD, 1903, p. 241.—MEISSNER, 1904, p. 1362.—H. L. CLARK, 1912-b, p. 229.—DJAKONOV, 1923, p. 222.—H. L. CLARK, 1925, p. 68.—TORTONESE, 1933, p. 110.—MORTENSEN, 1935, p. 505.—H. L. CLARK, 1946, p. 305.

Orthotype.—Echinus variolaris LAMARCK, 1816, p. 47 (Les mers australes).—*Stomopneustes variolaris* (LAMARCK) A. AGASSIZ, 1872-74, p. 437, pl. 4b, figs. 1-3 (Indian Ocean).—MORTENSEN, 1935, p. 507, pl. 71, figs. 3-5, pl. 72, figs, 1-2, pl. 89, figs. 16-26, text-figs. 301-302 (Indo-West Pacific, littoral).

Heliocidaris AGASSIZ and DESOR, 1846, p. 371.—A. AGASSIZ, 1863, p. 22.—COTTEAU, 1861-67 (67), p. 819.

Logotype.—Echinus variolaris LAMARCK, 1816, p. 47. [Cotteau, 1861-67 (67), p. 819]. (Non *Heliocidaris* AGASSIZ and DESOR: MORTENSEN, 1903-b, p. 116—nec H. L. CLARK, 1912-b, p. 281).

Test large, hemispherical forms. Ambulacra with compound plates consisting of 4-6 trigeminate plates covered by a very large primary tubercles; pore-zones relatively broad, somewhat petaloid on the oral side. Primary tubercles with a large, high boss, but a very narrow areole; they form regular series: in the large specimens the secondary interambulacral tubercles become as large as the primaries, there being at the ambitus six rows of large tubercles in each interambulacrum. A very conspicuous undulating, sunken median furrow in each interambulacrum. Apical system generally small, peristome somewhat larger; gill-slits rather deep and wide. Spines cylindrical, simply pointed; no outer layer, and accordingly no collar. Pedicellariae, of the ophicephalous, tridentate, triphyllous, and globiferous types. Sphaeridia placed along the tube-feet as usual, not in pits. Spicules of tube-feet large, hollow, spiny tubes, and small, irregular, fenestrated rods. Auricles high, slender, coalesced at the top (after MORTENSEN, 1955).

From the Eocene to Recent.

This genus has been classified into the family Echinometridae by BELL (1881-a, p. 424), DUNCAN (1889-a, p. 119) and later writers, but MORTENSEN (1903-b, 133) separated it as a distinct family, on account of differences in spicules of the pedicellariae. It differs from the genera of the Echinometridae also in that the oculars enter the periproct in the sequence of I, V, IV, not V, I, IV, as in that family; however, the most important character is the lantern, which shows at once to be strongly distinct from either the Echinidae or Echinometridae; and also the structure of ambulacral plates differs from the typical echinoid structure of the Echinometrids. As for the ambulacral plates of this genus H. L. CLARK (1912-b, p. 230) stated that "obviously make up of three elements, as in the Echinidae, an adoral primary element, and two secondary elements above it"; this seems to mean that they are of nearly the echinoid structure, but not the typical echinoid. MORTENSEN, however, interpreted the structure with giving the figure (1935, text-fig. 301a on p. 509) that "they consist of a large, median plate (the middle primary component) with a smaller one adorally and aborally (adoral and aboral demi-plate componets)", which indicates the arbacioid structure of the ambulacral plates. Thus, on the whole, the structure of ambulacral plates of this genus differs distinctly from the typical echinoid structure of the ambulacral plates of the Echinidae and Echinometridae.

The fossil of the genus *Stomopneustes* was first described by HERKLOTS (1854, p. 5, pl. 1, fig. 4—*Heliocidaris variolosa*), from the Tertiary of Java, but later MARTIN (1880, p. 76) and DUNCAN (1889-a, p. 186) identified this with the living *Stomopneustes variolaris* (LAMARCK, 1816). The fossil species (*St. pristinus*) was reported by JACKSON (1937, p. 229, pl. 12, fig. 1) from the Oligocene of Mexico.

There is an Eocene species in our collection, which is described below.

Stomopneustes antiquus NISIYAMA, n. sp.

(Pl. 2, figs. 14-17, pl. 3, figs. 1-4)

Holotype.—IGPS coll. cat. no. 73728.

Locality and geological horizon.—Beach rock on Nishi-ura, Haha-jima, in Bonin Islands. *Orthophragmina—Globigerina* Zone, Upper Eocene (Lutetian).

There are two relatively well preserved specimens of this new species at the writer's disposal.

Test finely arched with somewhat roundly pentagonal ambitus, slightly concave orally, peristome deeply sunken adorally; 15 interambulacral plates in each column and with about 17 ambulacral plates corresponding them. Apical system wanting, the vacant space of moderate size, about 4 mm across.

Dimensions of *Holotype*.—26 mm in horizontal diameter, and 18 mm in height.

Ambulacra slightly curved, broad at the ambitus and near the peristome, more or less petaloid orally; poriferous zones narrow, 1.5 mm wide at the ambital region, narrow adapically and broad adorally; ambulacra remarkable for the excessive development of certain primary tubercles. Ambulacral plates obviously made up of three components, median primary component with smaller (demi-plate components) adorally and aborally, crowded, apparently make a triserial row below the ambitus; but every fourth plate typically greatly enlarged at its innerside and shut out the three succeeding plates from the median line with introducing a small secondary tubercle nearly throughout. So far as known this structure of ambulacral plates does not occur elsewhere among the Echinoids, except for the living *St. variolaris* (LAMARCK, 1816), the type-species. Interporiferous areas with two prominent vertical series of large, imperforate, non-crenulate, primary tubercles besides several series of secondary tubercles and miliaries, some entering the poriferous zones, diminish at the peristomial edge, where the areas narrow; about 4 mm wide, over twice of the poriferous zones at the ambitus.

Interambulacra with a linearly undulating groove in each median area, broad above the ambitus, narrow near the peristomial region, with principal vertical series of primary tubercles resembling those of the ambulacra in feature, but decidedly larger, diminishing in size adorally Two series of large secondary tubercles on both sides of the primary series, smallest orally, which reach some distance above the ambitus, with small secondary and miliary tubercles irregularly distributed. Seen from aboral side, twenty radiating series of primary tubercles, two series in each area; of rather equal size and decidedly larger than the numerous accompanying secondaries.

Peristome small, only 6 mm in diameter, subpentagonal in outline, decidedly concave orally, rather indented by wide, well-developed gill-slits. There are several (3-5) papillae (attachment of sphaeridia) on the oral part of each ambulacrum; each is attached to a miliary tubercle (papilla), but is not associated with any depression or other shelter. Spines not accessible.

This new species undoubtedly belongs to an interesting and characteristic genus *Stomopneustes* AGASSIZ, 1841, on account of the character of the ambulacral structure of the ambulacral plates and a linearly undulating groove in each median area of the interambulacra; however, the writer is not accessible to the auricles. After careful examination of the living *St. variolaris* (Pl. 4, fis. 1-2), the writer feels justified in adhering to the present determination, too.

Distinction.—This new species closely resembles *St. variolaris* (LAMARCK, 1816) (op. cit.), the living species of the Indo-West Pacific Oceans, but the larger number of the coronal plates are easily distinguish this species from the latter; for example, in this species there are 15 interambulacral plates in each column of the test 26 mm in across; however, in the latter species, there are 13 interambulacral plates in each column in 36 mm of test diameter. Also the more depressed form, the smaller and decidedly concave orally peristome, and the narrower poriferous zones also distinguish this species from the living *St. variolaris*.

This is the oldest known representative of the genus *Stomopneustes* in the world.

COOKE (1957, p. 362) reported an occurrence of *Heterocentrotus* sp. (pl. 119, fig. 7) from the Lower Miocene (Tagpochau limestone) of Saipan Island. Through the observation on this specimen in the United States National Museum (no. 561581) together with COOKE's *Heliocidaris* sp. (not reported by him: USGS-17723), the writer found that these specimens are not assigned to the named genera, but, by the character of the ambulacral structure of the ambulacral plates and a linear undulating groove in median area of the interambulacrum (particularly in *Heliocidaris* sp.), they should be referred to the genus *Stomopneustes*. However, the relations of these specimens to either the Eocene species (*St. antiquus*) or to the Miocene-Recent species (*St. variolaris*) is not clear.

Suborder ARBACIOINA GREGORY, 1900

Arbacina GREGORY, 1900-b, p. 307 (pro parte; non *Arbacina* POMEL, 1883).—*Arbacioida* GREGORY: DURHAM and MELVILLE, 1957, p. 255 (order).

Type-family.—*Arbaciidae* GRAY, 1855.

Echinoids with stirodont teeth, with generally soild test. Ambulacra with compound plates of the arbacioid structure, usually trigeminate. Primary tubercles imperforate, smooth. Primary spines with solid axis, a cortex layer more or less developed. Periproct (always?) covered with four or five large valves. Surface of corona usually covered with an "epistroma". Base of corona not resorbed. Pedicellariae, in the Recent forms, of the tridentate, triphyllous, and ophicephalous types (from DURHAM and MELVILLE, 1957).

From the Upper Jurassic (Rauracian) to Recent.

This suborder is charcterized, as diagnosed above, by having the almost typically arbacioid structure of the ambulacral plates, the periproct being covered with four or five large valves, besides the character of the coronal plates: there is only one family Arbaciidae belonging to this suborder. Although MORTENSEN (1935, pp. 544, 546) questioned whether the Arbaciids do form really a quite natural group, or they represent various distinct lines that seems to have developed from different sources, he grouped the various Recent and fossil forms into a familly, the Arbaciidae. DURHAM and MELIVILLE (1957, pp. 252, 253) have proposed to erect an order Arbacioida for this family Arbaciidae for the reason that family could not be associated with any other families of the stirodont Echinoids, and they preferred to consider that the Arbaciids have probably the Hemicidarid ancestory.

Family ARBACIIDAE GRAY, 1855

Arbacidae GRAY, 1855, p. 36.—TROSCHEL, 1872, p. 293.—A. AGASSIZ, 1872-74, pp. 90, 399.—*Les Arbaciens* POMEL, 1883, p. 87.—DUNCAN and SLADEN, 1885, p. 25.—*Arbaciidae* GRAY: DUNCAN, 1889-a, p. 92.—GREGORY, 1900-b, p. 307.—DELAGE and HÉROUARD, 1903, p. 237.—

MEISSNER, 1904, p. 1360.—A. AGASSIZ, 1904, p. 53.—A. AGASSIZ and H. L. CLARK, 1908, p. 62.—JACKSON, 1912, p. 203.—LAMBERT and THIÉRY, 1914, p. 261.—GIGNOUX and POPOVITCH, 1924, p. 92.—H. L. CLARK, 1925, p. 68.—MORTENSEN, 1927-b, pp. 288, 290.—MORTENSEN, 1935, p. 529.—GRANT and HERTLEIN, 1938, p. 18.—H. L. CLARK, 1946, p. 306.—TERMIER and TERMIER, 1953, p. 902.

Type-genus.—*Arbacia* GRAY, 1835.

Test small to moderate in size, usually subconical, flattened below, but sometimes almost spherical; test is generally quite solid, the plate being soldered together by means of small knobs and sockets. Ambulacra with compound plates of the arbacioid structure, usually trigeminate, more rarely simple or polyporous. Tubercles imperforate, non-crenulate, mostly not of very large size; the primary tubercles of the ambulacra as a rule not smaller than those of the interambulacra; the latter may be numerous, arranged in both horizontal and longitudinal series. Aboral side of test may be naked, without tubercles (spines); besides the tubercles the test usually carry a number of not spine-bearing papillae, outgrowth of the plates, and "epistroma". Primordial interambulacral plates persistent, often conspicuously prolonged upwards, with a primary tubercle at the point, and base of corona not resorbed. Apical system usually dicyclic, but in some forms the oculars partly insert in the sequence V, I, IV; ocular pores usually double. Periproct (always?) covered with four or five large valves. Peristome often very large, covered with non-ambulacral plates to various extents, sometimes naked; gill-slits usually distinct. Primary spines with a more or less developed cortex layer, which may be lacking on spines of aboral side; they are usually smooth, not thorny. Secondary spines little developed, or may be totally lacking; they are simple, setaceous or club-shaped, not flattened, scale-like. Pedicellariae, in the Recent forms, of tridentate, triphyllous, and ophicephalous types; the stalk is peculiar in consisting of numerous threads, not connected with each other, except at the upper end. Sphaeridia generally placed in deep pits in the ambulacral midline. Spicules irregular, often straight rods, widened, and with a few holes in the middle (from MORTENSEN, 1935).

From the Upper Jurassic (Rauracian) to Recent.

This is a rather large family of eight Recent and fourteen fossil genera, comprising many diverse and heterogenous forms in general feature. After a careful reviewing of numerous genera of the family MORTENSEN (1935, pp. 544-546) divided them into various groups based on their relations and affinities. His discussion on the grouping of these genera may be summarized as follows. The fossil genera, *Cottaldia* DESOR, 1856, *Magnosia* MICHELIN, 1853, and *Eucosmechinus* LAMBERT and THIÉRY, 1914, form a distinct group, which is characterized by their globular shape and the numerous small tubercles arranged in transverse and longitudinal series continuing to the apical system. Another group is constituted by *Acropeltis* AGASSIZ, 1838, and *Goniopygus* AGASSIZ, 1838 (with a subgenus *Polygoniopygus* VALETTE, 1907); they are characterized by the large tubercles forming a single regular series in each column. The Recent deep-sea forms, on the other hand, form together a separate group. Another separate group comprises the genera *Glypticus* AGASSIZ, 1840, and *Plesiocyphus* POMEL, 1883; they are common in the general features. Finally, the genera *Coelopleurus* AGASSIZ, 1840, *Heteropodia* DE LORIOL, 1888, and *Baueria* NOETLING, 1884, form a nrtural group, which is characterized by naked or decorated by a network of striae on the aboral side of interambulacra. The writer, however, does not possess any material to convince him with this suggestion given by MORTENSEN.

This family is represented in Japan by two genera, *Goniopygus* and *Coelopleurus;* of the former one fossil and of the latter one fossil and two Recent species are known.

Genus *Goniopygus* AGASSIZ, 1838

Goniopygus AGASSIZ, 1838, p. 19.—DESOR, 1855-57 (56), p. 93.—COTTEAU, 1861-67 (65), p. 717.—COTTEAU, 1880-85 (83), p. 568.—LAMBERT and THIÉRY, 1914, p. 267.—GIGNOUX and POPOVITCH, 1924, p. 92.—MORTENSEN, 1935, p. 587, text-figs. 343-347.—NISIYAMA, 1950-a, p. 30.—TERMIER and TERMIER, 1953, p. 902.

Logotype.—Salenia peltata AGASSIZ, 1835, p. 140, pl. 14, figs. 13-15 (Neocomian of France).—*Goniopygus peltatus* (AGASSIZ) COTTEAU, 1861-67 (65), p. 721, pl. 1176 (Upper Neocomian (Urgonian) of France). [Lambert and Thiéry, 1914, p. 267].

Test small to medium in size, hemispherical, flattened below. Ambulacra with compound, trigeminate plates throughout, or sometimes quadrigeminate (subgenus *Polygoniopygus*) at the ambitus; pore-zones simple, more or less widened at the peristomial region. Primary tubercles of both areas large, continuing in a regular series throughout. Apical system large, with genital pores at the point of more or less elongate genital plates, usually concealed under the plates so as to be invisible from directly above; sometimes the pore is placed outside the genital plate, in the interambulacral midline. At the inner edge of the genital plates are at least three of small tubercles, placed in a depression; otherwise, the apical system is generally without tubercles, but not rarely with radiating impressions, or with pits in the sutures. Pores of the madreporite at the distal end of the plate usually symmetrically disposed. Oculars all exsert. Periproct with four valves, as is typical of Arbaciids. Peristome large, gill-slits small. Spines short, club-shaped, without collar. Pedicellariae unknown (after MORTENSEN, 1935).

This genus is characterized by the ambulacra with trigeminate ambulacral plates throughout, and it differs from the quadrigeminate plates of the subgenus *Polygoniopygus* (Type-species—*G.* (*Pol.*) *minor* SORIGNET: COTTEAU, 1861-67 (65), p. 756, pl. 1184, figs. 7-16—Montian). From the genus *Acropeltis* AGASSIZ, 1838 (Type-epecies—*Acr. aequituberculata* AGASSIZ: COTTEAU, 1880-85(83), p. 562, pl. 412, pl. 413, fig. 1-6—Rauracian) it differs in the apical system, in the former genus the genital plates are with a large tubercle in the center, while the latter are with three or more tubercles in a depression at the inner edge.

This Arbaciid genus ranges from the Upper Jurassic (Tithonian) to the Montian of Europe, the circum-Mediterranean countries, Asia, and North America. The occurrence of this genus in the Cretaceous of Northern Japan is noteworthy.

Goniopygus atavus NISIYAMA, 1950

Goniopygus atavus NISIYAMA, 1950-a, p. 40, pl. 4, figs. 2-4.

Holotype.—IGPS coll. no. 73694.

Locality and geological horizon.—IGPS loc. no. It-4.—Sea cliff northeast of Hiraiga, Tanohata-mura, Shimohei-gun, Iwate Prefecture. (tm Iwaizumi, Lat. 39°55′53″N., Long. 141°56′39″E.), Hiraiga sandstone (*Orbitolina*—horizon), Lower Cretaceous (probably Aptian or Albian). YABE and YEHARA, 1913.

This species has some affinities with *Gon. delphinensis* GRAS (COTTEAU, 1861-67 (65), p. 729, pl. 1179, figs. 1-15), from the Aptian of France, and *Gon. major* AGASSIZ, 1838 (AGASSIZ, 1838, p. 25, pl. 4, figs. 17-22.—Cotteau, 1861-67 (65), p. 740, pl. 1181, figs. 1-8, pl. 1182, figs. 1-4), from the Cenomanian of France, but is distinguished from them by the character of the apical system and the ambulacral plates.

Genus *Coelopleurus* AGASSIZ, 1840

Coelopleurus AGASSIZ, 1840-a, pp. 12, 19.—AGASSIZ and DESOR, 1846, p. 356.—DESOR, 1855-57 (56), p. 97.—LÜTKEN, 1864, p. 164 (96).—A. AGASSIZ, 1872-74, p. 267.—POMEL, 1883, p. 87.—DUNCAN and SLADEN, 1885, p. 27.—DUNCAN, 1889-a, p. 94.—COTTEAU, 1889-94 (93), p. 544.—A. AGASSIZ and H. L. CLARK, 1908, p. 82.—LAMBERT and THIÉRY, 1914, p. 264.—H. L. CLARK, 1925, p. 73.—MORTENSEN, 1935, p. 605, text-figs. 361-362.—GRANT and HERTLEIN, 1938, p. 21.—H. L. CLARK, 1946, p. 306.—COOKE, 1959, p. 22.

Logotype.—*Coelopleurus equis* AGASSIZ, 1840-a, p. 12.—DESOR, 1855-57 (56), p. 97, pl. 16, figs. 4-6.—*Cidaris coronalis* LESKE, 1778, p. 136, pl. 8, figs. A-B.—*Coelopleurus coronalis* (LESKE) COTTEAU, 1889-94 (93), p. 560, pl. 377 (Eocene (Lutetian) of France). [A. AGASSIZ and H. L. CLARK, 1908, p. 82].

Keraiophorus MICHELIN, 1862, p. 2.—POMEL, 1883, p. 88.

Haplotype.—*Keraiophorus maillardi* MICHELIN, 1862, p. 2, pl. 14 (Mauritius, Recent).

Spileccia HÉBERT and MUNIER-CHALMAS, 1878, p. 1313.—*Phrissopleurus* POMEL, 1883, p. 88.—*Delbosia* POMEL, 1883, p. 88.

Haplotype.—*Coelopleurus delbosi* DESOR: COTTEAU, 1889-94 (93), p. 552, pl. 333 (Eocene).

Sykesia Pomel, 1883, p. 88.

Haplotype.—*Coelopleurus pratti* HAIME in D'ARCHIAC and HAIME, 1853-54(53), p. 199, pl. 13, fig. 5 (Oligocene).

Test of small to moderate size, usually low hemispherical, more or less flattened below, rounded to subpentagonal in outline. Ambulacra usually somewhat elevated, with trigeminate compound plates; general arbacioid structure composed of middle primary, aboral and adoral demi-plates; pore-zones simple, slightly widened at the peristomial edge; the pore more or less reduced in size on the oral side. Primary ambulacral tubercles in a regular series throughout. Interambulacra with primary tubercles usually confined to the oral side, rather abruptly disappearing (or at least much reduced) above the ambitus, the upper of the interambulacrum providing a conspicuous, naked, more or less sunken, median space which is often decorated with oblique striae. In most of the fossil species the interambulacra are about twice as broad as the ambulacra, and carry four series of primary tubercles. In the Recent forms the interambulacra are only a broad as, or even narrower than, the ambulacra, and have only two series of primary tubercles; at most there are traces of the outer series. This outer series, when present, usually continues to the apical system, but the tubercles on the aboral side are much smaller than those at the ambitus. Usually, the median series generally disappears completely at the ambitus. Usually there is a conspicuous longitudinal line of granulations from the ambitus to the apical system, parallel to the outer series of tubercles (less developed in the Recent forms). Apical system regularly dicyclic, more or less decorated with granules and tubercles. Peristome rather small, gill-slits obsolete, but continuing in the shape of a "tag" till off the 3rd-4th ambulacral tubercles. Peristomial membrane naked, but with numerous small plates imbedded. Primary spines usually very long, curved, with a long collar, the distal part with a smooth outer layer; there are those triangular section in the Recent forms. Pedicellariae of the tridentate, triphyllous, and ophicephalous types. Sphaeridia in a series of sharp pits in the ambulacral midline. Spicules of the aboral tube-feet smooth, branched; in the oral side, irregular, thorny rods; no spicules in the internal organs. Colour, in the Recent forms, usually very strikingly red and purplish; the primary spines often banded (after MORTENSEN, 1935).

This genus, as described above, seems to have no affinity with the other shallow water, large, Recent forms, such as the genera *Arbacia* GRAY, 1835 (Type-species—*Cidaris pustulosa* LESKE, 1778, p. 150, pl. 11, figs. A, B, C, D.—*Arbacia pustulosa* (LESKE) A. AGASSIZ, 1872-74, pp. 92, 263, 402, pl. 2, fig. 4, pl. 5, figs. 1-18, pl. 1g, fig. 5, pl. 2a, figs. 15-33, pl. 5, figs. 19-21, pl. 28, fig. 6, pl. 38, figs. 10a-c) and *Tetrapygus* AGASSIZ and DESOR, 1846 (Type-species—*Echinus niger* MOLINA, 1782, p. 175.—*Arbacina nigra* (MOLINA) A. AGASSIZ, 1872-74, pp. 91, 401, pl. 1g, figs. 6-7.—*Tetrapygus niger* (MOLINA) MORTENSEN, 1935, p. 582, pl. 70, figs. 10-12, pl. 87, figs. 15-19), but seems to have affinity with the fossil genera *Heteropodia* DE LORIOL, 1888 (Type-species—*Het. whitei* DE LORIOL, 1888, p. 254, pl. 27, figs. 7-8—Cretaceous) and *Baueria* NOETLING, 1884 (Type-species—*Ba. geometrica* NOETLING, 1884, p. 686, pl. 11, figs. 1-9—Eocene). From the genus *Heteropodia* it differs in the pores of oral side, which are small but distinct, while in that genus they are wholly reduced. From the genus *Baueria* it is distinguished by the ambulacral tubercles, which continue in a series to the apical system, whereas in that genus the ambulacral and interambulacral tubercles disappear abruptly at the ambitus.

Tertiary (from the Eocene) of Europe, Egypt, Zanzibar, Asia, Australia, Brazil, and North America. Although, in the Recent forms, this genus is known from the West Indian and from South Africa, its real center of occurrence seems to be in the Malay Archipelago. About twenty-five fossil and nine Recnt species are known today. Although few species from the Cretaceous have been ascribed to *Coelopleurus*, they appear to be far from being typical and probably should be excluded entirely.

Coelopleurus singularis NISIYAMA, n. sp.

(Pl. 1, figs. 21-23)

Holotype.—IGPS coll. cat. no. 73718.

Locality and geological horizon.—IGPS loc. no. Sn-12.—In the 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) formation, probably Miocene.

Holotype specimen deformed laterally, but the detail of structure rather well preserved. Dimensions are about 18 mm in horizontal diameter of test and over 6 mm in height.

Test small, tumid, and more or less circular in outline at the ambitus; rather depressed dorsally, adoral surface concave orally. Apical system rather large, 6 mm in diameter, with an elongate periproct and anal plates lacking; genital plates large, about 2 mm long and 2 mm wide; ocular plates small and all plates exsert from the periproct.

Ambulacra narrow, about 4 mm broad at the ambitus, 10 ambulacral plates in each column; ambulacral plates rather high, 2 mm wide and 2.5 mm high at the ambitus, plates of the arbacioid structure as usual, the middle primary component, and demi-plate components aborally and adorally; pairs of pores in irregular arcs near the ambital region and aborally, some on the flanks of the tubercles, becoming slightly crowded adorally; primiary tubercles very large and occupy nearly the whole of each interporifeous area, small miliary tubercles filling the median ambulacral space very few.

Interambulacra rather broad, about 6 mm wide at the ambitus, 9 interambulacral plates in each oolumn; plates measure 3 mm wide and 2.5 mm high at the ambital region; interambulacral primary tubercles extend only to the fifth plate from the apical system; tubercles very large and occupy the median interambulacral space centrally; interambulacral plates, above the primary tubercles, covered on the outer side with a coarse granulation, leaving a straight, narrow, smooth median space ornamented with a marking of bare narrow band. Peristome rather large, 6 mm in diameter, with small branchial incisions.

Distinction.—This new species resembles *Co. forbesi* HAIME, 1853 (HAIME in D'ARCHIAC and HAIME, 1853-54(53), p. 200, pl. 13, fig. 6.—DUNCAN and SLADEN, 1885-a, p. 287, pl. 46, figs. 1-2, 4, 7, 9) from the Miocene (the Gaj Series) of Western Sind, India, but is distinguished from it by decidedly narrower poriferous zones and by the interambulacral primary tubercles begining at the fifth plate from the apical system. This species is also related to the Recent *Co. maculatus* A. AGASSIZ and H. L. CLARK, 1907 (A. AGASSIZ and H. L. CLARK, 1907-b, p. 116.—A. AGASSIZ and H. L. CLARK, 1908, p. 84, pl. 49, figs. 21-28, pl. 53, figs. 1-7, pl. 57, figs. 4-6) from Japan and the Philippines, but is easily distinguished from that species by the narrower ambulacra, and by the interambulacral primary tubercles begining at the fifth plate from the apical system. This species also may be regarded as an ancestor of the living *Co. maculatus;* as the interambulacral primary tubercles at the seventh plate from the fifth plate are reduced in size and the pore-zones enlarged by ambulacral development, it approaches to the living species in these features.

Coelopleurus maculatus A. AGASSIZ and H. L. CLARK, 1907

(Pl. 2, figs. 12-13)

Coelopleurus maillardi A. AGASSIZ, 1881-a, p. 60 (pro parte), pl. 5, fig. 3 (non *Co. maillardi* (MICHELIN, 1862)).—*Coelopleurus maillardi* (MICHELIN)?: SHIKAMA, 1964, pl. 61, fig. 20 (fossil).

Coelopleurus maculatus A. AGASSIZ and H. L. CLARK, 1907-b, p. 116.—A. AGASSIZ and H. L. CLARK, 1908, p. 84, pl. 49, figs. 21-28, pl. 53, figs. 1-7, pl. 57, figs. 4-6.—MORTENSEN, 1935, p. 631, pl. 67, fig. 4, pl. 68, figs. 1-3, pl. 69, figs. 10-16, pl. 88, figs. 26-29, text-figs. 369-370.—UTINOMI, 1954, p. 343.

Coeloplelurus elegans (BELL): H. L. Clark, 1925, p. 73 (pro parte).

Locality and geological horizon.—IGPS loc. no. Ch—1.—Road-side cutting west of

Jizôdô, Makuta-mura, Kimitsu-gun, Chiba Prefecture. (tm Anegasaki, Lat. 35°21′07″N., Long. 140°06′02″E.). Jizôdô (Narita) formation, Pleistocene.

Hypotype.—IGPS coll. cat. no. 73749.

There are two fragmentary specimens at the writer's disposal, one with two columns of ambulacra above the ambitus remaining, and the other also with two columns of interambulacra above the ambitus. The ambulacrum composed of five ambulacral plates at left hand, and four plates on right.

The largest ambulacral plates measures 4 mm high and 5 mm wide; pores are close to edge of the scrobicular area in irregular arcs of three pore-pairs to each plate; primary tubercle occupies nearly the whole of each plate with exception of small miliary tubercles filling the median ambulacral space.

The interambulacral primary tubercles extent only to the seventh plate from the apical system; small tubercles similar to those on ambulacral area, and occupy the adoral side of the median interambulacral plates, which extend at outer angle of each plate between the primary and the poriferous zone. The interambulacral plates, above the primary tubercles, covered on the outer sides with a coarse granulation, leaving a straight, narrow, smooth median area ornamented with a bare band marking; bare space very prominent, the granules with flank coloured violet in striking contrast to others, though more or less faded in this fossil specimen. The features of the ambulacrum and interambulacrum of these specimens seem to bear the characteristics of the living species of Japan, *Co. maculatus*, and may be safely assigned to this species.

A good figure of the aboral side of an Echinoid given by SHIKAMA (1964, loc. cit.), which he ascribed to *Co. maillardi* with doubt, cannot be assigned to this Malaysian species, judging from the character of aboral side of the test; it is to be assigned to the Japanese species, *Co. maculatus*; in point of the locality and geological horizon, SHIKAMA's specimen quite agrees with the writer's specimens. JEANNET (1935, p. 57, pl. 1, figs. 7-9) reported the fossil of *Co. maillardi* from the the Pliocene of Ceram, but the writer is not prepared to say for this identification with certainty.

This species is reported from Japan (as far North as the Sagami Bay, Korean Strait, and Kagoshima Gulf), the Philippines, Kei Islands, and Amboina; and in depths of about 70 to 360 metres.

The figures given by TOKUNAGA (1906, pl. 7) under the name *Coelopleurus maillardi* MICHELIN is apparently 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. 89, pl. 49, figs. 29-30, pl. 53, fig. 10—MORTENSEN, 1935, p. 619, pl. 67, figs. 7-9, pl. 88, figs. 19-21, text-fig. 366), which is only known from the Philippines, and figures 9 and 10 (locality unknown) probably represent *Co. maillardi* (MICHELIN, 1862), respectively.

Order ECHINOIDA CLAUS, 1876

Echinideae CLAUS, 1876, p. 356.—*Echinina* GREGORY, 1900-b, 311 (suborder).—*Echinoida* (GREGORY): NISIYAMA, 1954, p. 326 (order; in Japanese).—*Echinacea* CLAUS: DURHAM and MELVILLE, 1957, p. 253 (superorder; pro parte).

Camarodonta JACKSON, 1912, p. 203 (suborder).—H. L. CLARK, 1925, p. 75 (suborder).—MOR-

TENSEN, 1927-b, p. 291.—GRANT and HERTLEIN, 1938, p. 22 (suborder).—MORTENSEN, 1943, p. 1 (order).

Type-family.—*Echinidae* GRAY, 1825.

Regular endocyclic Echinoids of hemispherical or more or lesss globular form, with well developed masticatory apparatus. Coronal plates not imbricating; test sculptured or not. Only twenty columns of coronal plates. Tubercles generally imperforate or perforate, non-crenulate or crenulate. Primordial interambulacral plates not persisting, and basicoronal row resorbed. Ambulacra with generally compound plates of the diadematoid or echinoid structure. Apical system regular, dicyclic or with the oculars partly insert (usually oculars (1) and (V)), or monocyclic; suranal plate usually distinct, at least in the postembryonal stages; periproct generally plated with many small plates; but in one genus *Parasalenia* with four large anal plates. Peristome with a single pair of ambulacral plates, the buccal plates, otherwise only with usually small, irregular non-ambulacral plates. Gills present, gill-slits usually distinct. Spines solid, only exceptionally with a small axial cavity; no cortex layer. Lantern erect; epiphyses wide and joining above the teeth so as to form a closed foramen; pyramids pitted under the epiphyses; teeth keeled. Perignathic girdle consisting of radial auricles, usually joining at their upper ends, connected by an apophysis (interradial ridge). Pedicellariae richly developed, of the globiferous, tridentate, ophicephalous and triphyllous types; globiferous pedicellariae often with stalk glands, the head sometimes lacking (the claviform pedicellariae). Sphaeridia present, attached along to the midline of the ambulacra, not at the tube-feet. Spicules of the C-shaped, bihamate type, but may have more or less branched or thorny ends, or the ends may be obtuse, the spicules assuming the shape of dumb-bells; exceptionally they are bow-shaped (biacerate), with straight, pointed ends (from MORTENSEN, 1943).

From the Cretaceous to Recent.

The principal character of this order is found in the masticatory apparatus and in the ambulacral structure of compound plates. In the former the teeth have a keel on the inner face, and the epiphyses are wide, and meet in suture over the foramen magnum, and moreover they bear crests which support the teeth dorsally. As to the ambulacral structure all but the Glyphocyphids are of the echinoid type; Glyphocyphids alone possess the diadematoid pattern. The diadematoid strcuture is the older in the geological occurrence and more primitive in the structural development than the echinoid structure. From the former structure the latter has evolved, as clearly demonstrated by HAWKINS (1920, p. 468), and furthermore, GORDON (1926), in her embryological study of *Echinus*, found that the intermediate form between the diadematoid and echinoid structures is observable on the adapical or newly formed plates.

MORTENSEN (1943) referred to this order that it comprises the majority of the Recent Regular Echinoids and the sculptured and pitted family of the fossil Glyphocyphids. These Glyphocyphids have a close resemblance, in general features, to the sculptured and pitted family of the Temnopleurids, as pointed out by MORTENSEN, and would seem to indicate a close relation between the two families; the main differences being that the tubercles are perforate in the former, imperforate in the latter, and that the ambulacral structure of the Glyphocyphids is of the diadematoid structure, that of the Temnopleurids of the echinoid structure. MORTENSEN (1943, pp. 61, 390) takes a view that the sculptured and pitted family of the Temnopleurids is closely related to the non-sculptured family of the Toxopneustids; as is clearly shown through the Temnopleurid genus *Desmechinus* H. L. CLARK, 1923, the two families are evidently connected in general features; the sculpture of test alone, however, distinguishes the Temnopleurids from the Toxopneustids. The Toxopneustids are formerly considered to have a close relation with the non-sculptured families, i. e., the families of the Echinids and Strongylocentrotids.

Through the thorough researches of this order MORTENSEN (1943, p. 5) claimed that the stem of the Glyphocyphids—Temnopleurids—Toxopneustids must have evolved from the Pseudodiadematids of the Arbacioids; this resulted from the evidence of the perforate, crenulate tubercles, and the compound ambulacral plates of the diadematoid structure of the Glyphocyphids. He regarded this stem as a suborder, the Temnopleurina, of the order. DURHAM and MELVILLE (1957, p. 255) regarded this suborder as constituting a natural lineage, and proposed to raise it to an ordinal rank, the Temnopleuroida. On the other hand, MORTENSEN (1943, p. 5) preferred to consider that the stem of the Echinids—Strongylocentrotids—Parasaleniids—Echinometrids (the non-sculptured families possessing imperforate and non-crenulate tubercles, and the compound ambulacral plates of the echinoid structure) does not seem to have any close relations with the stem of the Temnopleurids—Toxopneustids, and that the Echinids would might have been derived from the Stomechinids, and the Echinometrids from the Phymosomatids (or Stomechinids) of the Arbacioids. For this stem of the Echinids—Echinometrids MORTENSEN (1942, p. 225.-1943, p. 5) proposed a suborder, the Echinina (not of GREGORY, 1900-b, p. 311); DURHAM and MELVILLE (1957, p. 255), however, proposed to raise this MORTENSEN's suborder to an ordinal rank, the Echinoida, admitting that the phylogenetic background of the families is not accessible.

At any rate, the families of the sculptured or non-sculptured forms, presumably referred to this order, as the whole, should be regarded as the descendants of the members of a single suborder Phymosomatoina, even though they differ in the family-level, and the families should be grouped in two suborders, i, e., the Temnopleuroina and Echinoina.

There are fossil representatives of the suborders Temnopleuroina and Echinoina in our collection.

Suborder TEMNOPLEUROINA MORTENSEN, 1942

Temnopleurina MORTENSEN, 1942, p. 225.—MORTENSEN, 1943, pp. 5, 20.—NISIYAMA, 1954, p. 326 (in Japanese).—*Temnopleuroida* MORTENSEN: DURHAM and MELVILLE, 1957, p. 225 (order).

Type-family.—*Temnopleuridae* A. AGASSIZ, 1872

Echinoids with camarodont condition of lantern and compound ambulacral plates of the diadematoid or echinoid structure. Test sculptured or not; if not sculptured the gill-slits are sharp, more or less deep. Tubercles perforate, crenulate; or imperforate, crenulate or smooth. Primary spines with solid axis, exceptionally with a small axial cavity.

From the Cretaceous to Recent.

This suborder comprises three families, the Glyphocyphids, Temnopleurids, and Toxopneustids, as described above, and they are discriminated from one another by according to the following key (after MORTENSEN, 1943).

Key to the families of the suborder Temnopleuroina.

1. Tubercles perforate, crenulate. Test sculptured. Compound ambulacral plates of the diadematoid structure .... Glyphocyphidae
   Tubercles imperforate. Compound ambulacral plates of the echinoid structure.. 2
2. Tubercles usually crenulate. Test usually sculptured. Gill-slits not deep and sharp .... Temnopleuridae
   Tubercles non-crenulate. Test not sculptured. Gill-slits generally deep and sharp .... Toxopneustidae.

There are fossil representatives of the families of the Temnopleuridae and Toxopneustidae in our collection.

Family TEMNOPLEURIDAE A. AGASSIZ, 1872

Temnopleuridae A. AGASSIZ, 1872-74(72), p. 285.—A. AGASSIZ, 1881-a, p. 37.—*Les Temnechiniens* POMEL, 1883, p. 85.—*Temnopleuridae* A. AGASSIZ: DUNCAN, 1889-a, p. 96 (pro parte).—GREGORY, 1900-b, p. 312 (pro parte).—DELAGE and HÉROUARD, 1903, p. 239.—MORTENSEN, 1903-b, p. 81.—MORTENSEN, 1904, p. 56.—MEISSNER, 1904, p. 1362.—DÖDERLEIN, 1906, p. 187.—H. L. CLARK, 1912-b, p. 290.—H. L. CLARK, 1925, p. 75.—LAMBERT and JEANNET, 1935, p. 3 (*Sculptés*).—MORTENSEN, 1943, p. 39.—H. L. CLARK, 1946, p. 306.—TERMIER and TERMIER, 1953, p. 906.

Type-genus.—*Temnopleurus* AGASSIZ, 1841

Test of very diversified shape and size, but the ambitus usually circular. Ambulacra compound, with trigeminate plates of the echinoid structure; pore-zones mostly narrow, without adoral widening, the pore-pairs monoserial or biserial, or even triserial to pluriserial. Primary tubercles imperforate, more or less distinctly crenulate, or quite smooth, often with the base indented. Test usually more or less conspicuously sculptured, by pits or depressions in the sutures or on the plates. Apical system varying from regularly dicyclic to very eccentric, with some of the oculars insert; often there is a large suranal plate. Buccal membrane generally naked outside the buccal plates, sometime also inside the buccal plates; more rarely completely covered with plates. Gill-slits usually short, low and indistinct, more rarely sharp and rather deep. Primary spines usually short; they are generally smooth, but in some small forms distinctly serrate, and may be small, but axial cavity distinct. Pedicellariae of the tridentate, triphyllous, ophicephalous, and the globiferous types, the tridentate type often lacking in the small forms. Spicules of the bihamate type, rarely triradiate. Pits in the pyramids. Colour often very bright (from MORTENSEN, 1943).

From the Cretaceous (Cenomanian) to Recent.

The great resemblance between this family and the Glyphocyphids, and the close relationship between Temnopleurids and Toxopneustids, as argued by MORTENSEN, leads to the conclusion that they must be placed together in the same suborder. It now seems certain, from the characters of their tubercles and their compound ambulacral structures, that there must exist an ascending line from the more primitive Pseudodiadematid-like form through the Glyphocyphids to the Temnopleurids and even to the Toxopneustids, the latter seems to represent the highest degree in the feature of this ascending series and the youngest occurrence in geological age.

This is a large family comprising more than thirty genera, of which at least sixteen include Recent forms. They fall into two or three subfamilies, according to H L. CLARK and MORTENSEN, respectively, distinguished chiefly by the characters of the ornamentation of the test, particularly of the aboral side.

Subfamily TEMNOPLEURINAE A. AGASSIZ, 1872

Temnopleuridae A. AGASSIZ, 1872-74 (72), p. 285.—*Temnopleurinae* DUNCAN, 1889-a, p. 97.—GREGORY, 1900-b, p. 312.—MORTENSEN, 1904, p. 113.—H. L. CLARK, 1912-b, p. 310.—H. L. CLARK, 1925, p. 75.—MORTENSEN, 1943, p. 72.

Angular pits or pores usually present (may be more or less obliterated in adult specimens, are lacking in *Pseudechinus* MORTENSEN, 1903). No depressions or sculpture on the coronal plates; but in the small forms of *Toreumatica* GRAY, 1855, the pits may widen considerably so as to produce a sculpture similar to that of member of the Trigonocidarinae. Plates united by dowelling in the large forms. Poison glands of the globiferous pedicellariae double (from MORTENSEN, 1943).

This subfamily comprises a rather large group of genera, e. g., *Temnopleurus* (with a subgenus *Toreumatica*), *Paratrema* KOEHLER, 1927, *Pseduodicoptella* JEANNET, 1935, *Medocechinus* JEANNET, 1936, *Trumechinus* LAMBERT and THIÉRY, 1911, *Temnechinus* FORBES, 1852, *Temnotrema* A. AGASSIZ, 1863, *Mespilia* DESOR, 1846, *Microcyphus* AGASSIZ, 1841, *Salmacis* AGASSIZ, 1841, *Amblypneustes* AGASSIZ, 1841, *Pseudechinus*, *Holopneustes* AGASSIZ, 1841, *Salmaciella* MORTENSEN, 1942, *Opechinus* DESOR, 1856, and *Erbechinus* JEANNET, 1935. The latter two are once assigned to the subfamily Trigonocidarinae owing to their test sculpture, but by the character of the globiferous pedicellariae they are referred to this subfamily. The greatest majority of these genera comprises the main stem of the family of the Temnopleurids, and seem to belong to the Recent Epoch, though such important genera as *Temnopleurus, Microcyphus, Temnotrema,* and *Opechinus* started in the Miocene.

Genus *Temnopleurus* AGASSIZ, 1841

Temnopleurus AGASSIZ, 1841, p. 7.—AGASSIZ, 1841-a, p. vii.—AGASSIZ and DESOR, 1846, p. 359.—D'ARCHIAC and HAIME, 1853-54 (53), p. 201.—DESOR, 1855-57 (56), p. 104.—VON MARTENS, 1866, pp. 133, 158.—A. AGASSIZ, 1872-74, pp. 166, 460.—ZITTEL, 1879, p. 505.—BELL, 1880-d, p. 423.—MARTIN, 1880-a, p. 73.—POMEL, 1883, p. 87.—DUNCAN, 1883, p. 350.—DUNCAN, 1888, p. 112.—DUNCAN, 1889-a, p. 106.—LAMBERT, 1897, p. 497.—DELAGE and HÉROUARD, 1903, p. 241.—MEISSNER, 1904, p. 1362.—MORTENSEN, 1904, p. 64.—LAMBERT and THIÉRY, 1911, p. 217.—H. L. CLARK, 1912-b, p. 311.—H. L. CLARK, 1925, p. 80.—LAMBERT and JEANNET, 1935, p. 6.—MORTENSEN, 1943, p. 72.—H. L. CLARK, 1946, p. 309.—TERMIER and TERMIER, 1953, p. 906.

Orthotype.—Cidaris toreumatica LESKE, 1778, p. 155.—*Temnopleurus toreumaticus* (LESKE) A. AGASSIZ, 1872-74, pp. 163, 463, pl. 8a, figs. 4-5 (Indian Ocean).—MORTENSEN, 1943, p.

76, pl. 1, figs. 1-3, 6-12, pl. 2, figs. 9-15, 19-21, pl. 45, figs. 27-28, text-figs. 53, 55b (widely distributed all over the Indo-Pacific regions, from East Africa to Japan, in depths about 0-45 metres).

Temnotrema POMEL, 1883, p. 87 (non A. AGASSIZ, 1863).—LAMBERT and JEANNET, 1935, p. 6.

Haplotype.—Temnopleurus hardwickii (GRAY) A. AGASSIZ, 1872-74, pp. 166, 460, pl. 8a, figs. 1-3 (Japan) (in which A. AGASSIZ included *Temnotrema sculptum*, a quite distinct species).

Test of moderate or small size, low, hemispherical or subconical, or flattened above; generally slightly sunken at the peristomial edge. Pore-zones narrow, only in the largest specimens slightly widening adorally; pore-pairs arranged more or less distinctly in slightly oblique arcs of three. Trigeminate ambulacral plates of the echinoid structure throughout; each plate with a primary tubercle of about the same size as the interambulacral primaries. Secondary tubercles in larger specimens well developed in the ambital region, almost as large as the primaries, forming horizontal and longitudinal series. Horizontal sutures aborally with deep and usually large pits, in ambulacra only one pit, ranging from the median suture to the base of the primary tubercle; in interambulacra two pits, one from median suture, the other from outer, adradial edge, the two being separated by the primary tubercle; pits sometimes widened towards the primary tubercle; on the oral side the pits become smaller or quite obsolete. Primary tubercles distinctly crenulate; the boss is sometimes distinctly serrate especially below the ambitus. There may be more or less distinct depressions on the plates, radiating from the primary tubercle. Apical system dicyclic, with subcentral or pronouncedly eccentric position of the anal opening. Peristomial membrane and buccal plates naked; in the adoral edge some small plates, outside the buccal plates. Gill-slits very shallow; gills small, bush-shaped. Primary spines simple, finely striated; marginal spines flattened towards the end, which is more or less concave on the adoral side; peristomial spines usually curved, somewhat widened and flattened at the point. Secondary spines simple, pointed. Globiferous pedicellariae of one kind only, with or without lateral teeth. Spicules simple, bihamate, or sometimes biacerate (from MORTENSEN, 1943).

The main point of distinction between this genus, to which *Tem. alexandri* (BELL, 1884) (*Salmacis alexandri* BELL, 1884-b, p. 118.—*Sal. virgulata* var. DÖDERLEIN, 1903, p. 713, pl. 42, figs. 5-7a) is referred, and the allied genus *Salmacis* is that in *Temnopleurus* there are large and deep sutural pits, while in the other there are only angular pores.

Temnopleurus is a well known genus among the family of the Temnopleurids, being characterized by the long and sharp angular pits, and by the well crenulated primary tubecles, of which one to three or rarely more are found on a coronal plate at the ambitus. Among the species which once placed in the genus *Temnopleurus* by LAMBERT and THIÉRY (1911, p. 218), *Tem. neuvillei* LAMBERT, 1912 (LAMBERT, 1912-a, p. 25, pl. 1, figs. 12-14—Eocene) and *Tem. tuberculosus* HAIME, 1853 (D'ARCHIAC and HAIME, 1953-54 (53), p. 206, pl. 13, fig. 11.—DUNCAN and SLADEN, 1882-a, p. 85, pl. 13, figs. 16-17) must be removed from this genus, and the former species is to be referred to *Medocechinus* JEANNET, 1936 (JEANNET, 1936-a, p. 2), and the latter to *Trumechinus* LAMBERT and THIÉRY, 1911 (1911, p. 218). Among the fossil, the species described by HERKLOTS from the Miocene of Java, *Tem. areolatus* HERKLOTS (1854,

p. 4, pl. 1, fig. 3) and *Tem. caelatus* HERKLOTS (1854, p. 5, pl. 1, fig. 5) are identified with the Recent *Tem. toreumaticus* (LESKE, 1778) by MARTIN (1880, p. 1) and later writers. Thus eliminating the species as discussed above, *Temnopleurus* at present contains the well-known Recent species and one fossil species all from the Indo-Pacific regions and dating from the Miocene Epoch.

The two common living species of the Indo-Pacific regions, *Tem. toreumaticus* (LESKE, 1778) and *Tem. hardwickii* (GRAY, 1855), are discriminated from each other as shown in the following key.

1. Spines, at least on the oral side, usually banded, dark olive with whitish, or white with reddish bands. Pits of the horizontal sutures large with sharp edge, also in large specimens. Apical system not raised. All oculars excluded from the periproct. Globiferous pedicellariae with 1-1 small, but distinct lateral teeth; ophicephalous pedicellariae distinctly sinuate at the edge; spicules bihamate only .... *Temnopleurus toreumaticus*
2. Primary spines very dark (almost black or dark brown) in colour at base, not banded. Pits of the horizontal sutures bevelled, especially in larger specimens. Anal opening subcentral. Apical area raised. Poriferous area 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 sinuate; spicules bihamate only .... *Temnopleurus hardwickii*.

There are two species of fossil of this genus in our collection.

Temnopleurus toreumaticus (LESKE, 1778)

(Pl. 4, figs. 3, 4, 7, 10, 12)

Cidaris toreumatica LESKE, 1778, p. 155.—*Temnopleurus toreumaticus* (LESKE) AGASSIZ, 1841-a, p. vii.—AGASSIZ and DESOR, 1846, p. 360, pl. 15, fig. 5.—DESOR, 1855-57 (56), p. 108, pl. 17, figs. 8-10.—A. AGASSIZ, 1872-74, pp. 166, 463, pl. 8a, figs. 4-5.—Bell, 1880-d, p. 424.—MARTIN, 1880, p. 1.—A. AGASSIZ, 1881-a, p. 107.—DUNCAN, 1883, p. 350, pl. 8, figs. 10-14.—DÖDERLEIN, 1885, p. 76.—BELL, 1887-b, p. 651.—BELL, 1888, p. 383.—IVES, 1891, p. 241—BEDFORD, 1900, p. 280.—MORTENSEN, 1904, p. 58, pl. 4, figs. 8, 14, 22, 49, pl. 7, figs. 3, 28.—TOKUNAGA, 1906, pl. 7, figs. 11-17.—A. AGASSIZ and H. L. CLARK, 1907-b, p. 125.—H. L. CLARK, 1908, p. 304.—DÖDERLEIN, 1911, p. 244.—LAMBERT and THIÉRY, 1911, p. 217.—H. L. CLARK, 1912-b, p. 312.—H. L. CLARK, 1921, p. 148.—GERTH, 1922, p. 501.—DJAKONOV, 1923, p. 259, pl. 1, figs. 1-2.—H. L. CLARK, 1925, p. 82.—KOEHLER, 1927, p. 76, pl. 13, figs. 14-17, pl. 14, figs. 1-2.—STOCKLEY, 1927, p. 114, pl. 21, figs. 1-2.—CURRIE, 1930, p. 173.—LAMBERT, 1931, p. 205, pl. 4, fig. 32.—IKEDA, 1931-a, p. 3.—H. L. CLARK, 1932, p. 212.—CLEGG, 1933, p. 20, figs. 6a-c.—LAMBERT and JEANNET, 1935, p. 18, text-fig. 3.—JEANNET and MARTIN, 1937, p. 224.—H. L. CLARK, 1938-a, p. 383.—MORTENSEN, 1943, p. 76, pl. 1, figs. 1-3, 6-12, pl. 2, figs. 9-15, 19-21, pl. 45, figs. 27-28, text-figs. 53b, 55b.—H. L. CLARK, 1946, p. 309.—UTINOMI, 1954, p. 346.—COOKE, 1954, p. 46, pl. 9, fig. 12.
Temnopleurus reynaudi AGASSIZ and DESOR, 1846, p. 360.
Temnopleurus areolatus HERKLOTS, 1854, p. 4, pl. 1, fig. 3.
Temnopleurus caelatus HERKLOTS, 1854, p. 5, pl. 1, fig. 5.
Toreumatica granulosa GRAY, 1855, p. 39.
Temnopleurus reevesii A. AGASSIZ, 1863, p. 23 (non GRAY 1855).—A. AGASSIZ, 1863-a, p. 358.
Temnopleurus granulosus (GRAY) BELL, 1880-d, p. 424.
Temnopleurus mortenseni DJAKONOV, 1923, p. 189.
Non *Temnopleurus toreumaticus* SLADEN, 1879, p. 438 (=*Temnotrema sculptum* A. AGASSIZ, 1863).—BELL, 1884-b, p. 119 (=*Tem. alexandri* BELL, 1884).—DE MEIJERE, 1904, p. 80,

pl. 16, fig. 269 (=*Salmacis virgulata* AGASSIZ, 1846, var.)

Locality and geological horizon.—Wanga, Goryû-shô, Chikunan-gun, Shinchiku-shû, Formosa. Byôritsu formation, Pliocene. *Hypotype.*—IGPS coll. cat. no. 73731.

Locality and geological horizon.—IGPS loc. no. Hy-12.—Roadside cutting at Maiko, Akashi City, Hyôgo Prefecture. (tm Suma, Lat. 34°37′46″N., Long. 135°02′18″E.). Maiko formation, Pleistocene. *Hypotype.*—IGPS coll. cat. no. 73731-A.

There are specimens referable to this species at hand, but many of them are partly broken and deformed, and the detailed features are not well preserved.

Dimensions of a specimen from the Byôritsu formation are: horizontal diameter 27 mm; height 11 mm; apical system 5 mm in diameter; peristome 9 mm in diameter; number of ambulacral plates in a column 22-23; number of interambulacral plates in a column 18-19; thickness of test 1 mm at oral side, and less on aboral side.

Ambulacra rather narrow, about 1 mm wide at the ambitus, pairs of pores rather large and in triplets; but in an interrupted vertical series, not close to margin of the interporiferous areas, one or more miliary tubercles are present between some pore-pairs and the margin; ambulacral plates rather low, about 3.5 mm wide and 1.5 mm high near the ambitus, formed of three components; pore-pair of middle demi-plate component slightly produced outward from the level general surface of the two pore-pairs of aboral and adoral primary components. Primary tubercles on ambulacra as large as or slightly smaller than those on interambulacra, the large primary tubercles form a vertical series on each side of the interporiferous areas near the poriferous zones throughout nearly all plates in each column; small primary (or large secondary) tubercles form also a vertical series inside the primary series and this series begins at 6th or 7th plate from the apical system; large secondary tubercles rather regularly on the plates inside, and above a primary tubercle; small secondary and miliary tubercles cover the rest of plates, forming close circle around the primary tubercle. Angular pits on ambulacra rather small and short (compare fig. 6 on plate 4 of the living specimen), but distinct and sharp, rectangular in outline, not triangular as in *Tem. hardwickii* (see below); the outermost part touches the base of the primary tubercle.

Interambulacra rather broad, about 10 mm wide at the ambitus; interambulacral plates rather low, about 5 mm wide and 1.7 mm high; large primary tubercle placed somewhat eccentrically and slightly adorally; they form a vertical series; small primary tubercles form two vertical series at the ambitus, one inside and the other outside of the large primary series; the two series begin at 4th or 5th plate from the apical system; small primary tubercles nearly as large as the large primary tubercles at the ambitus, and form a distinct series, contrasting to those of *Tem. hardwickii* (see below); some of secondary tubercles form a horizontal row above the primary tubercle and near the edge of angular pits; other small secondary and miliary tubercles cover the rest of plates, forming circles around the primary tubercles. Primary tubercles distinctly crenulate, number of crenulation on large primary tubercles seems to rather constant, i. e., 16. Angular pits on the interambulacra, long, distinct, and sharp (compare fig. 5 on pl. 4 of the living specimen), elongate rectangular in outline, sometimes connected by a shallow groove on sutural lines.

These specimens are safely identified with the living *Tem. toreumaticus* (LESKE,

1778) on account of the series of primary tubercles and the angular pits on both interambulacra and ambulacra. A specimen reported by COOKE (loc. cit.), as *Tem. toreumaticus* (LESKE) varieties, from the Pliocene of Okinawa (USNM coll. no. 561554) seems to have a delicate test, and the angular pits on the oral side are rather distinct, and, thus, it should not be safely ascribed to this species.

This diversified species, is widely distributed in the water over the Indo-West Pacific regions, from Central Japan (Tokyo Bay at the Pacific side and Toyama Bay at the Japan Sea side) to East Africa in the west and to Australia in the south; from the ebb-zone to 45 metres depth. This species dates back to the Miocene, which is the oldest age of the genus, and has the widest geographical distribution.

Temnopleurus hardwickii (GRAY, 1855)

(Pl. 4, figs. 8, 9, 13, Pl. 5, figs. 1-2)

Toreumatica hardwickii GRAY, 1855, p. 39.—*Temnopleurus hardwickii* (GRAY) A. AGASSIZ, 1872-74, pp. 166, 460, pl. 8a, figs. 1-3.—A. AGASSIZ, 1881-a, p. 120.—*Temnotrema hardwickii* (GRAY) POMEL, 1883, p. 87.—*Temnopleurus hardwickii* (GRAY) MORTENSEN, 1904, pp. 61 65, pl. 6, figs. 32, 34, pl. 7, fig. 21.—H. L. CLARK, 1908, p. 304.—LAMBERT and THIÉRY, 1911, p. 218.—H. L. CLARK, 1912-b, p. 312.—DJAKONOV, 1923, p. 279, pl. 1, fig. 3.—H. L. CLARK, 1925, p. 80.—MORTENSEN, 1929, p. 478, pl. 19, fig. 3.—*Temnotrema hardwickii* (GRAY) LAMBERT and JEANNET, 1935, p. 6.—*Temnopleurus hardwickii* (GRAY) NISIYAMA, 1937, p. 52.—MORTENSEN, 1943, p. 84, pl. 1, figs. 4, 5, pl. 2, figs. 16-18, pl. 3, figs. 21-30, text-fig. 53a.

Microcyphus elegans A. AGASSIZ, 1863-a, p. 357.

Temnopleurus japonicus VON MARTENS, 1866, p. 55.

Temnopleurus toreumaticus IVES, 1891, p. 214 (partim).—TOKUNAGA, 1903, p. 5 (non LESKE, 1728).

Non *Temnopleurus hardwickii* STOCKLEY, 1927, p. 114, pl. 21, fig. 3 (=*Tem. toreumaticus* (LESKE, 1778)).

Locality and geological horizon.—IGPS loc. no. Ch-25.—Roadside cutting near Somei, Tako-machi, Katori-gun, Chiba Prefecture. (tm Narita, Lat. 35°44′03″N., Long. 140°27′36″E.). Narita formation, Pleistocene. *Hypotype.*—IGPS coll. no. 27439.

Locality and geological horizon.—IGPS loc. no. Ch-26.—A point near Asakura, Chiyoda-mura, Sambu-gun, Chiba Prefecture. (tm Narita, Lat. 35°43′26″N., Long. 140°24′13″E.). Narita formation, Pleistocene.—IGPS coll. cat. no. 22242.

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. 58345.

Locality and geological horizon.—IGPS loc. no. Kn-12.—North side of Kagetsu-en, Tsurumi Ward, Yokohama City, Kanagawa Prefecture. (tm Yokohama, Lat. 35°30′N., Long. 139°40′04″E.). Tokyo formation, Pleistocene. *Hypotype.*—IGPS coll. cat. no. 58344.

There are five specimens referred to this species at hand, ranging from 33 mm to 45 mm in horizontal diameter, and these were yielded from the Pleistocene of Kantô region, Central Japan.

Dimensions are:

	No. 27439	No. 22242	No. 58345
Horizontal diameter	45 mm	37 mm	33 mm
Height	24 „	20 „	17 „
Apical system	8 „	7 „	6 „
Peristome	11 „	10 „	9 „
Number of ambulacral plates	29	27	26
Number of interambulacra plates	20	18	17
Thickness	2.5 mm	2 mm	—

Test large, thick and stout, low (less than two-thirds of horizontal diameter of test), and flat; apical system is lost from all the specimens, vacant area small (less than one-fourth of horizontal diameter of test); angular pits of ambulacral and interambulacral areas large, sharp and bevelled, united into one at the median suture on aboral surface (see figs. 1, 2 of the fossil specimen, and figs. 3, 4 on plate 4 of the living specimen), usually elongate triangular in outline and pointed inward. In the largest specimen, ambulacra narrow, about 10 mm wide at the ambital region; poriferous zones slightly sunken and narrow, about 1 mm wide at the ambitus, pore-pairs in triplets and in a nearly vertical series close to margin of the area, pore-pairs of middle demi-plate component slightly produced outward from the level of the two pore-pairs of aboral and adoral primary components; primary tubercles on ambulacra as large as those on interambulacra, the large primay tubercles very prominent and decidedly larger than the small primary (or large secondary) tubercles (which as large as the moderate secondary tubercles); large primary tubercles form a prominent vertical series on each side of interporiferous area near the poriferous zone; small primary tubercles form also a vertical series inside the large primary series; moderate secondary tubercles placed inside rather regularly on the plates and above the large primary tubercle; small secondary and miliary tvbercles cover the rest of plates, forming close circles around the large and small primary tubercles; along median line there is a depression united to angular pits.

Interambulacra broad, about 16 mm wide at the ambital region; interambulacral plates rather low, 8 mm wide and 3 mm high; large primary tubercles very prominent and decidedly larger than the small primary tubercles, being placed somewhat eccentrically and adorally, and form a prominent vertical series; small primary tubercles form two vertical series at the ambital region, one inside and the other outside of the large primary series, almost as large as the moderate secondary tubercles; moderate secondary tubercles placed rather in horizontal row above the large tubercles; small secondary and miliary tubercles cover the rest of plates, forming circles around the large and small primary (or large secondary) tubercles. Primary tubercles distinctly crenulate, number of crenulation on the large primary tubercles seems to be constantly 12.

From the specific character of these specimens, they may safely be identified with the Recent *Tem. hardwickii* (GRAY, 1855), which ranges from northern Japan to western Japan, around off Kobe, in geographical distribution, and commonly found in littoral waters (5 to down 35 metres) of northeastern Japan. This species is a unique boreal form of the genus, and seems to have descended from the related species of older occurrence, i.e., *Tem. toreumaticus,* by the specialization of the angular pits on coronal plates, and to have developed autochthonously in the Japanese region through the young geological age.

Subgenus *Toreumatica* GRAY, 1855

Toreumatica GRAY, 1855, p. 39.—MORTENSEN, 1943, p. 92.

Logotype.—Toreumatica reevesii GRAY, 1855, p. p. 39.—*Temnoplerus reynaudi* A. AGASSIZ, 1872-74, pp. 166, 461, pl. 8, figs. 22-24, pl. 8a, figs. 6-7 (non AGASSIZ and DESOR, 1846) (China Sea and Indian Ocean). [MORTENSEN, 1943, p. 92].

Prymnechinus KOEHLER, 1927, p. 109.

Haplotype.—Prymnechinus proctalis KOEHLER, 1927, p. 110, pl. 17, figs. 11, 12, 14.=*Genocidaris apodus* A. AGASSIZ and H. L. CLARK, 1907-b, p. 126 (Goto Islands, Japan).

Coptopleura IKEDA, 1940-a, p. 92.

Orthotype.—Coptopleura sema IKEDA, 1940-a, p. 92, pl. 6 (Bonin Islands).=*Temnopleurus* (*Toreumatica*) *reevesii* (GRAY, 1855).

This subgenus differs from the typical *Temnopleurus* in the strongly eccentric position of the anal opening and the presence of a distinct suranal plate. The angular pits usually remain distinct also on the oral side of the test, and the test sculpture may be very strongly developed, more particularly in the young specimens (as in *Coptopleura sema*).

The two Japanese living species, i. e., *Tem.* (*Tor.*) *reevesii* and *Tem. apodus*, belong to this subgenus. Although the latter species is classified with the former into this subgenus, it strikingly differs from the former in the character of the buccal plates. If there is the necessity of separating the latter species as a distinct genus (or subgenus) from the former, it is to bear the name *Prymnechinus*, just as in the case of separating of *Paratrema* KOEHLER, 1927, from *Temnotrema* A. AGASSIZ, 1863.

Temnopleurus (*Toreumatica*) *reevesii* (GRAY, 1855)

(Pl. 4, figs. 11, 14)

Toreumatica reevesii GRAY, 1855, p. 39.—*Temnopleurus reevesii* (GRAY) MORTENSEN, 1904, p. 62, pl. 4, figs. 3, 10, 12, pl. 7, fig. 37.—LAMBERT and THIÉRY, 1911, p. 218.—H. L. CLARK, 1912-b, p. 313.—H. L. CLARK, 1925, p. 81.—*Temnopleurus* (*Toreumatica*) *reevesii* (GRAY) MORTENSEN, 1943, p. 92, pl. 3, figs. 1-2, 12, 16-20, text-figs. 56-60.—UTINOMI, 1954, p. 346.

Temnopleurus reynaudi A. AGASSIZ, 1872-74, pp. 166, 461, pl. 8, figs. 22-24, pl. 8a, figs. 6-7 (non AGASSIZ and DESOR, 1846, p. 360).—SLADEN, 1879, p. 437.—BELL, 1880-d, p. 424.—DÖDERLEIN, 1885, p. 90 (19).—IVES, 1891, p. 214.—DE MEIJERE, 1904, p. 81, pl. 16, fig. 270, pl. 17, fig. 271.—TOKUNAGA, 1906, pl. 8, figs. 1-4.—A. AGASSIZ and H. L. CLARK, 1907-b, p. 124.—H. L. CLARK, 1908, p. 309.—HAYASAKA, 1948, p. 28.

Coptopleura sema IKEDA, 1940-a, p. 92, pl. 6.

Non *Temnopleurus reevesii* A. AGASSIZ, 1863, p. 23 (=*Tem. toreumaticus* (LESKE, 1778).—AGASSIZ, 1863-a, p. 358.

Locality and geological horizon.—IGPS loc. no. Ch-1.—Roadside cutting near Jizôdô, Makuta-mura, Kimitsu-gun, Chiba Prefecture. (tm Anegasaki, Lat. 35°21′07″N., Long. 140°06′02″E.). Jizôdô (Narita) formation, Pleistocene. *Hypotype.*—IGPS coll. cat. no. 73729.

Locality and geological horizon.—IGPS loc. no. Ch-25.—Roadside cutting near 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. 73730.

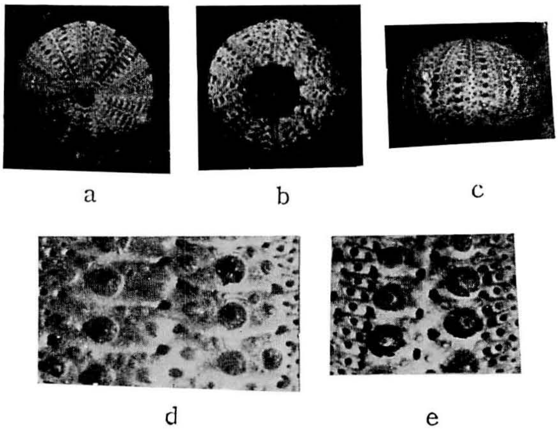


Fig. 8. *Temnopleurus* (*Toreumatica*) *reevesii* (GRAY, 1855). (Recent specimen, from Moroiso, Misaki, Kanagawa Prefecture; for comparison).

a. Aboral view, ×0.8; b. Adoral view, ×0.8; c. Side view, ×0.8; d. An interambulacrum at the mid-zone, ×4; e. An ambulacrum at the mid-zone, ×4.

There are two specimens referred to this species at hand, and they were derived from the Pleistocene of Chiba Prefecture.

Dimensions of the specimen from Jizôdô are: Horizontal diameter 15 mm; height 8 mm; apical system 4.5 mm in diameter; peristome 6 mm in diameter; number of ambulacral plates in a column 15–16; number of interambulacral plates in a column 14.

Test thin, rather fragile, and well rounded. Ambulacra rather broad, 5 mm wide at the ambitus; ambulacral plates slightly lower than the interambulacral ones, 2.5 mm wide and 1.3 mm high at the ambital region; ambulacral plates composed of three components, pore-pairs of middle demi-plate component slightly produced outward from the general level of other pore-pairs; poriferous zones rather broad, 1 mm wide at the ambital region, and pores distant from the edge of ambulacral area; large primary tubercles occupy nearly the center of plates and form a prominent vertical series on each side of interporiferous areas near to the poriferous zones; small primary tubercles, decidedly smaller than the large primary tubercles, also form a vertical series inside the primary series, which series begins at 6th or 7th plate from the apical system; small secondary and miliary tubercles rather few in number and cover sparsely the rest of plates, some of them forming a circle around the large primary tubercle; along median line there is a smooth space; angular pits on ambulacral plates very small, outer angular pits of the compound plates not so distinct as those of the living specimens, and scarcely observable.

Interambulacra rather narrow, about 6 mm wide at the ambital region; interambulacral plates rather high, about 3 mm wide and 1.5 mm high; large primary tubercles prominent, and placed slightly eccentric outward and adorally, and form a vertical series on each side of interambulacral column; small primary (or large secondary) tubercles form two vertical series at the ambital region, one inside and the other outside the large primary series, the outside series placed near the edge of plates; the two series begin at 5th or 6th plate from the apical system; small secondary and miliary tubercles rather few in number and cover sparsely the rest of plates, forming irregular row near the upper edge of plates, and forming a circle of somewhat irregular outlines around the primary tubercles; along median line there is a smooth space; angular pits on interambulacral plates very small, but distinct and the two pits usually connected by a shallow depression on suture lines at the ambital region and aborally. Primary tubercles on both ambulacra and interambulacra distinctly crenulate, the number of crenulation on the large primary tubercles seems to be constant, counting 14.

Present specimens can be safely identified with the Recent *Tem.* (*Tor.*) *reevesii* (GRAY, 1855), on account of their characters of the ambulacral pores, the small pits, and of the tuberculation. This species, in the Recent seas ranges from the Japanese seas (Tokyo Bay at the Pacific side and Obama Bay at the Japan Sea side) to the Philippines, and distributed over the Indo-West Pacific, from East Africa to the Malacca Strait, usually found in the main in the littoral waters, but rarely down to the depths of 565 metres.

Genus *Salmaciella* MORTENSEN, 1942

Salmaciella MORTENSEN, 1942, p. 226.—MORTENSNE, 1943, p. 138.—H. L. CLARK, 1946, p. 310.
Orthotype.—Salmacis dussumieri AGASSIZ in AGASSIZ and DESOR, 1846, p. 359 (55).

Primary ambulacral tubercles occurring fairly on every second plates on the aboral side; at the ambitus and below, however, they are found on all the plates, but on every second plate placed inwards, so the tubercles form here two longitudinal series; pore-zones narrow, the pore-pairs arranged in arcs of three. Test low, usually less than one-half the horizontal diameter, and the peristomial edge considerably sunken. Anal opening eccentric, pushed out towards the genital (1); the ocular (I) usually insert or nearly so.

This genus has a close affinity with the genus *Salmacis* AGASSIZ, 1841 (AGASSIZ, 1841-a, p. viii: Orthotype—*Salmacis bicolor* AGASSIZ, 1841-a, p. viii.—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, 20, text-fig. 67), to which the type-species was formerly referred by many authors. But it differs so much from that genus by having only a primary tubercle on every second ambulacral plate, low form of the test, and the deeply sunken peristome. It seems fairly certain that the arrangement of primary ambulacral tubercles on the adoral side, particularly on the proximal part of the ambulacra, of the large specimens of *Salmaciella* may strongly suggest the derivation of this genus from certain species of *Salmacis*, and it fairly fits in with the geological occurrence of both genera, e. g., *Salmacis* in the Miocene or Lower Pliocene and *Salmaciella* at least in the Pliocene Epoch.

Salmaciella cf. *dussumieri* (AGASSIZ, 1846)

Compared with:

Salmacis dussumieri AGASSIZ in AGASSIZ and DESOR, 1846, p. 359 (55).—A. AGASSIZ, 1872-74, p. 473, pl. 8b, figs. 7-8.—BELL, 1880-d, p. 429.—DUNCAN and SLADEN, 1888-a, p. 317.—DE

MEIJERE, 1904, p. 85.—MORTENSEN, 1904, p. 72, pl. 7, fig. 15.—H. L. CLARK, 1925, p· 85.—*Salmaciella dussumieri* (AGASSIZ) MORTENSEN, 1942, p. 226.—MORTENSEN, 1943, p. 139, pl. 8, fig. 9, pl. 9, fig. 7, pl. 10, fig. 3, pl. 11, figs. 8-13, pl. 46, figs. 8, 9, 19, 21-22, text-figs. 77-79, 48a.—H. L. CLARK, 1946, p. 311.—UTINOMI, 1954, p. 347.

Toreumatica concava GRAY, 1855. p. 39.

Salmacis lactea DÖDERLEIN, 1885, p. 99 (22).—DÖDERLEIN, 1903, p. 715, pl. 63, figs. 5-5c.—TOKUNAGA, 1906, pl. 8, figs. 13-16 (reproduced from DÖDERLEIN's, 1903).

Lytechinus okinawa COOKE, 1954, p. 46, pl. 9, figs. 3-5.

From COOKE's description and figures and the writer's observation on the paratype (USNM no. 561556), his *Lytechinus okinawa* from the Pliocene of Okinawa cannot be safely referred to the genus *Lytechinus* A. AGASSIZ, 1863 (A. AGASSIZ, 1863, p, 14. —Logotype—*Cidaris variegata* LESKE, 1778, p. 149, pl. 10, figs. B, C (partim). [VERRILL, 1867-71 (67), p. 302]), on the following reasons:

1. Primary tubercles crenulate—in *Lytechinus* they are smooth.
2. Gill-slits small and shallow—in *Lytechinus* they are sharp and deep as in the character of the family of the Toxopneustids.
3. Number of primary ambulacral tubercles are not so large as those of *Lytechinus* (in *Lyt. variegatus* (COOKE, 1959, pl. 2, fig. 12) 20 ambulacral primaries and 14 interambulacral primaries on the aboral side, while in COOKE's specimen 15 ambulacral primaries and 14 interambulacral primaries); moreover, in COOKE's specimen a primary tubercle occurs on every second plate as can be observed on the adapical part.
4. Small but distinct angular pits are observable on the coronal plates, and suture lines are fairly distinct as usual in the Temnopleurids.
5. The bare interambulacral space are not the characteristic feature only of *Lytechinus*, as it is also found in *Microcyphus*, *Salmaciella*, *Mespilia*, and in some species of *Salmacis* of the Temnopleurids; thus, the bare median space of interambulacra cannot be regarded as the only characteristic as the species having this character is found in the genus *Lytechinus*.
6. The low test and the conspicuously sunken peristomial edge are against the general feature of *Lytechinus*.

COOKE's specimen from the Pliocene of Okinawa, as a whole, has close affinities with the West Pacific Temnopleurids, but not with the East Pacific and Atlantic Lytechinids, as stated above. The features that characterized this Pliocene specimen, e. g., bare interambulacral space on the aboral side, primary ambulacral tubercles on the ambulacra, crenulated primary tubercles, angular pits on the coronal plates, small and shallow gill-slits, low test and conspicuously sunken peristomial region; all these features are confined to the Indo-west Pacific genus *Salmaciella*, almost certainly including *Sal. dussumieri* (AGASSIZ, 1846). It is however, found some degree of differences between the Recent specimens and this fossil specimen; i. e., the number of longitudinal series of primary tubercles on interambulacral column at the ambital region in the fossil specimen (ca. 45 mm in horizontal diameter) is four, whereas in the Recent specimen (30 mm in horizontal diameter at the writer's disposal, and 35 mm in horizontal diameter in the MCZ coll. no. 1475) it is three; but this difference would have to be regarded as the result of only the comparison of the sizes of specimens: in a specimen of 60 mm test-diameter (in the MCZ coll. no. 1474, from the

Philippines), 4 in a column adorally; and the small primary tubercles on the adoral side of this fossil specimen seem to be more developed than the proximal plates of the Recent specimens.

COOKE's fossil specimen from the Pliocene closely approaches in the specific characters to the Recent *Sal. dussumieri*, on the one hand, while on the other hand, it seems to retain some features that characterize the genus *Salmacis*, e. i., four longitudinal series of primary tubercles on interambulacral column at the ambitus (in that genus the interambulacral plates at the ambitus carry 4-9 subequal primary tubercles), and the arrangement of primary ambulacral tubercles on the adoral side. It is naturally assumed that the *Salmaciella* had been derived from certain form of *Salmacis* by specialization of ambulacral structure, particularly on the aboral side, by the reduction of the primary tubercles, and by lowing the test and increasing the depression of peristomial edge.

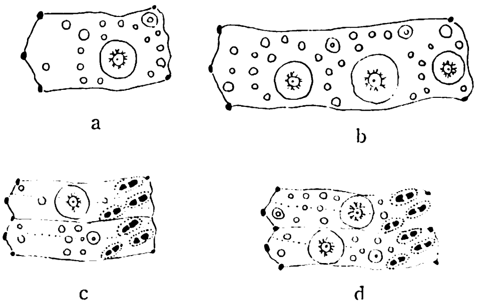


Fig. 9. *Salmaciella dussumieri* (AGASSIZ, 1846). (Recent specimen, from Amakusa Marine Biological Station, Kyushu; for comparison).

a. 5th interambulacral plate from the apical system, ×5; b. 10th interambulacral plate from the apical system, ×5; c. 11th and 12th ambulacral plates from the apical system, ×5; d. 17th and 18th ambulacral plates from the apical system, at the ambitus, ×5.

Sal. dussumieri (AGASSIZ, 1845) is distributed, in the present waters from Ceylon to Torres Strait, and as far north as to Tanabe Bay, Japan; depths about 10 to 180 metres.

Genus *Temnotrema* A. AGASSIZ, 1863

Temnotrema A. AGASSIZ, 1863-a, p. 358.—H. L. CLARK, 1912-b, p. 317.—DÖDERLEIN, 1914, p. 459.—H. L. CLARK, 1925, p. 89.—KOEHLER, 1927, p. 93.—NISIYAMA, 1936, p. 122.—MORTENSEN, 1943, p. 244, text-fig. 132.—H. L. CLARK, 1946, p. 312.—TERMIER and TERMIER, 1953, p. 907.

Haplotype.—Temnotrema sculpta A. AGASSIZ, 1863-a, p. 358 (Kagoshima Bay, Japan).—H. L. CLARK, 1912-b, p. 321, pl. 112, figs. 1-2.

Pleurechinus A. AGASSIZ, 1872-74, pp. 167, 464 (subgenus ad *Temnopleurus* AGASSIZ, 1841: non AGASSIZ, 1841).—A. AGASSIZ, 1881-a, p. 108.—DUNCAN, 1883-a, p. 447.-DUNCAN, 1889-a, p. 107.—DÖDERLEIN, 1903, p. 705.—MORTENSEN, 1904, p. 91.—MEISSNER, 1904, p. 1362.

Haplotype.—Temnopleurus bothryoides AGASSIZ and DESOR, 1846, p. 360 (Galapagos Island; in L'école de mines in Paris).—*Pleurechinus bothryoides* (AGASSIZ and DESOR) DÖDERLEIN, 1903, p. 705, pl. 61, figs. 1-2 (Thursday Ialand) (non *Pleurechinus bothryoides* (LESKE, 1778).—*Temnotrema decorum* DÖDERLEIN, 1914, p. 459).

Non *Pleurechinus* AGASSIZ, 1841, p. 7.—*Orthotype—Cidaris bothryoides* LESKE, 1778, p. 154 (from pl. 11, of KLEIN, 1734—probably from the Cretaceous of Germany). Nec *Pleurechinus* AGASSIZ, 1841-a, p. viii.—*Orthotype—Cidaris bothryoides* AGASSIZ, 1841-a, p. viii (probably a Recent species of *Microcyphus;* no longer in the STOKES collection).

Dicoptella LAMBERT and THIÉRY, 1911, p. 232.—LAMBERT and JEANNET, 1935, p. 31.—CURRIE, 1939, p. 225.

Orthotype.—Dicoptella agassizii LAMBERT and THIÉRY, 1911, p. 232.—*Pleurechinus bothryoides*

A. AGASSIZ, 1881-a, p. 108,(partim), pl. 10a, figs. 1-2 (Japan, off Kobe, 8-50 fathoms; non Agassiz, 1841). =*Temnotrema sculptum* A. AGASSIZ, 1863-a, p. 358.

Non *Temnotrema* POMEL, 1883, p. 87.—LAMBERT and JEANNET, 1935, p. 6.

Haplotype.—Temnopleurus hardwickii (GRAY) A. AGASSIZ, 1872-74, pp. 166, 460, pl. 8a, figs. 1-3 (Recent; Japan).

Test small, usually less than 20 mm in horizontal diameter, or very small, exceptionally of medium size, usually thick and strong; low hemispherical or almost globular. Podial pores in a straight or slightly undulating series, rarely with a tendency to a biserial arrangement, usually not widened at the peristomial region. Primary tubercles not, or only faintly, crenulate, often with the base more or less distinctly stellate, indented by depressions on the plates; secondary tubercles more or less developed, sometimes forming horizontal rows on the ambital plates, but generally smaller than the primaries. Horizontal interambulacral sutures with a deep pits at each end, of varying size, but in most species large and conspicuous. In the ambulacra a pit at the median end of the sutures well developed; the pits generally covered by a delicate membrane with a central hole. Apical system dicyclic; periproct with a distinct suranal plate, sometimes nearly or completely covered by the plate, the anal opening subcentral or pushed out to the posterior edge. Peristomial membrane naked; buccal plates small, but distinct, each with a buccal foot, otherwise naked, or with a few pedicellariae. Gill-slits very small. Spines short, rather robust, smooth, usually terminating in a small knob, or very slender, slightly serrate, terminating in a fine point. Globiferous pedicellariae with a lateral tooth on each side, or without lateral teeth; poison glands double. Tridentate pedicellariae only exceptionally found. Colour often very bright (after MORTENSEN, 1943).

From the Miocene to Recent.

The genus *Temnotrema* is clearly distinguished from *Temnopleurus* by its usually non-crenulate tubercles (though only slightly crenulate in some large specimens of *Tem. sculptum*), the uniform size of the spines, the uniform aspect of each sides of the test as to tuberculation, and the presence of membrane with a central hole, covering the pits. The beautiful and small-sized sea-urchins of this genus are confined in the geographical distribution to the Indo-Pacific regions, exceptionally in the Red Sea. Its occurrence in geological times dates back to the Miocene (Java and Burma), but the record of *Temnotrema* (as *Dicoptella*) from the Redonian stage (late Miocene) of Normandy is particularly noteworthy.

The history of this generic name was revised by the writer (NISIYAMA, 1936, pp. 122-124) and by MORTENSEN (1943, pp. 245-246), and there is no need of repetition here.

Among the three groups distinguished in this genus, as suggested by authors (MORTENSEN, 1904, p. 91.—NISIYAMA, 1936, p. 127), the third group, which comprises only one particular form (*Tem. doederleini* MORTENSEN, 1904) is separated from the *Temnotrema* as a distinct genus, *Paratrema*, by KOEHLER (1927, p. 90), it is characterized by having only five buccal plates and five tube-feet in the buccal membrane, and lacking anal plate. The other two groups are closely related each other in possession of ten buccal plates and ten tube-feet in the buccal membrane, and in a more or less distinct anal plate; but the groups differ from each other only in the feature of the pits; e. g., the first group comprises those forms characterized by having smaller pits; the pits are separated from the neighbouring by a distance longer than themselves and bordered by an indistinct membrane, viz. *Tem. sculptum* and *Tem. rubrum.* The second group comprises those forms with larger pits, which are longer than the distance between the two of them, and bordered by a distinct membrane with a central hole. It seems, however, unnecessary to make these two groups two different genera; here the writer prefers to leave them all in the genus *Temnotrema.*

The two living species of this genus were known to the specialists of Japan, e. g., the common and rather widely distributed species, *Tem. sculptum*, and the a rare species, *Tem. rubrum;* they are discriminated from each other by the following key:

1. Pores small; ambulacral plates usually as high as the interambulacral ones, their number being the same. Secondary tubercles not so distinct. Test gray in colour; the spines reddish at the base, mostly with a small dark band in the outer part. The outer part of the genital plates separated from the inner

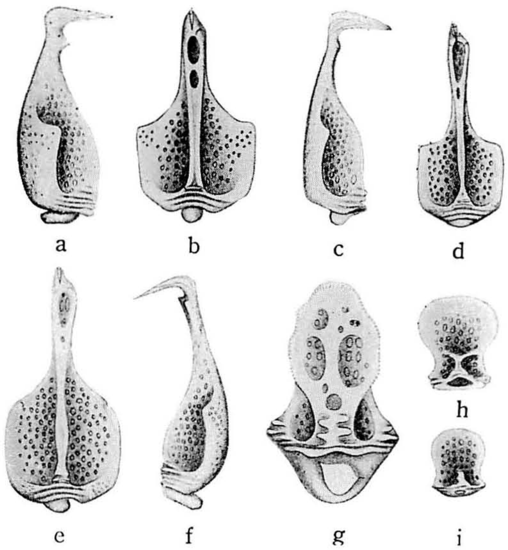


Fig. 10. Pedicellariae of the genus *Temnotrema* (after MORTENSEN, 1904) (magnified).

a–b. *Temnotrema rubrum* (DÖDERLEIN, 1885).
c–d, h. *Temnotrema maculatum* (MORTENSEN, 1904).
e–g, i. *Temnotrema siamense* (MORTENSEN, 1904).

a. Valve of globiferous pedicellaria. Side view.
b. „ „ „ . Front view.
c. „ „ „ . Side view.
d. „ „ „ . Front view.
e. „ „ „ . Front view.
f. „ „ „ . Side view.
g. „ of ophicephalous pedicellaria. Front view.
h. „ of triphyllous pedicellaria. Front view.
i. „ „ „ . Front view.

part by a sinuous line.............................. *Temnotrema sculptum*

2. Pores rather large; ambulacral plates rarely lower than the interambulacral ones. Secondary tubercles rather distinct. Test red in colour; the spines red with white bands. Ocular pore concealed by a knob........ *Temnotrema rubrum*

MORTENSEN (1904, p. 86) suggested that there may be two more species of *Temnotrema* in the Japanese seas. The one resembles *sculptum*, but differs in having larger pits and fewer tubercles than the latter; the other is closely related to *rubrum*, but differs from it in having distinct white patches on the adapical portion of interambulacra and on both ambulacra and interambulacra at the ambital region. Unfortunately, they lack the apical system, and the writer cannot decide the specific validity of these specimens.

There are two species of this genus occurred as fossil in Japan; they are described in the following lines.

Temnotrema sculptum A. AGASSIZ, 1863

(Text-figs. 10-14)

Temnotrema sculpta A. AGASSIZ, 1863-a, p. 358.—H. L. CLARK, 1912-b, p. 321, pl. 112, figs. 1-2.—*Temnotrema sculptum* A. AGASSIZ: H. L. CLARK, 1925, p. 92.—MORTENSEN, 1929, p. 474.—NISIYAMA, 1936, p. 121, pl. 11, figs. 10-16.—NISIYAMA, 1937, p. 53.—H. L. CLARK, 1938-a, p. 388, pl. 26, fig. 6 (Japan).—MORTENSEN, 1943, p. 249, pl. 19, figs. 1-2, pl. 45, figs. 1-3, 15, text-figs. 133a-b, 134, 135a.—UTINOMI, 1954, p. 347.—COOKE, 1954, p. 46, pl. 9, figs. 2 (?).

Temnopleurus hardwickii SLADEN, 1879, p. 436 (non GRAY, 1855).

Pleurechinus bothryoides A. AGASSIZ, 1881-a, p. 108 (partim), pl. 10a, figs. 1-2 (non AGASSIZ, 1841, nec 1846).—TOKUNAGA, 1906, pl. 8, figs. 11-12.

Pleurechinus variabilis DÖDERLEIN, 1903, p. 706 (partim), pl. 61, figs. 5a-b.

Pleurechinus variegatus MORTENSEN, 1904, p. 84, pl. 1, figs. 5-6, 8, 19, pl. 2, fig. 6.—A. AGASSIZ and H. L. CLARK, 1907-b, p. 125.

Dicoptella agassizii LAMBERT and THIÉRY, 1911, p. 233.

Non *Temnotrema sculpta* H. L. CLARK, 1921, p. 150, pl. 17, fig. 5 (=*Tem. siamense* (MORTENSEN, 1904)).

Non *Dicoptella agassizii* LAMBERT and JEANNET, 1935, p. 34, pl. 1, figs. 55-59, pl. 2, figs. 1-6, pl. 4. figs. 3-5, 7, text-figs. 27-39 (=*Tem. maculatum* (MORTENSEN, 1904)).

Locality and geological horizon.—IGPS loc. no. Ch—1.—Roadside cutting west of 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. 58340-A.

A fragmentary specimen at the writer's disposal, which is referred to this species.

Description of this species, including the Recent forms, is as follows.

Dimensions;

Horizontal diameter	5 mm	10 mm	11 mm	12 mm	13 mm	15 mm
Height	3″	6″	7″	7″	8″	10″
Apical system	1.6″	2.5″	3″	3.5″	3.5″	4″
Peristome	2″	4″	5″	5″	5.5″	6.5″
Number of ambulacral plates	8	14	14	15	16	18
Number of interambulacral plates	8	14	14	15	16	18

Test low, about 0.6 of horizontal diameter, beautifully rounded above, a little curved inwardly at the peristome. Pits (in both areas) small, not reaching to the base of primary tubercles, leaving thus a rather large part of horizontal suture not depressed; a faint covering membrane seen around the edge of pits. Primary tubercles (of both areas) form a distinct longitudinal series in a column, diminishing very little in size towards the apical system and the peristome; they are almost equally there in both areas; in larger specimens, tubercles rather crenulate, and there may be indication of a stellate structure at their base. Secondary tubercles rather numerous, in larger specimens very crowded, forming more or less distinct vertical and horizontal series; in the ambulacra inside the primary series there is a vertical series of secondary tubercles, which may be slightly smaller than the pri-

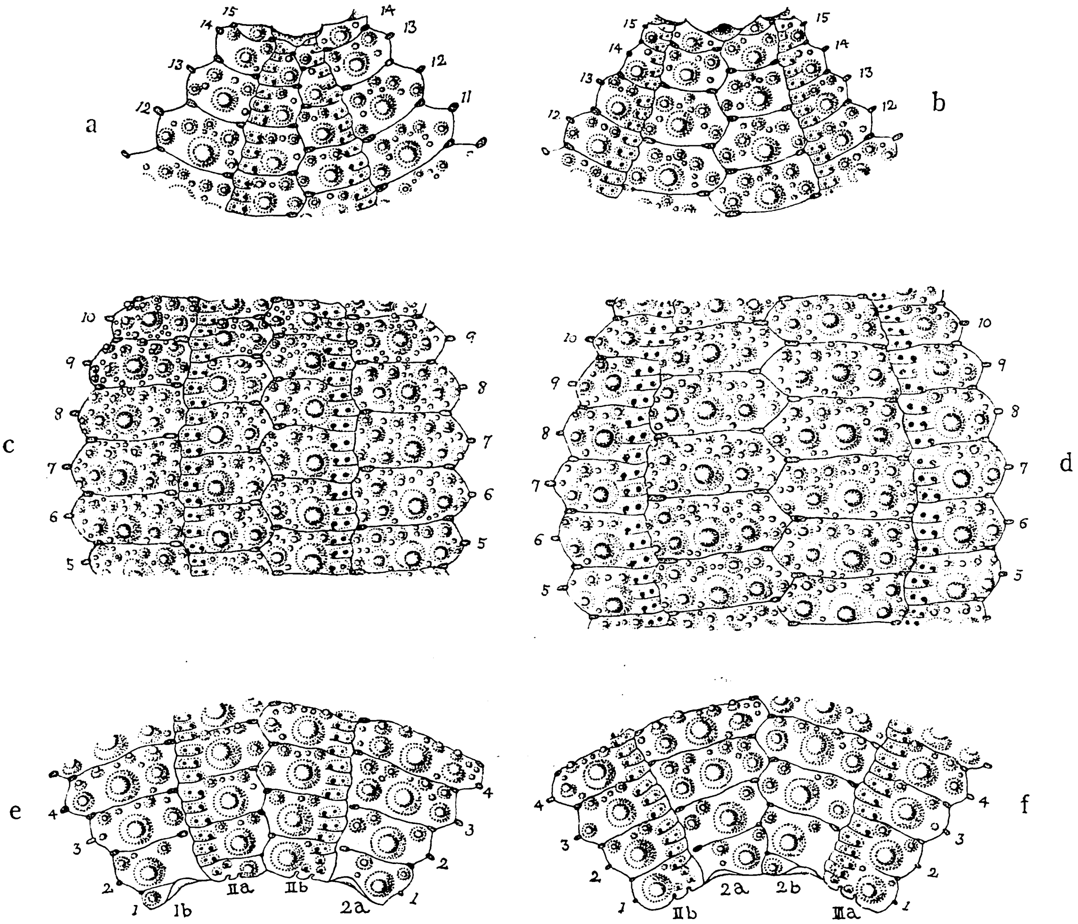


Fig. 11. *Temnotrema sculptum* A. Agassiz, 1863, 12 mm in test-diameter. ×8. Numerals on the figures indicate the ordinal number of plate from the peristome. a. An ambulacrum and two of half interambulacra on the adapical region; b. An interambulacra and two of half ambulacra on the adapical region; c. An ambulacrum and two of half interambulacra at the mid-zone; d. An interambulacrum and two of half ambulacra at the mid-zone; e. An ambulacrum and two of half interambulacra at the peristomial region; f. An interambulacrum and two of half ambulacra at the peristomial region.

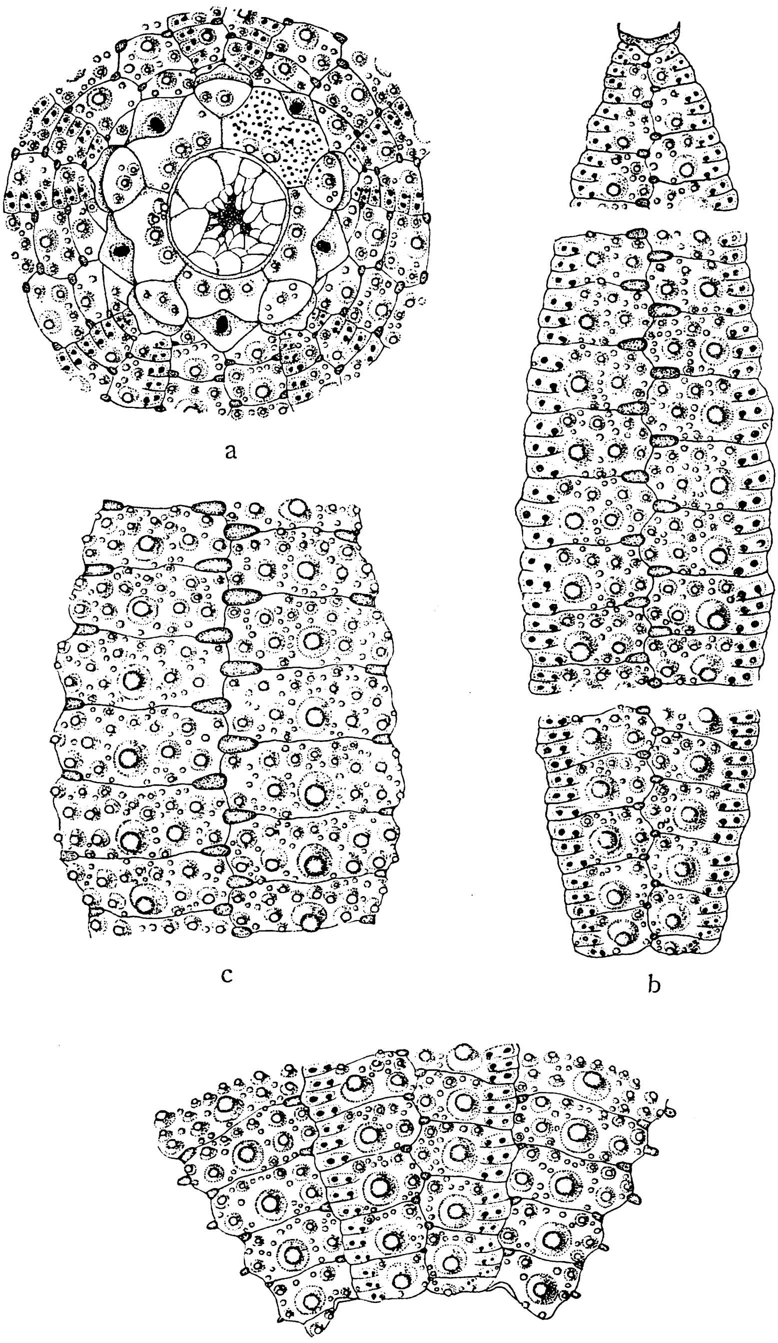


Fig. 12. *Temnotrema sculptum* A. AGASSIZ, 1863, 15 mm in test-diameter. ×8.
a. Apical system; b. View of ambulacrum (III); c. An interambulacrum at the mid-zone; d. An ambulacrum and two of half interambulacra at the peristomial region.

maries; in the interambulacra inside and outside the primary series there are two vertical series of secondary tubercles at the ambital region. Pores small, disposed in a very nearly vertical series, close to the edge of the area (only at the ambitus a little distant from the edge in the large specimens), no tubercles being found outside the pores. Poriferous zone rather narrow, less than one-fourth as broad as the interporiferous area. Ambulacral plates as high as the interambulacral ones, their number being the same. Small pits at outer edge of area become sometimes very indistinct. Genital plates show peculiar feature of outer part with genital pores being separated from the inner part by a distinct, mostly curved line, so that it seems as if the

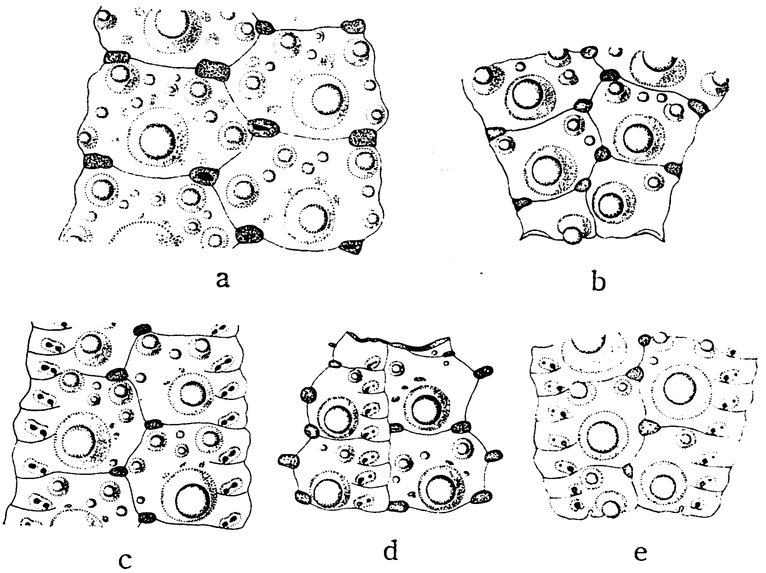


Fig. 13. View of *Temnotrema sculptum* A. Agassiz, 1863, in 5 mm test-diameter. ×25.

a. A part of interambulacrum at the mid-zone.
b. A part of interambulacrum at the peristomial region.
c. A part of ambulacrum at the mid-zone.
d. A part of half of ambulacrum and interambulacrum at the adapical region.
e. A part of ambulacrum at the peristomal region.

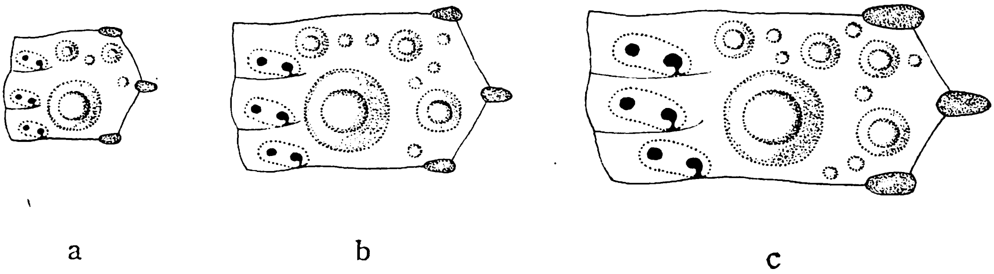


Fig. 14. *Temnotrema sculptum* A. Agassiz, 1863. View of an ambulacral plate at the mid-zone. ×20.

a. 5 mm in test-diameter; b. 10.5 mm in test-diameter; c. 15 mm in test-diameter.

plate were divided into two parts; sometimes the transverse line on all the plates obscured by tubercles, but often; on the madreporite it is never distinct; outer part of genital plates mostly darker coloured than the inner part; a circle of tubercles along the inner edge; genital opening placed near the outer edge; ocular pore placed on the outer edge of rather thick ocular plate and cannot be seen from the above; part of plate outside the pore white and looks like a small distinct plate; depression between ocular and genital plates small and indistinct.

Buccal membrane contains rather many bihamate spicules; plates along the oral edge may be rather numerous; buccal tube-feet sometimes placed one outside the other. Spines short, usually less than one-third of horizontal diameter of test, smooth, not thickened at the point; oral spines not widened or curved.

Valves of globiferous pedicellariae without lateral teeth, only a rounded knob on one side below the end-tooth; blade very short, basal part with sharp outer corners, not produced. Colour of test, shown by the living specimens, gray or grayish yellow, with some white spots; pore-areas white. Spines faintly greenish, or whitish with a faint red tint at the base, and a darker band in the outer part.

Temnotrema sculptum A. AGASSIZ, 1863, is evidently related to *Tem. rubrum* (DÖDERLEIN, 1885) in having much smaller pits than the other species of the genus *Temnotrema*, but the two species are easily distinguished from each other, as is evident from the above description, namely, in the feature of the apical system and in the colouration of the test. This species has also some resemblance to *Tem. siamense* (MORTENSEN, 1904) (*Pleurechinus siamensis* MORTENSEN, 1904, p. 79, pl. 1, figs. 2, 7, 11, 20, pl. 2, figs. 2, 9, 14-15, 22, pl. 6, figs. 16, 36, pl. 7, figs. 14, 44, 53, text-fig. 8) with respect to habits; this species, however, is easily distinguished from the latter by the small pits, the numerous tubercles, and not thickened spines, the impression on the genital plates, besides the form of pedicellariae.

In the COOKE'S specimens from the Pliocene of Okinawa, which he reported as *Tem. sculptum*, by the writer's observation on a specimen from USGS 17476 (USNM no. 561555), the pits are larger contrasting to its test-diameter than in the living specimens of *Tem. sculptum*, and its identification with the named species is not precise and uncertain to the writer; it stimulates *Tem. maculatum* (MORTENSEN, 1904) (Fig. 15) in respects.

Temnotrema sculptum A. AGASSIZ, 1863, is a Japanese species ranges from Northern Japan (Mutsu Bay at the north) to the Formosan Channel in the south, but does not occur south of Formosa; mainly in shallow seas, but rarely met with in the depth down to 500 metres.

Temnotrema rubrum (DÖDERLEIN, 1885)

(Text-fig. 16)

Pleurechinus ruber DÖDERLEIN, 1885, p. 92 (20).—DÖDERLEIN, 1903, p. 706 (partim), pl. 91, figs. 3-3b (non figs. 5a-b).—MORTENSEN, 1904, p. 84, pl. 6, fig. 28, pl. 7, fig. 6.—TOKUNAGA, 1906, pl. 8, figs. 8-9, 10 (reproduced from DÖDERLEIN, 1903).

Temnotrema ruber (DÖDERLEIN) H. L. CLARK, 1912-b, p. 319 (nominal).—*Temnotrema rubrum* (DÖDERLEIN) NISIYAMA, 1936, p. 125, pl. 11, figs. 1-9.—NISIYAMA, 1937, p. 54—MORTENSEN, 1943, p. 252, pl. 19, fig. 12, text-figs. 133c-d, 135b.

Arbacina rubra (DÖDERLEIN) LAMBERT and JEANNET, 1935, p. 6 (nominal).

Locality and geological horizon.—IGPS loc. no. Kn—12.—North side of Kagetsu-en, Tsurumi Ward, Yokohama City, Kanagawa Prefecture. (tm Yokohama, Lat. 35°30′N., Long. 139°40′04″E.). Tokyo formation, Pleistocene. *Hypotype.*—IGPS coll. cat. no. 58340.

The fossil of this species has been described by the writer (NISIYAMA, 1936). A distinction between this species and *Tem. sculptum* by the presence and absence of a transverse line in the genital plates made by the former authors, such as DÖDERLEIN and MORTENSEN, does not seem to be so sharp as hitherto considered, In the large specimen (ca. 20 mm in horizontal diameter) of this species at the writer's disposal the genital plates are separated, though less distinctly, by a sinuous line into the inner and outer parts as in *sculptum*. The ocular plates, however, showing peculiar feature of the pore is completely concealed by a prominent knob of white colour, and the part of plate outside the knob looks like a small, quite distinct plate. The angular pits in this specimen are more or less bevelled as in *Temnopleurus hardwickii*, though not so sharp as in *sculptum*. The ambulacral plates are evidently lower than the interambulacral plates in this specimen.

Temnotrema rubrum (DÖDERLEIN, 1885) is restricted in its distribution to the Central Japan (Tokyo Bay and Ubara in Bôsô Peninsula) and is known only from small depths (5-35 metres).

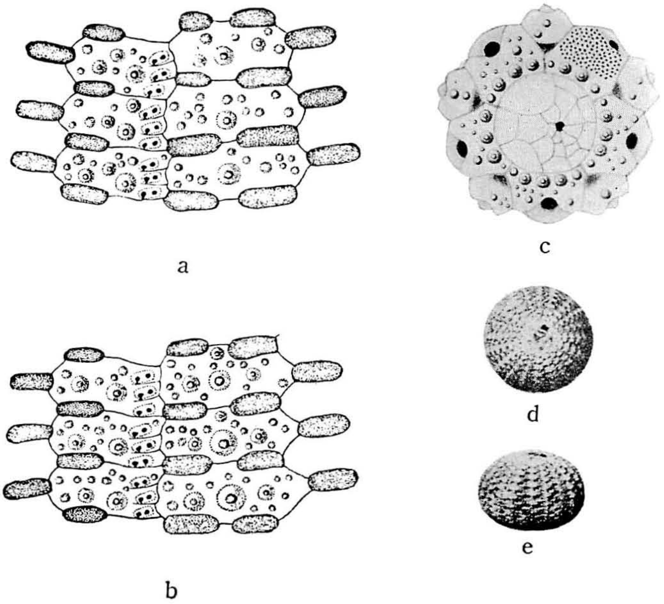


Fig. 15. *Temnotrema maculatum* (MORTENSEN, 1904) (for comparison).

a. Ambulacral and interambulacral plates on the aboral side. ×6 (after JEANNET, 1935).

b. Ambulacral and interambulacral plates at the mid-zone. ×6 (after JEANNET, 1935).

c. Apical system. ×5 (after MORTENSEN, 1904).

d. Aboral view. ×0.8 (after MORTENSEN, 1904).

e. Side view. ×0.8 (after MORTENSEN, 1904).

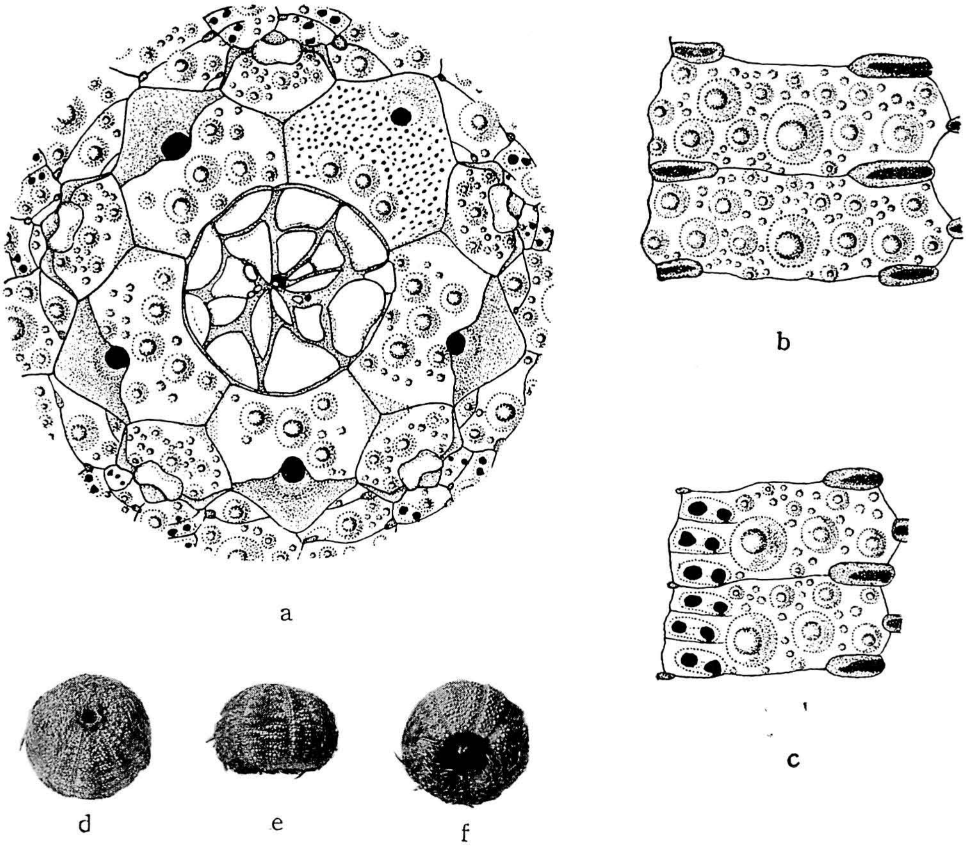


Fig. 16. *Temnotrema rubrum* (Döderlein, 1885). (Recent specimen, from Ubara Bay, Chiba Prefecture, in 5 metres; for comparison).

a. Apical system, ×10; b. Two interambulacral plates at the mid-zone, ×10; c. Two ambulacral plates at the mid-zone, ×10; d. Aboral view of holotype, ×1 (after Döderlein, 1903); e. Side view of the same, ×1; f. Adoral view of the same, ×1.

Genus *Mespilia* Desor, 1846

Mespilia Desor in Agassiz and Desor, 1846, p. 357.—Desor, 1855–57 (56), p. 110.—A. Agassiz, 1872–74, pp. 142, 477.—Duncan, 1888, p. 113.—Duncan, 1889-a, p. 110.—Meissner, 1904, p. 1364.—Lambert and Thiéry, 1911, p. 236.—H. L. Clark, 1912-b, p. 322.—H. L. Clark, 1925, p. 93.—Mortensen, 1943, p. 176.—H. L. Clark, 1946, p. 314.

Haplotype.—*Echinus globulus* Linnaeus, 1758, p. 664.—*Mespilia globulus* (Linnaeus) A. Agassiz, 1872–74, pp. 143, 477, pl. 6, fig. 1, pl. 8a, figs. 13–14, pl. 8c, fig. 14, pl. 38, figs. 22, 22a–c (Indo-Pacific regions, Recent).

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 spines and tubercles; the naked part of a peculiar porous-radiating structure. Trigeminate ambulacral plates of the echinoid structure, all with a primary tubercle; the tubercles are non-crenulate; pore-pairs distinctly biserial, pores of the inner series twice as numerous as those of the outer series. Gill-slits quite obsolete. Valves of small globiferous pedicellariae with the flattened and widened blade.

No recorded as fossils.

In possessing the test with very small pits and a distinctly limited naked area in the midline, this genus has resemblance to the genus *Microcyphus* AGASSIZ, 1841, as to the habits, but this genus is easily distinguished from the latter by distinctly biserial arrangement of the pore-pairs and much more numerous coronal plates. From the genus *Amblypneustes* AGASSIZ, 1841, this genus differs in having the median space of aboral interambulacral areas is more or less extensively bare and free from spines and tubercles.

This genus contains a well known and very diversified species, *M. globulus* (LINNAEUS, 1758) (with some varieties), and a doubtful species (or subspecies of that species), but there has been no record of occurrence as fossils from anywhere.

The very characteristic structure of the naked part of the coronal plates, i. e., a peculiar porous-radiating structure, was noticed first by MORTENSEN (1943, p. 177). This seems to be a peculiar feature among the test-structure of the Echinoids.

There are fragmentary specimens of a species of this genus in our collection, derived from the 'Raised Beach deposits' of Central Japan. They are not regarded as fossil in a strict sense, but for convenience's sake they are described herein.

Mespilia globulus (LINNAEUS, 1758)

(Pl. 6, fig. 1)

Mespilia globulus (LINNAEUS) AGASSIZ and DESOR, 1846, p. 358, pl. 15, figs. 17-17a.—A. AGASSIZ, 1872-74, pp. 143, 477, pl. 6, fig. 1, pl. 8a, figs. 13-14, pl. 8c, fig. 14, pl. 38, figs. 22, 22a-c.—BELL, 1880-d, p. 434.—BELL, 1881-b, p. 433.—MACKINTOSH, 1883, p. 255, pl. fig. 31.—DÖDERLEIN, 1885, p. 95 (24).—DE MEIJERE, 1904, p. 87.—MORTENSEN, 1904, p. 96, pl. 6, fig. 17, pl. 7, figs. 16, 22, 23, 47.—TOKUNAGA, 1906, pl. 8, figs. 17-19.—H. L. CLARK, 1912-b, p. 322.—H. L. CLARK, 1925, p. 93.—KOEHLER, 1927, p. 88.-ROXAS, 1928, p. 256, pl. 2, figs. 7-9.—IKEDA, 1935, p. 422.—MORTENSEN, 1943, p. 177, pl. 12, figs. 1-17, pl. 21. fig. 19, pl. 45, figs. 9, 18, 20, 32, text-figs. 47c, 48c, 96, 97a-b, 98a-b, 99, 100-102.—H. L. CLARK, 1946, p. 315.—UTINOMI, 1954, p. 347.

Mespilia levituberculatus YOSHIWARA, 1898, p. 58.—TOKUNAGA, 1906, pl. 8, figs. 20-23.

Salmacopsis pulchellimus YOSHIWARA, 1898, p. 59.

Locality and geological horizon.—IGPS loc. no. Ch—27.—Small cliff of the River Heguri at Kuwabara, Hôjô-machi, Tateyama City, Chiba Prefecture. (tm Nago, Lat. 35°0′23″N., Lat.139°53′08″E.). Raised Beach deposits, early Holocene. *Hypotype.*—IGPS coll. cat. no. 78305.

There are several fragmentary specimen referred to this species at hand, the largest one consists of one ambulacra and one and a half interambulacral areas.

Ambulacra broad, as broad as, or more or less narrower than, the interambulacra, 7 mm wide at the ambitus; ambulacral plates low and broad, 3.5 mm wide and about 1 mm high at the ambitus, composed of three components, a middle demi-plate component and aboral and adoral primary components; pore-pair of middle demi-plate component placed outside as broad as the distance of pores of a pair, and pore-pairs of aboral and adoral primary components arranged in a single series, as pore-pair of adoral primary just superposed on pore-pair of aboral primary of the successive lower plate; thus, pore-pairs distinctly arranged in double series, the pores of the inner series (of adoral and aboral primary components) twice as numerous as the pores of the outer series (of middle demi-plate component). The primary tubercles not conspicuous, placed more or less adorally than center and closely to poriferous zone; they form a longitudinal series throughout the column; large secondary tubercles, which are as large as, or slightly smaller than, the primaries, placed inside the primary series, and forming a longitudinal series at some distance below and above the ambital region. Small secondary tubercles also form a longitudinal series inside (or the innermost of the plates) of large secondary series at the ambitus. Outside the pore-pair of aboral primary component of each plate there are two secondary tubercles at the ambitus, the larger (the inner) seems to continue throughout the column. Other secondary tubercles of three or four form a row and placed near the aboral suture of a plate at the ambitus; other small secondary and miliary tubercles few in number and sparsely cover the rest of plates.

Interambulacra rather narrow, about 8 mm wide at the ambital region, scarcely broader than the ambulacra; interambulacral plates low and broad, about 4 mm wide and 1.5 mm high at the ambitus, slightly wider and more or less higher than the ambulacral plates. Median aboral interambulacral areas more or less extensively bare and free from tubercles. Primary tubercles not prominent, each placed slightly eccentric and adorally on a plate, and they form a longitudinal series throughout the column; large secondary tubercles, which are as large as, or slightly smaller than, the primaries, form four longitudinal series at the ambital region, two inside and the other two outside the primary series. Small secondary tubercles of five or six form an irregular row near the aboral suture of a plate at the ambitus. Other small secondary and miliary tubercles rather few in number and cover sparsely the rest of plates. Angular pits on both ambulacral and interambulacral plates very small, not elongate, but rather distinct, become obsolete adorally; outer pits also small and indistinct. Apical system and peristome not preserved.

Present specimens can be safely identified with the living *Mes. globulus* (LINNAEUS, 1758), on account of their characters of the naked median space of the interambulacral areas, the arrangement of pore-pairs, and of the tuberculation. This species ranges from the Central Japan (as far north as Bôsô Peninsula) to sruthward over the Malayan waters: found usually in the littoral water, but rarely in the depth down to 60 metres.

Genus *Erbechinus* JEANNET, 1935

Erbechinus JEANNET, 1935, p. 558.—JEANNET in LAMBERT and JEANNET, 1935, p. 16.—MORTENSEN, 1943, p. 313.—TERMIER and TERMIER, 1953, p. 907.

Orthotype.—Erbechinus erbi JEANNET, 1935, p. 558.—JEANNET in LAMBERT and JEANNET, 1935, p. 16, text-figs. 1-2, pl. 1, figs. 23-28, pl. 3, figs. 1-2 (Pliocene of Madioen, Java).

Test of moderate size, low, subconical, more or less flattened on the oral side. Pore-pairs arranged in slightly arcuate form, corresponding to each primary ambulacral tubercle, not widened near the peristomial edge. Many distinct depressions in the horizontal sutures, usually none on the plates. Larger interambulacral tubercles form horizontal row on the oral side; they are finely, but distinctly crenulate. Following characters are obtained by the observations on the living species.—Apical system dicyclic; anal opening central; no suranal plate. Peristomial membrane naked; gill-slits very small. Spines short, simple. Globiferous pedicellariae characterized by having rather large lateral prominences, which are not pointed like the usual lateral teeth; poison glands double (from MORTENSEN, 1943).

This genus has close affinity with the genus *Opechinus* DESOR, 1856 (DESOR, 1855-57 (56), p. 107.—Logotype—*Temnopleurus costatus* D'ARCHIAC and HAIME, 1853-54 (53), p. 204, pl. 13, fig. 9. [POMEL, 1833, p. 85]), in the distinct depressions in the horizontal sutures and in the double poison glands of the pedicellariae. This genus, however, differs from the latter in the strong development of the tubercles of the oral side, forming horizontal series, and in the characteristic low, subconical shape of the test, whereas the crenulation of tubercles, which is regarded by JEANNET (JEANNET in LAMBERT and JEANNET, 1935, p. 15) as the main character of this genus, is not really distinctive, as the crenulated tubercles occur also in *Op. variabilis* (DÖDERLEIN, 1885) (*Pleurechinus variabilis* DÖDERLEIN, 1885, p. 90.—DÖDERLEIN, 1903,

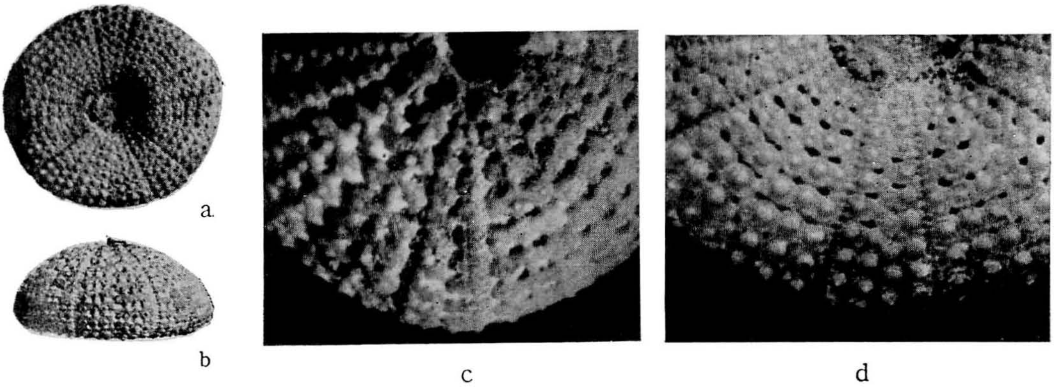


Fig. 17. *Erbechinus erbi* JEANNET, 1935 (for comparison). (Pliocene of Madioen, Java; after JEANNET, 1935).

a. Adoral view of holotype, ×1; b. Side view of the same, ×1. c. A part of the aboral side, ×2.75; d. A part of the adoral side, ×2.75.

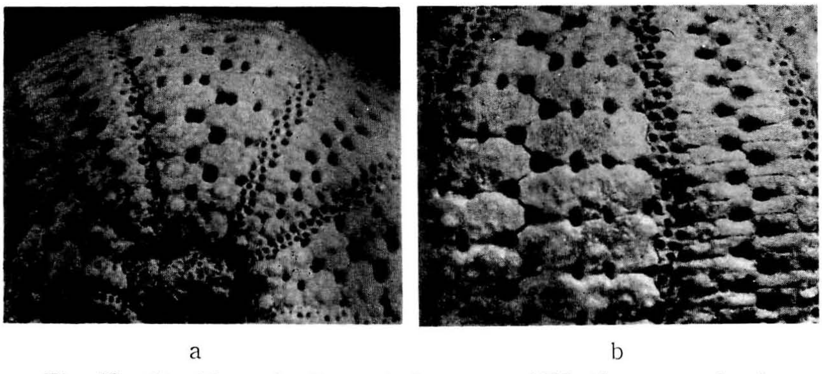


Fig. 18. *Opechinus cheribonensis* JEANNET, 1935 (for comparison). (Miocene of Java; after JEANNET, 1935).

a. A part of the aboral side. ×3; b. A part of the mid-zone, ×3.

p. 806, pl. 61, figs. 4-4b), a Recent species in the Japanese seas.

Erbechinus is confined in its geographical and geological distributions to the Indo-West Pacific regions, and it contains small number of species. This is the first record of occurrence as fossil from Japan: description follows.

Erbechinus gratus NISIYAMA, n. sp.

(Pl. 5, figs. 5-8)

Holotype.—IGPS coll. cat. no. 73720.

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, probably Miocene. R. TAYAMA and H. NIINO.

Holotype deformed laterally, but the details of structure rather well preserved. Dimensions are: about 18 mm in horizontal diameter, and nearly 11 mm in height.

Test rather low, aboral side somewhat conical, adoral side nearly flat or more or less concave orally. Apical system lacking, peristome rather large, gill-slits small and very shallow. Primary tubercles crenulate, of about equal size in both areas, diminishing a little in size towards the apical system.

Ambulacra narrow, about 4 mm wide at the ambitus, a little over a half the interambulacra. Ambulacral plates rather low, about 1 mm high and 2 mm wide at the ambitus, a little lower than the interambulacral plates; they number 19 against 16-17 interambulacral plates in each column; poriferous zone narrow, slightly sunken; pairs of pores in triplets, pore-pair of a middle component only slightly produced outside of two pore-pairs of aboral and adoral primary components, thus in almost simple succession; primary tubercles large, forming a vertical series on each side of interporiferous area near the poriferous zone; large secondary tubercles, which are as large as, or more or less smaller than, the primaries, form a distinct vertical series inside the primary series; small tubercles scattered irregularly on the plates inside and above the primary and large secondary tubercles, numbering three to four above and two inside the larger tubercles at the ambitus; along median line there is a smooth space; besides depression at median end of suture another depression opposite to space between the primary and large secondary tubercles, and this depression appears at about 4th plate from the apical system.

Interambulacra broad, 7 mm wide at the ambitus, less than twice as broad as the ambulacra. Interambulacral plates rather high, about 2.5 mm high and 3.5 mm wide at the ambitus; primary tubercles rather large, but not prominent, placed near the center of plates and forming a vertical series; large secondary tubercles, which are as large as, or slightly smaller than, the primaries, form at the ambitus two vertical series inside and one outside the primary series, the innermost one are much smaller than the primaries; below the ambitus the innermost series first disappear, the two other series being distinct almost to the peristomial region; the innermost series appears only aborally at 6th plate from the apical system; all these tubercles form an horizontal row on each plate near the ambital region to adoral surface; small tubercles cover the rest of plates, forming an irregular circle around each larger tubercles of the primary or large secondary tubercle; median line naked: no less than five depressions in each horizontal suture at the ambitus, two angular and three intermediate; the largest on each side of primary tubercles; outside the large depressions there is only one, angular depression; inside the large ones there are one each of intermediate and angular depressions; towards the apical system the depressions nearest angular ones gradually disappear, uniting with angular ones; below the ambitus all intermediate depressions become smaller, whereas the angular ones can be traced almost to the peristomial region. Spines and pedicellariae not accessible.

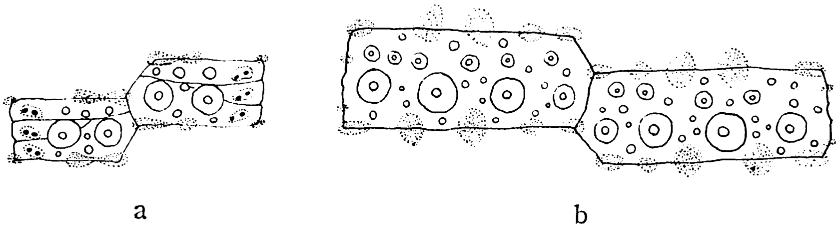


Fig. 19. *Erbechinus gratus* NISIYAMA.

a. Two ambulacral plates at the mid-zone, x3.
b. Two interambulacral plates at the mid-zone, x3.

Distinction.—This new species resembles *Erb. spectabilis* (MORTENSEN, 1904) (*Opechinus spectabilis* MORTENSEN, 1904, p. 94, pl. 1, fig. 15.—*Erb. spectabilis* (MORTENSEN) MORTENSEN, 1943, p. 314, pl. 20, figs. 20-25, text-figs. 176-178), a Recent species from near the Kei Islands, but is distinguished from it by the number of depressions on each horizontal suture in interambulacra above the ambitus, and by the distinct intermediate depressions on the oral surface. This species also resembles the type-species, *Er. erbi* JEANNET, 1935 (op. cit.), from the Pliocene of Java, but is distinguished from it by the arrangement of tubercles in the interambulacra. *Erb. gratus* is also superficially related to *Opechinus rousseaui* (D'ARCHIAC and HAIME, 1853) (*Temnopleurus rousseaui* D'ARCHIAC and HAIME, 1953-54 (53), p. 205, pl. 13, fig. 10.—*Opechinus rousseaui* (D'ARCHIAC HAIME): DUNCAN and SLADEN, 1883, p. 84, pl. 1, figs. 7-11), a Miocene species of Western India, but is easily distinguished from that species by the tuberculation on the coronal plates and number and form of depressions in the horizontal sutures in the ambulacra.

Subfamily TRIGONOCIDARINAE MORTENSEN, 1903

Trigonocidarinae MORTENSEN, 1903-b, p. 80.—DELAGE and HÉROUARD, 1903, p. 240.—CLARK, 1912-b, p. 293.—H. L. CLARK, 1925, p. 75.—MORTENSEN, 1943, p. 278.

Temnechinae LAMBERT, 1900, table (pro parte).—*Temnechininae* LAMBERT: MORTENSEN, 1904, pp. 112, 113.—*Temnechinae* LAMBERT: LAMBERT and THIÉRY, 1911, p. 231.

Type-genus.—*Trigonocidaris* A. AGASSIZ, 1869

Test with generally a conspicuous sculpture or depressions in the horizontal sutures, but no angular pits or pores. Coronal plates (apparently) not united by dowelling. Glands of globiferous pedicellariae single.

This subfamily contains mostly deep-water forms and usually of small size (usually under 20 mm in diameter), and is not very common in Japan and the ad-

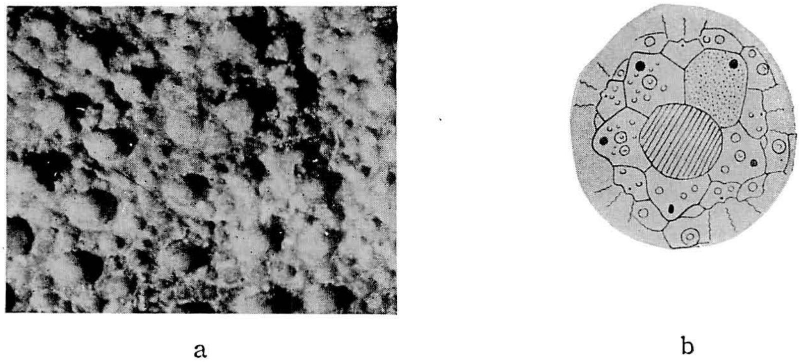

a b

Fig. 20. *Javanechinus erbi* JEANNET, 1935 (for comparison). (Miocene of Java and Madura Islands).

a. A part of the adoral side, ×8.5 (after JEANNET, 1935).
b. Apical system (all oculars excluded from the periproct) (after JEANNET and R. MARTIN, 1937).

jacent regions, but is represented by the following genera, viz., *Prionechinus* A. AGASSIZ, 1879, *Brochopleurus* FOURTAU, 1920, *Desmechinus* H. L. CLARK, 1923, *Printechinus* KOEHLER, 1927, and *Lamprechinus* DÖDERLEIN, 1905.

There is a species of the genus *Brochopleurus* in our collection.

Genus *Brochopleurus* FOURTAU, 1920

Brochopleurus FOURTAU, 1920, p. 25.—LAMBERT and THIÉRY, 1925, p. 570.—MORTENSEN, 1943, p. 354.—TERMIER and TERMIER, 1953, p. 908.—COOKE, 1959, p. 18.

Orthotype.—Temnechinus stellulatus DUNCAN and SLADEN, 1885-a, p. 304, pl. 47, figs. 8-9 (Miocene of Western India).

Javanechinus JEANNET in LAMBERT and JEANNET, 1935, p. 49.—JEANNET and MARTIN, 1937, p. 235.

Orthotype.—Javanechinus rembangensis JEANNET in LAMBERT and JEANNET, 1935, p. 50, text-figs. 66-68, pl. 2, figs. 35-37, pl. 4, figs. 17-18 (Lower Miocene; Rembang, Java).

Graphipleurus H. L. CLARK, 1945, p. 315.

Orthotype.—Graphipleurus granularis H. L. CLARK, 1945, p. 315, pl. 41, figs. F-G (Lower Miocene; Fiji Islands).

Small forms of hemispherical shape. Ambulacra with trigeminate plates of the echinoid structure; pore-pairs in a nearly straight line. Primary tubercles noncrenulate, in regular series in both areas, and imperforate; a distinct radiating sculpture from around the primary tubercles and partly also from around the secondaries. Apical system (as far as known in the species) regularly dicyclic; peristome small, with small and indistinct gill-slits. Spines and pedicellariae unknown.

Miocene of India, East Indies, Egypt, Australia, and Fiji Islands, and the Lower Pliocene of Japan.

It seems evident that this extinct genus is so closely related to the extinct genus *Javanechinus* that the two genera may in all possibility, be identical with each other, especially with regard to the sculpture of the test, shallow and indistinct gill-slits, and the structure of apical system; i. e., it is known in the species *Br.*

zadeki FOURTAU (1920, p. 22, pl. 2, figs. 6-7) and in *Jav. erbi* (JEANNET and MARTIN, 1937, p. 236, text-figs. 12-15) (Fig. 20b) that the apical system is simple and dicyclic in both genera. The genus *Graphipleurus* should be also identical with *Brochopleurus*, as the former has a dicyclic apical system (ocular plates all exsert), a similarity of test sculpture, and indistinct gill-slits also a similar feature. This is supported by the fact that H. L. CLARK (loc. cit.) included a Javanese species, *Arbacina cf. stellulata*, which is evidently identical with *Jav. rembangensis*, the type-species of *Javanechinus*, in his genus.

This genus has a noteworthy resemblance to the Recent genus *Desmechinus* H. L. CLARK, 1923 (H. L. CLARK, 1923-c, p. 342.—Orthotype—*Des. anomalus* H. L. CLARK, 1923-c, p. 342 (MCZ no. 4635).—MORTENSEN, 1943, p. 341, pl. 20, figs. 31-32, text-figs. 199-200—China Sea), particularly with respect to the sculpture of the test. But the simple and dicyclic apical system of this genus, together with the shallow gill-slits, and single series of the pore-pairs, show it to be more primitive than *Desmechinus*. In *Desmechinus* the apical system is more or less obliquely elongate towards the genital (1), and the ocular (I) and (II) may be broadly insert, and gill-slits are sharp. MORTENSEN (1943, p. 341) assumed that the two species of *Javanechinus* from the Miocene of Java may be the ancestors of the Recent *Desmechinus*-species, viz., *Jav. erbi* of *Des. anomalus*, and *Jav. rembangensis* of *Des. rufus* or *versicolor* (or both).

There is a single species of this genus in our collection. It is described below.

Brochopleurus pulcherrimus NISIYAMA, n. sp.

(Pl. 5, figs. 12-15, pl. 6, figs. 4-5)

Holotype.—IGPS coll. cat. no. 73719.

Locality and geological horizon.—IGPS loc. no. Ch—28.—In calcarerous sandstone of sea-side 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.). Komayama formation, probably Lower Pliocene or Miocene. F. UEDA, 1931. Collected by K. HATAI, K. KOTAKA, K. HATORI, and the writer.

There are four specimens of this species at the writer's disposal, the best preserved one is selected as the holotype.

Dimensions of holotype.—9 mm in horizontal diameter, 5 mm in height.

Test small, thick, and rather low; ambital outline circular, aboral surface moderately arched; adoral surface rather flat, more or less concave near the peristome. Apical system large, about 2.5 mm across; dicyclic, genital plates nearly an equal size, pores distinct and placed near distal end, small tubercles on the plates seem to be few in numbere; ocular plates nearly triangular in outline, and carry small number of small tubercles, and all oculars exsert from the periproct. Periproct oval in outline and 1 mm across in longer axis, all periproctal plates lacking.

Ambulacra rather narrow, about 3 mm wide at the ambitus; ambulacral plates lower than the interambulacral plates, numbering 15-16 in one column, 1.5 mm wide and 1 mm high at the ambitus, and composed of three components of the echinoid structure, the pore-pair of middle demi-plate component produced slightly pushed out of the general surface of two pore-pairs of aboral and adoral primary components on the plate; poriferous zones narrow and slightly sunken; primary tubercles form a vertical series on each side of the ambulacrum, close to the poriferous zone; costa-like, narrow and separate processes pass from the edge of base of the primary tubercles, adorally and aborally, to reach small granules placed in rather irregular circles around the primaries; large secondary tubercles also form a vertical series inside the primary series; primary tubercles placed so close to the poriferous zone that there are no space for intermediate granules, and the poriferous zones well defined from the interporiferous areas.

Interambulacra rather broad and slightly sunken along the median line, about 4 mm wide at the ambitus; interambulacral plates rather high, about 2 mm wide and 1.3 mm high at the ambitus; primary tubercles, which are slightly larger than those on the ambulacra, placed somewhat eccentrically and adorally on the plate, and form a vertical series on either side of the median line; large secondary tubercles also forming three vertical series, one outside and the other two inside the primary series near the ambital region; costa-like processes radiating from each primary tubercle and pass to an encircling series of granules; and usually these short costa-like processes do not pass from the tubercles of one plate to that immediately successive above or below; near the peristomial region these costa-like processes not so distinct as on the ambitus or aborally, but there are five or six small depressions discontinously developed around the primary tubercles.

Peristome rather large, nearly circular, 4.5 mm across, and gill-slits insigificant. Spines and pedicellariae not accessible.

Distinction.—This beautiful small sea-urchin resembles *Br. stellulatus* (DUNCAN and SLADEN, 1885) (*Temnechinus stellulatus* DUNCAN and SLADEN, 1885-a, p. 304, pl. 47, figs. 8-9), from the Gaj Series (Miocene) of Sind, Western India, but is distinguished from that species by the ornamentation on the interambulacra: in this species the primary and large secondary tubercles form three or four vertical series at the ambital region, whereas in that species the secondary tubercles are very small and scattered over the plates, and even numerous miliary tubercles join in the stellate appearance of the tuberculation. *Br. pulcherrimus* is also related to *Br. gajensis* (DUNCAN and SLADEN, 1885) (*Temnechinus gajensis* DUNCAN and SLADEN, 1885-a, p. 305, pl. 47, figs. 10-11) from the Gaj Series of Sind, but is also distinguished from that species by the lower coronal plates and by the tuberculation of the large secondary tubercles on both interambulacral and ambulacral areas.

Family TOXOPNEUSTIDAE TROSCHEL, 1872

Toxopneustidae TROSCHEL, 1872, p. 297 (pro parte).—MORTENSEN, 1903-b, p. 135.—DELAGE and HÉROUARD, 1903, p. 243.—MEISSNER, 1904, p. 1370.—DE MEIJERE, 1904, p. 88.—MORTENSEN, 1927-b, p. 309.—MORTENSEN, 1943, p. 382.—TERMIER and TERMIER, 1953, p. 909.

Les Schizechiens POMEL, 1883, p. 79.

Type-genus.—*Toxopneustes* AGASSIZ, 1841

Test of small to very large size. Ambulacra with trigeminate to multigeminate (polyporous) plates of the echinoid structure. Pore-zones narrow to very broad, sometimes conspicuously widened adorally. Primary tubercles imperforate, non-crenulate. Test not sculptured. Apical system varying from regularly dicyclic to very eccentric, some of the oculars sometimes broadly insert. Gill-slits usually sharp and distinct, sometimes very deep and divided by a longitudinal keel. Buccal membrane plated or more or less naked. Spines usually short, simple, without an axial cavity. Pedicellariae of the usual four kinds; the globiferous pedicellariae with single poison glands, the valves without lateral teeth. Spicules of the globiferous pedicellariae dumb-bell shaped, or C-shaped with obtuse ends, rarely simple bihamate; spicules of the tube-feet with branched ends, or C-shaped with obtuse ends. Colour, in the living, vary from uniform green to banded reddish or purplish (from MORTENSEN, 1943).

From the Cretaceous (?) to Recent, but the great number of the genera are Recent forms.

MORTENSEN (1943, p. 390) strongly argued that the Toxopneustids are very closely related to the Temnopleurids, and the sculpture of the test alone practically distinguishes the Temnopleurids from the Toxopneustids. It seems to be very natural that these two families are closely connected, the Toxopneustids undoubtedly representing the more specialized form, as is characterized by the non-crenulate tubercles, specialized structure of the compound plates, and sharp and deep gill-slits; the crenulation of the tubercles, simpler structure of the compound ambulacral plates, and indistinct and shallow gill-slits in some of the Temnopleurids being more primitive characters.

This family is not accepted by JACKSON and H. L. CLARK, they distributed the genera now assigned to this family into the families of the Echinids and the Strongylocentrotids. H. L. CLARK considered that the character of globiferous pedicellariae and gill-slits are not worth for distinction of families than of genera. H. L. CLARK's claim on this matter is as follows (H. L. CLARK, 1925, p. 103) " I have pinned my faith to the test structure, especially to the essential difference between triporous and polyporous ambulacra," and further he stated (1925, p. 106) " That Toxopneustid-like globiferous pedicellariae have arisen independently three times is at least as likely as the alternative, that polyporous ambulacra have arisen independently." This is quite against MORTENSEN's opinion (MORTENSEN, 1943-a, p. 11) when he says—" Having arrived at the conviction that the oligoporous or polyporous condition of the ambulacra is not of primary importance for classification, since the development from a simple linear arrangement through an oligoporous to a polyporous (or diploporous) condition has taken place along several different lines," and MORTENSEN's idea seems to be nearer to the nature.

This family of Japan and the adjacent regions are represented by the following genera, viz., *Nudechinus* H.L. CLARK, 1912, *Toxopneustes* AGASSIZ, 1841, *Tripneustes* AGASSIZ, 1841, *Pseudoboletia* TROSCHEL, 1869, and *Pseudocentrotus* MORTENSEN, 1903, besides the fossil genus *Mirechinus*.

There are fossil representatives of the genera, *Mirechinus*, *Tripneustes*, and *Pseudocentrotus* in our collection.

Genus ***Mirechinus*** NISIYAMA, n. gen.

Type-species.—Mirechinus mirabilis NISIYAMA, n. sp., from the Eocene of Bonin

Islands.

Test small, stout, thick and subconical on aboral surface; tumid adorally and concave toward the peristome. Apical system compact, madreporite in the largest genital (2), oculars partly insert. Ambulacra narrow, straight; poriferous zones narrow; ambulacra plates high, made up of three components of the echinoid structure; pore-pairs in more or less vertical arcs of triplets; interporiferous areas with two series of small, plain, and imperforate primary tubercles on aboral surface, with or without irregularly placed secondary tubercles, more or less bare median area in the ambulacra aborally; below the ambital region there is a vertical series of secondary tubercles inside the primary series. Interambulacra broad, interambulacral plates rather high; small, plain, and imperforate primary tubercles form vertical series on either side of median line on aboral surface, and a distinct naked median area in the interambulacra aborally; below the ambital region, one or two vertical series of secondary tubercles outside the primary series. Peristome rather small; gill-slits distinct, sharp and deep.

This genus has characters intermediate between *Tripneustes* and *Echinus* LINNAEUS, 1758, that the tuberculation on both aboral and adoral surfaces, particularly in the naked area, resembles that of the living *Tripneustes gratilla* (LINNAEUS, 1758) (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), on the other hand, the ambulacral structure of the typically echinoid type of trigeminate plates quite agrees with that of the species of *Echinus* and other allied genera. Gill-slits of this genus are sharper and deeper than those of *Echinus*, thus it is easily distinguished from that genus; but they are, in this genus, shallower and broader than those of *Tripneustes*. There are some doubts that this genus might represent a young form, but the tuberculation on both ambulacral and interambulacral areas prevents the identification of this genus with that one.

This genus also resembles the extinct genus *Gagaria* DUNCAN, 1889 (DUNCAN, 1889-a, p. 91 (subgenus ad *Micropsis* COTTEAU, 1856).—Haplotype—*Micropsis venustula* DUNCAN and SLADEN, 1884, p. 119, pl. 22, figs. 1-7—the Eocene (Khirtar Series) of Sind), in the characters of apical system and the structure of ambulacral plates, but is easily distinguished from that genus by having non-crenulate primary tubercles and deeper and broader gill-slits, while in that genus the primary tubercles are crenulate and the gill-slits shallow and narrow.

There is a single species, *Mir. mirabilis*, in our collection, which described herein.

Mirechinus mirabilis NISIYAMA, n. sp.

(Pl. 6, fig. 3, pl. 7, figs. 2, 4)

Holotype.—IGPS coll. cat. no. 73725.

Locality and geological horizon.—South cliff of Nishi-ura, Haha-jima in Bonin Islands. *Eorupertia-Alveolina*—Zone, Upper Eocene (Lutetian).

There is a single specimen (holotype) of this species at hand. Dimensions of holotype.—About 26 mm in horizontal diameter, and about 20 mm in height; peristome about 8 mm in diameter.

Test small, stout, thick, about 1.5 mm thick below the ambital region; nearly circular in ambital outline, with somewhat depressed interradial median area aborally, subconical in aboral surface; tumid on oral surface and concace with peristome at the bottom. Apical system, a half part lacking, preserved part raised, particularly pronounced in the madreporite; madreporite large, 3 mm wide and 1.5 mm long; genital plates rather small, about 1.5 mm wide and 1 mm high; ocular plates almost triangular in outline, not exsert in the preserved part; tuberculation on the genital-ocular ring very sparse, small secondary tubercles, one to two on each plate.

Ambulacra narrow, about 7 mm wide at the ambitus, and 2.5 mm at the peristomial region; ambulacral plates rather high, about 3.5 mm wide and 1.5 mm high at the ambital region, and made up of three components, aboral primary, middle demi-plate and adoral primary components; there are 24 or 25 plates in each column; poriferous zones narrow, about one mm wide at the ambitus; pore-pairs in more or less vertical arcs of triplets; pore-pair of middle demi-plate placed on the outermost, and pore-pair of adoral primary component just below that of aboral primary one; arcs gradually become more vertical series adapically and adperistomially; primary tubercles rather small, plane and imperforate, placed centrally and somewhat adorally; they form vertical series on either side of median line, and few small secondary and miliary tubercles irregularly around the primary tubercles, and there are more or less naked median spaces aborally; somewhat large secondary tubercles form vertical series inside the primary series from below the ambital region to near the peristomial region, but other small secondary and miliary tubercles rather few in number.

Interambulacra broad, about 12 mm wide at the ambital region, and about 3 mm wide at the peristomial region; interambulacral plates rather high, 6 mm wide and 2 mm high at the ambitus; each plate carries a small, plane, and imperforate primary tubercle, being placed centrally and adorally on a plate; 19 or 20 plates in each column; primary tubercles, which are as large as, or slightly larger than, those on the ambulacra, form a vertical series on middle of each column; more or less large secondary tubercles placed inside and outside, or above the primary tubercle on the plate aborally, and other small tubercles few in number; there are distinct bare median areas aborally; adorally, somewhat large secondary tubercles form vertical series two outside and one inside the primary series from below the ambitus approaching to the peristomial region, and other small secondary and miliary tubercles very few in number; the feature of this species resembles the living *Tr. gratilla* in the naked median area and in many (but fewer than in that species) vertical series of large tubercles on the adoral surface. Peristome rather small, markedly concave toward the peristome; gill-slits sharp, deep and broad, about 1 mm wide and 1.5 mm in length. Auricles well developed, stout and high, two auricles contact in rectangular form, about 3 mm high and 3 mm wide.

Distinction.—This Eocene species differs from allied genera and species, e. g., *Psammechinus hispaniae* LAMBERT, 1889 (LAMBERT, 1889, p. 703.—LAMBERT, 1902, p. 37, pl. 2, figs. 16-19—Echinidae), from the Eocene of Barcelona, and *Psam. biarritzensis* COTTEAU, 1863 (COTTEAU, 1863-b, p. 678.—COTTEAU, 1889-94 (93), p. 625, pl. 353, figs. 1-6), from the Eocene of Biarritz (Pyrénées), by the tuberculation on the coronal plates, the deeper and sharper gill-slits, the more globular form of the test, and by the more numerous coronal plates. *Mir. mirabilis* also differs from *Gajechinus subcrenatus* (DUNCAN and SLADEN, 1885) (*Echinus subcrenatus* DUNCAN and SLADEN, 1885-a, p. 317, pl. 49, figs. 5-6—Toxopneustidae), from the Gaj Series (Miocene) of Sind, Western India, by the tuberculation on the coronal plates, and by the more globular form of the test.

Genus *Tripneustes* AGASSIZ, 1841

Tripneustes AGASSIZ, 1841, p. 7.—AGASSIZ, 1841-a, p. viii.—AGASSIZ and DESOR, 1846, p. 363.—DESOR, 1855-57 (56), p. 132.—BELL, 1879-b, p. 655.—POMEL, 1883, p. 80.—DUNCAN, 1889-a, p. 132.—MORTENSEN, 1903-b, pp. 114, 136.—DELAGE and HÉROUARD, 1903, p. 244.—MEISSNER, 1904, p. 1372.—H. L. CLARK, 1912-b, p. 285.—LAMBERT and THIÉRY, 1914, p. 248.—H. L. CLARK, 1925, p. 123.—GRANT and HERTLEIN, 1938, p. 26.—MORTENSEN, 1943, p. 47.—H. L. CLARK, 1946. p. 325.—COOKE, 1959, p. 15.

Orthotype.—Echinus ventricosus LAMARCK, 1816, p. 44 (Habite l'Ocean des Grande-Indes).—[*Cidaris esculenta* LESKE, 1778, p. 74 (it has been confused with the preceding; but it is a synonym of *Echinus esculentus* LINNAEUS—MORTENSEN, 1943, p. 497).—*Hipponoe esculenta* (LESKE) A. AGASSIZ, 1872-74, p. 301, pl. 6a, figs. 1-3, pl. 8, fig. 29 (Caribbean Sea)].—*Tripneustes ventricosus* (LAMARCK) MORTENSEN, 1943, p. 490, pl. 33, fig. 4, pl. 36, figs. 1-4, pl. 37, figs. 3, 11, 12, pl. 38, figs. 5-8, pl. 56, figs. 3, 6, 7, 9, 15-17.

Hipponoe GRAY, 1848, p. 65 (nomen nudum; non AUDIAN and EDWARDS, 1830).—GRAY, 1855, p. 36.—A. AGASSIZ, 1872-74, pp. 134, 301.—TENISON-WOODS, 1878, p. 166.—DUNCAN and SLADEN, 1885-a, p. 310.

Haplotype.—Hipponoe sardica GRAY, 1855, p. 36.—*Echinus gratilla* LINNAEUS, 1758, p. 664 (Habitat in O. Indico).—*Tripneustes gratilla* (LINNAEUS) 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 (Indo-Pacific Oceans, in Ebb-zone to 75 metres depths).

Heliechinus GIRARD, 1851, p. 364.

Type-species.—Heliechinus gouldii GIRARD, 1851, p. 364.—*Echinus ventricosus* LAMARCK, 1816, p. 44.

Large forms of hemispherical to subglobular shape. Trigeminate ambulacra of the specialized echinoid structure; with a primary tubercle only on every three to four plates. Pore-zones broad, not widened adorally; the pores being, in the adult specimens, arranged in three vertical series, the outer and inner series regular, the median usually more or less irregular; in young specimens the pores are arranged in oblique arcs of three. Secondary ambulacral tubercles of interporiferous area usually not in four vertical series, whereas the tubercles of the pore-zones often form vertical series. There is usually a conspicuous naked median space aborally in both ambulacral and interambulacral areas. Apical system not transversely elongate, with anal opening subcentral; usually oculars (I) and (V) broadly insert; no distinct suranal plate. Angle of the interambulacral sutures sometimes slightly pitted. Buccal membrane with scattered small plates, usually carrying pedicellariae. Gill-slits deep and sharp. Lantern with process from the epiphyses supporting the teeth; auricles high, joining above. Spines short, rather slender, forming sometimes a uniform covering of the test; sections show the surface of the wedges smooth, without free thorns. Pedicellariae, of the tridentate, ophicephalous, triphyllous, and the globiferous types. Globiferous pedicellariae small, usually dark-pigmented; they usually densely cover the naked areas; stalk-glands may be present; the skin usually full of dumb-bell shaped spicules, not forming a prominent border; the other types are ordinary. Spicules of the tube-feet either dumb-bell shaped or C-shaped with obtuse, more or less thickened ends. Often conspicuously radially coloured. The body skeleton of the larva in the first stage forms a typical basket structures (from MORTENSEN, 1943).

From the Oligocene to Recent.

The specialized echinoid structure of the trigeminate ambulacra of this genus is so excellently described by MORTENSEN (1943, p. 498), that it is not necessary to add anything to the description.

There can be little doubt that it represents the very specialized development in the family of the Toxopneustids. The specialized apical system, deep gill-slits, wide poriferous zones with the pore-pairs arranged in the three vertical series, and great reduction of ambulacral primary tubercles, are all pointing to the same conclusion.

This genus dates back at least to the Oligocene, comprising 7 Miocene species and one Pliocene. The three living species are now recognized in this genus, e. g., *Tr. gratilla* (LINNAEUS, 1758), from the Indo-West Pacific regions, *Tr. ventricosus* (LAMARCK, 1816), from the West Indies, and *Tr. depressus* A. AGASSIZ, 1863 (A. AGASSIZ, 1863, p. 24.—A. AGASSIZ, 1872, pp. 134, 500), from the Western coast of Mexico and California; they are common in shallow water, usually less than 27 metres in depth, up to low-water mark, and sometimes attain to 150 mm or more in the horizontal diameter of test. MAYR (1954) claimed that these living species of the genus should be regarded as allopatric (p. 4), and may be ranked with *ventricosus*, *depressus* and *gratilla* as subspecies of the single species (*gratilla*) (p. 5).

There is a fossil species of this genus in our collection: following is the description of the species.

Tripneustes magnificus NISIYAMA, n. sp.

(Pl. 6, figs. 2, 7, 9, pl. 7, fig. 1)

Holotype.—IGPS coll. cat. no. 73786.

Locality and geological horizon.—Hill behind Forestry Industry, Saipan Island, Mariana (Ladrone) Islands, Micronesia, South Sea Islands. Laulau formation (*Eulepidina*—horizon), Lower Miocene (Oligocene of authors).

There are several fragmentary specimens at the writer's disposal that probably represent this new species. The writer succeeded in gluing the larger fragments together, so that one gets an idea of what it looked like when complete; but unfortunately, in it the large part of the aboral surface is broken away.

Test very large, probably 200 mm in horizontal diameter, and was probably circular in ambital outline, slightly depressed, height being about a half of the horizontal diameter; convex aborally, and probably with a tendency to become conoid towards the apical system; inflated at the ambitus, which passes gradually over on to the adoral surface, where the test slightly is concave to the peristome.

Ambulacral areas broad, about 43 mm wide at the ambitus, being somewhat narrower than the interambulacral areas; flush with general surface of test. Poriferous zones straight and of great breadth, about 13 mm wide at the ambitus, broader than width of a half interporiferous areas; the pores form three distinct, vertical, and widely spaced series; inner and outer series almost regularly uniserial, whilst disposition of pores in median series is more or less sporadic, with a tendency to fall into oblique triplets. Ambulacral plates very low, about 3 mm high and 21 mm wide at the ambitus; at least 150 plates in a column; component of plates very irregular, the echinoid structure, aboral primary, middle demi-plate and adoral primary components, with the triads very rare, often found on aboral surface from the apical system to downward to the ambitus; ambulacral plates at the ambitus are compound as in a specimen of abnormal *Echinus esculentus*, as figured by HAWKINS (1920, pl. 63, fig. 14), but the pore-pairs are much wider apart than in the latter; this abnormality is probably due to an unusual rapidity of plate development in this species. Two comparatively large secondary tubercles form two vertical series on each poriferous zone, excepting the adapical region. Interporiferous areas narrow, about 16 mm wide at the ambitus; primary tubercles form vertical series along poriferous zone on each side of interporiferous area; but the tubercle begins on the third or fourth plate form the apical system; inside the primary series large secondary tubercles, which are nearly as large as the primaries, forming four vertical series near the ambitus, but gradually being reduced in number both adapically and adorally.

Interambulacra rather narrow, about 54 mm wide at the ambitus; interambulacral plates low, about 45 mm high and 27 mm wide at the ambitus, slightly curved; each carries a horizontal line of uniform and equal-spaced tubercles, in which the primary tubercle is not conspicuous; the primary is slightly larger than those on ambulacral areas; there are eight tubercles in this horizontal line near the ambital region; the line is situated slightly adorally than centrally; a small secondary tubercle is on the adoral corner of plate close to the poriferous zone; number of vertical series reduced both aborally and adorally; small secondary tubercles and miliary irregularly scattered on plates.

Ambulacra at the peristomial region broad, about 12 mm wide, wider than the interambulacra. Gill-slits very sharp and well-defined, about 10 mm long, but rather narrow, and reached to the sixth ambulacral plate from the peristomial region. Peristome seems to be rather small, nearly 35 mm in diameter.

Distinction.—This magnificant species resembles *Tr. proavius* (DUNCAN and SLADEN, 1885) (*Hipponoe proavia* DUNCAN and SLADEN, 1885-a, p. 310, pl. 48, figs. 1-4, pl. 49, fig. 1), from the Gaj Series (Miocene) of Sind, Western India, in the tuberculation on coronal plates; but it is distinguished from the latter by the narrower ambulacra at the ambitus, as well as the lower coronal plates. *Tr. magnificus* is also related to *Tr. schneideri* (BÖHM, 1882) (*Hipponoe schneideri* BÖHM, 1882, p. 362 (6), pl. 1, figs. 1a-1c.—JEANNET in LAMBERT and JEANNET, 1935, p. 53, text-fig. 73, pl. 2, figs. 41-43, pl. 4, fig. 21), from the Miocene of Madura and Java Islands, but differs from it in having much wider poriferous zones, the lower interambulacral plates, and by developing numerous large tubercles on the coronal plates.

It seems evident that these three fossil species from the neighbouring areas, i. e., the India, Malay Archipelagoes, and Micronesia, and same geological age (Miocene), are so closely related one another, that they should be regarded as allopatric species or subspecies on the basis of geographical speciation in Echinoids.

Genus *Pseudocentrotus* MORTENSEN, 1903

Pseudocentrotus MORTENSEN, 1903-b, pp, 122, 137.—MORTENSEN, 1943, p. 540.

Orthotype.—*Toxocidaris depressa* A. AGASSIZ, 1863-a, p. 356.—*Pseudocentrotus depressus* (AGASSIZ) 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, 319, 320, 321 (Japan, Recent).

Large form of very low outline, the oral side being perfectly flat. Ambulacra polyporous, with 5-7 pore-pairs in each arc (except in the adoral part); pore-zones narrow adorally, then widening so as to become almost petaloid on the oral side. Secondary tubercles numerous, covering the plates so as to leave no naked median spaces aborally; the large secondary tubercles much smaller than the primaries and do not form horizontal series. Apical system with oculars (I) and (V) broadly insert; it is not transversely elongate, but the periproct is somewhat eccentric; anal opening subcentral. Buccal plates carry numerous pedicellariae, but no spines; plates in the buccal membrane rather sparse, the large ones carry pedicellariae; inside the buccal plates the membrane is densely covered with scale-like naked plates. Gill-slits rather long, but shallow; adambulacral ridge is rather small. Auricles high and slender, joining above; lantern not very large, but there are processes from the epiphyses, supporting the teeth. Spines of the aboral side rather long and coarse, short and slender on the oral side, almost hidden by the numerous tube-feet. Globiferous pedicellariae vary much in size, but all without stalk-glands. Spicules C-shaped with obtuse ends in the globiferous pedicellariae, and C-shaped with outer branches in the tube-feet. The body skeleton of the larva in its first stage is of the basket type; the fully formed larva has posterior transverse rod with bifurcating ends (from MORTENSEN, 1943).

From the Miocene to Recent.

Although this genus was established by MORTENSEN on a single Japanese species, '*Toxocidaris*' *depressa* A. AGASSIZ, 1863 (loc. cit.), it has been much disputed on the generic situation. H. L. CLARK (1912-b, pp. 340, 352.—1925, p. 130) did not accept this genus, and inclined to consider that it may be dropped into the synonymy of *Strongylocentrotus*, as stating (1925, p. 130) that " MORTENSEN's genus *Pseudocentrotus* may prove to be a natural group, but untill at least a second species is found, *P. depressus* may well be left in *Strongylocentrotus*." Thus, the systematic positions adduced by MORTENSEN and CLARK to '*Toxocidaris*' *depressa* are very notably different: namely, the Toxopneustid genus *Pseudocentrotus*, and the Strongylocentrotid genus *Strongylocentrotus*, respectively; even the suborders are different, the former the Temnopleuronia, and the latter the Echinoina.

This genus may prove to be a natural group, and is characterized by the well-defined and very prominent gill-slits, the more or less distinctly petaloid ambulacra on the oral side, the feature of globiferous pedicellariae, and by the form of spicules in the tube-feet. *Pseudocentrotus* is a Japanese genus known to be distributed geologically and geographically, and represented by only a single species known at present in the Recent seas. This is the first record of fossil species, a second spe-

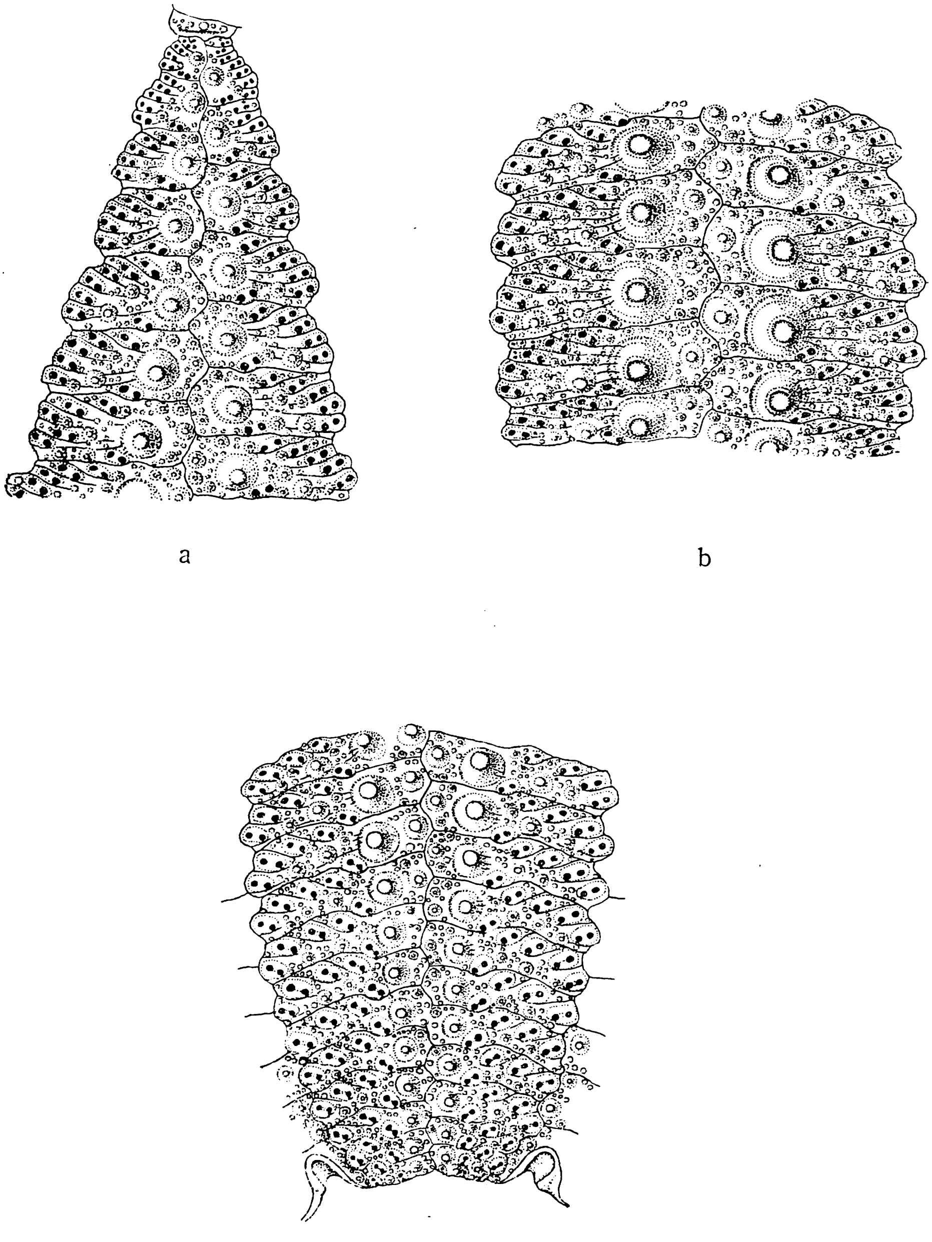


Fig. 21. Ambulacrum (III) of *Pseudocentrotus depressus* (A. AGASSIZ, 1863) (for comparison). (Recent specimen, from the south coast of Tateyama Bay, Chiba Prefecture). ×4.

a. Adapical part; b. Ambital part; c. Adoral part.

cies of the genus, from Japan. This is described as follows.

Pseudocentrotus stenoporus NISIYAMA, n. sp.

(Pl. 7, figs. 3-7)

Holotype.—IGPS coll. cat. no. 78207.

Locality and geological horizon.—IGPS loc. no. So—13.—In calcareous sandstone at sea-shore of Nagata, Shirahama-mura, Kamo-gun, Shizuoka Prefecture. (tm Shimoda, Lat. 34°41′30″N., Long. 138°58′E.). Shirahama (Susaki) formation, Miocene.—*Holotype.*

Locality and geological horizon.—IGPS loc. no. So—14.—A point of Itado, south of the Nawachi gold-mine, Shirahama-mura, Kamo-gun, Shizuoka Prefecture. (tm Shimoda, Lat. 34°42′44″N., Long. 138°59′E.). Shirahama (Susaki) formation, Miocene.—*Paratype.*

There are two specimens referable to this new species at disposal; one is composed of columns made up of seventeen ambulacral plates and thirteen interambulacral plates; the other is small, deformed and partly broken.

Ambulacra rather broad, about three fourths of the interambulacra at the ambitus, and about 1.6 times at the peristomial region as broad as the interambulacra, and somewhat petaloid on oral surface. Ambulacral plates composed of five components at the ambitus, 8 mm wide and 2.5 mm high; each plate carries a large primary tubercle, placed near the poriferous zone, gradually diminishing in size adapically and adorally, but not suddenly diminish the size below the ambitus as in *Anthocidaris crassispina* (A. AGASSIZ, 1863) (Fig. 25); secondary tubercles form a vertical series inside the primary series, and placed at inner corner of a plate; poriferous zones rather narrow, about almost to or a little broader than the interporiferous areas; five pore-pairs form rather more obliquely sharp and more strongly curved arcs than those of *Ps. depressus* (Figs. 21, 22); pore-pair of upper (aboral) primary component are placed outside a length of pore-pair of adoral primary of the succeeding upper plate, accompanying a small secondary tubercle; pore-pair of middle demi-plate placed somewhat outside the pore-pair of upper demi-plate, with a small secondary tubercle; pore-pair of lower (adoral) demi-plate also placed a little outside the pore-pair of middle demi-plate; and pore-pair of adoral primary placed near the base of primary tubercle; there are two large secondary tubercles placed inside pore-pairs on middle and lower (adoral) demi-plate components. On the oral surface, the pore-pairs of a plate usually decrease in number, 9th or 10th plate from the peristomial region usually with four pore-pairs; they are less than those of *Ps. depressus.*

Interambulacral plates higher than ambulacral plates, 11 mm wide and 3.2 mm high at the ambitus; on each plate, primary tubercle is placed at the center and somewhat adorally, and form a vertical series; a large secondary tubercle placed inside the primary and adorally; and four large secondary tubercles are placed outside the primary, and grouped in two row aborally and adorally to the primary tubercle; small secondary and miliary tubercles form close circle around the primary and the large secondaries.

Adoral surface nearly flat; and gill-slits well defined and rather large, structure is similar to that of *Ps. depressus*; but the pore-pairs fewer in number at the adperistomial region than in that species. Test is thick, about 2 mm thick in section; the larger specimen may attain to 65 mm in horizontal diameter.

Distinction.—This new species closely resembles Recent *Ps. depressus* (A. AGASSIZ, 1863) in the structure of ambulacra, and in the tuberculation on coronal plates; and hence, the writer once regarded this as a variety of that species. This species, however, is distinguished from that species by the narrower poriferous zones, and fewer pore-pairs in an ambulacral plate. Moreover, the arcs of pore-pairs are more

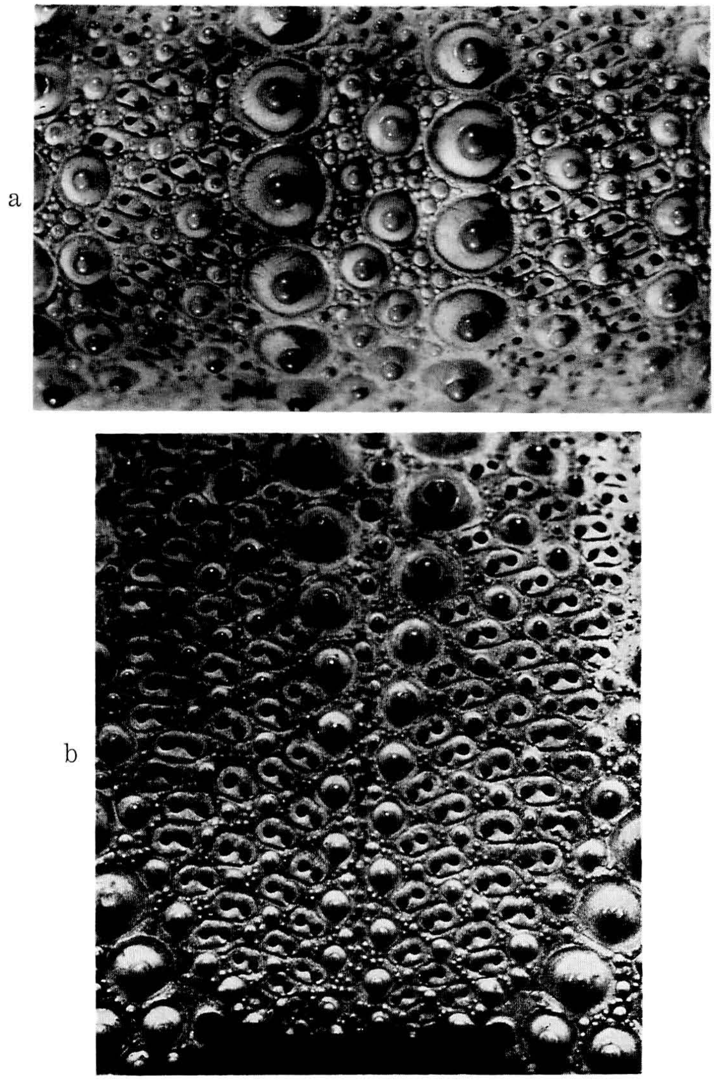


Fig. 22. *Pseduocentrotus depressus* (A. AGASSIZ, 1863) (for comparison). (IGPS coll. cat. no. 78228-1, from the south coast of Tateyama Bay, Chiba Prefecture). ×6.

a. An ambulacrum at the midzone; b. An ambulacrum on the peristomial region.

inclined and curved than in those of *Ps. depressus*. It may be an ancestral form of the Recent species, *Ps. depressus*, as the adult form of this resembles some young stages of the Recent form.

Suborder ECHINOINA CLAUS, 1876

Echinideae CLAU, 1876, p. 356.—*Echinina* MORTENSEN, 1942, p. 225 (non *Echinina* GREGORY, 1900-b, p. 311).—MORTENSEN, 1943-a, p. 1.—TERMIER and TERMIER, 1953, p. 909.—NISIYAMA, 1954, p. 327 (in Japanese).—*Echinoida* CLAUS: DURHAM and MELILLE, 1957, p. 255 (order).

Type-family.—*Echinidae* GRAY, 1825.

Regular Echinoids with camarodont type of lantern, and with compound ambulacra of the echinoid structure or its complex type. Test not sculptured. Tubercles imperforate, smooth. Gill-slits neither sharp nor deep. Spines with solid axis, without cortex layer.

From the Eocene to Recent.

The forms with circular ambital margin of this suborder, in general, resembles the forms of the suborder Temnopleuroina without sculptures on the test; but, the former are distinguished from the latter by both the indistinct and shallower gill-slits, and the character of the globiferous pedicellariae.

This suborder comprises a large number of Recent forms, in which four families are divisible, e. g., the Echinidae, Strongylocentrotidae, Parasaleniidae, and the Echinometridae. These families are distinguished from one another, according to MORTENSEN, mainly by the structure of their globiferous pedicellariae.

There are fossil representatives of the families of the Strongylocentrotids, Parasaleniids, and the Echinometrids, in our collection.

Family STRONGYLOCENTROTIDAE GREGORY, 1900

Strongylocentrotidae GREGORY, 1900-b, p. 313 (pro parte).—MORTENSEN, 1903-b, p. 137.—DELAGE and HÉROUARD, 1903, p. 245.—JACKSON, 1912, pp. 204, 216 (pro parte).—H. L. CLARK, 1912-b, p. 340 (pro parte).—H. L. CLARK, 1925, p. 130 (pro parte).—MORTENSEN, 1927-b, p. 312.—GRANT and HERTLEIN, 1938, p. 28 (pro parte).—MORTENSEN, 1943-a, p. 183.—H. L. CLARK, 1946, p. 327 (pro parte).—TERMIER and TERMIER, 1953, p. 910.

Type-genus.—*Strongylocentrotus* BRANDT, 1835.

Test regularly hemispherical, of moderate to very large size. Ambulacra polyporous of the complexity of the echinoid structure, apart from the adoralmost plates; pore-zones not widened adorally. Tubercles imperforate, non-crenulate, regularly developed in both areas; no sculpture on the test. Apical system is usually with oculars (I) and (V) broadly insert. Buccal membrane with a varying number of plates distally to the buccal plates, the larger ones carrying pedicellariae. Gill-slits shallow, neither deep nor sharp. Spines generally short, simple, only exceptionally about as long as the diameter of test. Globiferous pedicellariae very characteristic in having a well developed neck, provided with circular and longitudinal muscles; the stalk is hollow; the valves without lateral teeth. Spicules of tube-feet and globiferous pedicellariae C-shaped with distal prominences, or simply bihamate. The larva in its first stage does not form a basket structure; the fully formed larva has no posterior transverse rod, but is provided with ciliated epaulets (from MORTENSEN, 1943-a).

From the Pliocene (at least) to Recent.

In establishing the family of the Strongylocentrotids GREGORY (1900-b, p. 313) simply ignored the characters of pedicellariae, the character of their polyporous ambulacra making the foundation; and JACKSON (1912, pp. 204, 216) only followed similar manner. This course causes a perplexing dilemma, for within the limits of the family are three groups of genera: e. i., one with the remarkable globiferous pedicellariae, and sharp gill-slits, characterized *Lytechinus* and its allies; the other with a quite distinct type of globiferous pedicellariae, and shallow gill-slits, which are similar to those of *Echinometra;* and the last also with a characteristic type of globiferous pedicellariae, and shallow gill-slits of *Strongylocentrotus.* MORTENSEN has clearly assigned these groups to their proper positions. The first group constitutes the family of the Toxopneustids, the second the Echinometrids, and the third the Strongylocentrotids.

A close affinity between the Toxopneustids and the Strongylocentrotids, as formerly established by MORTENSEN (1903-b, pp. 135-137), must be denied now. The character of their larvae disproved the affinity between them, as recognized by later researches.

This family comprises the following three genera of chiefly Recent forms, e. g., *Hemicentrotus* MORTENSEN, 1942 (*Psammocentrotus* NISIYAMA, 1939, is not valid), *Allocentrotus* MORTENSEN, 1942, and *Strongylocentrotus* BRANDT, 1835. These genera are discriminated from one another as shown by the following key (after MORTENSEN, 1943-a).

Key to the genera of the Family Strongylocentrotidae.

1. Pores arranged in four vertical series; the arcs are almost horizontal. Spicules of the tube-feet and globiferous pedicellariae simply bihamate.............. .... *Hemicentrotus*
   Pores not arranged in four vertical series; the arcs more or less oblique. Spicules of the tube-feet with outer prominences at the ends..................... 2
2. Ambulacra gradually constricted on the oral side, at the peristomial edge distinctly narrower than the interambulabra. Spicules of the globiferous pedicellariae simply bihamate. Test very fragile.................. *Allocentrotus*
   Ambulacra not constricted on the oral side, at the peristomial edge broader than the interambulacra. Spicules of the globiferous pedicellariae usually with outer prominences at the ends, like those of the tube-feet. Test usually stout .... *Strongylocentrotus*.

There are fossil representatives of the genera *Strongylocentrotus* and *Allocentrotus* in our collection.

Genus *Strongylocentrotus* BRANDT, 1835

Strongylocentrotus BRANDT, 1835, p. 263 (in separate, p. 63), (Species in original list—*Echinus* (*Strongylocentrotus*) *chlorocanthus* BRANDT (p. 264) and ? *Echinus tuberculatus* BLAINVILLE (p. 264)).—GRAY, 1855, p. 37.—A. AGASSIZ, 1872-74, pp. 159, 276 (pro parte).—ZITTEL, 1879, p. 510.—BELL. 1881-a, p. 455 (pro parte).—POMEL, 1883, p. 78 (pro parte).—

DUNCAN, 1889-a, p. 121, (pro parte).—HOYLE, 1891, p. 408.—BELL, 1892, p. 155 (pro parte). —MORTENSEN, 1903-b, p. 137.—DELAGE and HÉROUARD, 1903, p. 137.—MEISSNER, 1904, p. 1374.—MORTENSEN, 1910-a, p. 124.—H. L. CLARK, 1912-b, p. 352 (pro parte).—H. L. CLARK, 1925, p. 138.—MORTENSEN, 1927-b, p. 312.—MORTENSEN, 1932-e, p. 355.—GRANT and HERTLEIN, 1938, p. 31.—MORTENSEN, 1943-a, p. 193.—COOKE, 1959, p. 25.

Haplotype.—Echinus (Strongylocentrotus) chlorocanthus BRANDT, 1835, p. 264 (in separate p. 64) (Sitka Island).—*Echinus droebachiensis* O. F. MÜLLER, 1776, p. 235, no. 2846 (Dröbak, south of Oslo, Norway).—*Strongylocentrotus dröbachiensis* (O. F. MÜLLER) A. AGASSIZ, 1872-74, pp. 162, 277, 441, pl. 4a, figs. 2, 3, 6 (North Pacific, North Europe, Northeast coast of North America).—MORTENSEN, 1903-b, pp. 162, 165, pl. 1, figs. 5-6, pl. 2, figs. 3-5, pl. 16, figs. 4, 9, 11, 13, 17, 21, 23, pl. 20, figs. 3-6, 12-13, 16, 18, 20, 26, 29 (wide distribution in the North Atlantic and the North Pacific Oceans). (Validated by Opinion 208 of the International Commission on Zoological Nomenclature).

Euryechinus VERRILL, 1866, pp. 340, 341, 352.—VERRILL, 1867-71(67), p. 304.

Orthotype.—Echinus droebachiensis O. F. MÜLLER, 1776, p. 235.

Large or medium in size, of more or less low hemispherical shape, generally scarcely sunken at the peristomial edge. Test usually rather stout. Ambulacra with 5-9 pore-pairs to an arc, rarely 4 or as many as 10; the arcs more or less oblique; the pores may be arranged in two to three vertical series. Ambulacra remain on the oral side of the same width to the peristome, and are at the peristomial edge usually distinctly broader the interambulacra. Secondary tubercles often well developed, the larger ones form distinct vertical, in some cases also horizontal series. Usually no distinct naked median areas aborally. Apical system usually with oculars (I) and (V) broadly insert; madreporite larger than the other genital plates; periproct subcentral, covered with numerous small plates, the larger of which carry each a small spine (tubercle); only in very young specimens a distinct suranal plate. Buccal membrane with a varying number of plates distally to the buccal plates, the larger of them carry pedicellariae; no spines on the buccal plates. Gill-slits shallow, not sharp. Spines simple. Globiferous pedicellariae with a well developed neck with longitudinal and circular muscles; no stalk-glands; poison-glands single; valves of the pedicellariae without lateral teeth. C-shaped spicules with branched ends in the tube-feet, and usually in the head of the globiferous pedicellariae (after MORTENSEN, 1943-a).

This genus was established as a subgenus under *Echinus*, by BRANDT in 1835, for *Echinus* (*Strongylocentrotus*) *chlorocanthus*. It is now certain that *Ech.* (*Str.*) *chlorocanthus* BRANDT, 1835, is conspecific with *Ech. droebachiensis* O. F. MÜLLER, 1776; the latter was described sixty years ago. This generic name was accepted by A. AGASSIZ (1872-74) and DUNCAN (1889), who, however, referred to it besides the type-species, a great number of the polyporous forms as synonyms. These forms and synonyms have been later shown (MORTENSEN, 1903-b, 1927-b, 1943-a, and H. L. CLARK, 1912-b, 1925) to belong to several different genera, even families; e. g., *Paracentrotus* MORTENSEN, 1903, and *Loxechinus* DESOR, 1856—Echinidae, *Caenocentrotus* H. L. CLARK, 1912, *Toxocidaris* A. AGASSIZ, 1863 (=*Heliocidaris* AGASSIZ and DESOR, 1846, as defined by H. L. CLARK, 1912-b, p. 281), and *Anthocidaris* LÜTKEN, 1864—Echinometridae, *Pseudocentrotus* MORTENSEN, 1903—Toxopneustidae, *Allocentrotus* MORTENSEN, 1942, *Hemicentrotus* MORTENSEN, 1942, and *Strongylocentrotus* BRANDT, 1835—Strongylocentrotidae.

This genus is characteristic of cold and temperate habitats; the two common Japanese species, *Str. intermedius* (A. Agassiz, 1863) (see below) and *Str. nudus* (A. Agassiz, 1863) (*Toxocidaris nuda* A. Agassiz 1863-a, p. 356.—*Str. nudus* (A. Agassiz) A. Agassiz, 1872-74, p. 165.—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), and the two common Californian species, *Str. franciscanus* (A. Agassiz, 1863) (*Toxocidaris franciscana* A. Agassiz, 1863, p. 22.—*Str. franciscanus* (A. Agassiz) A. Agassiz, 1872-74, pp. 163, 442, pl. 5b, figs. 1-2, pl. 7, figs. 10-10a) and *Str. purpuratus* (Stimpson, 1857) (*Echinus purpuratus* Stimpson, 1857, p. 86.—*Str. purpuratus* (Stimpson) A. Agassiz, 1872-74, pp. 165, 449, pl. 5a, figs. 5-6, pl. 16, fig. 7, pl. 36, fig. 9), are most abundant at shallow waters, generally among the rocks up to tide line, and caught by fishermen for edible purpose.

The genus dates back to at least as early as the Lower Pliocene. In the Recent seas, including eight species, it is wide-spread in Northern seas, especially in the Northern Pacific Ocean.

In fossil state, *Strongylocentrotus* is very hard to distinguished from the allied genera, as seen above; however, in the detailed observation on the oral surface, it is found that the arrangement of pore-pairs, and the tuberculation on the coronal plates, serve as good guide for distinction.

There are at least three species of fossil of this genus in our collection.

Strongylocentrotus intermedius (A. Agassiz, 1863)

(Pl. 8, fig. 9)

Psammechinus intermedius A. Agassiz, 1863-a, p. 357.—*Strongylocentrotus intermedius* (A. Agassiz) A. Agassiz, 1872-74, pp. 164, 445.—Döderlein, 1906-a, p. 517.—H. L. Clark, 1912-b, p. 353.—Lambert and Thiéry, 1914, p. 255.—H. L. Clark, 1925, p. 139.—Mortensen, 1929, p. 476, text-fig. 6, pl. 19, fig. 4.—Grant and Hertlein, 1938, p. 36.—Ikeda, 1940, p. 1.—Mortensen, 1943-a, p. 225, pl. 24, figs. 1-6, 13-14, pl. 25, figs. 12-14, pl. 55, figs. 2-3, 8-10, 19, text-figs. 86, 100b, 101b.—Utinomi, 1960, p. 341, pl. 39, figs. 9-12.

Strongylocentrotus dröbachiensis Tokunaga, 1906, pl. 11, figs. 8-11 (non O. F. Müller, 1776).

Locality and geological horizon.—IGPS loc. no. Ak-1.—Sea cliff at Anden, Iriaimura, Minami-Akita-gun, Akita Prefecture. (tm Funakawa, Lat. 39°58'N., Long. 139° 51'10"E.). Shibikawa formation, Pliocene (or Pleistocene). *Hypotype.*—IGPS coll. cat. no. 73759.

Locality and geological horizon.—IGPS loc. no. Sr-11.—A point south of Imagane, Toshibetsu-mura, Setana-gun, Shiribeshi, Hokkaido. (tm Imagane, Lat. 42°25'13"N., Long. 140°0'45"E.). Setana formation, Pliocene. *Hypotype.*—IGPS coll. cat. no. 73760.

Locality and geological horizon.—IGPS loc. no. Ao-1.—Cliff at river mouth of the Chikagawa, at Chikagawa, Tanabu-machi, Shimokita-gun, Aomori Prefecture. (tm Chikagawa, Lat. 41°11'N., Long. 141°16'26"E.). Chikagawa formation, Pliocene. *Hypotype.*—IGPS coll. cat. no. 73761.

There are several fragmentary specimens referred to this species at disposal. The characteristics of ambulacra and interambulacra in the specimens can be safely assigned them with this species.

Ambulacra rather broad, about 13 mm wide near the ambital region, a little narrower than the interambulacra. Ambulacral plates low, about 6.5 mm wide and 1.5 mm high at the ambitus; composed of five components; e. i., aboral primary, aboral (upper) demi-plate, middle demi-plate, adoral (lower) demi-plate, and adoral primary components; poriferous zones much wider than a half of the interporiferous areas, ratio being about 7:5; pore-pairs form an arc in nearly horizontal row at the ambitus, with pore-pairs tending to form three vertical series; the inner with two pore-pairs of adoral primary of the successive upper plate and of the aboral primary component; the middle with one pore-pair of aboral demi-plate, and the outer with two pore-pairs of middle demi-plate and adoral demi-plate components. Each plate carries a primary tubercle being placed slightly adorally; the tubercles form a vertical series on each side of median line close to the poriferous zone; large secondary tubercles also form a vertical series inside the primary series and very near to median line; the primary tubercles not conspicuous, as large as, or slightly larger than the large secondaries; other secondary tubercles also form vertical series outside the primary series in the poriferous zone; its distance from primary series is almost equal as that of inner secondary series from the primary series; and these tubercles cover sutures of adoral demi-plate and adoral primary components. Secondary tubercles and miliaries, in the interporiferous areas, form circles close to the primary tubercles and the secondaries; in the poriferous zones, small tubercles usually present inside the pore-pairs.

Interambulacra about 14 mm wide at the ambitus; interambulacral plates higher and slightly wider than the ambulacral plates, about 7 mm wide and 2.5 mm high at the ambitus; primary tubercles form a vertical series on the middle of column; a primary tubercle placed centrally and slightly adorally on plate; large secondary tubercles, which are slightly smaller than, or nearly large as, the primaries, form vertical series one inside and the other outside the primary series; small secondary tubercles, at the ambital region, also form two vertical series one inside and the other outside the large secondary series; thus, five vertical series of tubercles on a column at the ambital region; sometimes at the ambital region, two smaller secondary tubercles join with two series of secondary tubercles; small secondary tubercles and miliaries form close circles around the primary tubercles and large secondaries.

Str. intermedius (A. AGASSIZ, 1863) is reported from Sakhalin, Uladivostock, Sianukhu Bay, Hokkaido, Mutsu Bay, Sanriku coast, and Sendai Bay, from the tidal zone to 35 metres in depth. This is very common sea-urchin in the Sendai Bay and Sanriku coast, and caught by fishermen together with *Str. nudus* (A. AGASSIZ, 1863), and *Str. sachalinicus* DÖDERLEIN, 1906 (DÖDERLEIN, 1906-a, p. 517.—MORTENSEN, 1943-a, p. 215, pl. 25, figs. 15-22, pl. 59, figs. 11, 13-24, text-figs. 84, 88b, 91a, 93c, 97, 99b).

Strongylocentrotus echinoides A. AGASSIZ and H. L. CLARK, 1907

(Pl. 8, figs. 5, 6)

Strongylocentrotus echinoides A. AGASSIZ and H. L. CLARK, 1907-b, p. 122.—H. L. CLARK, 1912-b, p. 360, pl. 94, figs. 13-16, pl. 113, fig. 1.—LAMBERT and THIÉRY, 1914, p. 255.—GRANT and HERTLEIN, 1938, p. 33, pl. 21, fig. 7.—IKEDA, 1940, p. 3, pl. 2, fig. 3.—MORTENSEN, 1943-a, p. 219, pl. 24, figs. 7-12. pl. 55, figs. 1, 4-7, 14-15, text-figs. 93b, 98, 99a.—UTINOMI, 1960, p. 340, pl. 38, figs. 7-8.

Locality and geological horizon.—IGPS loc. no. Sr-4.—Akatamobuchi on the River Komebuto, about 2 km south of Kuromatsunai railway station, Kuromatsunai-mura, Suttsu-gun, Shiribeshi, Hokkaido. (tm Oshamanbe, Lat. 42°38′56″N., Long. 140°19′53″ E.). Setana formation, Pliocene. *Hypotype.*—IGPS coll. cat. no. 73796.

Locality and geological horizon.—IGPS loc. no. Sr-12.—A point of Miyakawa, Kami-Iso-mura, Suttsu-gun, Shiribeshi, Hokkaido (exact locality unknown to the writer). (tm Oshamanbe, ca. Lat. 42°36′N., Long. 140°27′E.). Setana formation, Pliocene. *Hypotype.*—IGPS coll. cat. no. 73814.

There are a few fragmentary specimens referred to this species at disposal; they can be assigned to *Str. echinoides* on account of the characteristics of the pore-pairs and the tuberculation on the plates.

Ambulacra rather narrow, about 15 mm wide near the ambital region; ambulacral plates rather high, about 7.5 mm wide and 2.7 mm high near the ambitus; composed of seven components, e. g., aboral primary, upper aboral demiplate, lower aboral demi-plate, middle demi-plate, upper adoral demi-plate, lower adoral demi-plate, and adoral primary; poriferous zones rather narrow, being nearly half of the interporiferous areas; three pore-pairs of aboral primary, upper aboral demi-plate, and lower aboral demi-plate with a pore-pair of adoral primary of successive upper (aboral) plate form a nearly horizontal, or somewhat inclined arc; four pore-pairs of lower aboral demi-plate, middle demi-plate, upper adoral demi-plate, and lower adoral demi-plate form an arc, which is nearly vertical, or strongly inclined. Primary tubercles placed centrally and slightly adorally, and close to the poriferous zone; they form rather conspicuous vertical series on each side of median line; large secondary tubercles form a vertical series inside, halfway between median line and the primary series; smaller secondary tubercles also form two vertical series, one close to median line and the other to middle part of the poriferous zone near the ambital region; small tubercles and miliaries on the poriferous zone numbering about 12, and those on the interporiferous area over 30, and the total over forty on an ambulacral plate near the ambital region.

Interambulacra rather broad, about 20 mm wide near the ambital region; interambulacral plates higher than the ambulacral plates, about 10 mm wide and 3.8 mm high near the ambital region; primary tubercles placed somewhat centrally and adorally, and form a rather conspicuous vertical series on the middle of a column; large secondary tubercles, which are much smaller than the primaries, form two vertical series one inside and the other outside the primary series; of these two, the inner series composed of two rows, one placed adorally and the other aborally on a plate near the ambital region; small secondary tubercles and miliaries rather numerous, over 45 of them being outside the primary tubercle, and even more than 50, inside: nearly 100 in total.

This species so closely resembles *Str. droebachiensis* (O. F. MÜLLER, 1776) (loc. cit.) that some writers consider that the former is only a form or variety of the latter. The former, however, may be distinguished from the latter by the higher ambulacral plates, the more inclined arcs of pore-pairs, which number seven against six, and by the more numerous tubercles on the plates.

This species is rather widely distributed on Northern Pacific Ocean, being reported from the Bering Sea, the Aleutians, the East Coast of Kamchatka, Sakhalin, off Hokkaido, Sea of Japan, and off Kinkasan Light house, in 45-70 metres depths. The fossil occurrence referred to in this paper is the first fossil record.

Strongylocentrotus magistrus NISIYAMA, n. sp.

(Pl. 8, figs. 1-3)

Holotype.—IGPS coll. cat. no. 73813.

Locality and geological horizon.—IGPS loc. no. Tm-8.—In fossiliferous sandstone on cliff back of Shimazaki, Jûnichô-machi, Himi-gun, Toyama Prefecture. (tm Ôchigata, Lat. 36°50′05″N., Long. 136°58′06″E.). Himi formation, Pliocene. *Holotype.*

Locality and geological horizon.—IGPS loc. no. Sr-4.—Akatamo-buchi, about 2 km southeast of Kuromatsunai railway station, Kuromatsunai-mura, Suttsu-gun, Shiribeshi, Hokkaido. (tm Oshamanbe, Lat. 42°38′56″N., Long. 140°19′50″E.). Setana formation, Pliocene. *Hypotype.*—IGPS coll. cat. no. 73797.

There are several fragmentary specimens referable to this new species at hand; the ambulacra represented by the plates of ambital region, aboral, and adoral surfaces; the interambulacra represented by the plates of ambital region, and a part of oral surface.

Ambulacra on adapical surface high trapezoidal in outline, 15 mm wide and 14 mm high, composed of fifteen ambulacral plates, in which nine plates are rather well preserved; both surfaces, defaced, and tubercles on upper surface obsolete. Poriferous zone very wide, as wide as the interporiferous area; first plate adapically on left column with an arc of four pore-pairs in nearly horizontal; from second plate to the fourth are with a more or less inclined arc of five pore-pairs; and fifth and sixth plates with an arc of six pore-pairs; pore-pairs of adoral primary component of successive upper (aboral) plate, aboral primary, upper aboral demi-plate, and lower aboral demi-plate, form a slightly inclined arc; and pore-pairs of lower adoral demi-plate, upper adoral demi-plate, and lower aboral demi-plate, form a markedly curved arc. Ambulacral plates near the ambital region very low, 16 mm wide and 2.5 mm high; primary tubercles placed closed to the poriferous zone and adorally, form a vertical series in each column; large secondary tubercles, which as large as, or slightly smaller than, the primaries, also form two vertical series inside the primary series, and also join with the primary tubercle in a horizontal row on a plate; on the poriferous zone, secondary tubercles, which as large as, or slightly smaller than, the large secondary tubercles on the interporiferous area, form three vertical series near the ambital region; on the interporiferous area, secondary tubercles form aborally an irregular row above the horizontal row of larger tubercles of the primary tubercle and large secondaries; the rest of plate sparsely covered by a few secondaries and miliaries. Ambulacral plates near the ambital region composed of seven components; e.g., the aboral primary, upper adoral demi-plate, lower aboral demi-plate, middle demi-plate, upper adoral demi-plate, lower adoral demi-plate, and adoral primary; pore-pairs of adoral primary component of successive upper (aboral) plate, aboral primary, upper aboral demi-plate, lower aboral demi-plate, and of middle demi-plate, form nearly horizontal arc, while pore-pairs of upper adoral demi-plate, and lower adoral demi-plate form an inclined arc. Ambulacral plates on oral surface with two vertical series of large tubercles on the interporiferous area, and two vertical series of secondary tubercles on the poriferous zone; the number of pore-pairs decreases to six.

Interambulacral plates near the ambital region very low, about 30 mm wide and 5 mm high; tubercles very numerous, and the primaries comparatively small, scarcely distinguishable from large secondaries; primary tubercle placed centrally and somewhat adorally on a plate; large secondary tubercles form four vertical series inside the primary series, and outside the primary series there are three irregular series, which also join to form two horizontal rows on a plate; small secondary tubercles form a horizontal row aborally and inside the primary tubercle; other small secondary tubercles and miliaries form close circles around the larger tubercles of primaries and secondaries. Adorally, the inner series of large secondary tubercles decrease in number from three to two, and the outer series irregularly from two to one series.

Distinction.—This new species closely resembles *Str. polyacanthus* A. AGASSIZ and H. L. CLARK, 1907 (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.—MORTENSEN, 1943-a, p. 223, pl. 25, figs. 1-3, pl. 55, figs. 11-13, 18, 23, text-figs. 97b, 100a, 101a), from the Northern Hokkaido and Kurile Islands, with respect to low ambulacral plates, and the arrangement of pore-pairs in the poriferous zone. However, this species is distinguished from that species by the tuberculation on the interambulacral and ambulacral plates; in that species the primary tubercles are much larger than the large secondary tubercles, and vertical series of large secondary tubercles much fewer than in this species, and by the number of pore-pairs. This species is also related to *Str. droebachiensis* (O. F. MÜLLER, 1776) (loc. cit.), but is distinguishable from it by the much lower interamblacral and ambulacral plates, the tuberculation on plates, and by the number of pore-pairs, e. g., seven pore-pairs of this species against six pore-pairs of that species.

Strongylocentrotus? *octoporus* NISIYAMA, n. sp.

(Pl. 8, figs. 7, 8)

Strongylocentrotus? octoporus NISIYAMA (MS): OZAKI, 1958, p. 177, pl. 10, fig. 17 (no description).

Holotype.—IGPS coll. cat. no. 73723.

Locality and geological horizon.—IGPS loc. no. Ao-11.—Roadside cutting at Yunosawa, Fukaura-machi, Nishi-Tsugaru-gun, Aomori Prefecture. (tm Fukaura, Lat. 40° 37′21″N., Long. 139°55′49″E.). Fukaura formation, Lower Pliocene or Miocene (HATAI and NAKAMARA, 1940, p. 165). *Holotype.*

Locality and geological horizon.—IGPS loc. no. Ao-12.—Roadside cutting at Metoki signal place, Tomesaki-mura, Sannohe-gun, Aomori Prefecture. (tm Sannohe, Lat. 40° 20′45″N., Long. 141°17′04″E.). Suenomatsuyama formation, Lower Pliocene or Miocene. *Hypotype.*—IGPS coll. cat. no. 73724.

There are several fragmentary specimens referred to this new species at the writer's disposal: the two large fragments show the characteristics of the ambulacrum and interambulacrum of this species.

Test rather small, judged from coronal plates preserved, stout and thick, about 1.5 mm thick below the ambital region. Ambulacra rather wide, as nearly broad as, or slightly narrower than, the interambulacra, about 10 mm wide at the ambital region; ambulacral plates rather low, about 5 mm wide and 2 mm high at the ambital region; made up of four components, the aboral primary, aboral demi-plate, adoral demi-plate, and adoral primary; poriferous zones rather narrow, half broad as the interporiferous areas; three pore-pairs of aboral primary, aboral demi-plate, and adoral demi-plate with pore-pair of adoral primary of the successive upper plate, form an inclined arc; the outermost pore-pair is that of adoral demi-plate, and of adoral primary component very close to the base of primary tubercles. Primary tubercles large, placed close to the poriferous zone, form conspicuous vertical series on each side of median line; large secondary tubercles also form two vertical series one outside, on the poriferous zone, and the other inside the primary series; secondary tubercles on the poriferous zone rather large, and cover the suture of aboral demi-plate and adoral demi-plate; small secondary tubercles and miliaries very few in number, and roughly form circles around the primary tubercles.

Interambulacra rather wide, slightly broader than the ambulacra at the ambital region, about 11 mm wide; interambulacral plates higher than the ambulacral plates, about 4.5 mm wide and 2.5 mm high at the ambital region; primary tubercles, which are larger than those on the ambulacra, placed somewhat centrally and adorally, form a conspicuous vertical series on the middle of each column; large secondary tubercles, which are slightly smaller than the primaries on the interambulacra, or nearly as large as the primaries on the ambulacra, form two vertical series, one outside and the other inside the primary series from the ambital region to aborally; below the ambitus, the outside series is composed of two horizontal rows, one placed adorally and the other aborally on a plate; small secondary tubercles and miliaries few in number, and form circles around the larger tubercles of the primaries and large secondaries.

Apical system, peristome, and gill-slits are not accessible.

Distinction.—The arrangement of the pore-pairs in arcs of four is very characteristic of this new species. The similar quadrigeminate ambulacral plates are found among the species of allied genera in the families of polyporous forms, e. g., *Polyechinus* MORTENSEN, 1942 (MORTENSEN, 1942, p. 231.—Orthotype—*Paracentrotus agulhensis* (DÖDERLEIN, 1905) DÖDERLEIN, 1906, p. 207, pl. 27, figs. 1-4, pl. 35, fig. 17, pl. 47, fig. 1—Echinidae), *Caenocentrotus* H. L. CLARK, 1912 (H. L. CLARK, 1912-b, p. 348.—Orthotype—*Strongylocentrotus gibbosus* (VALENCIENNES, 1846) A. AGASSIZ, 1872-74, pp. 164, 444—Echinometridae), *Pachycentrotus* H. L. CLARK, 1912 (H. L. CLARK, 1912-b, p. 349.—Orthotype—*Pac. australiae* (A. AGASSIZ, 1872) H. L. CLARK, 1912-b, p. 349, pl. 98, figs. 5-8—Echinometridae), *Hemicentrotus* MORTENSEN, 1942 (loc. cit.), and *Pseudoboletia* TROSCHEL, 1869 (TROSCHEL, 1869-b, p. 96.—Logotype—*Ps. maculata* TROSCHEL, 1869-b, p. 96.—MORTENSEN, 1903-b, p. 118, pl. 21, figs. 1, 15, 17—Toxopneustidae).

This new species somewhat resembles *Caen. gibbosus* (VALENCIENNES, 1846), in the arrangement of pore-pairs in ambulacra. The latter is a Recent species from the Galapagos and coast of Peru, but differs from that species by the wider ambulacra, and by the tuberculation on the coronal plates. This species also resembles *Pac. australiae* (A. AGASSIZ, 1872), a Recent species from Southwestern Australia, in respect to the structure of ambulacral plates, but is distinguished from that species by the tuberculation on interambulacra, and by the lower coronal plates. Among the Japanese species, *Hem. pulcherrimus* (A. AGASSIZ, 1863) (*Psammechinus pulcherrimus* A. AGASSIZ, 1863-a, p. 375.—*Sphaerechinus pulcherrimus* (A. AGASSIZ) TOKUNAGA, 1906, pl. 13, figs. 1-4) a species with pore-pairs in arcs of four, but is easily distinguished from *Str.* ? *octoporus* by the much wider poriferous zones, and arcs of pore-pairs are nearly horizontal at the ambital region, much closer tuberculation on coronal plates, and by much lower interambulacral and ambulacral plates. The arrangement of pore-pairs in an arc, and the tuberculation on coronal plates of *Str.* ? *octoporus*, suggest that it may be a primitive species among the Japanese Strongylocentrotids, and it is the oldest Strongylocentroid hitherto known in Japan.

Associated fauna (HATAI and NAKAMURA, 1940, p. 166).—*Ostrea gigas* THUNBERG and *Chlamys igeniosa* YOKOYAMA.

Genus *Allocentrotus* MORTENSEN, 1942

Allocentrotus MORTENSEN, 1942, p. 232.—MORTENSEN, 1943-a, p. 254.—H. L. CLARK, 1948, p. 276.

Orthotype.—Strongylocentrotus fragilis JACKSON, 1912, p. 128.—H. L. CLARK, 1912-b, p. 354, pl. 94, figs. 28-29, pl. 113, figs. 3-6 (from Washington to Lower California, 75-1152 metres in depth).

Large forms of regularly hemispherical shape. Test very delicate and fragile. Ambulacral plate 5- or 7-geminate; the arcs of pore-pairs very oblique, though not quite horizontal; the pore-pairs not arranged in vertical series. Ambulabra on the oral side gradually narrowing towards the peristome so that they are distinctly narrower than the interambulacra at the peristomial edge. Primary tubercles rather small, not conspicuous; secondary tubercles small on the aboral side; better developed on the oral side. Spicules of globiferous pedicellariae simply C-shaped, those of tube-feet with outer prominences at the ends. Auricles conspicuously widened above. Globiferous pedicellariae as in *Strongylocentrotus* (after MORTENSEN, 1943-a).

This genus is very interesting, as it has hitherto considered to comprise only a single species, and is confined in its geographical distribution to the West Coast of North America. The type-species, *All. fragilis* (JACKSON, 1912), is characterized by the thin, fragile and low test, shallow gill-slits, high and slender auricles, the tuberculation on coronal plates, and especially by the constriction of the ambulacra on the oral side; it is a rather rare species even in California. The occurrence of second and fossil species from Central Japan, as described herein, gives us very interesting and important problems in geological history and the derivation of this genus.

Allocentrotus japonicus NISIYAMA, n. sp.

(Pl. 8, figs. 4, 10-14, pl. 9, figs. 1-2, 4-6)

Holotype.—IGPS coll. cat. no. 73798.

Locality and geological horizon.—IGPS loc. Ch-12.—Tuffaceous sandstone of sea cliff below shrine at Tômiya, Takeoka-mura, Kimitsu-gun, Chiba Prefecture. (tm Futtsu, Lat. 35°12′52″E., Long. 139°51′E.). Kurotaki formation (Tômiya tuffaceous sandstone), Lower Pliocene. Collected by K. HATAI, T. KOTAKA, K. HATORI, and the writer, 1950.

There is a large somewhat depressed specimen at the writer's disposal. It measures about 95 mm in horizontal diameter, and 38 mm in height.

Test large, low, and rather thin, about 1.5 mm thick at the ambital region; apical system lacking, vacant area about 11 mm in diameter; peristome more or less deeply sunken adorally, and about 24 mm in diameter. Ambulacra rather narrow, about 24 mm wide at the ambital region, and narrowed to the peristomial edge, not subpetaloid on oral surface; there are 38 or 39 ambulacral plates in each column; ambulacral plates rather high, about 12 mm wide and 3.5 mm high at the ambital region; from apical system to the ambitus 19 or 20 plates in one column; fifth plate from the apical system, 5 mm wide and 3 mm high. Poriferous zones broad, about 7 mm wide at the ambital region; second plate from the apical system with five pore-pairs of an inclined arc, from third to sixth plates with six pore-pairs of an inclined arc, and from seventh plate to the plate on the ambital region with seven pore-pairs of a rather oblique arc; ambulacral plates at the ambital region composed of seven components; the aboral primary, upper aboral demi-plate, lower aboral demi-plate, middle demi-plate, upper adoral demi-plate, lower adoral demi-plate, and adoral primary; pore-pairs of these components are large, and form, with pore-pair of adoral primary component of successive upper plate, an oblique arc, and the arcs themselves approach horizontal in form, at the ambital region, but not quite horizontal. Secondary tubercles, on the poriferous zones, form three vertical series from ninth or tenth plate to the plate on the ambital region, and each pore-pair with a small secondary tubercle inside. Each ambulacral plate carries a primary tubercle, which has relatively large base, but small mamelon; they form vertical series on each side of median line, and close to the poriferous zones; the rest of plates covered by few and small secondary tubercles and miliaries; secondary tubercles also form a vertical series inside the primary series; secondaries and miliaries on the interporiferous areas very small, and there are bare median areas aborally.

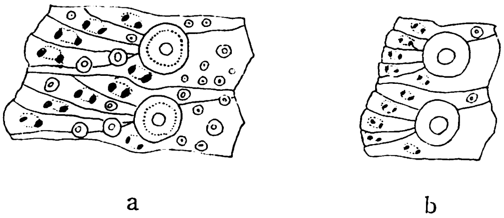

a b

Fig. 23. *Allocentrotus fragils* (JACKSON, 1912) (for comparison). (sketched from MCZ's coll., from California) (enlarged).

a. Two ambulacral plates at the ambital region; b. Two ambulacral plates on the adapical part.

Interambulacra broad, 40 mm wide at the ambital region; interambulacral plates rather high, about 20 mm wide and 7 mm high at the ambital region; there are 25 or 26 plates in each column, also 10 or 11 plates from the apical system to the ambitus; each plate carries a primary tubercle, which has large base and small mamelon; it placed somewhat outside the middle and decidedly adorally, its base reaches adoral suture of the plate; they form a vertical series outside the middle of column; large secondary tubercles, decidedly smaller than the primaries, form two vertical series inside and other two outside the primary series; the inner two large secondary tubercles placed somewhat aborally and join in a horizontal row; four outer large secondary tubercles are placed in two horizontal rows on a plate at the ambital region; two inner series of large secondary tubercles begin at 8th plate from the apical system, and continue adorally to 4th plate below the ambitus; small secondary tubercles and miliaries, which are very small in size, are numerous and form circles close to the base of the larger tubercles of the primaries and large secondaries.

Gill-slits shallow; auricles high, slender and rather racquet-shaped. Spines and pedicellariae are not accessible.

Distinction.—This new species resembles *All. fragilis* (JACKSON, 1912) (*Strongylocentrotus fragils* JACKSON, 1912, p. 128 (Catalina Islands, California (MCZ no. 3395)).—*All. fragilis* (JACKSON) MORTENSEN, 1943-a, p. 255, pl. 30, figs. 10-17, pl. 61, figs. 4-5, 7, 11-12, 14, text-figs. 113b-c, 117-119.—H. L. CLARK, 1948, p. 276, pl. 44, fig. 21), from Vancouver Islands to Lower California, of Western Coast of North America, in moderate depths (50-1150 metres), in the form of test, the tuberculation on interambulacral plates, the manner of arrangement of pore-pairs, shallow gill-slits, and in high auricles. This species, however, is distinguished from that species by the number of pore-pairs in each arc, i. e., seven pore-pairs of this species against five pore-pairs of that species, and by the more prominent tuberculation on the ambulacral plates. This species has also some resemblance to the species of *Strongylocentrotus*, such as *Str. echinoides* A. AGASSIZ and H. L. CLARK, 1907 (loc. cit.), from the Northern Pacific, but is easily distinguished from it by the lower test, the tuberculation on coronal plates, and by the constriction of ambulacra on the oral side.

Family PARASALENIIDAE MORTENSEN, 1903

Parasaleninae MORTENSEN, 1903-b, p. 138 (subfamily of the *Toxopneustidae*).—DELAGE and HÉROUARD, 1903, p. 245.—MEISSNER, 1904, p. 1375.—*Parasaleniidae* MORTENSEN: MORTENSEN, 1943-a, p. 259.—TERMIER and TERMIER, 1953, p. 910.

Type-genus.—*Parasalenia* AGASSIZ, 1863

Small to moderate-sized forms of more or less elongate shape; the long axis about in the line of ocular (III)—genital (5). Trigeminate ambulacra of the typical echinoid structure; pore-zones narrow. Primary tubercles begin at on every second or third plate from the apical system. Secondary tubercles little developed. Apical system dicyclic, more or less elongate; periproct consequently more or less elongate; anal plates typically four of equal size, as those of *Arbacia*. Gill-slits shallow. Buccal membrane plated. Spines simple, without axial cavity, not showing growth cycles. Pedicellariae of the usual four kinds; globiferous pedicellariae without neck, but with stalk-glands; valves without lateral teeth. Spicules of tube-feet biacerate, with a couple of processes on the inside (from MORTENSEN, 1943-a).

From the Lower Miocene (or Oligocene) to Recent.

The very peculiar combination of the characters found in the type-genus *Parasalenia:* e.g., the test more or less elongate as in *Echinometra* of the Echinometrids, but only trigeminate ambulacra of the echinoid structure as in *Echinus* of the Echinids, and four anal plates as in *Arbacia* of the Arbaciids, that naturally causes much difficulty as to its real affinities. H. L. CLARK (1912-b, pp. 366, 370.—1925, pp. 105, 141.—1946, p. 330) classified it into the family of the Echinometrids, founded on its elliptical ambitus. The larval form of *Parasalenia* is not known to H. L. CLARK (1925, p. 105); from the recent research of the larvae, however, MORTENSEN (1943-a, p. 265) stated that the larvae of this genus cannot prove any close relationship with the Echinometrids, because the larval skeletal type of *Parasalenia* is found in the larvae of both genera, *Echinometra* and *Stomopneustes.*

MORTENSEN (1943-a, p. 275) referred a superfically very different Eocene form, which he called *Diplosalenia,* to this family. The relationship of *Diplosalenia* (MORTENSEN, 1942, p. 232.—1943-a, p. 275.—Orthotype—*Parasalenia gosseleti* COTTEAU (COTTEAU, 1889-94 (93), p. 663, pl. 353, figs. 12-16—Eocene of Cassel)) to *Parasaelnia* is quite uncertain; *Diplosalenia* may be left aside as an incertae sedis. The family of the Parasaleniids may be regarded as a distinct family separated from the families of the Echinometrids and the Strongylocentrotids.

There is a fossil species of the genus *Parasalenia* in our collection.

Genus *Parasalenia* A. AGASSIZ 1863

Parasalenia A. AGASSIZ, 1863, p. 22.—A. AGASSIZ, 1872-74, pp. 148, 435.—STEWART, 1880. p. 910.—POMEL, 1883, p. 78.—PFEFFER, 1887, p. 107.—DUNCAN, 1889-a, p. 120.—COTTEAU, 1889-94(93), p. 631.—MORTENSEN, 1903-b, pp. 128, 138.—MEISSNER, 1904, p. 1375.—LAMBERT, 1910-b, p. 21.—H. L. CLARK, 1912-b, p. 368.—LAMBERT and THIÉRY, 1914, p. 269.—H. L. CLARK, 1925, p. 141.—MORTENSEN, 1943-a, p. 267.—H. L. CLARK, 1946, p. 331.—TERMIER and TERMIER, 1953, p. 910.

Haplotype.—Parasalenia gratiosa A. AGASSIZ, 1863, p. 22.—A. AGASSIZ, 1872-74, p. 435, pl. 3d, figs. 1-2 (Hawaiian Islands).

Cladosalenia A. AGASSIZ, 1872-74(72), p. 148 (as a synonym of *Parasalenia* A. AGASSIZ, 1863).

Ambulacral primary tubercles occupy most of the interporiferous area, but leaving a narrow median space, in which some small secondaries are found. Secondary tubercles on interambulacra little developed, not forming vertical or horiontal series. Apical system more or less elongate; genital plates prolonged distally. Other characters are given in the diagnosis of the family.

This is a very interesting and perplexing genus, and its true affinities are by no means clear. Besides the characters of ambulacra, as described above, and anal plates, and the form of test, the lantern, teeth, and auricles of this are like those of small *Echinometra.* It is clear from these important structure of the teeth and peristome, that there is no clear kinship to *Arbacia* of the Arbaciids, and the pedicellariae and larval form confirmed by the Recent forms assure this conclusion. This genus, however, differs from *Echinometra* in the long axis of test, which is through ocular (IIIb)—genital (5b), but not genital (3)—ocular (I) as in *Echinometra*.

LAMBERT and THIÉRY (1914, p. 269) listed three fossil species under the genus *Parasalenia*, e. g., *Par. gosseleti* COTTEAU, 1893 (loc. cit.), *Par. fontannesi* COTTEAU, 1888 (COTTEAU, 1888, p. 118, pl. 13, figs. 9-11.—COTTEAU, 1890, p. 134, pl. 16, figs. 11-12—Aquitanian of Marseille), and *Par. prisca* COTTEAU, 1875 (COTTEAU, 1875, p. 12, pl. 1, figs. 19-27.—JACKSON, 1922, p. 25, pl. 1, figs. 21-24—Miocene (Anguilla formation) of West Indies). The first species is made the type of a distinct genus, *Diplosalenia*, by MORTENSEN; the second species was assigned to this genus, by MORTENSEN, but the systematic position of this fossil is uncertain; the third species was previously established by POMEL (1883, p. 78), the type of his *Plagiechinus*, but MORTENSEN (1943-a, p. 353) treated it as a junior synonym of *Echinometra*. This species, however, was assigned to *Parasalenia* by COOKE (1957, p. 361), because of the longer diameter of the test seems to coincide with the longitudinal axis, as in *Parasalenia*, and only three pairs of pores on one ambulacral plate. *Ech. prisca* from the Anguilla formation of West Indies (in USNM) lacks the apical system, and the primary tubercles are smaller and the gill-slits are deeper than in the species of *Parasalenia*.

This genus includes two living species, viz., *Par. gratiosa* A. AGASSIZ, 1863 (loc. cit), with subspecies (or variety) *boninensis* MORTENSEN, 1930 (1930-a, p. 388, pl. 1, figs. 2-5), and *Par. poehlii* PFEFFER, 1887 (1887, p. 110). It is very interesting to refer to the find of fossil of the typical species from the Lower Miocene (or Oligocene) of Saipan Island.

Parasalenia marianae COOKE, 1957

(Pl. 10, figs. 8-10)

Parasalenia marianae COOKE, 1957, p. 361, pl. 119, figs. 1-3.

Locality and geological horizon.—In a doliné on Denshin-yama, Saipan Island, Mariana (Ladrone) Islands, Micronesia, South Sea Islands. Donney formation (*Spiroclypeus*—horizon), Lower Miocene (Oligocene of authors). *Hypotype.*—IGPS cat. no. 73736.

There is a single specimen referred to this species at the writer's disposal. It is very small, 9 mm in longer axis, 7.5 mm in shorter one, and about 4 mm in height; but well shows the characters of the species.

The holotype lacks the apical system (USNM no. 561578—about 23 mm in longer axis), as well as in the specimen at the writer's disposal; but the vacant area is very large as in the species of *Parasalenia*, much larger than in the species of *Echinometra*; the area measures 3 mm in longer axis in the specimen at disposal. Ambulacra narrow; trigeminate ambulacral plates of the echinoid structure; pores of a pair large and peripodia distinct as in *Parasalenia*. Ambulacral primary tubercles rather large; the primary begins at every second plate from the apical system; although COOKE (1957, p. 361) failed to describe this feature, it is found in the holotype also. Gill-slites very shallow, and median notches on ambulacra not well observed. Spines and pedicellariae are not accessible.

This species can be safely assigned to typical *Parasalenia*, on account of the characteristic of the ambulacra, form of test, and the tuberculation on coronal plates, particularly of the ambulacral primary tubercles.

This species closely resembles *Par. gratiosa* A. AGASSIZ, 1863 (loc. cit), a Recent species from the Indo-Pacific Oceans; but is distinguishable from the latter by the narrower poriferous zones, and by the larger primary tubercles on ambulacra. The difference of two species is clearly recognized when the specimen of this species is directly compared with the young specimens (12-25 mm in longer axis) of *Par. gratiosa* from Palao Islands, Micronesia. It seems evident that this species has certain affinities with Recent species of the Indo-West Pacific, but not with the Miocene *Par. prisca* (COTTEAU, 1875) (loc. cit.) of the West Indies, as suggested by COOKE (1957, p. 361).

Family ECHINOMETRIDAE GRAY, 1855

Echinometradae GRAY, 1855, p. 37.—*Echinometridae* GRAY: A. AGASSIZ, 1872-74, p. 423 (pro parte).—BELL, 1881-a, p. 410.—POMEL, 1883, p. 77.—DUNCAN, 1889-a, p. 115.—GREGORY, 1900-b, p. 313 (pro parte).—MORTENSEN, 1903-b, p. 138.—DELAGE and HÉROUARD, 1903, p. 246.—MEISSNER, 1904, p. 1375.—JACKSON, 1912, pp. 146, 204, 267.—H. L. CLARK, 1912-b, p. 365.—H. L. CLARK, 1925, p. 141 (pro parte).—GIGNOUX, 1933, p. 121.—GRANT and HERTLEIN, 1938, p. 39.—MORTENSEN, 1943-a, p. 277.—H. L. CLARK, 1946, p. 330 (pro parte).—TERMIER and TERMIER, 1953, p. 910.

Type-genus.—*Echinometra* (BREYNIUS) GRAY, 1825

Test of small to very large size, varying in shape from round to elliptical, being transversely elongate. Ambulacra with trigeminate to multigeminate (polyporous) plates of the echinoid structure, or its complex type; pore-zones often petaloid, widened adorally. No pits or sculpture in coronal plates aborally. Primary tubercles imperforate, non-crenulate. Apical system usually with oculars (I) and (V) broadly insert; suranal plate usually indistinct. Buccal membrane usually with scattered plates, which carry number of pedicellariae, sometimes spines also; at least the membrane contains a varying number of delicate plates imbedded in the skin. Primary spines mostly long and strong, sometimes particularly long and thick, pencil-like (*Heterocentrotus*), or flattened, shield-like (*Colobocentrotus*). Pedicellariae, of the usual four kinds; globiferous pedicellariae mostly without neck, with double poison glands, and with compact stalk. Valves of globiferous pedicellariae with a single, unpaired lateral tooth. Spicules usually of the simple bihamate type, but sometimes with branched ends, or biacerate, with pointed ends (*Anthocidaris*), or coarse, triradiate (*Echinometra mathaei oblonga*). In the first larval stage, the body skeleton forms a complicate basket structure, the recurrent rod being double; in the second fully formed stage, the larva has a well developed posterior transverse rod (after MORTENSEN, 1943-a).

From the Miocene to Recent.

This is a rather well marked tropical family of some 10 genera, which are characterized by their high specialization of the ambulacral structure and spines. As no fossil genera are known which can be referred to this family, it might be in the Recent Epoch that these specialized forms have had their main development. About the source from which this highly specialized family of the Echinometrids have derived nothing certain can be said at the present state of our knowledge. The subdivision of the family into two or three subfamilies, as stated by MOREENSEN (1943-a, p. 288), seems to be superfluous.

This family of Japan and the adjacent regions is represented by the following genera, viz., *Echinostrephus* A. AGASSIZ, 1863, *Anthocidaris* LÜTKEN, 1864, *Echinometra* (BREYNIUS) GRAY, 1825, *Heterocentrotus* BRANDT, 1835, and *Colobocentrotus* BRANDT, 1835; they are discriminated from one another as shown by the following key.

Key to the Japanese genera of the Echinometridae.

1. Ambitus circular; primary spines long and strong, usually simple 2
   Ambitus more or less elliptical; spines usually modified into heavy or flat-topped, only exceptionally simple and normal 3
2. Test usually with ambitus above equator, or rarely not; only three or four pore-pairs to the arc; a primary tubercle to each ambulacral plates; gill-slits very shallow .... *Echinostrephus*
   Test generally with ambitus below equator; ambulacra polyporous, 7-8, or rarely 9 pore-pairs in an arc; distinctly petaloid on the oral side; spicules of tube-feet bow-shaped ("biacerate"), with pointed ends .... *Anthocidaris*
3. Long axis of test through A. I-I.A. 3; marginal spines not forming a lateral fringe or otherwise specially developed; ambulacra with 4-10 pore-pairs to each arc; buccal plates with small spines..................... *Echinometra*
   Long axis through A. II (a)-I. A. 4 (a) 4
   Long axis through A. IV (b)-I. A. I (b) 5
4. Primary spines very strongly developed, long, thick, heavy and pencil-like; primary tubercles very large; ambulacra with 9-19 pore-pairs in an arc .... *Heterocentrotus*
5. Aboral spines flattened, thick and very short, forming like a dense mosaic; primary tubercles moderate, in mid-zone 10-12 in two horizontal rows on each interambulacral plate .... *Colobocentrotus.*

There are fossil representatives of the genera *Echinostrephus* and *Echinometra* in our collection.

Genus *Echinostrephus*[1] A. AGASSIZ, 1863

Echinostrephus A. AGASSIZ, 1863, p. 20.—A. AGASSIZ, 1872-74, pp. 119, 457.—BELL, 1881-a, p. 433.—POMEL, 1883, p. 78.—DUNCAN, 1889-a, p. 123.—MORTENSEN, 1903-b, p. 139.—MEISSNER, 1904, p. 1376.—H. L. CLARK, 1912-b, p. 342.—LAMBERT and THIÉRY, 1914, p. 254.—H. L. CLARK, 1925, p. 130.—MORTENSEN, 1943-a, p. 304.—H. L. CLARK, 1946, p. 327.

Haplotype.—Echinostrephus aciculatus A. AGASSIZ, 1863, p. 20 (Sandwich Islands).—A. AGASSIZ, 1872-74, p. 457, pl. 5a, figs. 10-12, pl. 6, fig. 20.

Raphidechinus LAMBERT and THIÉRY, 1914, p. 241.

Orthotype.—Echinus molaris BLAINVILLE, 1825, p. 88.—DE LORIOL, 1883-a, p. 31, pl. 4, figs. 2-2c (Indian Ocean).

Small forms of generally unusual shape of test, or rarely usual shape; the greatest diameter is generally above the midzone (equator); aboral side usually flat; circumference of test often pentagonal. Ambulacra with trigeminate plates (*molare*),

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[1] *στρεφος=στερφος, εος, το,* is neuter gender, not masculine.

or quadrigeminate (*aciculatum*). Primary ambulacral tubercles form regular vertical series; secondary tubercles small, not forming distinct vertical series. Secondary interambulacral tubercles well developed, forming horizontal rows. Apical system small; ocular plates generally exsert. Peristome large; gill-slits rather shallow. Buccal membrane with scattered plates carrying pedicellariae. Auricles rather narrowly united above, apophyses low. Spines of the aboral side long, forming an erect tuft; spines of the side of test short, the adoral ones rather long, curved. Globiferous pedicellariae with or without stalk glands; valves with an unpaired lateral tooth; poison glands double. Spicules slender, bihamate. Larvae of the Echinometrid type (from MORTENSEN, 1943-a).

From the Lower Miocene to Recent.

The generic distinction between oligoporous (ambulacra with trigeminate plates —*Raphidechinus*) and polyporous (with quadrigeminate plates—*Echinostrephus*) forms in this genus, as mentioned by LAMBERT and THIÉRY (1914, pp. 234, 241), seems to be unnatural, as the two forms are so closely related each other that their generic separation is impossible.

This interesting genus comprises only two living species, as described above, from the Indo-Pacific Oceans. The two species were often confounded with each other, e.g., A. AGASSIZ (1872-74, p. 457) described specimens under the the name *Ech. molaris* and figured *Ech. aciculatus;* and YOSHIWARA (1898, p. 59) established a new species, *Ech. pentagonus*, from Bonin Islands, but it is now clear that YOSHIWARA's species is only a junior synonym of *Ech. molare.*

The two species, *molare* and *aciculatum*, are distinguished from each other by the characters of test as follows:

Ech. molare	*Ech. aciculatum*
Pore-pairs 3 in an arc; ambitus more or less evidently pentagonal.	Pore-pairs 4 in an arc; ambitus circular.
Genital and ocular plaes with few tubercles only on outer margin.	Genital and ocular plates with more or less numerous tubercles.
Test usually more or less bright green.	Test dull purplish or greenish.

There is a fossil specimen of *Ech. aciculatum* A. AGASSIZ, 1863, in our collection.

Echinostrephus aciculatum A. AGASSIZ, 1863

(Pl. 9, fig. 3, pl. 10, figs. 2, 3)

Echinostrephus aciculatus A. AGASSIZ, 1863, p. 20.—H. L. CLARK, 1912-b, p. 342, pl. 95, figs. 23-24, pl. 105, fig. 9.—LAMBERT and THIÉRY, 1914, p. 254.—*Echinostrephus aciculatum* A. AGASSIZ: H. L. CLARK, 1925, p. 96.—H. L. CLARK, 1938-a, p. 402.—NISIYAMA, 1942, p. 19 (in Japanese).—*Echinostrephus aciculatus* A. AGASSIZ: MORTENSEN, 1943-a, p. 306, pl. 35, figs. 11-29, pl. 58, figs. 3, 5-8, 11-15, text-figs. 145, 146a, 148, 150c-d.—*Echinostrephus aciculatum* A. AGASSIZ: H. L. CLARK, 1945, p. 318, pl. 41, figs. J, M.—H. L. CLARK, 1946, p. 328.—*Echinostrephus aciculatus* A. AGASSIZ: UTINOMI, 1954, p. 350.

Echinostrephus molaris A. AGASSIZ, 1872-74, pp. 119, 457 (partim), pl. 5a, figs. 10-12, pl. 6, fig. 20 (non BLAINVILLE, 1825).—A. AGASSIZ and H. L. CLARK, 1907-a, p. 242.

Locality and geological horizon.—A point on Ishigaki-jima in Ryukyu Islands. Ryukyu Limestone, Pleistocene. *Hypotype.*—IGPS coll. cat. no. 73763 (colleceed by the

H. L. CLARK, 1912-b, p. 370.—H. L. CLARK, 1925, p. 142.—GRANT and HERTLEIN, 1938, p. 39.—MORTENSEN, 1943-a, p. 352.—H. L. CLARK, 1946, p. 332.—COOKE, 1959, p. 25.

Logotype.—Echinus lucunter LINNAEUS, 1758, p. 665.—*Echinometra subangularis* (LESKE) A. AGASSIZ, 1872-74, p. 283, pl. 10a, figs. 2-4 (Caribbean, east coast of South America, and west coast of Africa).—*Echinometra lucunter* (LINNAEUS) COOKE, 1959, p. 125, pl. 6, figs. 1-2 (Florida to Brazil, and the Bermuda, and western coast of Africa). [COTTEAU, 1861-67(67), p. 820.—LAMBERT, 1910-b, p. 48.—H. L. CLARK, 1912-b, p. 370].

Ellipsechinus LÜTKEN, 1864, p. 165.—COTTEAU, 1861-67(67), p. 820.—LAMBERT and THIÉRY, 1914, p. 256.—SANCHEZ ROIG, 1926, p. 40.

Haplotype.—Ellipsechinus macrostomus LÜTKEN 1864, p. 165, pl. 1, fig. 10.—*Echinometra van-brunti* A. AGASSIZ, 1863, p. 21 (Acapulco, Mexico).—H. L. CLARK, 1910, p. 346, pl. 11, fig. 1 (Panama) (This species includes *Heliocidaris stenopora* H. L. CLARK, 1912-b, p. 351, pl. 95, figs. 18-22, pl. 104, figs. 1-3, pl. 110, figs. 4-5 (Acapulco and Gulf of California)).

Plagiechinus POMEL, 1883, p. 78. (Accoriding to MORTENSEN, 1943-a, p. 353).

Haplotype.—Echinometra prisca COTTEAU, 1875, p. 12, pl. 1, figs. 19-27.—JACKSON, 1922, p. 25, pl. 1, figs. 21-24 (Miocene of Anguilla Island). (According to COOKE (1957, p. 136), this species should be assigned to *Parasalenia*).

Mortensenia DÖDERLEIN, 1905, p. 633.—DÖDERLEIN, 1906, p. 233.

Haplotype.—Echinus oblongus BLAINVILLE, 1825, p. 95.—*Echinometra oblonga* (BLAINVILLE) H. L. CLARK, 1912-b, p. 373, pl. 114, figs. 1-2.—*Echinometra mathaei oblonga* (BLAINVILLE) MORTENSEN, 1943-a, p. 393, pl. 48, figs. 1-20 (Pacific Ocean, littoral).

Test is rather stout; size moderate to rather large; usually distinctly elongate, the longitudinal axis being I. A. 3-A. I, but sometimes the elongation is almost subtle. Ambulacra polyporous, with 4-10 pore-pairs to each arc, except adoral region, where the pore-pairs are only 3 at the peristomial edge; pore-zones may be distinctly petaloid adorally, or not at all widened. Median space between the two series of primary ambulacral tubercles very narrow, leaving room only for quite small secondary tubercles, the largest ones, placed at the upper corner of the plates, form an inconspicuous zigzag series. Interambulacral tubercles in regular vertical series, usually not in distinct horizontal rows. Apical system with all oculars exsert, or one or two of them insert; periproctal plates not very numerous; suranal plate indistinct. Buccal plates with few or numerous small spines; buccal membrane always contains a number of plates imbedded in the skin; usually some of them are thickened and carry pedicellariae, sometimes also small spines. Gills usually have a long tag on the side turning towards the test, but it is mostly very delicate and not easily preserved on dried and clearned tests. Auricles may have a large superstructure (particularly strongly developed in *Ech. lucunter*). Primary spines moderately long, usually strong and pointed, sometimes distinctly clavate. Globiferous pedicellariae with double poison glands, usually without stalk glands; the valves with well developed lateral tooth. Spicules of tube-feet simply C-shaped or triradiate, in the latter case usually being arranged in two dense longitudinal series. Body skeleton of the larva in its first stage is of a complicate basket structure; fully formed larva has a posterior trnasverse rod (after MORTENSEN, 1943-a).

As for the genus *Mortensenia*, DÖDERLEIN, (1905, p. 633.—1906, p. 233) established it because of the character of its peculiar triradiate spicules in the tube-feet of *Ech. mathaei oblonga*, but this form of spicules also occur in *Ech. mathaei*. Thus, the character of the spicules in the tube-feet is untenable as feature to distinction of generic level in this case.

or quadrigeminate (*aciculatum*). Primary ambulacral tubercles form regular vertical series; secondary tubercles small, not forming distinct vertical series. Secondary interambulacral tubercles well developed, forming horizontal rows. Apical system small; ocular plates generally exsert. Peristome large; gill-slits rather shallow. Buccal membrane with scattered plates carrying pedicellariae. Auricles rather narrowly united above, apophyses low. Spines of the aboral side long, forming an erect tuft; spines of the side of test short, the adoral ones rather long, curved. Globiferous pedicellariae with or without stalk glands; valves with an unpaired lateral tooth; poison glands double. Spicules slender, bihamate. Larvae of the Echinometrid type (from MORTENSEN, 1943-a).

From the Lower Miocene to Recent.

The generic distinction between oligoporous (ambulacra with trigeminate plates —*Raphidechinus*) and polyporous (with quadrigeminate plates—*Echinostrephus*) forms in this genus, as mentioned by LAMBERT and THIÉRY (1914, pp. 234, 241), seems to be unnatural, as the two forms are so closely related each other that their generic separation is impossible.

This interesting genus comprises only two living species, as described above, from the Indo-Pacific Oceans. The two species were often confounded with each other, e.g., A. AGASSIZ (1872-74, p. 457) described specimens under the the name *Ech. molaris* and figured *Ech. aciculatus*; and YOSHIWARA (1898, p. 59) established a new species, *Ech. pentagonus*, from Bonin Islands, but it is now clear that YOSHIWARA's species is only a junior synonym of *Ech. molare.*

The two species, *molare* and *aciculatum*, are distinguished from each other by the characters of test as follows:

Ech. molare	*Ech. aciculatum*
Pore-pairs 3 in an arc; ambitus more or less evidently pentagonal.	Pore-pairs 4 in an arc; ambitus circular.
Genital and ocular plaes with few tubercles only on outer margin.	Genital and ocular plates with more or less numerous tubercles.
Test usually more or less bright green.	Test dull purplish or greenish.

There is a fossil specimen of *Ech. aciculatum* A. AGASSIZ, 1863, in our collection.

Echinostrephus aciculatum A. AGASSIZ, 1863

(Pl. 9, fig. 3, pl. 10, figs. 2, 3)

Echinostrephus aciculatus A. AGASSIZ, 1863, p. 20.—H. L. CLARK, 1912-b, p. 342, pl. 95, figs. 23-24, pl. 105, fig. 9.—LAMBERT and THIÉRY, 1914, p. 254.—*Echinostrephus aciculatum* A. AGASSIZ: H. L. CLARK, 1925, p. 96.—H. L. CLARK, 1938-a, p. 402.—NISIYAMA, 1942, p. 19 (in Japanese).—*Echinostrephus aciculatus* A. AGASSIZ: MORTENSEN, 1943-a, p. 306, pl. 35, figs. 11-29, pl. 58, figs. 3, 5-8, 11-15, text-figs. 145, 146a, 148, 150c-d.—*Echinostrephus aciculatum* A. AGASSIZ: H. L. CLARK, 1945, p. 318, pl. 41, figs. J, M.—H. L. CLARK, 1946, p. 328.—*Echinostrephus aciculatus* A. AGASSIZ: UTINOMI, 1954, p. 350.

Echinostrephus molaris A. AGASSIZ, 1872-74, pp. 119, 457 (partim), pl. 5a, figs. 10-12, pl. 6, fig. 20 (non BLAINVILLE, 1825).—A. AGASSIZ and H. L. CLARK, 1907-a, p. 242.

Locality and geological horizon.—A point on Ishigaki-jima in Ryukyu Islands. Ryukyu Limestone, Pleistocene. *Hypotype.*—IGPS coll. cat. no. 73763 (colleceed by the late Dr. H. IKEDA).

There is an internal mold referred to this species at disposal; a part of the aboral surface is lacking.

Dimensions of the specimen: 24 mm in horizontal diameter, which lies 3 mm above the mid-zone, and hence, it is nearly full-grown adult; and 14 mm in height.

Ambitus nearly circular; aboral surface broad, nearly flat or slightly raised to the apical system. Apical system lacking, vacant area about 7 mm in diameter; adoral surface sharply convex to the peristomial region and narrowed; peristome rather small, about 14 mm in diameter; gill-slits shallow and rather broad. Ambulacra narrow, about 4 mm wide near the peristomial region, 6 mm wide between mid-zone and the ambitus, and narrowed again on aboral surface; ambulacral plates rather high, about 3 mm wide and 2 mm high at the mid-zone; poriferous zones narrow with clearly 4 pore-pairs in an arc.

This is the first record of the fossil occurrence of this species in the Western Pacific. *Echinostrephus aciculatum* A. AGASSIZ, 1863, is reported from the Hawaiian Islands, Micronesia, Sulu Islands, and Northern Australia, ranging as far north as to Shirahama in Wakayama Prefecture, Japan; in shallow water from littoral to 50 metres depths. On the other hand, *Ech. molare* (BLAINVILLE, 1825) is known from Zanzibar, Mauritius, Maldives, Solomon Islands, Fiji, and the Bonin Islands being the northern limit hitherto known, and shows more western distribution than *Ech. aciculatum.*

The writer collected the living specimens of this species in a hole on the reef flat developed on the Palao Islands, Micronesia, South Sea Islands. On the habitat of this species in Southern Japan (Shirahama, Wakayama Prefecture), UTINOMI (1954, p. 350) stated " This species is commonly found, each invariably buried in a hole on the surf-washed or sublittoral rockface, but often dredged from the bottom of the bay. Probably it seems to be able to creep out of the hole for feeding at any time as confirmed in my field observation at night low tide." This species is easily recognizable by the very characteristic shape of test and ambulacra with quadrigeminate plate; and has rather peculiar habitat.

Echinostrephus saipanicum COOKE, 1957

Echinostrephus saipanicum COOKE, 1957, p. 362, pl. 119, figs. 4–6.

There is no authentic specimen of this species at the writer's disposal. However, by personal examination of COOKE's specimen (USNM no. 561579), from the Miocene (Tagpochau) limestone of Saipan Island, the writer found that the general features, except the characteristic form of the test, of this species assure it to be referable to the genus *Echinostrephus.* It seems to have a more or less intermediate features, as suggested by COOKE (1957, p. 362), of the two living species; i. e., the trigeminate ambulacral plates of *Ech. molare,* and the arrangement of tubercles as in *aciculatum;* this species may be regarded as an acenstral form of the Recent. The small apical system, moreover, and the ocular plates as well, seem to push out periproct, and the subpentagonal circumference of test of this species indicate its affinity with the living species.

Genus *Anthocidaris* LÜTKEN, 1864

Anthocidaris LÜTKEN, 1864, p. 164.—MORTENSEN, 1903-b, p. 138.—DÖDERLEIN, 1914, p. 487.—MORTENSEN, 1943-a, p. 327.

Logotype.—Anthocidaris homalostoma LÜTKEN, 1864, p. 165 (China?). =*Toxocidaris crassispina* A. AGASSIZ, 1863-a, p. 356 (Hongkong, China). [COTTEAU, 1861-67(67), p. 820.—MORTENSEN, 1943-a, p. 327].

Test rather strong and low; oral side flattened. Ambulacra polyporous, 7-8, or rarely 9 pore-pairs in an arc; distinctly petaloid on the oral surface. Spines rather long and stout. Pedicellariae, of the four usual types; globiferous pedicellariae small, with a small lateral tooth; no stalk-glands. Spicules of the tube-feet bow-shaped (" biacerate "), with pointed ends and usually prominence on the middle of the arched side.

From the Miocene? to Recent.

This is a rather well-marked and separate genus comprising only known species, *Ant. crassispina* (A. AGASSIZ, 1863), of Japan and China. It now seems evident that this species is not congeneric with Australian *Heliocidaris tuberculata* (LAMARCK, 1816), by the differences of ambulacra on the oral side, and spicules of the tube-feet in the two species.

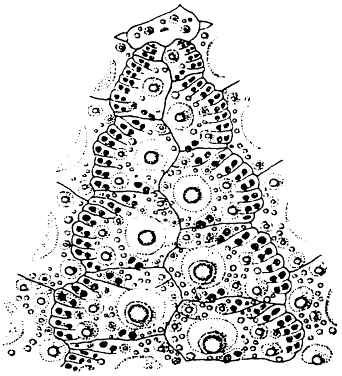


Fig. 24. Ambulacrum (III) of *Anthocidaris crassispina* (A. AGASSIZ, 1863) (for comparison). (Recent specimen, from the south coast of Tateyama Bay, Chiba Prefecture). Adapical part, ×4.

Anthocidaris? sp.

Acanthocidaris sp., COOKE, 1957, p. 362, pl. 19, fig. 8.

The name *Acanthocidaris* of COOKE may be a lapsus calami of *Anthocidaris;* the former is a Cidarid genus allied to *Stylocidaris* MORTENSEN, 1903. COOKE's specimen, from the Miocene (Tagpochau) limestone of Saipan Island, consisting of a part of ambulacrum and of interambulacrum on oral side. The ambulacrum is somewhat petaloid as in *Anthocidaris* or *Echinometra;* large secondary tubercles, which are close to the pore-pair of upper aboral demi-plate component, form a vertical series in the poriferous zone as in *Anthocidaris;* and pore-pairs are 7 or 8 in arc on 7th or 8th plate from the peristomial region preserved. Interambulacral large secondary tubercles form a conspicuous vertical series close to the poriferous zone. These characters of the specimen seem to indicate that it may be assigned to *Anthocidaris* rather than to *Echinometra* or *Pseudocentrotus*.

It is an interesting fact that the very characteristic genus of Japan already appeared in the Miocene of Central Pacific Islands.

Genus *Echinometra* (BREYNIUS) GRAY, 1825

Echinometra BREYNIUS: Gray, 1825, p. 426 (BREYNIUS, 1732, p. 53 (pro parte)—pre-Linnaean). BLAINVILLE, 1834, p. 224.—GRAY, 1835, p. 59.—AGASSIZ and DESOR, 1846, p. 372.—GRAY, 1855, p. 37.—DESOR, 1855-57 (56), p. 136.—VON MARTENS, 1866, p. 164.—*Echinometra* KLEIN: A. AGASSIZ, 1872-74, pp. 115, 282.—ZITTEL, 1879, p. 510.—BELL, 1881-a, p. 421.—DUNCAN, 1889-a, p. 118.—*Echinometra* GRAY: MORTENSEN, 1903-b, p. 246.—MEISSNER, 1904, p. 1377.—

H. L. CLARK, 1912-b, p. 370.—H. L. CLARK, 1925, p. 142.—GRANT and HERTLEIN, 1938, p. 39.—MORTENSEN, 1943-a, p. 352.—H. L. CLARK, 1946, p. 332.—COOKE, 1959, p. 25.

Logotype.—Echinus lucunter LINNAEUS, 1758, p. 665.—*Echinometra subangularis* (LESKE) A. AGASSIZ, 1872-74, p. 283, pl. 10a, figs. 2-4 (Caribbean, east coast of South America, and west coast of Africa).—*Echinometra lucunter* (LINNAEUS) COOKE, 1959, p. 125, pl. 6, figs. 1-2 (Florida to Brazil, and the Bermuda, and western coast of Africa). [COTTEAU, 1861-67(67), p. 820.—LAMBERT, 1910-b, p. 48.—H. L. CLARK, 1912-b, p. 370].

Ellipsechinus LÜTKEN, 1864, p. 165.—COTTEAU, 1861-67(67), p. 820.—LAMBERT and THIÉRY, 1914, p. 256.—SANCHEZ ROIG, 1926, p. 40.

Haplotype.—Ellipsechinus macrostomus LÜTKEN 1864, p. 165, pl. 1, fig. 10.—*Echinometra van-brunti* A. AGASSIZ, 1863, p. 21 (Acapulco, Mexico).—H. L. CLARK, 1910, p. 346, pl. 11, fig. 1 (Panama) (This species includes *Heliocidaris stenopora* H. L. CLARK, 1912-b, p. 351, pl. 95, figs. 18-22, pl. 104, figs. 1-3, pl. 110, figs. 4-5 (Acapulco and Gulf of California)).

Plagiechinus POMEL, 1883, p. 78. (Accoriding to MORTENSEN, 1943-a, p. 353).

Haplotype.—Echinometra prisca COTTEAU, 1875, p. 12, pl. 1, figs. 19-27.—JACKSON, 1922, p. 25, pl. 1, figs. 21-24 (Miocene of Anguilla Island). (According to COOKE (1957, p. 136), this species should be assigned to *Parasalenia*).

Mortensenia DÖDERLEIN, 1905, p. 633.—DÖDERLEIN, 1906, p. 233.

Haplotype.—Echinus oblongus BLAINVILLE, 1825, p. 95.—*Echinometra oblonga* (BLAINVILLE) H. L. CLARK, 1912-b, p. 373, pl. 114, figs. 1-2.—*Echinometra mathaei oblonga* (BLAINVILLE) MORTENSEN, 1943-a, p. 393, pl. 48, figs. 1-20 (Pacific Ocean, littoral).

Test is rather stout; size moderate to rather large; usually distinctly elongate, the longitudinal axis being I. A. 3-A. I, but sometimes the elongation is almost subtle. Ambulacra polyporous, with 4-10 pore-pairs to each arc, except adoral region, where the pore-pairs are only 3 at the peristomial edge; pore-zones may be distinctly petaloid adorally, or not at all widened. Median space between the two series of primary ambulacral tubercles very narrow, leaving room only for quite small secondary tubercles, the largest ones, placed at the upper corner of the plates, form an inconspicuous zigzag series. Interambulacral tubercles in regular vertical series, usually not in distinct horizontal rows. Apical system with all oculars exsert, or one or two of them insert; periproctal plates not very numerous; suranal plate indistinct. Buccal plates with few or numerous small spines; buccal membrane always contains a number of plates imbedded in the skin; usually some of them are thickened and carry pedicellariae, sometimes also small spines. Gills usually have a long tag on the side turning towards the test, but it is mostly very delicate and not easily preserved on dried and clearned tests. Auricles may have a large superstructure (particularly strongly developed in *Ech. lucunter*). Primary spines moderately long, usually strong and pointed, sometimes distinctly clavate. Globiferous pedicellariae with double poison glands, usually without stalk glands; the valves with well developed lateral tooth. Spicules of tube-feet simply C-shaped or triradiate, in the latter case usually being arranged in two dense longitudinal series. Body skeleton of the larva in its first stage is of a complicate basket structure; fully formed larva has a posterior trnasverse rod (after MORTENSEN, 1943-a).

As for the genus *Mortensenia*, DÖDERLEIN, (1905, p. 633.—1906, p. 233) established it because of the character of its peculiar triradiate spicules in the tube-feet of *Ech. mathaei oblonga*, but this form of spicules also occur in *Ech. mathaei*. Thus, the character of the spicules in the tube-feet is untenable as feature to distinction of generic level in this case.

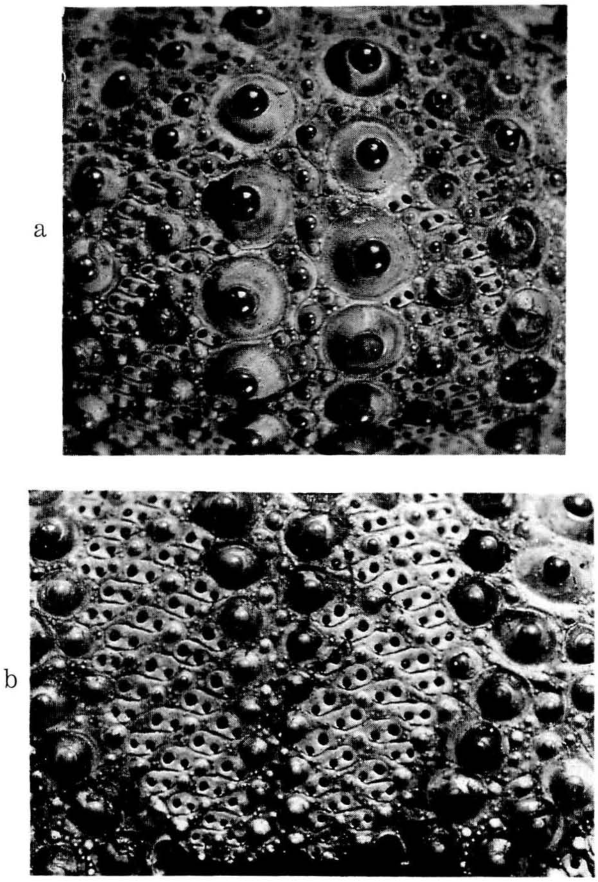


Fig. 25. *Anthocidaris crassispina* (A. AGASSIZ, 1863) (for comparison). (IGPS coll. cat. no. 78226, Recent specimen from the south coast of Tateyama Bay, Chiba Prefecture).

a. An ambulacrum at the mid-zone, ×5; b. An ambulacrum on the adoral surface, ×5.

This genus consists of tropical and warm temperature sea-urchins, and dates back at least to the Miocene in geological age; and it is one of the oldest genera of the family of the Echinometrids. Although this genus is well charcterized, the specimens in the test become more or less rounded and have close resemblance to individuals of *Heliocidaris* (=*Toxocidaris*) or *Anthocidaris;* but they can usually be distinguished by the flatness of the test, as well as by the large size of auricles. The nine or more Recent species have been hitherto recognized in this genus, and in distinguishing the species, the number of pore-pairs in an arc seems to be considered as of importance; the normal number of pore-pairs, at the ambital region, in a species, is rather constant. The structure of the auricles and the character of the primary spines prove to be more or less useful points in distinguish them.

There are fossil representatives of this genus in our collection.

Echinometra hondoana NISIYAMA, n. sp.

(Pl. 10, fig. 1)

Holotype.—IGPS coll. cat. no. 73733.

Locality and geological horizon.—IGPS loc. no. Mi-51.—In the shaft of Edano coal mine about 500 west of Kozai pass, Edano-mura, Igu-gun, Miyagi Prefecture. (tm Kakuda, Lat. 37°54′40″N., Long. 140°50′56″E.). Kozai formation, Miocene.

There is a single specimen of this new species at the writer's disposal; a part of it excellently shows the characters of this species.

Dimensions of holotype.—Longer axis 48 mm, shorter axis 42 mm, and 18 mm in height. Test large and low, the longer axis a little larger than the shorter one; apical system and peristome not observable.

Ambulacra rather narrow, about 12 mm wide at the ambital region; ambulacral plates rather high, about 6 mm wide and 3 mm high at the ambital region; each plate carries a large primary tubercle that is placed adradially; the primary tubercles form a vertical series on either side of median line; large secondary tubercles form a vertical series outside the primary series, and small secondary tubercles also form a vertical series outside the primary: poriferous zones rather broad, about 3.5 mm broad at the ambital region; ambulacral plates, at the ambital region, made up of seven components; i.e., the aboral primary, upper aboral demi-plate, lower aboral demi-plate, middle demi-plate, upper adoral demi-plate, lower adoral demi-plate, and adoral primary; four pore-pairs of aboral primary, upper aboral demi-plate, lower aboral demi-plate, and middle demi-plate, gradually placed outsidely and form somewhat inclined an arc outwardly; three pore-pairs of middle demi-plate, upper adoral demi-plate, and lower adoral demi-plate, form an arc below and outwardly the upper arc; large secondary tubercles of the poriferous zone cover sutures of upper adoral demi-plate, lower adoral demi-plate, and adoral primary; pore-pairs of aboral primary and upper aboral demi-plate usually carry a small secondary tubercle inside each pore-pair.

Interambulacra rather broad, about 17 mm wide at the ambital region; interambulacral plates wider and higher than the ambulacral plates, about 8.5 mm wide and 5 mm high at the ambital region; each plate carries a large primary tubercle, which is as large as, or slightly larger than, that on the ambulacra, being plced centrally; the primary tubercles form somewhat obliquely vertical series in a column; large secondary tubercles, which are more or less smaller than the primaries, form also somewhat obliquely vertical series one outside and the other inside the primary series; in the area between mid-zone and the ambitus, a short vertical series of small secondary tubercles are placed outside the outer large secondary series and near to the edge of plates; other small secondary tubercles and miliaries are placed around the primary tubercles and large secondaries, and do not form close circlets, but arranged in pentagonal form, and the corners are occupied by small secondary tubercles, as in *Ech. mathaei.*

Distinction.—This new species resembles, in structure of interambulacra, *Ech. mathaei* (BLAINVILLE, 1825) (see below), a Recent as well as fossil species from the Indo-Pacific regions; but this is easily distinguished from it by the number of pore-pairs in an arc. In the number of pore-pairs in an arc, this species agrees with the West Indian *Ech. lucunter* (loc. cit.), and the Mexican *Ech. van-brunti* (loc. cit.), but is distinguished fom these latter by the tuberculation on both interambulacra and ambulacra.

The occurrence of this large, and full-grown fossil species from Northern Japan (Lat. 38°N.) suggests that this region was warmer at that time than at the present day; the northern limit of this genus at present seems to be in Central Japan (Lat. 35°N.)

Echinometra mathaei (BLAINVILLE, 1825)

(Pl. 10, figs. 4-6)

Echinus mathaei BLAINVILLE, 1825, p. 94.—*Echinometra mathaei* (BLAINVILLE) BLAINVILLE, 1830, p. 206.—KOEHLER, 1895, p. 415.—DÖDERLEIN 1903, p. 688(56).—H. L. CLARK, 1912-b, p. 372.—*Ellipsechinus mathaei* (BLAINVILLE) LAMBERT and THIÉRY, 1914, p. 257.—*Echinometra mathaei* (BLAINVILLE) H. L. CLARK, 1925, p. 143.—BONNET, 1926-a, p. 267, fig. 36.—KOEHLER, 1927, p. 121, pl. 16, figs. 1-4.—NISIYAMA, 1942, p. 20, text-figs. 6.—MORTENSEN, 1943-a, p. 381, pl. 4, figs. 1-10, pl. 47, figs. 1-4, pl. 65, figs. 16-26, text-figs. 185-194.—H. L. CLARK, 1946, p. 332.—HAYASAKA, 1948, p. 30, pl. 6, figs. 3-4.—UTINOMI, 1954, p. 350.

Echinometra lucunter (LESKE) A. AGASSIZ, 1872-74, p. 431, pl. 4b, fig. 4 (non LINNAEUS, 1758).—TOKUNAGA, 1906, pl. 10, figs. 3-7.

Echinometra picta A. AGASSIZ and H. L. CLARK, 1907-a, p. 241.—H. L. CLARK, 1912-b, p. 373, pl. 95, figs. 6-12, pl. 114, figs. 5-6.—*Ellipsechinus pictus* (A. AGASSIZ and H. L. CLARK) LAMBERT and THIÉRY, 1914, p. 257.

Ellipsechinus sp., LAMBERT and JEANNET, 1935, p. 55, text-figs. 74-75.

Locality and geological horizon.—A point on Ishigaki-jima in Ryukyu Islands. Ryukyu Limestone, Pleistocene. *Hypotype.*—IGPS coll. cat. no. 73764 (collected by the late Dr. H. IKEDA).

There is a single specimen referable to this species at hand. This is an internal mold and partly broken away so that identification is somewhat uncertain. However, the structure of ambulacral plates and the other characters of this specimen may be referred to the living *Ech. mathaei* (BLAINVILLE, 1825).

Dimensions of the specimen are: Longer axis about 40 mm, shorter one 31 mm, and height 15 mm; longer axis of the apical system 7 mm, and longer axis of peristome 20 mm.

Ambulacra rather narrow, about 9 mm wide at the ambital region; 17 or 18 ambulacral plates may be in one column; pore-pairs in an arc four in number. Interambulacra broad, about 14 mm wide at the ambital region; 15 or 16 interambulacral plates may be in one column. Peristome large compared to the living specimens; this is because the former is the internal mold of the specimen. Tubercles on both aboral and adoral surfaces not preserved.

This species is represented by the great diversity in form of test and spines, as well as in colour; and various forms have been given different names. It is probably the most abundant sea-urchins in the world, and widely distributed all over the Indo-Pacific regions; i. e., from Red Sea to Paumotus and Hawaiian Islands, on the one hand, and from Australia to Southern Japan, on the other. The northern limits of distribution of this species may be about Central Japan (as far north as

Lat. 35° N.), where the writer has collected the *Echinometra picta*-form, from the southeastern coast of Bôsô Peninsula.

The following orders, e. g., the Holectypoids, Cassiduloids, Clypeasteroids, and Spatangoids, are common in the character of the anal opening (periproct), which lies outside the apical system in the posterior interambualcrum (5). On this only character, these orders are practically and customarily grouped into a subclass Irregularia (LATREILLE, 1825, p. 533—GREGORY, 1900-b, p. 315—MORTENSEN, 1948-a, p. 1.—Exocycloida WRIGHT 1864-82(64), p. 29—JACKSON, 1912, p. 204—H. L. CLARK, 1925, p. 148.—Exocysta LAMBERT, 1900, p. 49—LAMBERT and THIÉRY, 1924, p. 277), and distinguished clearly from the other orders of the Regular Echinoids, the subclass Regularia or Endocycloida, in which the anal opening is inside the apical system. This major classification of the Echinoids seems to be meaningless, however.

It is very probable the so-called Irregular Echinoids have evolved along many different lines, and may contain various independent stem or branches, derived from various sources among the Regular Echinoids or primitive Irregular forms. We cannot, however, trace these lines in detail, and our knowledge at present state of fossil forms is too incomplete to deal with the problems.

Order HOLECTYPOIDA DUNCAN, 1889

Holectypoida DUNCAN, 1889-a, pp. 25, 135.—MEISSNER, 1904, p. 1379,—HAWKINS, 1912-b, pp. 440-495.—HAWKINS, 1920, p. 423.—BEURLEN, 1933, p. 7.—MORTENSEN, 1948-a, pp. 8, 9.—NISIYAMA, 1954, p. 327 (in Japanese).—DURHAM and MELVILLE, 1957, p. 256.

Holectypina GREGORY, 1900-b, p. 315 (pro parte).—DELAGE and HÉROUARD, 1903, p. 248.—JACKSON, 1912, p. 204.

Brachygnatha LAMBERT, 1915-b, p. 224.—LAMBERT and THIÉRY, 1921, p. 326.

Holectypoidea DUNCAN: TERMIER and TERMIER, 1953, p. 912.

Tpye-family.—*Holectypidae* LAMBERT, 1900.

Forms of mainly regular shape, only exceptionally (*Echinoneus*) elongate; test usually inflated. Ambulacra simple, forming neither petals on aboral surface nor phyllodes on oral side; no bourrelets. Ambulacral plates simple primaries or trigeminate of the diadematoid or echinoid structure. Apical system and peristome usually central; periproct in close contact with apical system, almost touching the peristome at least, or more or less removed from it. Peristome is regular, forms in primitive, with distinct gill-slits and with dental apparatus, and corresponding auricles; in the specialized forms the dental apparatus is completely resorbed in the adult; and in consequence the peristome becomes oblique, and gill-slits disappear. Apical system completely restored by the reappearance of the genital (5). Spines are quite simple and small. Primary tubercles usually arranged in conspicuous vertical series, while in the specialized forms the series become obscure. Teeth with lateral flanges. Pedicellariae, of all four main types; globiferous pedicellariae of a primitive type. Sphaeridia placed at the tube-feet, not in the midline of the ambulacrum (from MORTENSEN, 1948-a, and others).

From the Lower Jurassic (Lias) to Recent.

The affinities and classification of this order have become more or less clear through the exhaustive researches of HAWKINS (1909-1934); MORTENSEN (1948-a) also devoted to these problems through his life-long researches and excellent knowledge on the Echinoids, and DURHAM and MELLILLE (1957) offered new material for the problems. It now seems evident that this order comprises very various forms, that are derived from different sources, and evolved along different lines. MORTENSEN (1948-a) divided them into two suborders, viz., the Holectypina (including the Pygasteridae) and Echinoneina, both having their more important structural features in common. DURHAM and MELVILLE (1957, pp. 246-247, 253) have separated the Pygasterids from the true Holectypoids, and erected a new order Pygasteroida. The two authors, however, removed the Conoclypina from the Cassiduloids to the Holectypoids, based on an idea of the great value of the lantern and girdle in the Echinoid classification (1957, pp. 257-258). This removal of the Conoclypina from the Cassiduloids met a strong objection of PHILIP (1963-c, p. 723).

In this order, two suborders, viz., the Holectypoina and Echinoneoina, are recognizable.

Suborder HOLECTYPOINA DUNCAN, 1889

Holectypoida DUNCAN, 1889-a, pp. 25, 135 (order).—*Holectypina* GREGORY, 1900-b, p. 315 (pro parte).—JACKSON, 1922, p. 27.—MORTENSEN, 1948-a, pp. 10, 11.—NISIYAMA, 1954, p. 327 (in Japanese).—DURHAM and MELVILLE, 1957, p. 256.

Test of regular shape, not elongate. Ambulacra simple, not forming petals. Ambulacral plates compound, with reduced plates. Peristome regular, with distinct gill-slits, buccal plates persistent. Masticatory apparatus and perignathic girdle persistent; auricles radial in position. Primary tubercles usually in distinct regular vertical series.

From the Lower Jurassic (Lias) to the Upper Cretaceous (Senonian).

Among the five families of MORTENSEN's suborder Holectypina, the first, the Pygasterids, is removed to the Diadematoids, by DURHAM and MELVILLE, and the three families, the Conulids, Discoidiids, and Galeritids, to other suborder Echinoneina; thus, the Holectypids alone remain in this suborder.

Family HOLECTYPIDAE LAMBERT, 1900

Holectypidae LAMBERT, 1900, p. 49.—HAWKINS, 1912-b, p. 450.—LAMBERT and THIÉRY, 1914, p. 277.—HAWKINS, 1920, p. 434.—BEURLEN, 1933, p. 7.—MORTENSEN, 1948-a, p. 23.—TERMIER and TERMIER, 1953. p. 912.

Type-genus.—*Holectypus* DESOR, 1842.

Tubercles perforate, crenulate. Periproct contiguous with the apical system, or not. Auricles well developed, radial in position, connecting ridges (apophyses) feeble. No internal radiating wall. Other characters as given in the diagnosis of the suborder.

From the Toarcian to Senonian.

This is a small family including five or more extinct genera, represented in Japan and the adjacent regions by a single genus, *Caenholectypus*.

Genus *Caenholectypus* POMEL, 1883

Coenholectypus POMEL, 1883, p. 75 (typographical error for *Caenholectypus*).—*Caenholectypus* POMEL, 1883, p. 125.—HAWKINS, 1912-b, p. 450 (subgenus ad *Holectypus* DESOR, 1842).—LAMBERT, 1931-a, p. 302.—COOKE 1946, p. 216 (subgenus).—MORTENSEN, 1948-a, p. 30, text-figs. 17-18.—NISIYAMA, 1950-a, p. 32 (subgenus).—TERMIER and TERMIER, 1953, p. 913.—COOKE, 1955, p. 94 (subgenus).

Logotype.—Discoidea macropyga AGASSIZ, 1835, p. 137, pl. 14, figs. 7-9.—DESOR, 1842, p. 73, pl. 7, figs. 8-11.—*Holectypus macropygus* (AGASSIZ) COTTEAU, 1861-67(61), p. 44, pl. 1014 figs. 1-14, pl. 1015, figs. 1-4 (Neocomian to Lower Aptian of France). [HAWKINS, 1912-b, p. 450].

Small to medium-sized, or rarely large forms; test of regular outline. Ambulacra narrow, simple, the pores uniserial; aborally the ambulacral plates simple, on the oral side trigeminate; a primary tubercle on every third plate. Primary tubercles more or less distinctly concentrically arranged on the oral side. Apical system central, madreporite large; five genital pores. Periproct large, wholly on the oral side or marginal. Spines simple, striated; pedicellariae not known.

This genus ranges from the Lower Cretaceous to Senonian, and is rather widely distributed in Europe and North America, with about twenty species. The occurrence of a species from the Cretaceous in Northern Japan is noteworthy.

This genus differs from the allied genus *Discholectypus* POMEL, 1883, by having the simple ambulacral plates on the aboral side; and from the *Holectypus* Desor, 1842, by having five genital pores.

Caenholectypus peridoneus (NISIYAMA, 1950)

Holectypus (*Coenholectypus*) *peridoneus* NISIYAMA, 1950-a, p. 32, pl. 4, figs. 5-7.

Holotype.—IGPS coll. cat. no. 73695.

Locality and geological horizon.—IGPS loc. no. It -4.—Sea cliff northeast of Hiraiga, Tanohata-mura, Shimohei-gun, Iwate Prefecture. (tm Iwaizumi, Lat. 39° 55′ 53″ N., Long. 141° 56′ 39″ E.). Hiraiga sandstone (*Orbitolina*—horizon), Lower Cretaceous (probably Aptian or Albian).

This species resembles *Ca. neocomiensis* (GRAS) (COTTEAU, 1861-67(61), p. 49, pl. 1015, figs. 5-10), from the Aptian of France, in the outline of test, the depressed peristome, and in the tuberculation on the test; but it is distinguished from that species by the numerous coronal plates in each column, and by the lower test. *Ca. peridoneus* is also related to *Ca. cenomaniensis* (GUÉRANGER) (COTTEAU, 1861-67(61), p. 53, pl. 1016, figs. 8-13), from the Cenomanian of France, but has a greater number of coronal plates on the oral side. This species is also similar to *Ca. adkinsi* (SMISER, 1936) (SMISER, 1936, p. 461, pl. 62, figs. 12-15; this species, according to COOKE, 1955, p. 94, pl. 21, figs. 1-3, is a junior synonym of *Ca. planatus* (ROEMER, 1849)), from the Fredericksburg formation of Texas, but possesses narrower ambulacral zone and a smaller number of coronal plates in each column.

Suborder ECHINONEOINA HAWKINS, 1925

Echinoneina HAWKINS: H. L. CLARK, 1925, p. 176 (non *Echinoneina* GRAY, 1855-a, p. 31—under the *Galeritidae*).—H. L. CLARK, 1946, p. 352.—MORTENSEN, 1948-a, pp. 10, 65.—*Echinoneina* H. L. CLARK: NISIYAMA, 1954, p. 327.—DURHAM and MELVILLE, 1957, p. 256.

Globatoroida LAMBERT, 1915-b, p. 224.—LAMEBRT and THIÉRY, 1921, p. 326.

Type-family.—*Echinoneidae* WRIGHT, 1857.

Test of regular shape, or often elongate. Ambulacra simple, not forming petals. Ambulacral plates usually compound, or rarely simple primaries throughout. Masticatory apparatus and perignathic girdle persistent, or present only in the young stage; auricles interradial in position, or present only in the young. Primary tubercles usually in distinct regular vertical series, or not (after Durham and Melville, 1957, and others).

From the Lower Jurassic? to Recent.

Durham and Melville (1957, p. 256) recognized four families of their suborder Echinoneina. Their idea is that the Conulids, Discoidiids, and particularly the Galeritids, have many points of difference from the Holectypids proper, not only in the structure of the girdle, but also in their ambulacral ornament, and these forms should be grouped together with the Echinoneids.

The family of the Echinoneids is represented in Japan and the adjacent regions.

Family Echinoneidae Wright, 1857

Echinonidae Wright, 1857-78(57), pp. 20, 23.—*Echinoneidae* Wright: Desor and de Loriol, 1868-72(71), p. 285 (pro parte).—A. Agassiz, 1872-74, p. 332.—Cotteau, 1885-89(87), p. 452.—Duncan, 1889-a, p. 168.—Gregory, 1900-b, p. 320 (pro parte).—Meissner, 1904, p. 1385.—Westergren, 1911, p. 2.—Hawkins, 1912-b, p. 490.—H. L. Clark, 1917, p. 9.—Hawkins, 1920, p. 424.—Lambert and Thiéry, 1921, p. 326.—H. L. Clark, 1925, p. 176.—Smiser, 1935, p. 41.—Grant and Hertlein, 1938, p. 103.—H. L. Clark, 1946, p. 352.—Mortensen, 1948-a, p. 65.—Termier and Termier, 1953, p. 914.

Type-genus.—*Echinoneus* Leske, 1778.

Ambulacra simple, not forming phyllodes on the peristomial region. Peristome central, mostly oblique, without gill-slits; no buccal plates. Masticatory apparatus and perignathic girdle present only in the young stages. Periproct not contiguous with the apical system, generally on oral surface. Trigeminate ambulacral plates of the echinoid structure. Tubercles not in the regular vertical series in the adult, perforate or not.

This is a very perplexing family which Hawkins (1920, pp. 423-424) regarded as the only surviving group of the Holectypoids. However, as to the much discussed problem of the derivation of the Ectinoneids, the lack of sufficient our knowledge on the older forms related to them, prevents us from reaching a definite conclusion.

This family includes but few Recent species; the Recent forms have been beautifully monographed by Westergren (1911, pp. 35-68, pls. 1-31), and by Mortensen (1948-a, pp. 71-81, pls. 1, 12).

There is a fossil representative of the genus *Echinoneus* in our collection.

Genus *Echinoneus* Leske, 1778

Echinoneus Leske, 1778, pp. xviii, 173.—DesMoulins, 1835-37(35), p. 206.—Desor, 1842, pp. 40, 91.—Gray, 1855-a, p. 31.—A. Agassiz, 1872-74, p. 332.—Pomel, 1883. p. 54.—Duncan, 1889-a, p. 169.—Westergren, 1911, p. 5.—H. L. Clark, 1917, p. 101.—Lambert and Thiéry, 1921, p. 330.—H. L. Clark, 1925, p. 176.— Grant and Hertlein, 1938, p. 103.—H. L. Clark, 1946, p. 352.—Mortensen, 1948-a, p. 71, text-figs. 59a-b.—Termier and Termier, 1953, p. 914.

Logotype.—*Echinoneus cyclostomus* Leske, 1778, p. 173, pl. 37, figs. 4-5.—Westergren, 1911, pp. 44-63, pls. 1-28(West Indies and southwestern Pacific Ocean). [H. L. Clark, 1917, p. 101—Leske included two species in the genus, but the second is undoubtedly a synonym of the first, which of course is the type].

Koehleraster LAMBERT and THIÉRY, 1921, p. 331.

Orthotype.—Echinoneus abnormalis DE LORIOL, 1883-a (as *abnormis*), p. 41, pl. 5, figs. 2-2d (Mauritius).—MORTENSEN, 1948-a, p. 80, pl. 12, figs. 20, 22 (South Sea Islands, Rotuma and Hawaiian Islands).

Moderate-sized forms. Test ovoid, fairly strong. Ambulacra narrow, not petaloid aborally; pore-zones very narrow, slightly sunken, straight; trigeminate ambulacral plates of the echinoid structure, but the pores form only one straight series; each pore-pair with a distinct peripodium throughout the ambulacrum. Apical system compact; genital pores four; genital plates not separate. Peristome oblique, without branchial slits; peristomial membrane densely covered with small plates; periproct close to the peristome, of ovoid outline, covered with spine-bearing plates. Tubercles imperforate, or perforate, non-crenulate, not arranged in vertical series in the adult; glassy tubercles may be very numerous and conspicuous. Spines short, simple, straight, with a small axial cavity. Pedicellariae, of the globiferous, tridentate, ophicephalous, and triphyllous types. Sphaeridia placed along the tube-feet. Spicules of the tube-feet in the shape of irregular rods; the tube-feet generally have a well developed sucking disk (after MORTENSEN, 1948-a).

From the Oligocene to Recent.

Micropetalon purpureum A. AGASSIZ and H. L. CLARK, 1907 (A. AGASSIZ and H. L. CLARK, 1907-a, p. 251.—WESTERGREN, 1911, p. 63, pl. 29, figs. 1-14, pl. 30, pl. 31, figs. 1-17), from the Hawaiian and Macclesfield Bank (MCZ no. 4752), has been included, by LAMBERT and THIÉRY (1921, p. 331), in *Echinoneus*. But it differs from LESKE's genus in that the apical spstem with separate genital plates, and that the pores in ambital region being rudimentary, without peripodia. The Cretaceous genus *Paleoechinoneus* GRANT and HERTLEIN, 1938 (GRANT and HERTLEIN, 1938, p. 105.—Orthotype—*Pal. hannai* GRANT and HERTLEIN, 1938, p. 105, pl. 23, figs. 4-5—Upper Cretaceous of Lower California) has a striking similarity to *Echinoneus*, but it differs from the latter by having the podial pores arranged in arcs of three adorally. LAMBERT and THIÉRY (1921, p. 331) have considered that the perforate tubercles of *Ech. abnormalis* (loc. cit.) (MCZ no. 4097, from Hilo, Hawaii) are sufficient to erect for it a distinct genus, *Koehleraster*. This procedure, however, is rejected by the later writers, by the reason that the perforate tubercles (occur in *Paleoechinoneus* also) are to be expected to occur in this surviving group of the Holectypoids. JACKSON (1922, p. 54) mentioned records of *Ech. cyclostomus*, the type-species, to have occurred as fossil in the West Indies in the Oligocene, Miocene, and Pliocene formations.

Echinoneus cyclostomus LESKE, 1778

Echinoneus cyclostomus LESKE, 1778, p. 173, pl. 37, figs. 4-5.—DESOR, 1842, p. 43, pl. 6, figs. 13-15.—GRAY, 1855-a, p. 32.—DESOR, 1855-57(57), p. 197, pl. 27, figs. 1-3.—A. AGASSIZ, 1872-74, pp. 117, 550, pl. 14, figs. 6-8, pl. 14a, figs. 5-10.—DE LORIOL, 1883-a, p. 38, pl. 5, figs. 3-6.—TOKUNAGA, 1907, pl. 17, figs. 1-2.—WESTERGREN, 1911, pp, 44-63, pls. 1-28.—COTTREAU, 1913, p. 106, pl. 12, figs. 1-2.—H. L. CLARK, 1917, p. 101.—JACKSON, 1922, p. 54, pl. 9, figs. 1-2, 4-5.—H. L. CLARK, 1925, p. 177.—H. L. CLARK, 1926-a, p. 191.—H. L. CLARK 1945, p. 321.—HAYASAKA, 1948, p. 26, pl. 6, fig. 2.—MORTENSEN, 1948-a, p. 75, pl. 1, figs. 14, 26, pl. 12, figs. 21, 23.—TOKIOKA, 1953, p. 146.—UTINOMI, 1954, p. 351.—COOKE, 1954, p. 46, pl. 9, fig. 6.—MORISHITA, 1964, p. 278, pl. 14, figs. 6-8.

Echinoneus abruptus H. L. CLARK, 1925, p. 177, pl. 10, figs. 1-3.

Locality and geological horizon—Some 3 km north of Kaikô (Haikou), Chôshû-gun (Chao-chou County), Takao-shû (Kao-hsiung Prefecture), Formosa. Raised Coral Reef, Pleistocene. *Hypotype.*—IGPS coll. cat. no. 73732.

There are two well preserved specimens and a fragmentary one referred to this species at hand. The description of a specimen, which is well preserved, is as follows.

Test small, 19.5 mm and 15 mm in longitudinal and transverse diameters, respectively, and 9 mm in height; oval in marginal outline, margins inflated, aboral surface but rather flat, oral surface concave at the peristomial region. Apical system as in the living specimens. Ambulacra all subequal in width, about 3.5 mm wide at the ambital region; poriferous zones very narrow. Posterior interambulacrum (5) slightly narrower than other interambulacra, which measure about 7.5 mm wide at the ambital region, whereas the former measures about 6.5 mm wide. Peristome slightly eccentric to front, oblique, 4 mm long and 3 mm wide. Periproct slightly larger than the peristome, and longitudinally oval with the point directed marginally. Tubercles imperforate and non-crenulate.

The specimens are safely referred to the variable and wide-spreaded Recent and fossil *Ech. cyclostomus.* This species ranges from Kagoshima Bay to as far north as Kii Peninsula, in Japan; this is mainly a littoral form, but is found down to the depth of about 120 metres.

The writer has had access to a well preserved and full-grown fossil specimen, which is decidedly referable to this species, now preserved in the Museum of Seto Marine Biological Laboratory at Shirahama, Wakayama Prefecture; for this through privilege the writer is indebted to the kindness of Dr. UTINOMI of the Laboratory. The specimen came from the sea coast of Ezura near the Laboratory, and it is undoubtedly regarded as fossil on its general feature. But the geological horizon of its occurrence is not certain whether it came from the Yakugawa formation (Pleistocene) or the Fujishima formation (Miocene), as the both formations are typically developed in that region. MORISHITA (1960, p. 55.-1964, p. 278) ascribed it to the Miocene (Kanayama Series—Fujishima formation). At any rate, the fossil occurrence of this species in this region is very noteworthy.

COOKE reported *Echinoneus cyclostomus* from the Pliocene of Okinawa (1954, p. 46, pl. 9, fig. 6), and *Echinoneus* sp. from the Miocene (Tagpochau) limestone of Saipan Island, Mariana Islands (1957, p. 362). By personal examination of COOKE's specimen (USNM no. 561557), from the Pliocene of Okinawa, the writer found that the characters of apical system, podial pores, tuberculation on the test, and the periproct of this specimen assure it to be safely refer to this well-known and wide-spreaded species, *Ech. cyclostomus.*

(The end of Part 1).

Plate 1

Explanation of Plate 1

(Size as stated)

Figs. 1–2. *Miocidaris spinifera* NISIYAMA, n. sp. 1, radioles attached to matrix, ×1 ; 2, side view of radiole, ×1.2 (*holotype*, IGPS coll. cat. no. 6442, from tne Akasaka Limestone of Gifu Prefecture).

Fig. 3. *Miocidaris platyacantha* NISIYAMA, n. sp. Side view of radiole, ×1 (*holotype*, IGPS coll. cat. no. Ep. 12, from the Akasaka Limestone of Gifu Prefecture).

Fig. 4. *Stereocidaris grandis fusana* NISIYAMA, n. subsp. Side view of an interambulacral area and adjoining two columns of half ambulacral area, ×2 (*holotype*, IGPS coll. cat. no. 73741, from the Tômiya tuffaceous sandstone of Chiba Prefecture).

Figs. 5–6. *Stereocidaris* (*Phalacrocidaris*) *japonica multipora* NISIYAMA, n. subsp. 5, side view of an interambulacral area and adjoining two columns of half ambulacral area, ×1.2 (*holotype*, IGPS coll. cat. no. 737421-1, from the Koshiba formation of Kanagawa Prefecture) ; 6, side view of an interambulacral area and adjoining two columns of half ambulacral area of other specimen, ×1.2 (*paratype*, IGPS coll. cat. no. 73742-2, from the Koshiba formation of Kanagawa Prefecture).

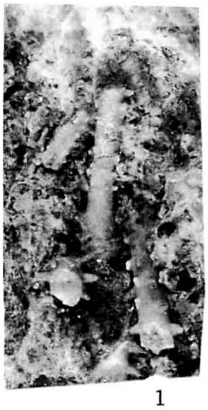
Figs. 7–14. *Prionocidaris bispinosa* (LAMARCK, 1816). 7, side view of fossil radiole, ×1 (IGPS coll. cat. no. 73727-1, from the Ryukyu Limestone of Kikai-jima, Ryukyu Islands) ; 8, lateral view of the same, ×1 ; 9, side view of other specimen, ×1 (IGPS coll. cat. no. 73727-2, from same horizon and locality) ; 10, lateral view of the same, ×1 ; 11, side view of other radiole, ×1 (IGPS coll. cat. no. 73727-3, from same horizon and locality) ; 12, lateral view of the same, ×1 ; 13, side view of other radiole, ×1 (IGPS coll. cat. no. 73727-4, from same horizon and locality) ; 14, lateral view of the same, ×1.

Figs. 15–18. *Balanocidaris japonica* NISIYAMA, n. sp. 15, side view of radiole, ×2 (*holotype*, IGPS coll. cat. no. 73767-1, from the Torinosu Limestone of Kôchi Prefecture) ; 16, apical view of the same, ×2 ; 17, side view of other radiole, ×2 (*paratype*, IGPS coll. cat. no. 73767-2, from the Torinosu Limestone of Kôchi Prefecture) ; 18, apical view of the same, ×2.

Figs. 19–20. *Chondrocidaris marianica* NISIYAMA, n. sp. 19, side view of radiole, ×2 (*holotype*, IGPS coll. cat. no. 73740, from the Donney formation of Saipan Island, Mariana Islands) ; 20, lateral view of the same, ×2.

Figs. 21–23. *Coelopleurus singularis* NISIYAMA, n. sp. 21, aboral view of *holotype*, ×2 (IGPS coll. cat. no. 73718, from the Shirahama (Susaki) formation of Shizuoka Prefecture) ; 22, oral view of the same, ×2 ; 22, side view of the same, ×2.

Photo by K. KUMAGAI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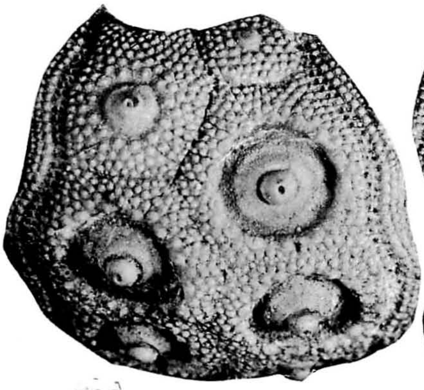
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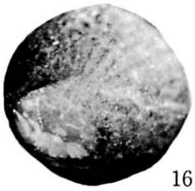
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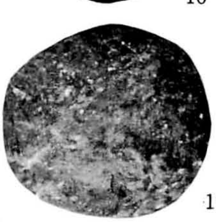
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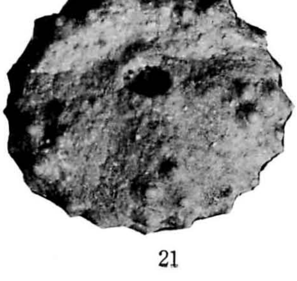
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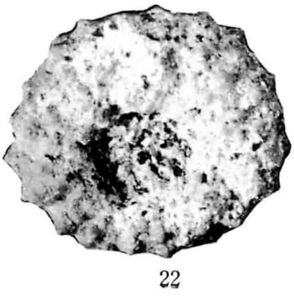
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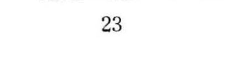
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Plate 2

Explanation of Plate 2

(Size as stated)

Figs. 1–3. *Phyllacanthus imperialis* (LAMARCK, 1816). 1, side view of fossil radiole, ×1 (IGPS coll. cat. no. 78201-1, from the Peliliu Limestone of Palao Islands) ; 2, side view of other radiole, ×1 (IGPS coll. cat. no. 78201-2, from same horizon and locality) ; 3, side view of other radiole, ×1 (IGPS coll. cat. no. 78201-3, from same horizon and locality).

Figs. 4–5. *Phyllacanthus* cf. *javanus* MARTIN, 1885. 4, side view of radiole, ×1 (IGPS coll. cat. no. 78202-1, from the Donney formation of Saipan Island, Mariana Islands) ; 5, side view of other radiole, ×1 (IGPS coll. cat. no. 78202-2, from same horizon and locality).

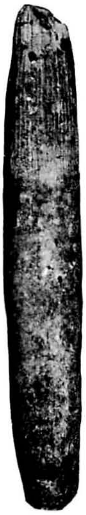
Figs. 6–9. *Salenia novemprovincialis* NISIYAMA, n. sp. 6, side view of *holotype*, ×2.5 (IGPS coll. cat. no. 73750-1, from the Kakinoura formation of Nagasaki Prefecture) ; 7, oral view of *paratype*, ×2.5 (IGPS coll. cat. no. 73750-2, from same horizon and locality) ; 8, oral view of other *paratype*, ×2.5 (IGPS coll. cat. no. 73760-3, from same horizon and locality) ; 9, side view of the same, ×2.5.

Figs. 10–11. *Glyptocidaris crenularis stenozona* NISIYAMA, n. subsp. 10, side view of a part of ambulacrum near the peristomial region, ×2 (*holotype*, IGPS coll. cat. no. 73754-1, from the Tômiya tuffaceous sandstone of Chiba Prefecture) ; 11, side view of a part of interambulacrum near the peristomial region, ×2 (IGPS coll. cat. no. 73754-2, from same horizon and locality).

Figs. 12–13. *Coelopleurus maculatus* A. AGASSIZ and H. L. CLARK, 1907. 12, side view of two columns of interambulacra above the ambitus of fossil, ×2 (IGPS coll. cat. no. 73749-2, from the Jizôdô formation of Chiba Prefecture) ; 13, side view of two columns of ambulacra above the ambitus of fossil, ×2 (IGPS coll. cat. no. 73749-1, from same horizon and locality).

Figs. 14–17. *Stomopneustes antiquus* NISIYAMA, n. sp. 14, oral view of *holotype*, ×3 (IGPS coll. cat. no. 73728-1, from the Eocene of Bonin Islands) ; 15, side view of the same, ×3; 16, aboral view of *paratype*, ×1 (IGPS coll. cat. no. 73728-2, from same horizon and locality) ; 17, side view of the same, ×1.

Photo by K. KUMAGAI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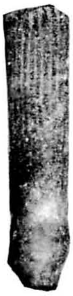
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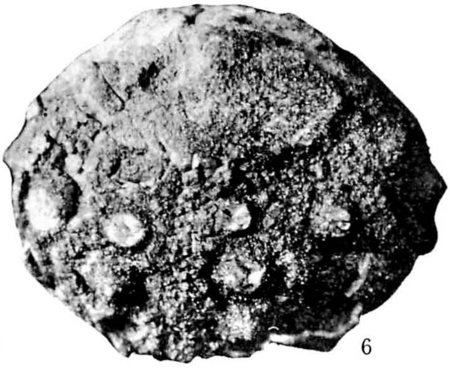
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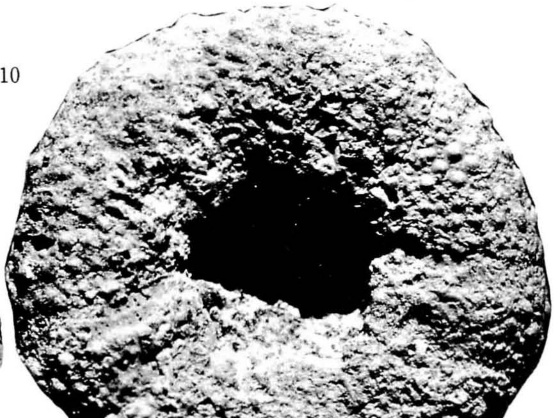
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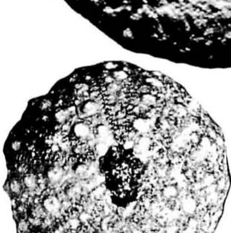
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Plate 3

Explanation of Plate 3

(Size as stated)

Figs. 1–4. *Stomopneustes antiquus* NISIYAMA, n. sp. 1, oral view of *paratype,* ×1 (IGPS coll. cat. no. 73728–2, from the Eocene of Bonin Islands) ; 2, aboral view of *holotype,* ×1 (IGPS coll. cat. no. 73728–1, from same horizon and locality) ; 3, side view of the same, ×1 ; 4, oral view of the same, ×1.

Figs. 5, 7. *Glyptocidaris* (*Eoglyptocidaris*) *arctina* NISIYAMA, n. sp. 5, oral view of *holotype,* ×1 (IGPS coll. cat. no. 73752, from the Poronai formation of Teshio Province, Hokkaido) ; 7, oral view of a part of adoral surface of the same, ×2.

Figs. 6, 8–9. *Echinothrix calamaris* (PALLAS, 1774). 6, aboral view of a mold, ×1 (IGPS coll. cat. no. 73776, from the Ryukyu Limestone of North Borodino Island (Kita-Daitô-jima), Ryukyu Islands) ; 8, oral view of the same, ×1 ; 9, side view of the same, ×1.

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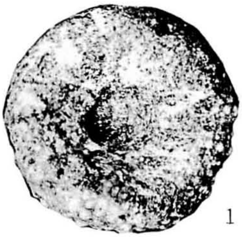
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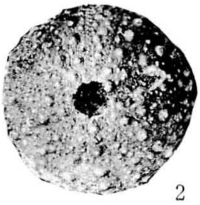
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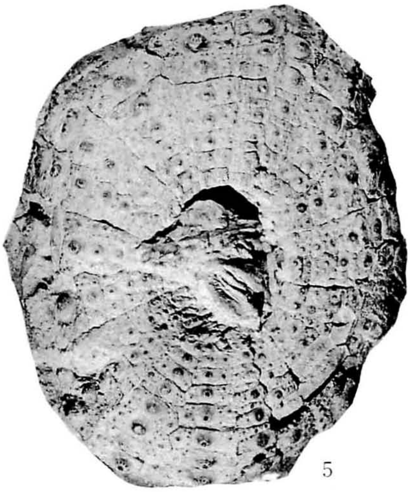
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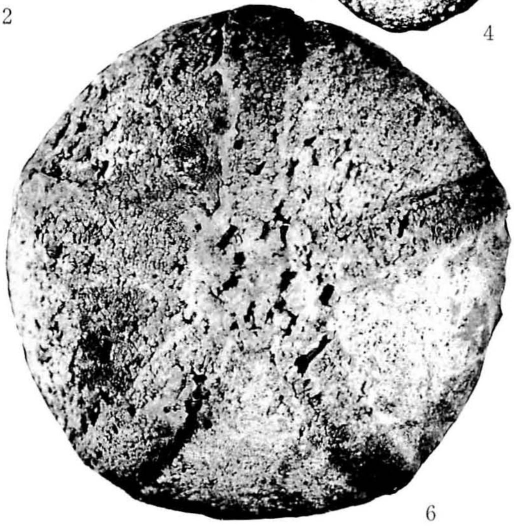
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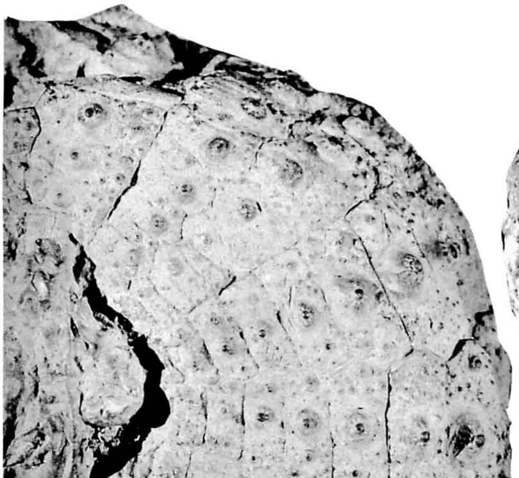
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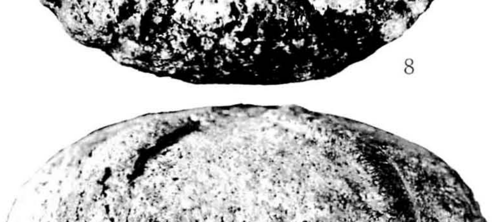
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Plate 4

Explanation of Plate 4

(Size as stated)

Figs. 1–2. *Stomopneustes variolaris* (LAMARCK, 1816) (for comparison). 1, aboral view of Recent specimen, ×1 (IGPS coll. cat. no. 78203, from the beach of Amami-Ôshima, Ryukyu Islands) ; 2, oral view of the same, ×1.

Figs. 3–7, 10, 12. *Temnopleurus toreumaticus* (LESKE, 1778). 3, aboral view of fossil, ×2 (IGPS coll. cat. no. 73731-1, from the Byôritsu formation of Shinchiku-shû, Formosa) ; 4, aboral view of other fossil, ×2 (IGPS coll. cat. no. 73731-2, from same locality and horizon) ; 5, side view of an interambulacrum at the mid-zone of Recent specimen, ×5 (for comparison) (IGPS coll. cat. no. 78204, from Wakasa Bay, Fukui Prefecture) ; 6, side view of an ambulacrum at the mid-zone of the same, ×5 (for comparison) ; 7, oral view of specimen in figure 3, ×2 ; 10, side view of specimen in figure 3, ×2 ; 12, side view of specimen in figure 4, ×2.

Figs. 9, 13. *Temnopleurus hardwickii* (GRAY, 1855). 9, oral view of fossil, ×1 (IGPS coll. cat. no. 27439, from the Narita formation of Chiba Prefecture) ; 13, side view of the same, ×1.

Figs. 11, 14. *Temnopleurus* (*Toreumatica*) *reevesii* (GRAY, 1855). 11, side view of a part of aboral side of fossil, ×3 (IGPS coll. cat. no. 73730, from the Narita formation of Chiba Prefecture) ; 14, side view of other fossil, ×2.5 (IGPS coll. cat. no. 73729, from the Jizôdô formation of Chiba Prefecture).

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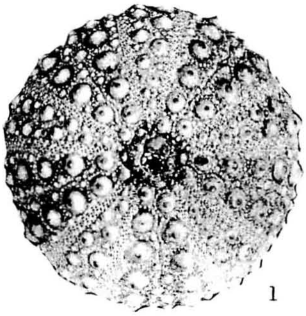
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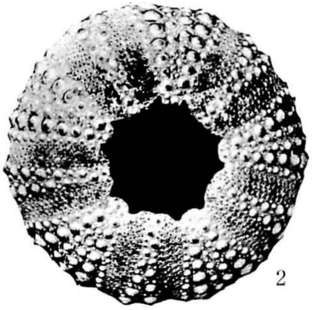
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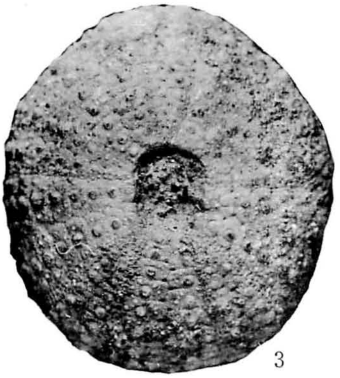
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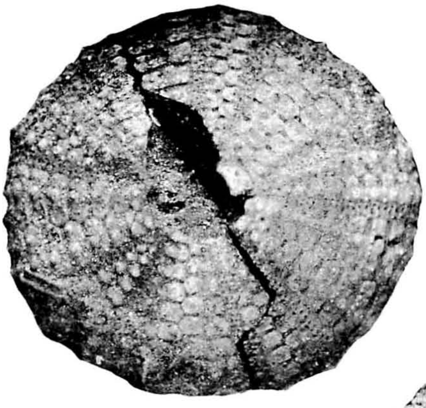
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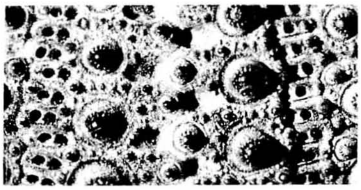
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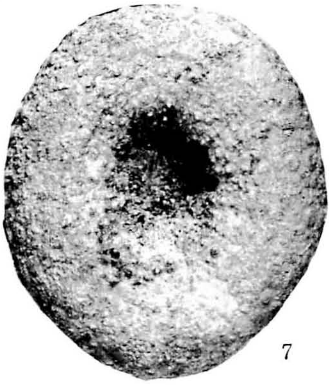
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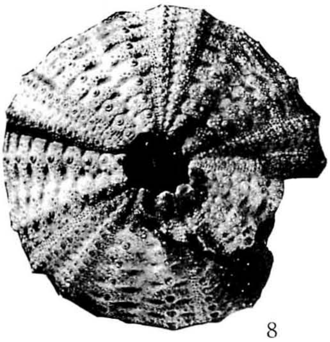
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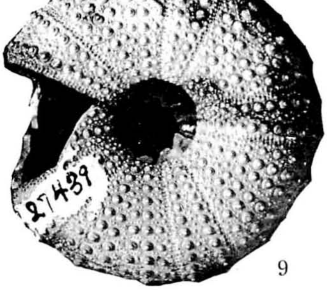

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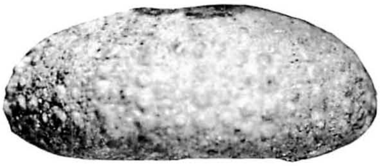
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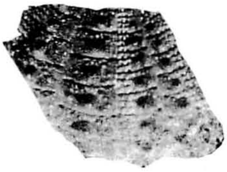
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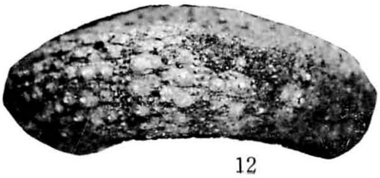
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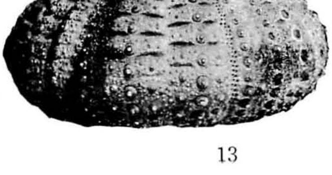
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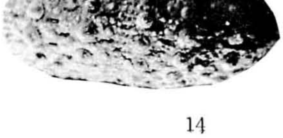
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Plate 5

Explanation of Plate 5

(Size as stated)

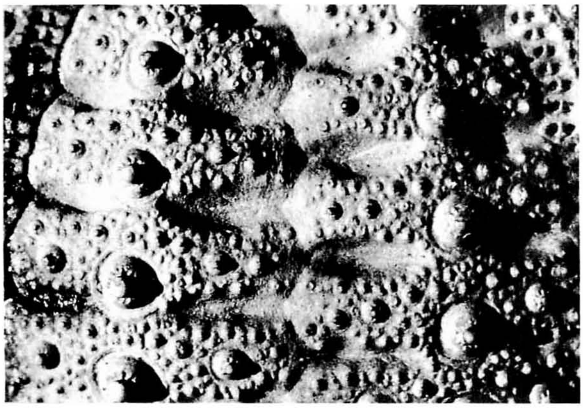
Figs. 1–4. *Temnopleurus hardwickii* (GRAY, 1855). 1, side view of an interambulacrum at the mid-zone of fossil, ×5 (IGPS coll. cat. no. 22242, from the Narita formation of Chiba Prefecture); 2, side view of an ambulacrum at the mid-zone of the same, ×5; 3, side view of an interambulacrum at the mid-zone of Recent specimen, ×4 (for comparison) (IGPS coll. cat. no. 78205, from Ojika Peninsula, Miyagi Prefecture); 4, side view of an ambulacrum at the mid-zone of the same, ×4 (for comparison).

Figs. 5–8. *Erbechinus gratus* NISIYAMA, n. sp. 5, aboral view of *holotype*, ×2 (IGPS coll. cat. no. 73720, from the Shirahama (Susaki) formation of Shizuoka Prefecture); 6, side view of the same, ×2; 7, other side view of the same, ×2; 8, oral view of the same, ×2.

Figs. 9–10. *Opechinus variabilis* (DÖDERLEIN, 1885). 9, side view of Recent specimen, ×3 (for comparison) (IGPS coll. cat. no. 58317, from off Wada-machi, Chiba Prefecture, in 130–147 metres); 10, oral view of the same, ×3 (for comparison).

Figs. 11–15. *Brochopleurus pulcherrimus* NISIYAMA, n. sp. 11, oral view of *holotype*, ×3 (IGPS coll. cat. no. 73719-1, from the Komayama formation of Chiba Prefecture); 12, aboral view of the same, ×3; 13, oral view of *paratype*, ×3 (IGPS coll. cat. no. 73719-2, from same horizon and locality); 14, side view of *holotype*, ×3; 15, aboral view of other *paratype*, ×3 (IGPS coll. cat. no. 73719-3, from same horizon and locality).

Photo by K. KUMAGAI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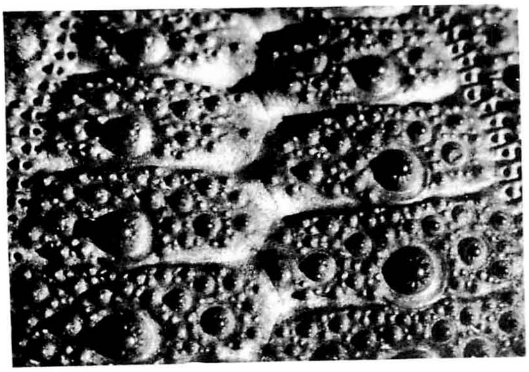
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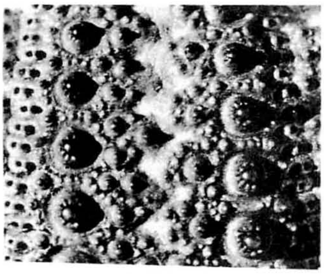
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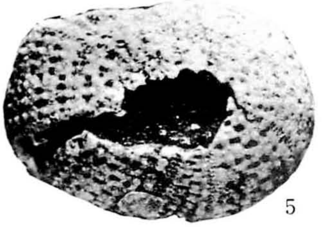
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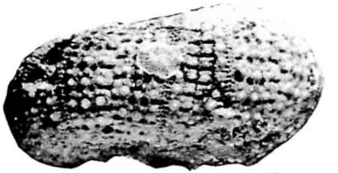
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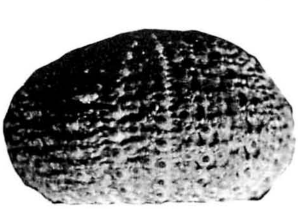
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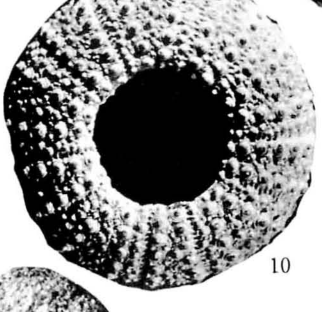
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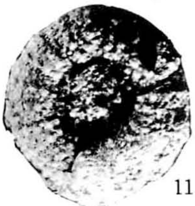
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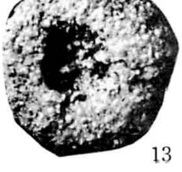
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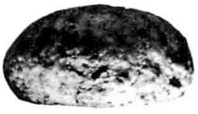
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Plate 6

Explanation of Plate 6

(Size as stated)

Fig. 1. *Mespilia globulus* (LINNAEUS, 1758). Side view of a part of test, ×2 (IGPS coll. cat. no. 78205, from the Raised Beach deposits of Tateyama City, Chiba Prefecture).

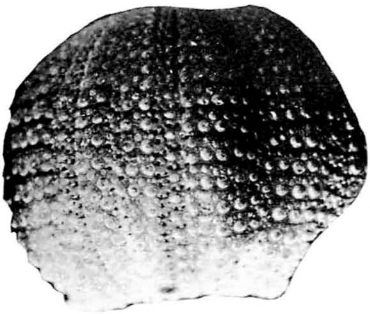
Figs. 2, 7, 8. *Tripneustes magnificus* NISIYAMA, n. sp. 2, side view of adapical part of ambulacrum, ×1 (IGPS coll. cat. no. 73786-4, from the Laulau formation of Saipan Island, Mariana Islands) ; 7, side view of a part of oral surface, ×1 (IGPS coll. cat. no. 73786-3, from same horizon and locality) ; 9, side view of *holotype*, ×1 (IGPS coll. cat. no. 73786-1, from same horizon and locality).

Fig. 3. *Mirechinus mirabilis* NISIYAMA, n. sp. Aboral view of *holotype*, ×2 (IGPS coll. cat. no. 73725, from the Eocene of Bonin Islands).

Figs. 4-5. *Brochopleurus pulcherrimus* NISIYAMA, n. sp. 4, oral view of *paratype* in figure 15 on plate 5, ×3 (IGPS coll. cat. no. 73719-3, from the Komayama formation of Chiba Prefecture) ; 5, side view of the same, ×3.

Fig. 6. *Strongylocentrotus? octoporus* NISIYAMA, n. sp. 6, side view of an interambulacrum at the mid-zone, ×2 (IGPS coll. cat. no. 73723-2, from the Fukaura formation of Aomori Prefecture).

Photo by K. KUMAGAI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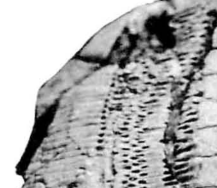
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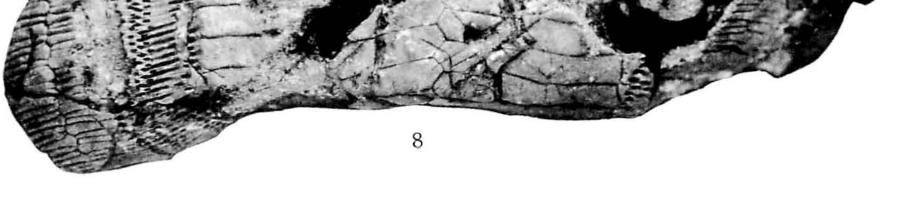
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Plate 7

Explanation of Plate 7

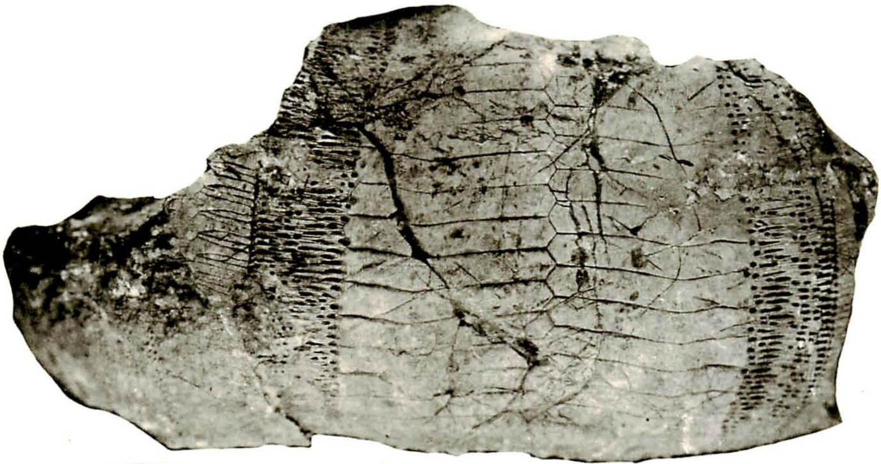
(Size as stated)

Fig. 1. *Tripneustes magnificus* NISIYAMA, n. sp. Side view of *paratype*, ×1 (IGPS coll. cat. no. 73786-2, from the Laulau formation of Saipan Island, Mariana Islands).

Figs. 2, 4. *Mirechinus mirabilis* NISIYAMA, n. sp. 2, oral view of *holotype*, ×2 (IGPS coll. cat. no. 73725, from the Eocene of Bonin Islands); 4, side view of the same, ×2.

Figs. 3, 5-7. *Pseudocentrotus stenoporus* NISIYAMA, n. sp. 3, side view of a part of test, ×2 (*paratype*, IGPS coll. cat. no. 78207-2, from the Shirahama (Susaki) formation of Shizuoka Prefecture); 5, aboral view of *holotype*, ×1 (IGPS coll. cat. no. 78201-1, from same horizon and locality); 6, side view of the same, ×1; 7, oral view of the same, ×1.

Photo by K. KUMAGAI



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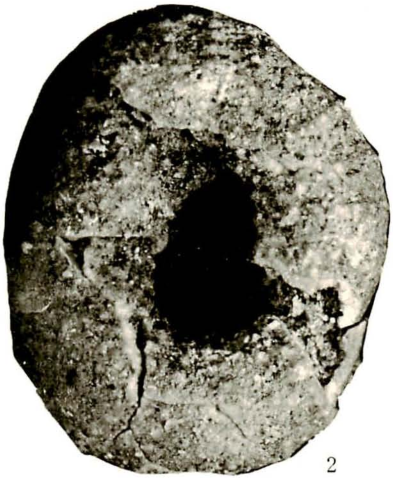

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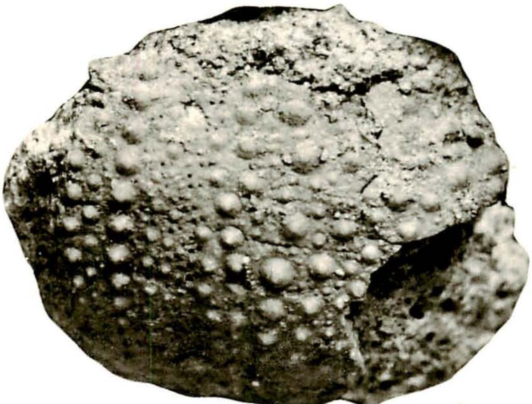

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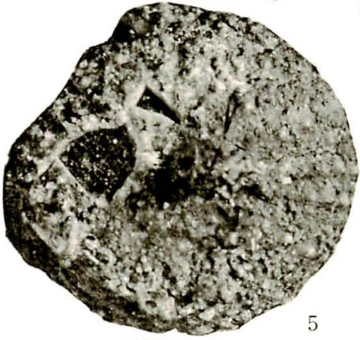

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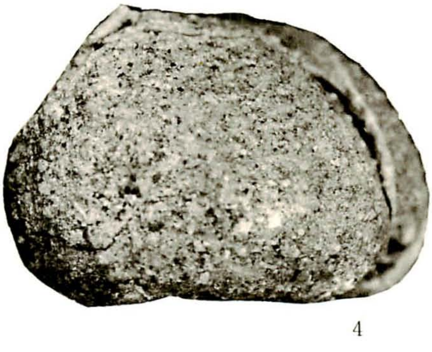

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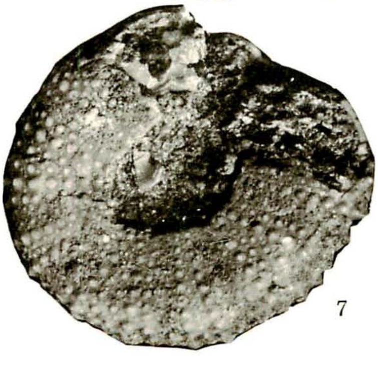

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Plate 8

Explanation of Plate 8

(Size as stated)

Figs. 1–3. *Strongylocentrotus magistrus* NISIYAMA, n. sp. 1, exterior view of an ambulacrum on the adapical region, ×2 (IGPS coll. cat. no. 73813-1, from the Himi formation of Toyama Prefecture); 2, interior view of the same, ×2; 3, side view of two interambulacral plates at the mid-zone, ×2 (IGPS coll. cat. no. 73813-2, from same horizon and locality).

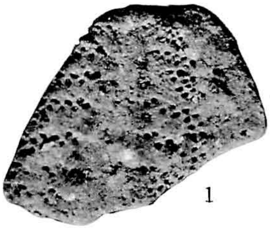
Figs. 4, 10–14. *Allocentrotus japonicus* NISIYAMA, n. sp. 4, side view of half ambulacrum at the adapical region, ×1.5 (IGPS coll. cat. no. 73798-3, from the Tômiya tuffaceous sandstone of Chiba Prefecture); 10, side view of half ambulacrum at the mid-zone, ×1.5 (IGPS coll. cat. no. 73798-2, from same horizon and locality); 11, side view of ambulacrum and interambulacrum below the ambitus, ×1.5 (IGPS coll. cat. no. 73798-4, from same horizon and locality); 12, oral view of adoral region, ×1 (IGPS coll. cat. no. 73798-1, from same horizon and locality); 13, interior view of ambulacral and interambulacral plates near the peristome, ×1 (IGPS coll. cat. no. 73798-5, from same horizon and locality); 14, side view of half interambulacrum above the ambitus, ×1 (IGPS coll. cat. no. 73798-6, from same horizon and locality).

Figs. 5–6. *Strongylocentrotus echinoides* A. AGASSIZ and H.L. CLARK, 1907. 5, side view of half ambulacrum on the adapical region of fossil, ×3 (IGPS coll. cat. no. 73796-1, from the Seatana formation of Shiribeshi Province, Hokkaido); 6, side view of half ambulacrum at the mid-zone of fossil, ×3 (IGPS coll. no. 73796-2, from the Setana formation of Shiribeshi Province, Hokkaido).

Figs. 7–8. *Strongylocentrotus? octoporus* NISIYAMA, n. sp. 7, side view of an interambulacrum at the mid-zone, ×2 (IGPS coll. cat. no. 73723-2, from the Fukaura formation of Aomori Prefecture); 8, side view of an ambulacrum at the mid-zone, ×2 (IGPS coll. cat. no. 73723-1, from same horizon and locality).

Fig. 9. *Strongylocentrotus intermedius* (A. AGASSIZ, 1863). Side view of half ambulacrum and interambulacrum on the adapical region of fossil, ×3 (IGPS coll. cat. no. 73759, from the Shibikawa formation of Akita Prefecture).

Photo by K. KUMAGAI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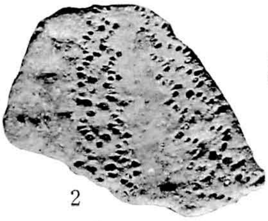
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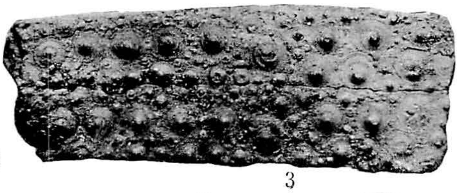
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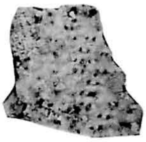
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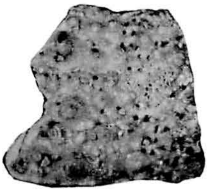
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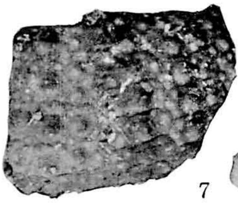
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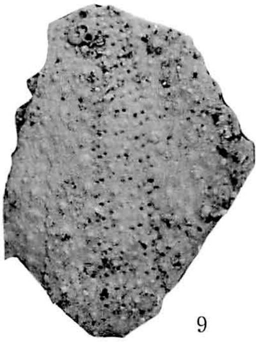
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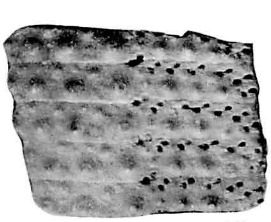
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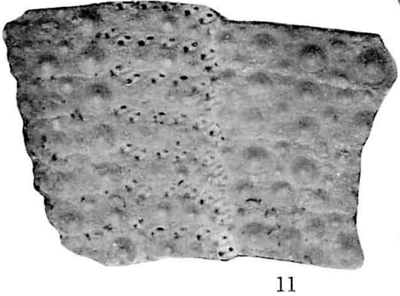
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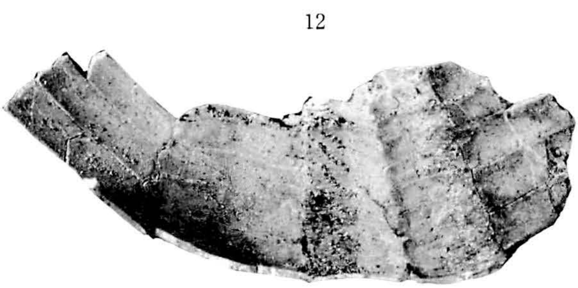
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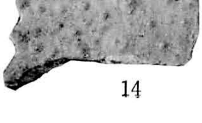
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Plate 9

Explanation of Plate 9

(Size as stated)

Figs. 1-2, 4-6. *Allocentrotus japonicus* NISIYAMA, n. sp. 1, aboral view of *holotype*, ×1 (IGPS coll. cat. no. 73798-1, from the Tômiya tuffaceous sandstone of Chiba Prefecture) ; 2, interior view of adoral side of *holotype*, ×1 ; 4, side view of two interambulacral plates on the adapical region, ×3 (IGPS coll. cat. no. 73798-7, from same horizon and locality) ; 5, interior view of a part of aboral side, ×1 (IGPS coll. cat. no. 73798-8, from same horizon and locality) ; 5, side view of a part of the ambital region, ×1 (IGPS coll. cat. no. 73798-9, from same horizon and locality).

Fig. 3. *Echinostrephus aciculatum* A. AGASSIZ, 1863. Aboral view of fossil, ×1.3 (IGPS coll. cat. no. 73763, from the Ryukyu Limestone of Ishigaki-jima, Ryukyu Islands).

Photo by K. KUMAGAI

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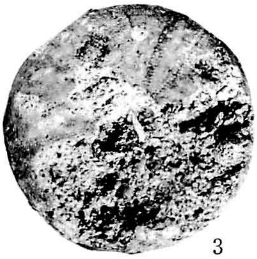

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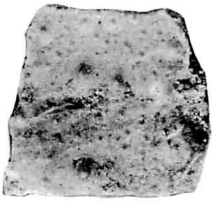

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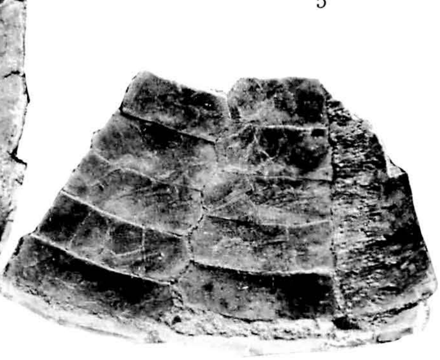

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Plate 10

Explanation of Plate 10

(Size as stated)

Fig. 1. *Echinometra hondoana* NISIYAMA, n. sp. Aboral view of a part of aboral surface ×2 (*holotype*, IGPS coll. cat. no. 737333, from the Kozai formation of Miyagi Prefecture).

Figs. 2–3. *Echinostrephus aciculatum* A. AGASSIZ, 1863. 2, oral vidw of fossil, ×1.3 (IGPS coll. cat. no. 73763, from the Ryukyu Limestone of Ishigaki-jima, Ryukyu Islands); 3, side view of the same, ×1.3.

Figs. 4–6. *Echinometra mathaei* (BLAINVILLE, 1825). 4, aboral view of fossil, ×1 (IGPS coll. cat. no. 73764, from the Ryukyu Limestone of Ishigaki-jima, Ryukyu Islands); 5, oral view of the same, ×1.3; 6, side view of the same, ×1.3.

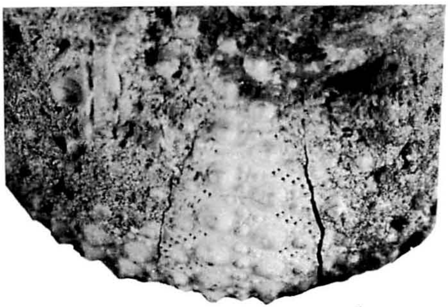
Fig. 7. *Echinolampas yoshiwarai* DE LORIOL, 1902. Aboral view of specimen, ×1 (IGPS coll. cat. no. 73794, from the Tsugawa formation of Niigata Prefecture).

Figs. 8–10. *Parasalenia marianae* COOKE, 1957. 8, aboral view of secimen, ×2 (IGPS coll. cat. no. 73736, from the Donney formation of Saipan Island, Mariana Islands); 9, side view of the same, ×2; oral view of the same, ×2.

Figs. 11–12. *Echinolampas bombos* NISIYAMA, n. sp. 11, aboral view of *paratype*, ×2 (IGPS coll. cat. no. 73726-2, from the Eocene of Bonin Islands; 12, oral view of the same, ×2.

Figs. 13–14. *Planilampas sternopetala* (A. AGASSIZ and H. L. CLARK 1907). 13, aboral view of Recent specimen, ×1 (for comparison) (from Tanabe Bay, Wakayama Prefecture); 14, oral view of the same, ×1 (for comparison).

Photo by K. KUMAGAI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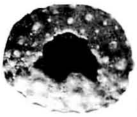
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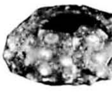
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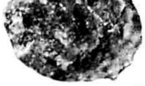
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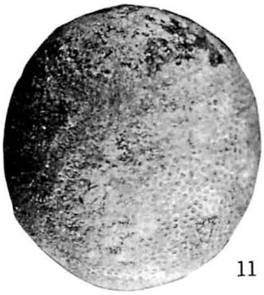
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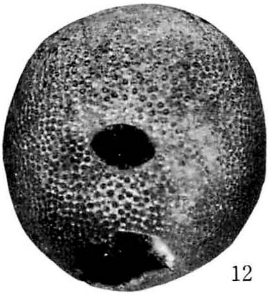
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Plate 11

Explanation of Plate 11

(Size as stated)

Figs. 1-6, 9. *Echinolampas bombos* Nisiyama, n. sp. 1, aboral view of *holotype*, ×2 (IGPS cat. no. 73726-1, from the Eocene of Bonin Islands); 2, oral view of the same, ×2; side view of the same, ×2; 4, aboral view of *paratype*, ×2 (IGPS coll. cat. no. 73726-3, from same horizon and locality); 5, oral view of the same, ×2; 6, side view of the same, ×2; 9, side view of *paratype* in figures 11 and 12 on plate 10, ×2 (IGPS coll. cat. no. 73726-2, from same horizon and locality).

Figs. 7, 8, 11. *Planilampas sternopetala* (A. Agassiz and H.L. Clark, 1907). 7, aboral view of Recent specimen, ×1 (for comparison) (from Tanabe Bay, Wakayama Prefecture); 8, oral view of other specimen, ×1 (from Tanabe Bay, Wakayama Prefecture); 11, side view of specimen in figures 13 and 14 on plate 10, ×1 (from same locality).

Fig. 10. *Echinolampas koreana* H.L. Clark, 1925. Aboral view of Recent specimen, ×1 (for comparison) (IGPS coll. cat. no. 78208, from Toyama Bay, Toyama Prefecture, in 100 metres).

Photo by K. Kumagai

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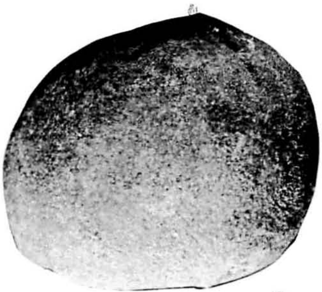

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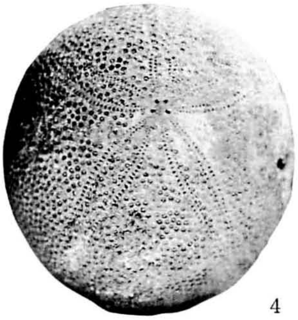

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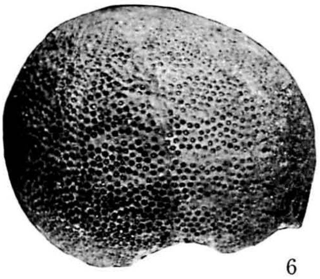

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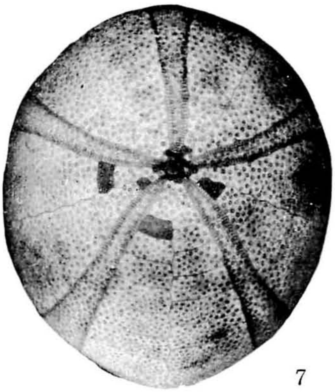

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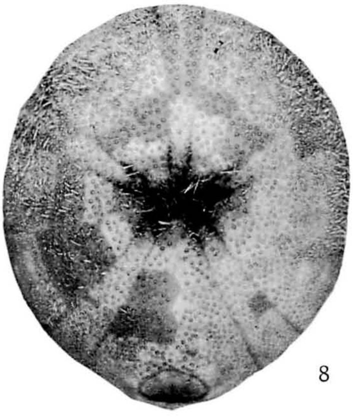

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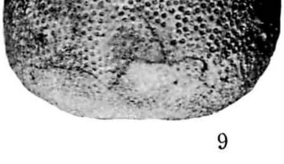

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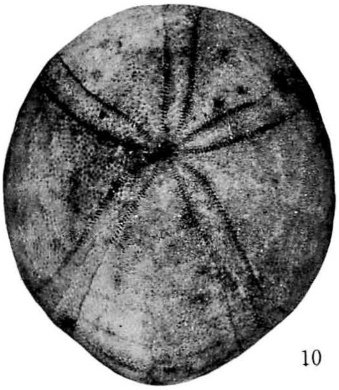

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Plate 12

Explanation of Plate 12

(Size as stated)

Figs. 1, 4. *Clypeaster* (*Stolonoclypus*) *virescens* DÖDERLEIN, 1885. 1, aboral view of fossil, ×1 (IGPS coll. cat. no. 8319, from the Ryukyu Limestone of Okinawa Island, Ryukyu Islands) ; 4, oral view of the same, ×1.

Figs. 2, 3, 5. *Clypeaster* (*Stolonoclypus*) *humilis* (LESKE, 1778). 2, aboral view of fossil, ×1 (IGPS coll. cat. no. 35059-1, from the Byôritsu formation of Shinchiku-shû, Formosa) ; 3. side view of the same, × 1 ; 5, oral view of the same, ×1.

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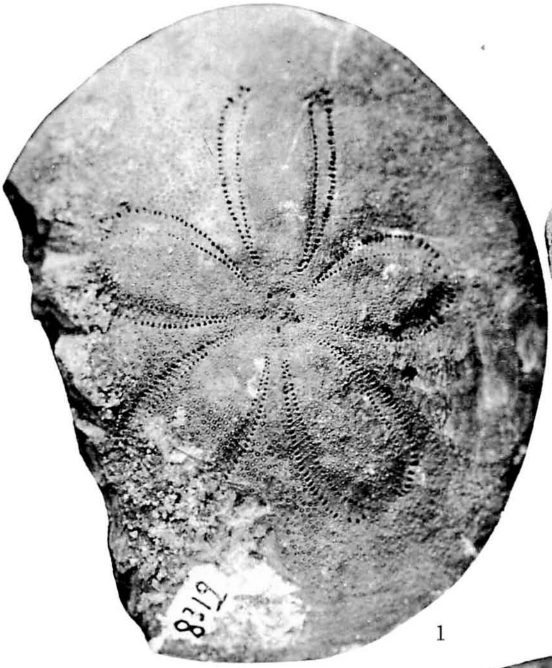

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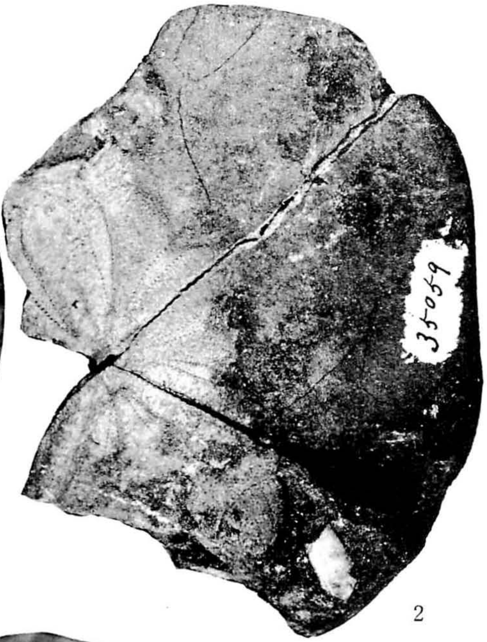

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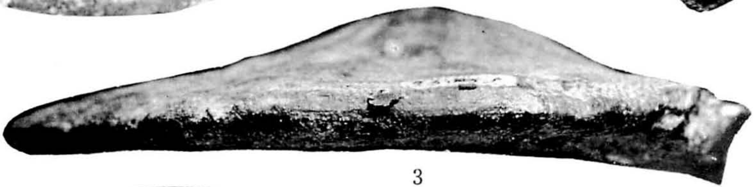

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Plate 13

Explanation of Plate 13

(Size as stated)

Figs. 1-2, 7. *Clypeaster* (*Stolonoclypus*) *virescens* DÖDERLEIN, 1885. 1, aboral view of fossil, ×1 (IGPS coll. cat. no. 78211, from the Byôritsu formation of Shinchiku-shû, Formosa) ; 2, oral view of the same, ×1 ; 7, side view of the same. ×1.

Figs. 3-4, 11. *Fibularia* (*Fibulariella*) *acuta* YOSHIWAWA, 1898. 3, aboral view of fossil, ×2.5 (IGPS coll. cat. no. 27454, from the Narita formation of Chiba Prefecture) ; 4, oral view of the same, × 2.5 ; 11, side view of the same, ×2.5.

Figs. 5, 12. *Fibularia* (*Fibulariella*) *acuta septemtrionalis* NISIYAMA, n. subsp. 5, side view of *holotype*, ×3.5 (IGPS coll. cat. no. 78210-1, from the east coast of Shiogama Bay, Miyagi Prefecture) ; 12, side view of *paratype*, ×2.5 (IGPS coll. cat. no. 78210-2, from same locality).

Figs. 6, 8-10, 13-16. *Sismondia javana ladronensis* NISIYAMA, n. subsp. 6, aboral view of *holotype*, ×3 (IGPS coll. cat. no. 73737-1, from the Denshinyama formation of Saipan Islnad, Mariana Islands) ; 8, aboral view of other specimen, ×3 (IGPS coll. cat. no. 73738-1, from the Donney formation of Saipan Island, Mariana Islands) ; 9, aboral view of other specimen, ×3 (IGPS coll. cat. no, 73738-2, from the Donney formation of Saipan Island) ; 10, oral view of *holotype*, ×3 ; 13, aboral view of *paratype*, ×3 (IGPS coll. cat. no. 73737-2, from the Denshinyama formation of Saipan Island, Mariana Islands) ; 14, aboral view of other *paratype*, ×3 (IGPS coll. cat. no. 73737-3, from same horizon and locality) ; 15, oral view of *paratype* in figure 13, ×3 ; 16, oral uiew of specimen in figure 9, ×3.

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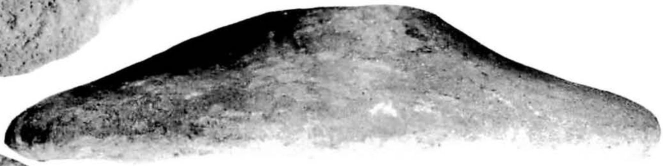

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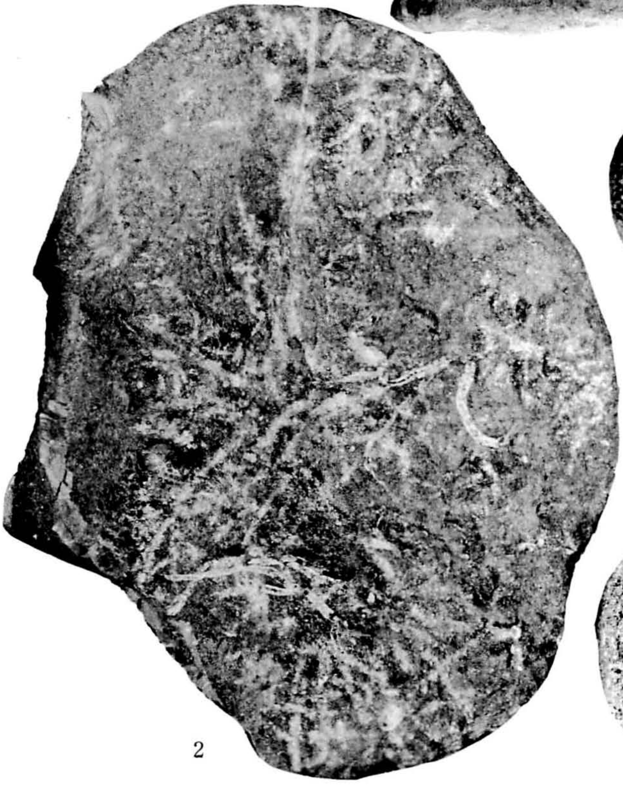

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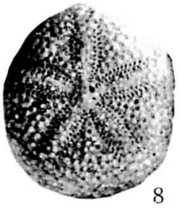

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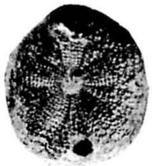

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Plate 14

Explanation of Plate 14

(Size as stated)

Fig. 1. *Clypeaster* (*Stolonoclypus*) cf. *virescens* DÖDERLEIN, 1885. aboral view of fossil, ×1 (IGPS coll. cat. no. 35058, from the Byôritsu formation of Shinchiku-shû, Formosa).

Fig. 2. *Clypeaster* (*Stolonoclypus*) *japonicus* DÖDERLEIN, 1885. Oral view of fossil, ×1 (IGPS coll. cat. no. 8318, from the Ryukyu Limestone of Okinawa Island, Ryukyu Islands).

Figs. 3-8. *Sismondia javana ladronensis* NISIYAMA, n. sp. 3, oral view of *paratype* in figure 14 on plate 13, ×3 (IGPS coll. no. 73737-3, from the Denshinyama formation of Saipan Island, Mariana Islands); 4, side view of *holotype*, ×3; 5, side view of specimen in figure 14 on plate 13, ×3 (IGPS coll. cat. no. 73737-3); 6, oral view of specimen in figure 13 on plate 13 (IGPS coll. cat. no. 73737-2); 7, side view of specimen in figure 13 on plate 13, × 3; 8, side view of specimen in figure 8 on plate 13, × 3 (IGPS coll. cat. no. 73738-1, from the Donney formation of Saipan Island, Mariana Islands).

Figs. 9-10. *Peronella japonica* MORTENSEN, 1948. 9, aboral view of fossil, ×1 (IGPS coll. cat. no. 7907-1, from the Tokyo formation of Tokyo City); 10, aboral view of other fossil, ×1 (IGPS coll. cat. no. 7907-2, from the Tokyo formation of Tokyo City).

Figs. 11-12. *Peronella pellucida* DÖDERLEIN, 1885. 11, aboral view of fossil, ×1 (IGPS coll. cat. no. 73765, from the Ryukyu Limestone of Kikai-jima, Ryukyu Islands); 12, oral view of the same, ×1.

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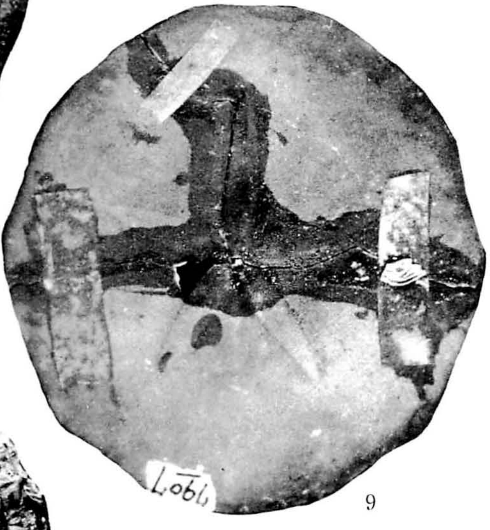

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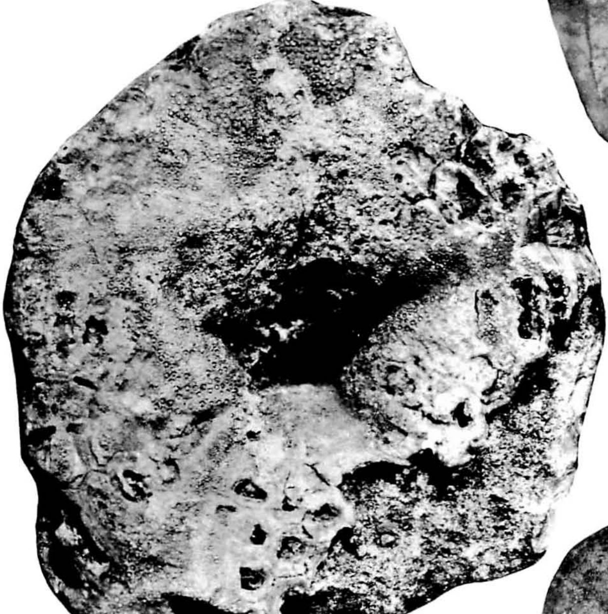

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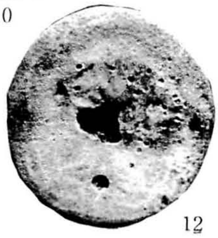

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Plate 15

Explanation of Plate 15

(Size as stated)

Figs. 1-3, 5. *Peronella rubra* DÖDERLEIN, 1885. 1, aboral view of Recent specimen, ×1 (for comparison) (IGPS coll. cat. no. 58324-1, from Ubara Bay, Chiba Prefecture, in 5 metres); 2, oral view of the same, ×1; 3, oral view of other specimen, ×1 (IGPS coll. cat. no. 58324-2, from Ubara Bay, Chiba Prefecture, in 5 metres); 5, side view of specimen in figure 1.

Figs. 4, 6-8. *Peronella pellucida* DÖDERLEIN, 1885. 4. aboral view of Recent specimen, ×1 (for comparison) (IGPS coll. cat. no. 78212, from Sagami Bay, Kanagawa Prefecture, in 120 metres); 6, oral view of the same, ×1; 7, side view of the same, ×1; 8, anterior view of the same, ×1.

Figs. 9-10, 17. *Laganum pachycraspedum* NISIYAMA, n. sp. 9, aboral view of *holotype*, ×1 (IGPS coll. cat. no. 73759-1, from the Shirahama (Susaki) formation of Shizuoka Prefecture); 10, oral view of *paratype*, ×1 (IGPS coll. cat. no. 73759-2, from the Shirahama (Susaki) formation of Shizuoka Prefecture); 17, side view of the same, ×1.

Figs. 11-16. *Laganum depressum* LESSON, 1841. 11, aboral view of fossil, ×1 (IGPS coll. cat. no. 73771-1, from the Byôritsu formation of Shinchiku-shû, Formosa); 12, aboral view of other fossil, ×1 (IGPS coll. cat. no. 73771-2, from same horizon and locality); 13, oral view of specimen in figure 11, ×1; 14, oral view of specimen in figure 12, ×1; 15, side view of specimen in figure 11, ×1; 16, side view of specimen in figure 12, ×1.

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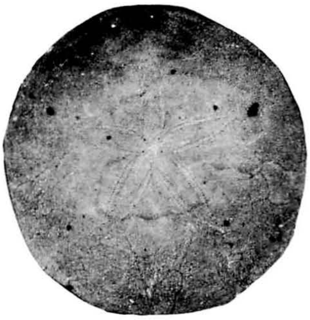
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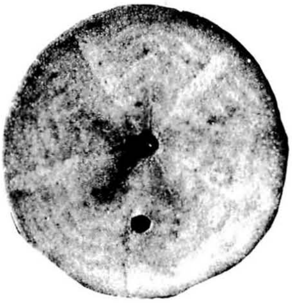
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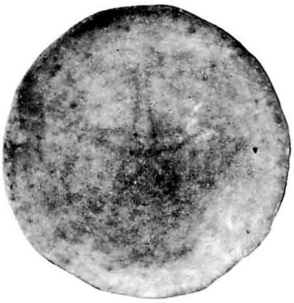
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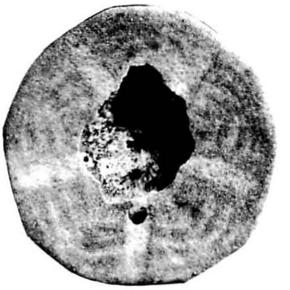
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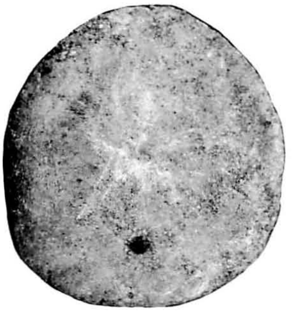
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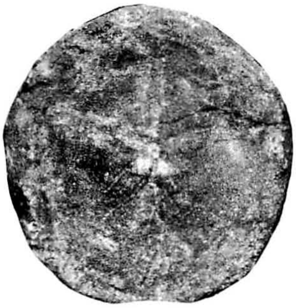
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Plate 16

Explanation of Plate 16

(Size as stated)

Figs. 1-3, 6. *Laganum* cf. *decagonale* (BLAINVILLE, 1827) (for comparison). 1, oral view of fossil, ×1 (IGPS coll. cat. no. 37624-1, from the Neogene formation of Java, Malay Region) ; 2, aboral view of the same, ×1 ; 3, oral view of other fossil, ×1 (IGPS coll. cat. no. 37624-2, from the Neogene formation of Java, Malay Region) ; 6, aboral view of the same, ×1.

Figs. 4-5. *Echinarachnius* cf. *parma obesus* H.L. CLARK, 1914. 4, aboral view of fossil, ×1 (IGPS coll. cat. no. 30663, from the Paromai formation (*Echinarachnius*-zone) of the River Paromai, North Sakhalin) ; 5, side view of the same, ×1.

Fig. 7. *Echinarachnius* cf. *parma* (LAMARCK, 1816). Side view of fossil, ×1 (IGPS coll. cat. no. 73775, from the Sawane formation of Sado Island, Niigata Prefecture).

Fig. 8. *Echinarachnius humilis* NISIYAMA, n. sp. Aboral view of *holotype*, ×1 (IGPS coll. cat. no. 73775, from the Chôkai formation of Akita Prefecture).

Figs. 9-12, 14. *Pseudoastrodapsis intermedius* NISIYAMA, n. sp. 9, aboral view of *holotype* ×1 (IGPS coll. cat. no. 73803-1, from the Kawabata formation of Teshio Province, Hokkaido) ; 10, oral view of the same, ×1 ; 11, aboral view of *paratype*, ×1 (IGPS coll. cat. no. 73803-2, from the Kawabata formation of Teshio Province, Hokkaido) ; 12, side view of *holotype*, ×1 ; 14, side view of *paratype*, ×1.

Fig. 13. *Peronella pellucida* DÖDERLEIN, 1885. Anterior view of fossil in figures 11 and 12 on plate 14 (IGPS coll. cat. no. 73765), ×1.

Figs. 15-17. *Pseudoastrodapsis nitidiusculus* NISIYAMA, n. sp. 15, aboral view of *holotype*, ×1 (IGPS coll. cat. no. 73805-1, from the upper Neogene formation of central Hokkaido) ; 16, oral view of the same, ×1 ; 17, side view of the same, ×1.

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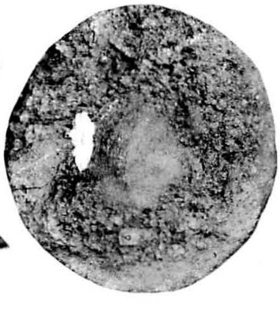

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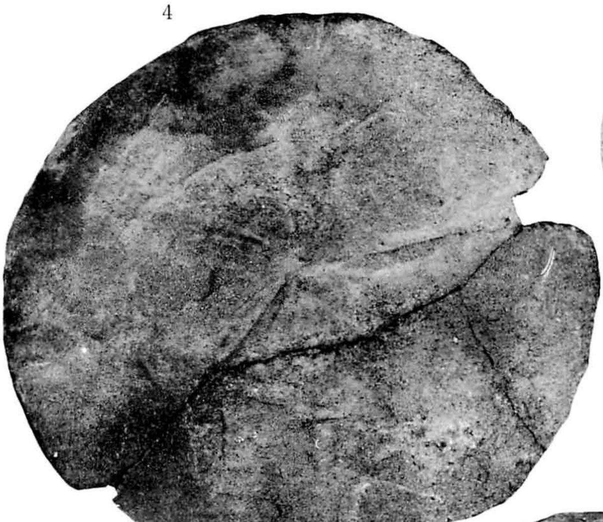

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Plate 17

Explanation of Plate 17

(Size as stated)

Fig. 1. *Echinodiscus transiens* Nisiyama, n. sp. Aboral view of *holotype*, ×1 (IGPS coll. cat. no. 73773, from the Yamaga formation of Hiko-shima, Yamaguchi Prefecture).

Figs. 2, 3, 6. *Pseudoastrodapsis nitidiusculus* Nisiyama, n. sp. 2, aboral view of *paratype*, ×1 (IGPS coll. cat. no. 73805-2, from the upper Neogene formation of central Hokkaido) ; 3, oral view of other *paratype*, ×1 (IGPS coll. cat. no. 73805-3, from same horizon and locality) ; 6, side view of *paratype*, ×1 (IGPS coll. cat. no. 73805-2).

Fig. 4. *Astriclypeus mannii* Verrill, 1867. Aboral view of fossil (IGPS coll. cat. no. 8315, from the Ryukyu Limestone of Okinawa Island, Ryukyu Islands), ×1.

Fig. 5. *Allaster rotundus* Nisiyama n. sp. Side view of *holotype*, ×2 (IGPS coll. cat. no. 73768-1, from the Takinouye formation of Hidaka Province, Hokkaido).

Photo by K. Kumagai

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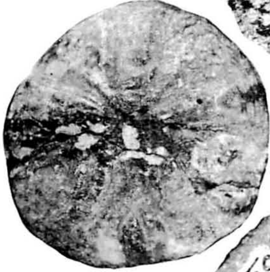

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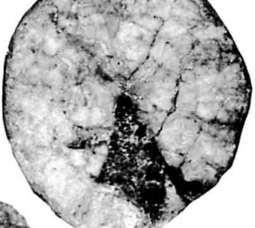

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Plate 18

Explanation of Plate 18

(Size as stated)

Figs. 1, 4. *Allaster rotundus* NISIYAMA, n. sp. 1, aboral view of *holotype*, ×2 (IGPS coll. cat. no. 73768-1, from the Takinouye formation of Hidaka Province, Hokkaido); 4, aboral view of *paratype*, ×2 (IGPS coll. cat. no. 73768-2, from same horizon and locality).

Figs. 2, 5, 9. *Hemiaster uwajimensis* MORISHITA, 1962. 2, aboral view of *hypotype*, ×2 (IGPS coll. cat. no. 73747, from the Miyakura (Furushiroyama) formation of Ehime Prefecture); 5, oral view of the same, ×2; 9, side view of the same, ×2.

Figs. 3, 12-13. *Paraheteraster macroholcus* (NISIYAMA, 1950). 3, aboral view of *holotype*, ×1 (IGPS coll. cat. no. 72981, from the Arita formation of Wakayama Prefecture); 12, side view of the same, ×1; 13, anterior view of the same, × 1.

Figs. 6-7. *Cardiaster perorientalis* NISIYAMA, n. sp. 6, aboral view of *holotype*, ×1 (IGPS coll. cat. no. 72981, from the Miyakura (Furushiroyama) formation of Ehime Prefecture); 12, side view of the same, ×1.

Fig. 8. *Echinarachnius* cf. *parma obesus* H.L. CLARK, 1914. Oral view of fossil specimen in figure 4 on plate 16, ×1 (IGPS coll. cat. no. 30663, from the Paromai formation (*Echinarachnius*-zone) of the River Paromai, North Sakhalin).

Figs. 10-11. *Cottreaucorys* (*Cordastrum*) *sulcatus* NISIYAMA, n. sp. 10, aboral view of *holotype*, ×2 (IGPS coll. cat. 73746, from the Miyakura (Furushiroyama) formation of Ehime Prefecture); 11, oral view of the same, ×2.

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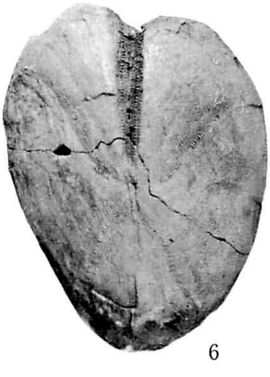
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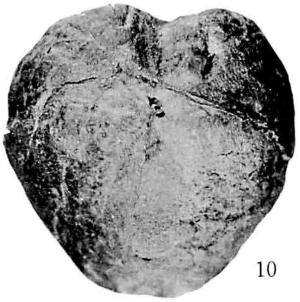
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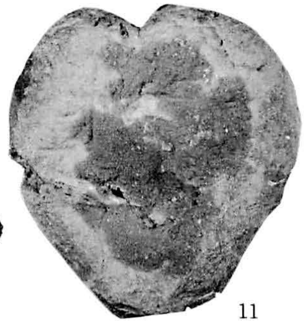
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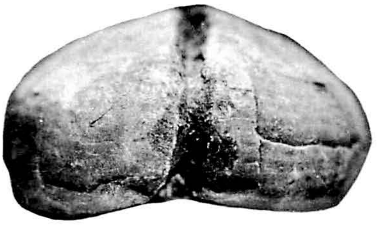
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