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ASTEROIDEA OF THE NORTH PACIFIC AND ADJACENT WATERS

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PART 2. FORCIPULATA (PART)

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PART 2. FORCIPULATA (Part)

FOREWORD

Part 1 of this work, comprising the Phanerozonia and Spinulosa, was issued on June 30, 1911. The present part contains an account of the families Brisingidae, Zoroasteridae, and four subfamilies of the Asteriidae—the Pedicellasterinae, Labidiasterinae, Coscinasteriinae, and Pycnopodiinae. The remainder of the Forcipulata will be described in the final installment, the manuscript of which is completed.

Material for study has been derived from the sources which were indicated in Part 1 (p. 1). In addition I have gone over the British Museum collection; some of the types in the Muséum d'Histoire Naturelle at Paris; the collection of the Peabody Museum, Yale University (including a part of Verrill's material); and all of the collection of the United States National Museum. Through the kindness of Dr. T. Odhner, of the Riksmuseum, Stockholm, I received a small collection from the *Vega* Expedition as well as miscellaneous Arctic specimens for comparison. The Victoria Memorial Museum (now the National Museum of Canada), Ottawa, forwarded certain of Verrill's types. Dr. Th. Mortensen loaned cotypes of *Asterias amurensis* and an authentic example of *Leptasterias ochotensis*. Dr. Jules Richard, of the Musée Océanographique at Monaco, loaned a cotype of *Sclerasterias guernei*. Dr. H. L. Clark loaned a considerable amount of material from the rich collection of the Museum of Comparative Zoölogy and, with great patience, has allowed me to dissect many of the Asteriidæ in his care; while Mr. Austin H. Clark has been equally liberal with material from the National Collection. Prof. Wesley R. Coe has aided me in my study of Verrill's types at the Peabody Museum and in the search for those which are missing. I have been greatly indebted to Dr. R. Kirkpatrick, of the British Museum, for a number of photographs, notes on types, and for the loan of specimens prior to a special trip which I made in 1923 to the British Museum. Dr. C. McLean Fraser, formerly director of the Canadian Biological Station, Nanaimo, British Columbia, has contributed specimens and aided my search for others at Departure Bay, British Columbia. The California Academy of Sciences has financed considerable collecting in the region of Puget Sound and in Lower California. The material is credited in the lists of specimens. My thanks are due to several friends who have collected for me in different localities, namely: Mr. Philip Baxter, Dr. J. C. Brown, Dr. C. H. Gilbert, Dr. H. Heath, Dr. Carl Hubbs, Dr. G. Dallas Hanna, Mr. H. C. McMillin, Dr. Charles H. O'Donoghue, Mrs. Ida S. Oldroyd, Mr. E. F. Ricketts, Mr. S. P. Smith, Prof. J. O. Snyder, Prof. E. C. Starks, Dr. F. W. Weymouth, and Mr. George Willetts.

After completion of part 1, work on the collections was discontinued in order to allow for the publication of Verrill's "Shallow-water Starfishes,"[1] which was delayed until 1914. In the meantime I had undertaken a report on the very extensive collection of sea stars made by the *Albatross* in the East Indies from 1907 to 1910. Work on the north Pacific collections was resumed in 1918, but other duties have interfered with the completion of the manuscript, of which this installment is about one-half. It is hoped, however, that the results have been improved by a ripening process and may therefore be of more permanent value.

Additions to the bibliographic list will be deferred to part 3. References have been made sufficiently full to obviate any inconvenience from this omission.

The photographic figures were made in the photographic laboratory of the United States National Museum. The drawings are by the writer.

SYSTEMATIC DISCUSSION OF THE FAUNA

Class ASTEROIDEA Burmeister[2]

Order FORCIPULATA Perrier

Stelleridae Forcipulatae Perrier, Mém. Étoiles de Mer, 1884, p. 167.
Forcipulata Perrier Expéd. sci. *Travailleur* et *Talisman*, 1894, p. 27.
Cryptozonia (part) Sladen, *Challenger* Asteroidea, 1889, p. 397.
Forcipulosa Verrill, Shallow-water Starfishes, etc., 1914, p. 24.

Differing from all other orders of Asteroidea chiefly in the presence of crossed (forcipiform) and straight (forciform) pedicellariae, or of either alone. Form always stellate, the rays, five to many, frequently slender and long. Abactinal skeleton when present formed of skeletal arches (transverse on rays), either independent or bound together by intermediate plates, forming a network with rectangular or very irregular meshes. The skeletal arches usually correspond to every other or to every third adambulacral and are composed of pieces exactly or approximately corresponding in the ventral, lateral, and dorsal regions of ray. In most cases the plates also form more or less definite longiseries, among which the actinal (when present) and marginal are almost always regular, the carinal usually regular, and the dorsolaterals usually irregular; marginal plates usually not greatly larger than abactinal, sometimes partly or wholly suppressed, especially when abactinal skeleton is imperfect; latter sometimes absent. Ambulacral ossicles frequently short and crowded, compressing the primitively double series of tube-feet (always with suckers) into two zigzag, four, or even six longiseries; adambulacral plates generally short and crowded (except Brisingidae) equal in number to the ambulacrals; mouth plates frequently inconspicuous

[1] Monograph of the Shallow-water Starfishes of the North Pacific Coast from the Arctic Ocean to California. Smithsonian Institution. Harriman Alaska Series, vol. 14, 1914. This work is referred to in this report as "Shallow-water Starfishes, 1914."

[2] Key to the orders of Asteroidea, see part 1, p. 16.

and sunken in actinostome but primitively strong and spiny, as in the Brisingidae, Labidiasterinae, and most Pedicellasterinae. Papulae few to many, frequently in clusters, usually on all surfaces, in adult. Spines vary in form from coarse granules to long delicate needles.

SYNOPSIS OF THE KNOWN SUBORDERS AND FAMILIES OF FORCIPULATA

a^1. Ambulacral ossicles not compressed; upper end of ossicle sub-cylindrical or hour-glass-shaped, the pair closely joined by a muscular symphysis; consecutive pairs articulated end to end without overlapping and resembling centra of a vertebral column; ambulacral pores large, biserial; adambulacral ossicles stout, cylindrical, or hour-glass-shaped; odontophore superficially visible on margin of small circular disk, as an "interradial" plate; papulæ often lacking --Suborder Brisingina Fisher, new.

Deep-water Forcipulata with characteristic small circular disk, slender, often deciduous rays, sharply differentiated from disk, and long, delicate, sacculate, acicular marginal and adambulacral spines; dorsal skeleton weak, that of ray variable, never reticulate, confined to proximal third or half of ray, composed of transverse, independent parallel ridges or costae, separated by areas of integument without plates; or the intervals may be partly or completely filled with more or less perfectly developed plates immersed in the body wall; or the arches may be absent and a tessellation of these plates may cover the genital region of ray; or there may be thin plates, more or less spiniferous, together with differentiated transverse costae; straight pedicellariae absent; crossed, abundant; gonads two to many attached to lateral integument of basal portion of ray; actinostome relatively large, peristome broad; mouth plates expanded, usually with prominent spines--*Brisingidae* Sars.

a^2. Ambulacral ossicles compressed, the upper ends short, often imbricated (not subcylindrical and centriform); adambulacral plates short, compressed; odontophore entirely hidden, never exposed on margin of disk; papulae never lacking in adult; marginal plates normally well developed; abactinal skeleton normally of lobed plates imbricated in series or linked by intermediate plates into a regular or irregular reticulum. Suborder Asteriadina Fisher, new.

b^1. Only straight pedicellariae present; deep-water species with very small disk and normally five, slender, usually subterete rays, the plates of which are arranged in regular, usually closely juxtaposed, longiseries; alternate adambulacral plates (in one genus, all) with a prominent spiniferous projection into furrow--------------------*Zoroasteridae* Sladen.

b^2. Straight and crossed pedicellariae; abactinal skeleton normally a regular or irregular reticulum; adambulacral plates without a prominent spiniferous projection into furrow; rays five to many and disk variable; shore to moderate depths.

c^1. Cœlom of disk separated from that of ray (except for a small dorsal passage) by a continuous oblique or horizontal shelf or discobrachial wall,[3] which extends from the actinostomial ring to the dorsal surface of disk, fusing with the inner edges of the interradial septa which it covers; the inner edge of the shelf passes over the upper end of the second pair of ambulacral ossicles and just external to outer border of odontophore so that the ambulacral ridge (distad to the first plate) can not be seen from cœlom of disk; ventrally, cœlom of ray ends in a shallow cul-de-sac near inner end of ambulacral ridge where in Asteriidae the cœlom of disk communicates with that of ray. Rays numerous, disk large; bases of rays fused for a variable, but considerable, distance, the juxtaposed sides forming the so-called double interradial septum; skeleton reticulate, robust. West Coast of Mexico, Central, and south America----*Heliasteridae* Viguier.

[3] First described by Clark, The Starfishes of the Genus *Heliaster*, Bull. Mus. Comp. Zoöl., vol. 51, No. 2, 1907, p. 67, pl. 6, fig. 1.

c^3. No discobrachial septum separating disk and ray coelom as in Heliasteridae; rays 5 to 45, but usually 5 or 6; skeleton of rays, aside from ambulacral and adambulacral plates, consists of 5 primary longiseries of ossicles—1 carinal, 2 superomarginal, 2 inferomarginal, to which is generally added 2+ dorsolateral, 2+ actinal, and rarely 2 intermarginal; dorsal skeleton generally elaborated into a reticulate structure with or without secondary intermediate ossicles; ambulacral ossicles usually crowded; tube-feet in 2 or 4 (occasionally more) longiseries ________________ Family *Asteriidae* Gray.

Suborder BRISINGINA Fisher

Family BRISINGIDAE G. O. Sars

Archaic deep-sea Forcipulata with small, circular disk, numerous, slender, sharply differentiated, often deciduous rays, and long, delicate, sacculate, acicular marginal and adambulacral spines; ambulacral plates massive, uncrowded, the dorsal articulating region centrum-like, nonimbricating; adambulacrals usually elongate, hour-glass-shaped; dorsal skeleton weak, that of rays variable, never reticulate, confined to proximal third or half of ray, composed of transverse, independent, parallel ridges or costae, separated by areas of integument without plates; or the intervals may be partly or completely filled in with more or less imperfectly developed plates immersed in the body wall; or the arches may be absent and a tessellation of thin plates may cover the genital region of the ray; or there may be thin plates more or less spiniferous together with differentiated transverse costae; straight pedicellariae absent; crossed, abundant; gonads, two to many, attached to lateral integument of basal portion of ray; typically a series of spaced solitary long marginal spines and one to several similar shorter subambulacral spines incased in a sacculus covered with tiny crossed pedicellariae; actinostome relatively large, peristome broad; mouth plates expanded, usually with prominent spines.

SYNOPSIS OF THE GENERA OF BRISINGIDAE

a^1. Abactinal surface of disk and genital region of ray provided with numerous conspicuous papulæ; two gonads to each ray; mouth plates broad and fan-shaped toward the actinostome, nearly closing entrance to ambulacral furrow; genital region of ray with transverse skeletal arches, between which the integument is strengthened by immersed plates and pierced by papular pores; ray with regularly spaced lateral, transverse combs of upward of seven conspicuous, slender spines; adambulacral plates higher than long, with a single, prominent subambulacral spine frequently truncate and more or less spatulate on proximal part of ray; first three to five pairs of adambulacral plates united in each interradius, and above them the marginal plates similarly united; a syzygy between first and second adambulacral plates, and also sometimes a partial syzygy between the second and third and between the third and fourth plates. Genotype *Brisinga semicoronata* Perrier ________ *Odinia* Perrier.

a^2. A single circle of rather small papulae near margin of disk, two papulae corresponding to each ray; rays, as in *Brisinga*, without papulae. First and second adambulacral plates united by a syzygy (nonmuscular symphysis) and upper part of second and third ambulacral plates united by syzygy; gonads numerous, in series; first pair of adambulacral plates and first pair of marginal plates in each interbrachium closely united. Genotype *Brisinga mimica* Fisher ________________ *Brisingenes* Fisher.

a^3. No papulae present either on disk or on rays; abactinal skeleton present on disk and on proximal portion of rays, at least, either in the form of transverse independent skeletal arches or as a continuous covering of thin plates, or both arches and intervening thin plates.

b^1. Disk plates large, with one to three fairly large acicular spines; a vertical series of about four conspicuous, lateral spines to each successive skeletal arch of the rays (of which there are 9 or 10 well-spaced complete ones, confined to basal fourth of ray), these lateral combs occurring at regular intervals all along side of ray; integument between costae has spaced embryonic platelets of various sizes and irregular outline, invisible until dry; adambulacral plates short without furrow spinelets; subambulacral spine with a modified, capitate, truncate tip throughout costal region; syzygy between first and second adambulacral plates; first pair of adambulacral plates and sometimes most of second pair united interradially; in young specimens the united pair of conspicuous first marginals normally above the first pair of adambulacrals, may drop between the distal ends of latter, as normally in *Brisinga;* mouth plates expanded fanwise toward actinostome, nearly closing entrance to ambulacral furrow; gonads in a series of eight or nine, proximally, just above adambulacral plates; related to *Odinia*. Genotype *Brisingaster robillardi* de Loriol -- *Brisingaster* de Loriol.[4]

b^2. Disk plates small, bearing one to several small spinelets; on the ray only one lateral or marginal spine corresponding to the variably spaced inferomarginal plates; never a vertical comb of conspicuous lateral spines.

c^1. First and second adambulacral plates as well as the upper part of the second and third ambulacral plates united by syzygy (nonmuscular symphysis).

d^1. Abactinal skeleton of rays in the form of independent, spaced arches or costae composed of elongate, more or less compressed, overlapping plates, projecting well above the level of the intervening integument and bearing small spinelets; intercostal integument not fortified by thin, immersed, spineless, fenestrated plates.

e^1. Gonads numerous, in a series along either side of each ray; at least the first pair of adambulacral plates is joined by their lateral faces, and above them is a united. pair of first marginal plates—four in all.

f^1. Subambulacral spines of proximal adambulacral plates slender, acicular; the accessory subambulacral spine, if present, is on the adoral half of the plate; adambulacral armature is not dense and crowded. Genotype *Brisinga endecacnemos* Asbjørnsen -- *Brisinga* Asbjørnsen

f^2. Subambulacral spines of proximal adambulacral plates with modified, capitate, often truncate, tips; second subambulacral spine regularly present, prominent, and near aboral end of plate; adambulacral plates short, with crowded armature; second and third pairs of adambulacral plates sometimes united interradially. Genotype *Brisinga panopla* Fisher -------------------- *Craterobrisinga* Fisher

e^2. Gonads two to each ray (one on each side); subambulacral spines all delicate and acicular.

f^1. The interradial (first) pair of adambulacral plates is joined by their lateral faces, and above them, a united pair of first marginal plates—four in all. Genotype *Brisinga moluccana* Fisher ---------------------------- *Astrostephane* Fisher.

f^2. The interradial (first) pair of adambulacral plates is not joined, but separate, the outer end of the combined mouth plates usually interpolated between the inner ends of these adambulacral plates; first pair of marginal plates not closely united by their lateral faces, but only by the adoral ends, to which also is closely united the lower end of the interradial plate, forming a rude inverted Y, of which the angle is the apex of the interbrachial angle and the arms are the first marginal plates; adambulacral plates slender with delicate subambulacral spine; rays delicate, very deciduous. Genotype, *Brisinga fragilis* Fisher. *Brisingella* Fisher.

[4] I have examined specimens in the British Museum since my first keys were published (Ann. and Mag. Hist., ser. 8, vol. 20, 1917, p. 419; Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 502).

d^2. Abactinal skeleton of rays consisting of independent, compressed arches or costae, as in *Brisinga*, but the integument between the arches is crowded with numerous spineless, immersed, fenestrated, thin plates which touch or slightly overlap, and leave the integument entirely flexible; gonads two or four to each ray.

e^1. First pair of adambulacral plates united, and joined to their upper side is a united pair of marginal plates, four in all, as in *Brisinga*; proximal adambulacral plates higher than long; gonads two to each ray. Genotype *Brisinga* (*Stegnobrisinga*) *placoderma* Fisher ---------- *Stegnobrisinga* Fisher.

e^2. First pair of adambulacral plates not joined together by their lateral faces, but separate; first pair of marginal plates is not united by their lateral faces but only by the adoral ends, to which also is closely united the lower end of the interradial plate, forming a rude inverted Y, of which the angle is the apex of the interbrachial angle and the arms are the first marginal plates; proximal adambulacral plates not higher than long; gonads two or four to each ray. Genotype, *Brisinga panamensis* Ludwig ---------- *Astrolirus* Fisher.

d^3. Abactinal skeleton of genital region of ray composed of a uniform armor of thin, spiniferous, more or less overlapping plates, but not of independent arches or costae.

e^1. Primary plates of disk much larger than the others which are small; gonads two to each ray; an interradial plate, vertical in position, is interpolated between the proximal ends of the first adambulacral plates, and touches the mouth plate, but does not encroach upon the actinal surface as in *Colpaster*. Genotype *Belgicella racovitzana* Ludwig ---------- *Belgicella* Ludwig.

e^2. Primary plates of disk not conspicuous, and not distinguishable from the other abactinal plates of disk.

f^1. An azygous interradial plate, shield-shaped and conspicuous superficially on the actinal surface, separates the first pair of free adambulacral plates; gonads unknown. Genotype, *Colpaster scutigerulus* Sladen ---------- *Colpaster* Sladen.

f^2. First pair of adambulacral plates not separated by an azygous plate but united as in *Brisinga*, and above them is a pair of conspicuous, united, first marginal plates—four in all in each interradial angle; gonads numerous, in a series along either side of the ray. Genotype *Freyella fecunda* Fisher ---------- *Freyellaster* Fisher.

c^2. No syzygy, or nonmuscular symphysis, between the first and second adambulacral plates nor between the upper part of the second and third ambulacral plates, but a normal muscular symphysis not different from the others; no marginal plates directly above the first pair of adambulacral plates; the latter are not united except sometimes by the proximal ends; *touching the lower end of the interradial plate is a pair of very inconspicuous plates lying in the same plane, and superficially appearing to be a part of the interradial plate.*[5] These are really the outer ends of the mouth plates which project dorsally behind the first pair of adambulacral plates. The latter, by sometimes touching at their inner ends or apposing their lateral faces, segregate this dorsal portion of the mouth plates from the actinal, spine-bearing part. For this reason they may easily be mistaken for two entirely independent plates.

d^1. Abactinal skeleton of ray composed of a uniform armor of thin, spiniferous, more or less overlapping plates, as in *Freyellaster*, not of spaced independent arches or costae; furrow spinelets not modified or expanded at the tip. Genotype, *Freyella spinosa* Perrier ---------- *Freyella* Perrier.

d^2. Abactinal skeleton of ray composed of independent transverse arches, composed, on radial area, of flattened overlapping plates (not of elongate, narrow, more or less compressed ossicles as in *Brisinga*); these costae bear spinelets and are separated by intervals devoid of plates; furrow spinlets with curiously modified expanded tips. Genotype, *Astrocles actinodetus* Fisher ---------- *Astrocles* Fisher.

[5] The interradial plate described by Ludwig in *Belgicella* is very probably the true interradial plate plus these extreme outer ends of the mouth plates, which, unless treated with potash, appear to be a part of the interradial plate. (Ludwig, 1903, p. 60.)

a.[4] No papulae present either on disk or on rays; no visible abactinal skeleton on rays but embryonic plates may be concealed in the thin integument; gonads unknown.

b[1]. Minute embryonic lattice plates are present in abactinal integument of ray; functional skeleton of ray reduced to ambulacral and adambulacral plates; disk finely spinulate, a few spinelets extending upon ray; interbrachial skeleton resembling that of *Brisingella*, but the first marginals unequal in size; first adambulacral plates entirely separated; adambulacral armature very simple. Genotype, *Hymenodiscus agassizi* Perrier__*Hymenodiscus* Perrier.[6]

b[2]. Rays composed of ambulacral and adambulacral plates, and an abactinal integument devoid of skeleton, but covered with numerous, relatively large pedicellariae arranged in transverse bands. Disk not known. Genotype, *Gymnobrisinga sarsii* Studer__*Gymnobrisinga* Studer.[6]

Genus BRISINGA Asbjørnsen

Brisinga Asbjørnsen, Fauna Litt. Norvegiae, 1856, andet hefte, p. 95. Type, *B. endecacnemos* Asbjørnsen.—Fisher, Annals and Mag. Nat. Hist., ser. 8, vol. 20, 1917, pp. 421, 426; Bull. U. S. Nat. Mus., 100, vol. 3, 1919, p. 509.

Diagnosis.—Brisingidae without papulae; with the abactinal skeleton of rays in the form of transverse independent arches separated by intervals lacking plates (except sometimes microscopic plates carrying minute prickles); with numerous gonads forming a series along either side of each ray; with a syzygy or nonmuscular symphysis between the first and second adambulacral plates, and between the upper end of the second and third ambulacral plates; with a united pair of first adambulacral plates, and first marginal plates in each interbrachial angle—four plates in all; with the subambulacral spines of proximal plates acicular, unmodified; accessory subambulacral spine if present on adoral half of plate.

Remarks.—In *B. trachydisca* Fisher the distal ends of the first or united pair of adambulacral plates of each interradius are wedged apart by the united first marginal plates—or rather appear to be. In Sars's admirable monograph of *Brisinga coronata*, two figures of *B. endecacnemos* (Sars, 1875, pl. 8, figs. 8 and 9) show that the first adambulacral plates are not joined so closely as in *Brisingenes*, *Astrostephane*, or *Stegnobrisinga*. But the structure of these interradially situated adambulacrals and marginals is quite different from that of the same plates of *Brisingella*, as may be readily determined by examining Plate 4, Figures 4 and 6, of the same work. These figures show the structure of the plates in *Brisingella coronata* (G. O. Sars).

No species of *Brisinga* are known to occur in the North Pacific region.

Genus CRATEROBRISINGA Fisher

Craterobrisinga Fisher (subgenus), New East Indian Starfishes, Proc. Biol. Soc., Washington, vol. 29, p. 33, Feb. 24, 1916. Type, *Brisinga panopla* Fisher; Ann. and Mag. Nat. Hist., ser. 8, vol. 20, 1917, pp. 421, 426; Bull. U. S. Nat. Mus., 100, vol. 3, 1919, p. 512.

Diagnosis.—Differing from typical *Brisinga* (which it resembles in appearance and in the possession of serial gonads and of closely apposed first adambulacral and first marginal plates of adjacent rays) in having proximally two subambulacral spines of conspicuous size, the larger of which (and also sometimes the smaller) has an enlarged, modified, capitate, often truncate tip. Costae usually numerous, and genital region extended; first adambulacral plate, and sometimes the first 2.5, joined

[4] See Fisher, Bull. U. S. Nat. Mus. 100, vol, 3, 1919, p. 502, footnote; Ann. and Mag. Nat. Hist., ser. 9, vol. 2, 1918, p. 104 (fig.).

to corresponding plate or plates of the adjacent ray, or if rays are less than 10, the joined pair of first marginal plates may be more or less interpolated between the distal ends of the first adambulacrals. But the first adambulacral plates of adjacent rays are never separated to their proximal ends, so that the mouth plates form the apex of the interradial angle as in *Brisingella*. No matter what the number of rays may be, the first pair of marginal plates is closely apposed for the whole length of the plate, and, as stated above, their lower sides may be squeezed in between the outer ends of the first or interradial pair of adambulacral plates. When there are fewer than 10 rays these plates descend and separate the outer ends of the normally united pair of adambulacrals in such a way that the marginals can be seen from below. This seems to be a means of strengthening the actinostomial ring. A non-muscular symphysis or syzygy between the first and second adambulacral plates, and between the dorsal end of the second and third ambulacral ossicles. Adambulacral plates short, with a crowded, characteristic armature consisting of an aboral, obliquely transverse series of two subambulacral spines and one or two furrow spinelets, and usually also one adoral spinelet. The lateral spines and the major adambulacral spines are typically long and bristling. Mouth plates small, with one to three suboral spines.

Remarks.—This genus is not so sharply differentiated as *Brisingella* and *Stegnobrisinga*, but is readily to be recognized by the crowded adambulacral armature and the curiously modified, capitate, proximal subambulacral spines, which are similar to those of *Brisingaster* de Loriol.

The species to be included in this group are: *Craterobrisinga panopla* (Fisher), *C. parallela* (Kœhler), *C. alberti* (Fisher), *C. cricophora* (Sladen), *C. eucoryne* Fisher, *C. analoga* Fisher, *C. variispina* (Ludwig), *C. multicostata* (Verrill), and probably also the aberrant *C. evermanni* (Fisher). In this species the proximal subambulacral spines are longer and slenderer than is usual in *Craterobrisinga*, and the modified tip is not so heavy as in typical species, nor is the adambulacral armature so crowded. The second subambulacral spine is frequently quite small and easily mistaken for an aboral furrow spinelet, but on certain plates, without any regularity that I can discover, this inner subambulacral becomes nearly as large as the outer. On such plates there is usually also an aboral furrow spinelet, making three in an oblique transverse series, with the lateral spine additional, if such happens to be present. These enlarged inner subambulacral spines are present on the outer part of the costal region and beyond, and are not shown in the figures of the adambulacral plates given by me in connection with the original description. (Fisher, 1906, pl. 48, figs. 2, 2*a*.) In these figures only the dwarfed inner subambulacral spines are shown. The adoral spinelet appears never to be present.

CRATEROBRISINGA SYNAPTOMA Fisher

Plate 1; Plate 6; Plate 7, Figure 3; Plate 12, Figure 3

Craterobrisinga synaptoma FISHER, Ann. and Mag. Nat. Hist., ser. 8, vol. 20, 1917, p. 426.

Diagnosis.—Rays 12, 14, and 15, with very long genital area crossed by 35 to 40 irregular, fairly well-spaced, complete and incomplete prominent spiniferous costae; genital region equal to about 8.5 to 10 r, or 0.6 total length of ray; disk with prominent spinelets, solitary except on primary radial plates, about 1 mm. long; no disk pedicellariae; adambulacral plates short and broad, with proximally usually two aboral furrow spinelets and two subambulacral spines all in a transverse series, and sometimes also a furrow spinelet on the proximal half of plate; first 10 or 12 outer subambulacral spines with circular, enlarged, sharply truncate tip; mouth plates decidedly small, with two or three actinostomial spinelets, and on the outer part of plate a transverse series consisting of one or two adoral furrow spinelets and one tapering suboral spine; first 2 or 2.5 adambulacral plates of each ray fused to those of adjacent ray by a nonmuscular articulation. R 220+ mm., r 15 mm. (14 rays); R 245 mm., r 13 mm. (12 rays).

Description.—Disk fairly large and elevated above base of rays as a rule, the margin being rounded. Abactinal surface plane, covered with terete, papilliform, blunt, uniform, skin-covered spinelets which are sharp when dried, and spaced about 0.5 mm. apart. The calcareous part of the spinelet is quite slender, about 1 mm. long, and the tip is provided with numberous microscopic points. The abactinal plates of the disk are subcircular with irregular margin and the spinelets are ordinarily one to a plate, although a few plates near the border have two to six spinelets in one or two rows. There are no pedicellariae among the spinelets. In among the ordinary plates are small irregular spineless plates, one-fourth to one-half the diameter of the primary plates. The larger plates with several spinelets probably represent the primary apical plates.

Genital region of ray very long, equal to 8.5 to 10 r, or on the only complete ray of an adult specimen about 0.6 the length of the ray.

The costae are somewhat irregular in spacing and form. Ordinarily they are opposite alternate (short) adambulacral plates with intervals where they correspond to two or three consecutive adambulacral plates. The arches are typically brisingoid in being composed of compressed plates so that they form an elevated ridge, which is ordinarily sinuous on the mid-dorsal region, and frequently incomplete in the mid-dorsal region as that part of the arch may be suppressed. Sometimes the arches branch and join the adjacent arches. At the base of the ray the ridges vary greatly on different rays of the same specimen, there sometimes being only disconnected plates. These are present, more or less, on the dorsal region when the arches are incomplete. The costae and independent plates bear a single series of conspicuous spinelets, 0.75 to 1.25 mm. long, and numerous slender pedicellariae. There are 35 to 40 complete and incomplete arches reaching 0.6 to 0.7 the length of rays or 8 to 10 r from base of ray.

Lateral spines long, except the first few; first spine at upper border of fifth or sixth adambulacral plate. The succeeding spines increase rapidly in length; about 4 r from base they are five adambulacral plates, or 10 to 11 mm., in length, and very slender.

Adambulacral plates shorter than broad at base of ray, and only slightly longer than broad throughout the remainder of genital region. Armature consists of a transverse series, along the aboral margin of the plate, of two spinelets and two spines, or beyond the base of the ray, one spinelet and two spines. The spinelets are about as long as the plate, or a little longer, and are directed into the furrow. They are incased in a loose sacculus bearing small pedicellariae. The outer of the two large subambulacral spines is heavier than the inner and the first 10 or 12 are shorter and heavier than the succeeding ones, and bear a subcircular, flaring truncate claviform tip. The tip appears as if sharply cut off with a knife and is provided with numerous sharp points. The end of the spines narrow as the spine lengthens. The fifth spine from base of ray is about as long as three consecutive plates and the tenth about as long as four; succeeding spines reach a length of 4.5 to 5 plates in length. The inner subambulacral is somewhat shorter, slenderer, and usually is only slightly thickened at the tip on the proximal plates. But in the cotype on two of the rays some of the proximal plates have the second or inner subambulacral spine nearly or quite as large as the outer, and have only one aboral furrow spinule. (See pl. 1, fig. 3*b*.) On the distal plates there is but one (distal) furrow spinelet. Some plates have a spinelet just adorad of the middle and directed into the furrow, or about midway between the middle and the adoral margin of the plate. There does not seem to be any regularity in the presence of this spinelet which is about the length of the shorter of the two aboral furrow spinelets. The sheaths covering the adambulacral spines are closely covered with minute pedicellariae.

The joint between the first and second adambulacral plates is nonmuscular, the transverse edges of the two plates being fitted tightly together. The ray breaks off at this point. The first two adambulacrals of any ray are fused by their lateral faces with the corresponding two of the adjacent ray by a nonmuscular joint. The first two lateral or marginal plates are similarly joined. There is a continuous series of marginal plates from the interbrachial angle to the first spiniferous marginal (about 15 plates). The articulation surface of the second pair of ambulacral ossicles (distal face) where a ray has been broken from disk is rather high and narrow and broader above than below. (See pl. 1, fig. 1.) This articulation surface is one side of a nonmuscular or syzygial joint.

Mouth plates small, joined to first adambulacrals by a muscular joint; actinostomial margin rather short. Armature: on the actinostomial margin three, or two, spinelets; the outer slightly longer than the innermost; near the aboral margin of each plate, a transverse series consisting of one or two furrow spinelets, and a tapering, pointed, suboral spine as long as the first three adambulacral plates. All the spines and spinelets bear pedicellariae.

Madreporic body prominent, about its own diameter from the margin of disk.

Gonads very numerous, serially arranged along the genital stolon. The ovaries are spherical bodies, the largest about 3 mm. in diameter. Numerous smaller ovaries are crowded among the larger, and they all decrease in size on the outer half of the long genital region. The testes are also numerous, and each is a many-lobed body, the series extending to the end of the genital region. The surface of the ambulacral plates facing the coelom is roughened by many little points or thornlets, which in the male seem to be, in some cases at least, ossifications between the crowded lobes of the gonads where these press against the ambulacralia.

Type.—Cat. No. E. 1413, U.S.N.M.

Type-locality.—Station 3342, off British Columbia, 52° 39′ 30″ N., 132° 38′ W., 1, 588 fathoms, gray ooze, coarse stones; bottom temperature, 35.3; four specimens.

Distribution.—Known only from the type-locality.

Remarks.—*Craterobrisinga synaptoma* is a very distinct species, so far as the present knowledge of this group of forms allows one to judge. It is the only species known from the Pacific coast of America. Its nearest known relatives are *C. variispina* (Ludwig), 807 fathoms, off the Paumotu Islands; *C. panopla* and *C. alberti* (Fisher), from the Hawaiian Islands; and *C. cricophora* (Sladen), from off St. Thomas, Virgin Islands, 390 fathoms. It resembles also in a general way the other species noted in the remarks under the generic diagnosis, namely *C. encoryne* and *C. analoga* Fisher, and *C. parallela* (Koehler).

Craterobrisinga synaptoma is characterized by the very long genital region and the numerous, irregular, uncrowded costae. *C. alberti* has a long costal region but it has a small disk, only nine rays, shorter abactinal spinelets, more regular and fewer costae, longer lateral and subambulacral spines, intercostal integumentary prickles, and especially a characteristic arrangement of the first adambulacral plate of adjacent rays. These, instead of being joined as in species with more numerous rays, are separated by the lower ends of the conspicuous first marginal plates. This seems to be a necessary arrangement to complete the circle of plates bounding the actinostome in those forms with fewer than 10 rays. In *C. synaptoma* the *first two* adambulacrals of each ray are joined to the corresponding plates of the adjacent ray, and the first marginal plates are smaller and entirely obscured from below by these proximal adambulacrals.

In *C. panopla* the adambulacral plates are shorter and higher as seen from the side of the ray, than in *synaptoma*, the costal region is shorter, the costae are complete, more regular, and closer together, and their spinelets conspicuously shorter. The costae are more often opposite every adambulacral than opposite alternate adambulacral plates. It is characteristic of *panopla* that the lateral and subambulacral spines are long and rigid, while in *synaptoma* they are not, and the lateral spines are more closely placed owing to the more frequent annular costae. In *panopla* the disk is provided with two sizes of pedicellariae; in *synaptoma* there are none.

In *C. variispina* the costae are close together. There is a complete arch opposite each adambulacral and in the interval a nearly complete ridge, which does not fuse with an adambulacral. The arches and secondary ridges are quite regular and the narrow strips of intervening integument bear small spinelets. Moreover, the genital region is relatively short.

Genus BRISINGENES Fisher

Brisingenes Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 20, 1917, p. 427. Type, *Brisinga mimica* Fisher; Bull. U. S. Nat. Mus., 100, vol. 3, 1919, p. 517.

Diagnosis.—Closely similar in appearance to typical *Brisinga* but differing in having on the margin of disk directly over the first pair of enlarged ambulacral plates of each ray a pair of papulae. There is thus a circle of these papulae, twice as numerous as the number of rays, and the papulae of each pair are separated slightly less than the space between the pairs. Gonads numerous, in close series on either side of each ray; first adambulacral plate and first marginal plate joined for their whole length to the respective plates of adjacent ray; thus there are four closely joined plates in each interradius; a nonmuscular symphysis, or syzygy, between first and second adambulacral plates and between the dorsal part of the second and third ambulacral plates, as in *Brisinga*.

Remarks.—*Brisingenes mimica* and *B. anchista* of Buton Strait, Celebes (Fisher, 1919, pp. 518, 521), are in most respects closely similar to *Brisinga, s. s.*, except for the regular circle of papulae near the margin of the disk, there being two papulae for each radius. The first pair of adambulacral plates is more closely joined than in true *Brisinga* judging by the figure of *B. endacnemos* Asbjørnsen given by G. O. Sars (1875, pl. 7, figs. 8 and 9) and the condition of these plates in *B. trachydisca*. The outer ends of the plates tend to radiate apart somewhat, and in the latter species the united first pair of marginals slips down between them.

No member of this genus is known from the north Pacific.

Genus BRISINGELLA Fisher

Brisingella FISHER, Ann. and Mag. Nat. Hist., ser. 8, vol. 20, p. 427. Type, *Brisinga fragilis* Fisher; Bull. U. S. Nat. Mus., 100, vol. 3, 1919, p. 523.

Diagnosis.—Differing from typical *Brisinga* in having only one gonad on either side of each ray; in having the first adambulacral plate separated from that of the adjacent ray by the outer ends of the combined mouth plates; in having the interradial pair of marginal plates joined only by the adoral ends, and forming a ⅄-shaped structure with the unpaired interradial plate. Rays slender, usually very deciduous, a nonmuscular symphysis or syzygy uniting first and second adambulacral plates and the dorsal part of the second and third ambulacral plates; adambulacral plates longer than broad, with few or no furrow spinelets, and a sharp, unmodified, subambulacral spine; integument of disk thin, weak; mouth plates small, with small suboral spine; entrance of furrow into actinostome broad.

Remarks.—This genus includes a number of species of the old genus *Brisinga* which are very distinct from the type, *B. endacnemos*. They are outwardly distinguished by the delicate rays which are very deciduous, by the delicate dorsal skeleton, both of disk and rays, by the thin disk, and more definitely by the fact that the first adambulacral plate is not united with its neighbor of the adjacent ray, but is separated by the outer end of the combined mouth plates. Correlated with this, the first marginal plate is not joined to its *vis-a-vis* as in typical *Brisinga*, forming thus a pair of plates snugly apposed, above the closely apposed first adambulacrals. But instead they join only by their adoral or inner ends, and with the interradial plate form an inverted Y-shaped structure, the two arms of which represent the first marginal plates, while the acute angle represents the interbrachial angle bounded by these plates. If the lateral face of a disk which has lost several rays is examined it will be noted that the rays have broken at the syzygial or nonmuscular symphysis between the first and second adambulacral plates. In *Brisinga* one sees two distal facets close together and immediately above them two smaller, usually unequal, closely joined facets—the distal ends of the first marginal plates. The two lower (adambulacral) facets are very slightly spaced. In *Brisingella* the adambulacral and marginal plate of each ray are joined, the former above the latter, but never those of adjacent rays. Always the interbrachial angle or sinus extends to the proximal end of the plates and keeps those of adjacent rays apart.

More important still, in *Brisinga* the gonads are numerous in each ray and form a series of independent bodies along either side of the genital region. In

Brisingella there are always two gonads to each ray, and although they may be branched each gonad has but a single aperture on the side of the ray at a little distance from the base.[7]

Brisingella includes the following species: *B. fragilis* (Fisher), *B. coronata* (G. O. Sars), *B. exilis* (Fisher), *B. pusilla* Fisher, *B. pannychia* Fisher, *B. tenella* (Ludwig), *B. monacantha* H. L. Clark, and probably also the following species described by Sladen: *B. verticillata*, *B. armillata*, *B. discincta*, and *B. membranacea*. Among the species described by Perrier, the following belongs in this genus: *B. mediterranea*.

KEY TO THE SPECIES OF BRISINGELLA HEREIN DESCRIBED

a^1. Costae 9 to 11, extending 4.5 r along ray, or about one-fourth total length of ray; disk plates not unusually few or widely spaced; disk spinelets usually two or three to a plate; the furrow spinelet present on all plates except near end of ray; interradial plate not markedly convex or keeled; dorsal end of first ambulacral ossicle about twice as long as that of the second ---------- *exilis*.

a^2. Costae 20 or more extending far along the ray; disk spinelets usually one to a plate; interradial plate markedly convex; dorsal end of first ambulacral ossicle less than twice as long as that of the second.

- b^1. Disk plates unusually few, widely spaced, embryonic, with ordinarily a single tiny spinelet, occasionally two, to each plate; furrow spinelet absent except an adoral one on first 3 to 14 plates ---------- *pusilla*.
- b^2. Disk plates not unusually few, spaced about the length of the spinelets, which are about 0.5 mm. long; an adoral and an aboral furrow spinelet, extending far along ray ---------- *pannychia*.

BRISINGELLA EXILIS (Fisher)

Plate 2, Figures 2, 2*a*—2*c*; Plate 8, Figures 2, 2*a*, 2*b*

Brisinga exilis Fisher, New Starfishes from Deep Water off California and Alaska, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 318.

Brisingella exilis Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 20, 1917, p. 427. Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 524.

Diagnosis.—Rays 10. R. 250 mm.; r 10 mm.; R = 25 r; thickness of disk, 4 mm.; breadth of ray at base, 5 mm.; at widest part of genital inflation, 6 mm. Rays deciduous, delicate, long and very slender, with an attenuate lashlike outer portion; costal ridges, prominent, slender, well spaced, 9 to 11, opposite alternate adambulacral plates, and extending 4.5 r along ray, or about one-fourth total length of ray; lateral spines long, very fragile, opposite alternate adambulacrals; adambulacral plates with one adoral furrow spinelet and 1 slender, delicate subambulacral; mouth plates with one to three actinostomial spinelets, often one aboral furrow spinelet, and one suboral sharp spinule; upper end of second ambulacral ossicle about half as long as first and third; a movable plate at upper end of the interradial plate, the latter with a flat or grooved surface.

Description.—Disk thin with a beveled border, and not elevated above the rays to any extent. Integument of disk thin and very flexible, the plates delicate, roundish, oval, elliptical, or irregular, with irregular patches of the integument between them. The plates touch or are slightly separated, and bear one to five, usually two

[7] G. O. Sars: On some Remarkable Forms of Animal Life from the Great Depths off the Norwegian Coast, Christiania, 1875, pl. 1, fig. 12*a*.

or three, delicate, sharp, spinelets 0.5 to 0.75 mm. long and sheathed in delicate membrane. These groups of spinelets are spaced about 1 mm. apart in the center of disk, and near the border, about half that distance, or even less. Madreporic body prominent, on edge of disk. On its adcentral side is a group of plates (eight or nine) which are tightly fitted together, and combined are about as large as the madreporite. Interradial plate small, broader below than above (somewhat oval in form) the surface subplane sometimes with a shallow groove in the middle of the upper half. The lower end meets the inner ends of the interradial pair of marginal plates. (See pl. 2, fig. 2.) At the upper end of the interradial plate is an irregular thick movable plate in the abactinal integument. It may bear a few spinelets and is much larger and thicker than the other abactinal plates. No pedicellariae on disk.

Rays fragile, very deciduous, the abactinal membrane thin and devoid of integumentary prickles. Costal ridges delicate, widely spaced (opposite alternate adambulacral plates), narrow, irregular, prominent, composed of elongate plates which imbricate by their ends. These plates in the proximal portion of the genital area, at least, bear one or two rather stout, subconical prickles, and in life each costal ridge is overlaid by a cushion of pedicellariae. Between the costae, and corresponding to the alternate adambulacral plates, is a transverse prominent saccular band of pedicellariae. These are continued throughout the ray, and after the costae have ceased they occur opposite about every adambulacral plate. The costae number 9 to 11, possibly 12 in some cases, and they extend 4.5 r along the ray, or only one-fourth total length of the ray.

Lateral spines attached to the rather prominent lowermost plate of the costae, and hence at the upper edge of alternate adambulacral plates. They are very fragile and it is difficult to find a complete one. At the middle of the ray of a specimen from station 4387 the spine is 14.5 mm. long (=7 adambulacral plates) and one at the middle of the costal area is 9 mm. long (=4 adambulacral plates).

Adambulacral plates comparatively slender, longer than broad, and at base of ray fully twice as long as the height seen from the side. Furrow margin deeply excavated. The armature consists of a very delicate furrow spinelet at the adoral end of plate, surmounting a slight boss and armed with a terminal pad of minute pedicellariae; and on the actinal surface of the distal half of the plate is a delicate subambulacral spine about 5 mm. long covered in life by a rather thick sheath closely beset with pedicellariae. This spine is shorter on the plates opposite which there is a lateral spine. The small furrow spinelet continues to very near the tip of ray. On the outer attenuate portion of ray the adambulacral plates are, of course, slenderer than proximally, and the furrow spinelet is spaced about one-third the length of the plate from the proximal end.

The first adambulacral is joined to the second by a nonmuscular articulation. The ray breaks at this point. The first adambulacral plate is separated from that of the adjacent ray by the outer ends of the combined mouth plates. The interbrachial angle is formed by the first marginal plates of each ray, which join by their inner ends, and form a reversed Y with the interradial plate. The first marginal lies along the upper edge of the first adambulacral; the second along the upper border of the second adambulacral, while there is a small third marginal above the third adambulacral, and the first costal arch commonly occurs at the distal end of the plate. If the dorsal integument of disk is stripped off so that the upper end of the first two pairs of ambulacral plates can be seen, the length of the upper end of the first pair will be seen to be about twice that of the second pair. In the following species the length of the first pair is only slightly greater than that of the second. In *exilis* the length of the third and succeeding pairs is about twice that of the second, measured the same way. The articulation surface of distal face of second ambulacral ossicle is narrowly oval, more or less acute below, the height about equal to width of the combined pair.

Actinostome 12.5 mm. in diameter. Mouth plates small, much narrower at the inner than at the outer end, where the combined width is about equal to the breadth of furrow at inner end of the plates. Armature: One short, delicate, actinostomial spinelet directed across mouth of furrow, and one small, tapered, sharp suboral spine at about the center of the plate. In the type about 20 per cent of the mouth plates have a small spinelet at the corner adjacent to the first adambulacral, and it is regularly present in a specimen from station 4387. This specimen has two or three actinostomial spinelets to each plate.

Gonads (testes) two to each ray, and opening on each side at a distance of 4 r from the base (opposite twentieth adambulacral). They have many slender branched lobes.

Type.—Cat. No. 22348, U.S.N.M.

Type-locality.—Station 4398, off San Diego, Calif., 32° 43′ 20″ N., 117° 42′ 10″ W., 620 fathoms, green mud, rocks; one specimen (disk and three rays).

Distribution.—Off southern California from San Diego to Santa Barbara Island, 448 fathoms to 1,059 fathoms, green mud.

Specimens examined.—In addition to type:

Station 4387 (probably 4387*a* is meant), vicinity of San Diego, Calif., 32° 32′ 40″ N., 118° 04′ 20″ W.; 1,050 fathoms, green mud; one specimen (disk and four rays).

Station 4416, off Santa Barbara Island, Calif.; 448 fathoms, dark-green mud; one ray.

Remarks.—I examined and compared directly with specimens of *B. exilis* a ray of the type of *B. tenella* (Ludwig) from 1,322 fathoms, east of the Galapagos Islands. Although the disk of *tenella* is not known, the presence of only two gonads to each ray, as well as the general appearance of the rays, makes its generic position fairly certain. *B. tenella* differs from *exilis* in having 40 or more very closely placed costae, there being two, or sometimes three, to every adambulacral plate. The adambulacral plates, in addition to the subambulacral spine, bear one or two adoral furrow spinelets and one aboral furrow spinelet. The lateral spines, in spite of the crowded costae, are less numerous than the adambulacral plates. They are at the upper border of each of two consecutive plates (. .); then a plate is skipped (–), somewhat as follows, the dashes representing the plates missed (sixth plate): . . – . . – . – . – . – . . – . . – . . – . . – , etc.

The short swollen genital region and numerous crowded costae give to *B. tenella* a considerably different appearance from that which is characteristic of the other known species of this group.

A nearer relative than *tenella* is *Brisingella fragilis* (Fisher) of the Hawaiian Islands, which is the type of the genus. This species is rather variable in regard to the adambulacral armature and the relative size of the secondary costae between the primary ridges. But it differs from *exilis* in having on the proximal adambulacral plates an aboral furrow spinelet and also sometimes two or even three adoral furrow spinelets; the genital area is longer than in *exilis* (6 to 8 r from base of ray) and the costae more numerous; the disk plates bear usually a single very small sharp spinelet; the interradial plate is subcarinate; the first marginal is shorter in proportion to its breadth at the inner end; the upper end of the second ambulacral ossicle is more than half that of the first; there are regularly three actinostomial spinelets, and two aboral furrow spinelets standing in a diagonal line with the suboral spinule.

BRISINGELLA PUSILLA Fisher

Plate 2, Figures 1, 1*a*–1*f*; Plate 8, Figures 3, 3*a*, 3*b*

Brisingella pusilla Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 20, 1917, p. 427.

Diagnosis.—Rays 10. R 165+ mm.; r 8 mm., R=20+ r; thickness of disk, 2.5 mm.; breadth of ray at base, 4 mm. Similar in general appearance to *B. exilis*, having thin disk and deciduous, slender, flexible rays, thin delicate abactinal integument, and very fragile spines. Differing from *B. exilis* in having 25 to 30 costae which extend at least three-fourths length of ray; comparatively few, widely spaced, embryonic abactinal disk plates, bearing one, or occasionally two, small spinelets; a narrower, keeled, interradial plate; second ambulacral ossicle more than half as long as the first, measured on the summit of the ridge; furrow spinelet confined to first few adambulacral plates (first 3 to 14).

Description.—Abactinal integument of disk very thin and translucent. Abactinal plates few, very small, and widely spaced, each with one, or sometimes two, very small sharp spinelets, some of which bear a minute pedicellaria at the base. The plates can only be seen when the integument is dried. They are irregular in form, 0.1 to 0.5 mm. in diameter and unevenly scattered, there being sometimes so much as 2 mm. between plates. About 20 to 35 may be counted across the disk between the borders of the actinostome. Madreporic body prominent, convex, on the border of disk, with a number (five or more) of closely fitted plates on its adcentral side. These combined are about as large as the madreporite. Interradial plate narrow, prominently keeled, the upper end angular, the lower end truncate or slightly angular. It is narrower than that of *exilis* and the surface is convex or keeled instead of being more or less plane, with typically a longitudinal groove.

Rays very deciduous, slender, with an attenuate, flexible, distal portion. Abactinal membrane very thin, devoid of intercostal spinelets or prickles. Costae delicate, rather widely spaced (opposite alternate adambulacral plates), and composed of slender, elongate, overlapping ossicles which bear each a conical sharp spinelet. On the proximal part of the genital inflation the ridges are bent distally as a rule, and are more or less irregular throughout the long costal region, which extends much beyond the genital area proper, *or fully three-fourths the length of ray.* There are 25 to 30 costæ, the distal ones being very inconspicuous and difficult to determine unless the specimen is dry. There is a band of pedicellariae between each pair of costae, and the ridges themselves are covered with minute pedicellariae. The first complete ridge usually meets the fifth adambulacral plate.

Lateral spines very slender and fragile, usually closely appressed to side of ray. On the genital region they are about 7 mm. long (four adambulacral plates in length). At the middle of ray a spine measures 8 mm. (4.6 adambulacral plates) in length.

Adambulacral plates slender, as usual in this genus, with a very concave furrow margin. Armature: On the first 3 to first 14 plates is a delicate furrow spinelet about as long as half the length of plate (or less) and spaced a third the plate's length from the adoral end. Over the rest of ray there is no furrow spinelet. There is one slender subambulacral spine situated just aborad of the middle of the plate. It is 4 mm. long (two adambulacral plates), or on alternate plates, between lateral spines, a little longer. The subambulacral and lateral spinelets normally are covered with a delicate sacculus beset with minute pedicellariæ.

The first and second adambulacral plates are joined by syzygy, or nonmuscular articulation. The first adambulacral plates of adjacent rays are separated, as in *exilis*, by the outer ends of the combined mouth plates. Interradial angle formed by the first marginal of each ray, which lies along the upper edge of the first adambulacral plate. These marginals join by their inner end and are also joined to the lower end of the interradial plate. The articulation surface of the ambulacral ossicle (the distal face of the second) where ray has been removed, is very small, broadly elliptical, and the combined width of the pair is considerably more than the height. They are smaller and broader than in *exilis*. The second ambulacral ossicle is two-thirds to three-fourths the length of the first, measured on summit of ridge.

Mouth plates small, very similar in form to those of *exilis* but slightly narrower. Armature: One or two actinostomial spinelets; when there are two, one is usually directed over the peristome and one across mouth of furrow; rarely there may be an aboral furrow spinelet. There is one slender, sharp, suboral spine situated on the middle of the plate, and equal to the length of the first two adambulacral plates. In some specimens the marginal spinelets are absent.

Type.—Cat. No. E. 1414, U.S.N.M.

Type-locality.—Station 4427, off Point San Pedro, Santa Cruz Island, Calif.; 447 to 510 fathoms, black mud and rocks; 18 disks, 15 rays, more or less broken.

Distribution.—Off southern California, from San Diego to Santa Cruz Island, 301 to 1,059 fathoms, green and black mud.

Specimens examined.—Five disks, 27 rays, from the following stations:

Station 4333, off Point Loma, Calif. (13.6 miles southwest), 301–487 fathoms, green mud; bottom temperature, 40.1° F.; about 16 rays, in fragments, one disk.

Station 4387 (probably 4387*a*), vicinity of San Diego, Calif., 32° 32′ 40″ N., 118° 04′ 20″ W.; 1,059 fathoms, green mud; three disks, nine broken rays.

Station 4416, off Santa Barbara Island, Calif., 448 fathoms, dark green mud; disk and two rays, broken.

Remarks.—The differences which separate this species from *exilis* are mentioned in the synopsis, the diagnosis, and the foregoing description. It differs from *B. tenella* (Ludwig) in having widely spaced costae which extend three-fourths the length of ray, in having no furrow spinelets except a small adoral one on the first few plates of the series, and in having much smaller articulation facets on the proximal face of the third pair of ambulacral ossicles. In *tenella* each facet is higher than wide and the combined pair about as broad as the height (in *pusilla* the combined pair is much broader than high, and in rays of the same size actually much smaller). The disk of *tenella* is unknown.

The rudimentary scattered plates of the disk will at once separate this species from *fragilis*, which, furthermore, does not have costae on the outer half of ray, has regularly three actinostomial spinelets and two aboral furrow spinelets to each mouth plate; in addition the first marginal plates of *pusilla* are slenderer, the outer end of the combined marginal plates is broader, and the rays decidedly narrower and weaker to disks of the same size. Putting it conversely, the disk of *fragilis* is proportionately smaller.

BRISINGELLA PANNYCHIA, new species

Plate 8, Figure 4, 4*a*

Diagnosis.—Resembling *B. fragilis* in having a long costal region with numerous, rather widely spaced costae, in having the dorsal end of the first ambulacral plate less than twice the length of the second, and in having both an adoral and aboral furrow spinelet. Differing from *B. fragilis* in lacking entirely any trace of the secondary, intercostal, calcareous, incomplete arches, in having coarser costal spinelets, and in having conspicuously longer and less numerous abactinal disk spines. Rays 10; r = 8 mm.; rays incomplete.

Description.—Disk of the usual *Brisingella* form, thin, with a beveled margin. Spinelets about 0.5 to 0.6 mm. in length, spaced about the same amount, generally solitary, but occasionally with two or three to a plate, very delicate and sharp, but when incased in the usual membranous covering blunt and papilliform. They are fully twice as long as the disk spinelets of *B. fragilis* and much less numerous. As compared to *B. pusilla*, the disk spinelets of *pannychia* are more numerous and somewhat longer; they appear to be more like those of *pusilla* than like the minute close-set spinelets of *fragilis*. There are relatively few tiny pedicellariae attached to the basal portion of the spinelets. Interradial plate rather prominently convex but with a more rounded surface than in *pusilla*; the plate is a little shorter and broader than in either *pusilla* or *fragilis*.

Rays represented only by basal parts, none complete; longest fragment with 19 costae; there are apparently many more. Costae slender, spaced 3 to 5 mm. and bearing relatively few spaced, sharp spinelets about 0.75 mm. long. There is a slender rather inconspicuous intercostal band of pedicellariae. The costae correspond to every alternate adambulacral and there is a slender lateral spine on either side at the base of each arch, as usual in this genus. When fully developed this spine is equal to a little over three consecutive adambulacral plates in length.

Adambulacral armature: One aboral furrow spinelet about as long as one-third the length of the plate; an adoral spinelet about two-thirds the length of the plate and spaced about half its own length from the adoral margin of plate; a slender subambulacral spine (none perfect). There is a syzygy between the first and second adambulacral plates. The second ambulacral ossicle is about two-thirds the length of first measured on summit of ridge.

The mouth plates are in general form very similar to those of *pusilla* and *fragilis*; they extend externally between the first adambulacrals of adjacent rays, these plates being conspicuously separated and touch the first marginal plates. There are three marginal spinelets to each plate, two on actinostome and one in the furrow separating the first and second tube-feet. The suboral, situated at about the middle of the plate but nearer the furrow than the median suture, is short and slender, a little longer than the width of the actinostomial margin of combined plates. The spinelets bear the usual terminal pads of pedicellariae. In *B. fragilis* there are generally three actinostomial spinelets and two aboral furrow spinelets. The suboral spine is small and stands in line with the furrow spinelets, forming a diagonal series. In *B. pusilla* there is usually only one actinostomial spinelet, rarely one aboral spinelet (usually none), and the slender suboral spine is longer than usual in the genus *Brisingella*.

The articulation surface (distal) of the second ambulacral ossicle (where a ray has been removed) is very small, broadly elliptical, and the combined width of the pair exceeds the height. This character is more like the same in *B. pusilla* than in *B. fragilis*, where the distal facets are relatively larger. The first marginal plates are characteristic of the genus in their relation to the adambulacrals and the interradial.

Type.—Cat. No. 37038, U.S.N.M.

Type-locality.—Station 4767, Bowers Bank, Bering Sea, 54° 12′ N., 179° 07′ 30″ E.; 771 fathoms, green mud; bottom temperature, 36.5° F.

Remarks.—The synopsis of species will sufficiently indicate differences between this species and the California forms. *Brisingella coronata* (Sars) is not closely related, as it is characterized by a short costal region and only 10 to 14 skeletal arches which do not extend more than 6 r from the base of ray. The adambulacral plates have two adoral furrow spinelets. The species is the largest known in this genus. Sars figures a specimen with a disk 28 mm. in diameter and a ray 320 mm. long, which is large even for a typical *Brisinga*.

Genus ASTROSTEPHANE Fisher

Astrostephane Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 20, 1917, p. 421. Type, *Brisinga moluccana* Fisher; Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 525.

Diagnosis.—Differing from typical *Brisinga* in having but two gonads to a ray, and the proximal adambulacral plates longer than high, as in *Brisingella*. In appearance, especially that of rays, closely resembling *Brisingella*, but differing in having the first adambulacral plate tightly joined for its whole length to that of the adjacent ray, and in having directly above these a closely joined pair of first marginal plates, as in *Brisinga* and *Craterobrisinga*; in having very prominent suboral spines bent at the base so that they extend horizontally into the actinostome. A nonmuscular joint, or syzygy, between the first and second adambulacral plates and between the upper part of the second and third ambulacral plates; costae thin, well spaced; intercostal integument without spinelets, rather delicate; only one subambulacral spine; gonads large, with numerous lobes emptying by a single aperture just above the ambulacral plates a little over 2 r from the base of ray; disk with close-set small spinelets.

Remarks.—It seems probable that this genus is more nearly related to *Brisingella* than to *Brisinga*. Fortunately there are two very distinct species, so that the characters given in the diagnosis as of generic value are probably reasonably accurate.

If it is contended that the condition of the interradial pair of adambulacral plates, whether separated (*Brisingella, Astrolirus*) or joined (*Brisinga, Craterobrisinga*, *Stegnobrisinga, Astrostephane*), is dependent upon the number of rays, it may be stated that *A. acanthogenys* with 11 rays has the plates as tightly joined as *A. moluccana*, with 16 rays. In *Brisingella*, where this interradial pair of adambulacrals is separated by the outer end of the combined mouth plates, so that they do not touch by the lateral faces, the first marginal plates have a different relation also. With the unpaired interradial plates they form an inverted Y, each arm being applied to the upper edge of the first adambulacral plate, and the angle of the ⅄ being that of the interradius. In *Craterobrisinga alberti* (Hawaiian Islands) which has nine rays (less than *Brisingella fragilis*, type), the mouth plates do not separate the first or interradial pair of adambulacrals as might be expected if the number of rays only determined the characteristic structure of the interradial angle of *Brisingella*. The proximal part of the plates in *alberti* are normally joined, and the *closely apposed* first pair of marginals has slipped down between the outer ends of the adambulacrals, cementing firmly the ring of plates. There is no hint of the separation of the marginals to form the ⅄ of *Brisingella*.

This genus is not represented in the north Pacific region. *A. moluccana* was taken in 265 to 559 fathoms in the Molucca Islands and Celebes; *A. acanthogenys* was dredged in 172 fathoms, Lingayan Gulf, Luzon.

Genus STEGNOBRISINGA Fisher

Stegnobrisinga Fisher, New East Indian Starfishes, Proc. Biological Soc., Washington, vol. 29, p. 33, Feb. 24, 1916 (subgenus). Type, *Brisinga* (*Stegnobrisinga*) *placoderma* Fisher; Ann. and Mag. Nat. Hist., ser. 8, vol. 20, 1917, p. 428 (genus); Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 530.

Diagnosis.—Resembling *Brisinga* in general appearance, and especially in having definite transverse skeletal ridges, or costae, on the genital region, but differing in having the integument between the costal arches of ray strengthened by many close-set, mostly contiguous or sometimes overlapping papery, spineless plates of irregular form, completely filling the interspaces; in having two gonads to each ray. Proximal subambulacral spines acicular; first adambulacral plate and first marginal plate joined for their whole length to the respective plates of adjacent ray; thus there are four closely joined plates in each interradius; a nonmuscular symphysis, or syzygy, between the first and second adambulacral plates and between the upper parts of second and third ambulacral plates, as in *Brisinga*.

Known only from a single species, *S. placoderma*, China Sea to Buton Strait, Celebes, 525 to 559 fathoms.

Genus ASTROLIRUS Fisher

Astrolirus Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 20, 1917, pp. 424, 428. Type *Brisinga panamensis* Ludwig; Fisher, Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 504.

Diagnosis.—Resembling *Stegnobrisinga* in the presence of spineless, immersed, fenestrated thin plates in the intercostal integument, but differing in the structure of the interbrachial angle, where the first pair of adambulacral plates are not joined together by the interradial faces but are separate; first pair of marginal plates not closely united by their interradial faces, but only by the adoral ends, to which also is closely united the lower end of the interradial plate, forming a rude reversed Y of which the angle is the apex of the interbrachial angle, and the arms are the first marginal plates; proximal adambulacral plates not higher than long; gonads two or four to each ray.

The type, *Brisinga panamensis* Ludwig, is the only species known. The genus has much the same relation to *Stegnobrisinga* that *Brisingella* bears to *Brisinga*, with the exception of the gonads, which are two to each ray in *Stegnobrisinga*, and two or four in *Astrolirus*.

Genus FREYELLASTER Fisher

Freyella Fisher (not Perrier), Ann. and Mag. Nat. Hist., ser. 8, vol. 20, 1917, p. 428.
Freyellaster Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 2, 1918, p. 104. Type, *Freyella fecunda* Fisher, Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 537.

Diagnosis.—Brisingidae with numerous gonads arranged serially along either side of the more or less inflated genital region of ray, each opening by its own pore; plates of genital region forming a continuous covering or armor, more or less spiniferous, and not segregated as independent skeletal arches, separated by intervals without plates; no papulae; in interbrachial angle the first pair of adambulacral plates (of adjacent rays) closely joined throughout their length, and directly above them is a pair of closely joined first marginal plates; primary apical plates not conspicuous; a nonmuscular symphysis, or syzygy, between the first and second adambulacral plates, and between the upper part of the second and third ambulacral plates.

Remarks.—This group includes those species of the old genus *Freyella* in which the gonads are numerous and arranged in series along either side of the ray, as in typical *Brisinga*. In this restricted genus *Freyellaster*, as in the restricted *Brisinga*, the first adambulacral plate is closely united to its fellow of the adjacent ray, at the apex of the interbrachial angle; and immediately above them and joined to their upper side is a closely apposed pair of marginal plates, the first of a series which extends a variable distance along the base of the ray just above the adambulacral plates. The adoral end of these marginal plates abuts against the base of the interradial plate. In some species part of the second adambulacral plate, as well as the first, is joined to its *vis-a-vis*.

In addition to the California species, the following belong to *Freyellaster: F. spatulifer* (Fisher), Macassar Strait; *F. scalaris* (A. H. Clark), Galápagos Islands; probably *F. polycnemus* (Sladen).

FREYELLASTER FECUNDUS (Fisher)

Plate 3, Figures 1, 1*a*–1*f*; Plate 7, Figure 2; Plate 9; Plate 12, Figure 1

Freyella fecunda Fisher, Bull. Bur. Fisheries for 1904, vol. 24, June 10, 1905, p. 319.
Freyellaster fecundus Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 2, 1918, p. 104; Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 538.

Diagnosis.—Rays 13. R. 330 mm., approximately; r 13.5 mm.; R = approximately 25 r; greatest diameter of disk, 27 mm.; of elevated portion, 24 mm.; thickness of disk, 5 mm.; diameter of ray at base, 6 mm.; at widest portion of genital inflation (25 to 75 mm. from the base), 7.5 mm. Genital region very extensive, comprising about half the length of ray, and not conspicuously inflated; plates thin, delicate, beset with one to three small prickles, pretty evenly distributed, but more numerous along the mid-dorsal line; disk with solitary spinelets spaced about their own length; first 12 or 15 subambulacral spines with a truncate, circular flaring tip; proximal plates with three aboral spinelets in a transverse series, and a subambulacral, also close to distal border; plates of outer part of genital region with two aboral spinelets $\left(\frac{\text{ii}+1+\text{I}}{\text{o}} \text{ or } \frac{\text{i}+1+\text{I}}{\text{o}}\right)$; no transverse rows of more prominent abactinal spines; lateral spine opposite alternate adambulacrals, longer than the subambulacral spine.

Description.—The rays are very long, narrow, tapering gradually, a trifle narrower at the base than throughout the very extensive genital region, which is not inflated at all conspicuously. The rays are subcylindrical at the base, depressed on the genital region and of the ordinary three-sided form beyond the genital region. The latter, or, more correctly speaking, the portion of the ray covered by the small papery abactinal plates, comprises nearly or sometimes quite half the total length of ray.

The edge of the fairly large disk is evenly rounded and somewhat undulating in outline. The abactinal integument is very tight and is beset with equal, solitary, small, terete, blunt spinelets, spaced about their own length, those about the anal aperture being a trifle longer than the others. The shape of the spinelets is due to the membrane investing each one, as the calcareous portion is acicular. Interradial plate rather high and narrow, confined to side wall of disk.

The abactinal membrane of rays is rather thin and papery, the delicate plates being invisible except in a thoroughly dried specimen. They are very thin, consisting of a single layer of delicate calcareous network, and are irregular in outline. The plates are not uniform in size and overlap by the edges. Over the extensive genital region the integument is beset with minute, evenly spaced prickles or spinelets, incased in membrane which gives them a blunt appearance. There are one to three, commonly one or two, to each plate, and they are shorter and more widely spaced than on the disk; those of the midradial area are more closely placed than are those on the sides of the ray. On the outer part of the genital region the prickles are still more widely spaced and many of the plates are without them. Except on the first 50 mm. of the ray, the indistinct bands of microscopic pedicellariae from each lateral and ambulacral plate proceed toward the median radial line, before reaching which they break up. On the semitransparent membrane of the outer half of the ray, where there are no integumentary prickles, these bands of pedicellariae are more conspicuous, and extend entirely across the abactinal surface, but are frequently irregular on the median keel of the ray. Extending upward from the rudimentary marginal or lateral plates are a few plates stouter than the other abactinal plates which sometimes reach halfway to the median radial line.

Partly fused to the lateral face of alternate adambulacral plates is a lateral plate, bearing a long, slender spine (13 mm.) sheathed in membrane covered with microscopic pedicellariae. (On plates adjacent to the lateral spine, the subambulacral spine is conspicuously shorter than on alternate plates.) At the base of ray are five marginal plates without spines. The first of these is strongly fused with its fellow of the adjacent ray, at the apex of the interbrachial angle and above the first adambulacral plates.

Adambulacral plates longer than high and on the basal portion of ray about as wide as long. The armature consists of, on the aboral margin of the plate, a transverse series of three spinelets and one spine (the subambulacral), or beyond the middle of genital region two spinelets and one spine. At the base of the ray the two inner spinelets are subequal and the third longer, or the innermost is slightly shorter than its plate, the second subequal to the plate in length, and the third about 1.5 plates in length. The subambulacral spine is 10 to 11 mm. long or 4.5 to 5 plates. On plates which have a lateral plate and spine on their outer side, the subambulacral is shorter than on alternate plates with no lateral spine. The first 12 to 15 subambulacral spines have a flaring, circular, truncate tip beset with numerous little points as in *Craterobrisinga*. The sixth to ninth spines have the broadest tips. On the distal attenuate portion of the ray there is one furrow spinelet and one subambulacral, two to the plate, as over most of the ray of the immature example. First adambulacral plate joined to its fellow of adjacent ray, and proximal ends of the second plates touching one another.

Actinostome rather wide, 16 mm. in diameter. Mouth plates small, inconspicuous, rather narrow, with a flaring inner or free margin, the combined pair being shield-shaped. Armature consists of three or four membrane-invested pedicellariae bearing spinelets on the inner, free, flangelike margin of the plate, that nearest the median suture the shortest, the rest evenly graduated in size outward. At the aboral end of the plate are one or two similar spinelets reaching nearly across furrow. On the actinal surface two much heavier and larger, pointed, sacculate spinules stand in a longitudinal series, the inner the longer, and slightly nearer the median suture. Sometimes there is only one spine, or as many as three.

Madreporic body small, subtubercular, situated near margin of raised portion of disk. Its borders are beset with numerous spinelets.

The articulating surface of the ambulacral plates, on the border of disk where a ray has been broken off, is small, about 2.25 mm. high, and oval in form, slightly broader above than below.

Color in life: Abactinal surface of disk flame scarlet; rays salmon pink with a yellowish cast, much lighter than disk; edges of furrow pinker; spines salmon pink; tube-feet pinkish orange.

Immature specimen.—An example having R 99 mm. has the full number of rays. The genital region extends a little less than one-third the total length of ray. The prickles of the middorsal area are less compactly placed, and the plates are even thinner than in the adult. On the first eight or nine adambulacral plates there are two aboral spinelets and the large spine; beyond that point only one furrow spinelet and the subambulacral. The proximal subambulacral spines are not much enlarged at the tip and only the first four or five are modified. The mouth plates have only one suboral to each plate, and there are two actinostomial spinelets, the outer at the entrance of the ambulacral furrow, the inner immediately adjacent to the outer spinelet and slightly spaced from the median suture.

Anatomical notes.—There are along each side of the ray 20 to 23 mature gonads in the form of independent globular sacs, 2 to 3 mm. in diameter, attached to a genital stolon. Beyond these are about 20 immature, often very small, gonads, which extend beyond the end of the long genital region, or a distance equal to about five times the diameter of disk (10 r) from the base of the ray. The mature gonads end at a distance of about 5 r from the base of ray. The hepatic coeca extend nearly as far as the immature gonads or about 10 r from base of ray. The exposed ridge of the ambulacral ossicles toward the coelom is roughened by numerous minute spiny points.

Type.—Cat. No. 22349, U.S.N.M.

Type-locality.—Station 4530, 6.8 miles northwest of Point Pinos, Monterey Bay, Calif.; 847 to 755 fathoms, soft gray mud; four specimens.

Distribution.—Taken only off Point Pinos, Calif., in 755 to 1,062 fathoms, on soft gray mud and on hard sand and mud.

Specimens examined.—Seven; four from type-locality and three from station 4537, 7.4 miles northwest of Point Pinos, 1,062 to 861 fathoms, hard sand and mud; bottom temperature, 38.5° F., approximately.

Genus FREYELLA Perrier

Freyella PERRIER, Ann. sci. nat., zool., vol. 19, art. 8, 1885, p. 5. Type *Freyella spinosa*, first species, by subsequent designation, Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 20, 1917, p. 428; ser. 9, vol. 2, p. 104.

Freyellidea FISHER, Ann. and Mag. Nat. Hist., ser 8, vol. 20, 1917, p. 429. Type *Freyellidea microplax;* also Ann. and Mag. Nat. Hist., ser. 9, vol. 2, p. 104.

Diagnosis.—Differing from *Freyellaster* Fisher in having only two gonads to each ray, in having a normal muscular symphysis between the first and second adambulacral plates (no syzygy), in lacking marginal plates entirely in the interbrachial angles, and in having the first adambulacral plates either joined, with tissue between or else separated nearly or quite to their proximal ends. Touching the lower end of the interradial plate is a pair of very inconspicuous plates lying in the same plane, and superficially appearing to be a portion of the interradial plate. They are really the extreme outer end of the mouth plates. They have the appearance of being separate plates because the inner end of the first pair of adambulacral plates nearly or entirely segregates them from the actinal or spine-bearing surface of the mouth plates. In those genera which have marginal plates in the interradius, this dorsal part of the mouth plate is entirely hidden by the marginals. Proximal subambulacral spines usually with modified tips.

Remarks.—The species of this genus superficially resemble those of *Freyellaster.* I do not think they are so near to that group as to *Astrocles.* Both *Freyella* and *Astrocles* have only two gonads, and lack the marginal plates which form a characteristic part of the skeleton of the interradial angle in *Freyellaster.*

I have examined the following species which belong to this genus: *Freyella spinosa* Perrier, *elegans* Verrill, *insignis* Ludwig, *propinqua* Ludwig, *pacifica* Ludwig. H. L. Clark[8] has reported *F. tuberculata* Sladen from 2,320 fathoms, eastern tropical Pacific, and has added the following new species from the same region: *F. brevispina, octoradiata,* and *oligobrachia.*

Without knowing the disposition of the gonads it is not possible to be certain that the following species belong to *Freyella*: *sexradiata* Perrier, *benthophila* Sladen, *fragilissima* Sladen, *heroina* Sladen, *dimorpha* Sladen, *remex* Sladen. *F. bracteata* Sladen is a synonym of *elegans* according to Verrill.

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[8] Mem. Mus. Comp. Zoöl., vol. 29, 1920, no. 3, pp. 108-113, pls. 5, 6; the region is between 9° 2′ S. and 0° 3′ N. and 83° and 123° W.

SYNOPSIS OF SPECIES OF FREYELLA HEREIN DESCRIBED

a[1]. Plates of genital region smaller (20 to 30 in a line across ray at widest part) and very numerous; spinelets very small in small groups; one aboral furrow spinelet; proximal subambulacral spine terete with a slightly capitate truncate tip; three actinostomial oral spinelets; pedicellariae all minute..*microplax*.

a[2]. Plates of genital region large (8 to 12 in a line across ray at widest part) and fewer; spinelets larger; one or two aboral furrow spinelets; proximal subambulacral spines spatulate, with 2 to 4 pronged tip, or with prongs only; two actinostomial oral spinelets; pedicellariae of adambulacral, oral, and abactinal spinelets large..............................*insignis*.

FREYELLA MICROPLAX (Fisher)

Plate 4, Figures 1, 1*a*–1*f*; Plate 7, Figure 1; Plate 10; Plate 12, Figure 4

Freyellidea microplax Fisher, Ann. and Mag. Nat. Hist., ser 8, vol. 20, 1917, p. 430.
Freyella microplax Fisher, Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 538.

Diagnosis.—Rays 12, not deciduous, only moderately long, with a short swollen genital region about 4 r in length. Disk closely covered with short spinelets, four or five to a plate; genital region of ray covered with small transversely oriented, elliptical, somewhat irregular plates bearing groups of two to eight small spinelets; 19 or 20 plates can be counted across ray at widest part. Short lateral spine opposite alternate adambulacral plates. Adambulacral armature, one aboral furrow spinelet, and one subambulacral spine, with truncate enlarged tip at base of ray; first adambulacral plates of adjacent rays not fused, the outer end of mouth plates intervening; oral armature: three actinostomial spinelets and one short, sharp, suboral spine. R 170+ mm., r 10 mm., R = 17 + r; thickness of disk, 4 mm.; width of ray at base, 4.5 mm.; breadth of actinostome, 13 mm.

Description.—The top of the disk is flat and only slightly elevated above the rays, which slope gradually into the disk without a break, or shoulder. The disk is thickly covered with terete blunt spinelets usually four or five to each plate. The spinelets are sheathed in membrane which gives them their characteristic blunt form, the calcareous portion being very sharp. Certain scattered plates have only two or three spinelets. The spinelets are about 0.5 mm. long and those of each plate tend to radiate apart slightly, the separate groups being usually less than 0.5 mm. apart. There are a few larger plates observable in favorable specimens which have 15 to 20 spinelets. These are probably primary apical plates. At the base of the spinelets are one to several very minute inconspicuous pedicellariae.

The genital region is conspicuously inflated, short, and thickly covered with very numerous transversely oriented groups of about five (two or three to five, less commonly, six, seven, and eight) delicate, skin-covered, blunt spinelets (very sharp when dried) borne on elliptical transversely oriented plates which usually are slightly spaced when the ray is swollen to its maximum. When the ray is only slightly swollen, the plates touch, especially in the mid-dorsal region. Minute, inconspicuous pedicellariae are present on the basal portion of the spinelets. The spaces between the groups of spinelets are small, usually about one-half the width of the group of spinelets in undried specimens. Beyond the region of plates (which is about twice the diameter of disk from base of ray) there are broad bands of pedicellariae, the alternate ones usually much interrupted. The spaces between the bands are less than the width of the band itself.

Lateral spines opposite alternate adambulacral plates. They are very slender but are heavily sheathed with membrane. At the middle of the genital area they are about the length of four adambulacral plates, and beyond the genital region, of 5 to 5.5 adambulacral plates. The pedicellariae covering the sheaths are very small.

Adambulacral plates of genital region short, the width at first exceeding the length, but at the outer limit of the genital region the plates are slightly longer than wide. Armature consists of one aboral furrow spinelet, a little shorter than the plate (measured at middle of actinal face) and one subambulacral spine next to the aboral border, but on the first 10 plates occupying a considerable part of the surface of plate. The furrow spinelet is sometimes clavate at the tip, and its sheath is rather plentifully supplied with small pedicellariae. A variable number of the proximal subambulacral spines usually from about the third to the tenth or twelfth, have a truncate swollen tip, which varies considerably in size. Sometimes it is scarcely broader than the rather thick spine; again, it is nearly twice the breadth near tip. These proximal spines are a trifle over two adambulacral plates in length; farther along, after they become sharp, they are about three plates long. The pedicellariae are on the outer side of the spine. On the terminal portion of the ray the furrow spinelet is lacking.

The first adambulacral plate is not in contact with that of the adjacent ray, the outer end of the combined mouth plates leaving a narrow interval between the two. There is no syzygy between the first and second adambulacral plates.

The articulating surface of the ambulacral ossicles, after a ray is detached, is small, broad above and narrow below, rather narrowly cordate in outline.

The mouth plates are rather broad at the outer end. Actinostomial margin with three spinelets, the innermost the shortest, and occasionally there is a rudimentary spinelet on the furrow margin adjacent to first adambulacral plate. Each plate bears one suboral spine about as long as the first two adambulacral plates.

Anatomical notes.—Gonads, two to each ray with six or seven divisions to each, which extend along the ray a distance only a little greater than the diameter of disk. The coeca extend about twice as far; or to the end of the genital region. The inner surface of the ambulacral ossicles is smooth. Although the proximal adambulacral plates of adjacent series are not in contact at the base of ray, they are not separated by an azygous plate as in *Colpaster*. The narrow exposed outer part of the combined mouth plates intervenes between the proximal ends of the first adambulacral plates of the two adjacent series, and continues upward to abut against the lower end of the interradial plate. The surface of this dorsal extension of the oral plates is flush with that of the interradial plate. The dividing suture between the two dorsal parts of the pair is at the bottom of a shallow sulcus which is continued above upon the surface of the interradial plate. Unless the specimen is dry or treated with caustic potash, it is not easy to distinguish the dividing sutures, and consequently the three plates appear to be one large interradial plate. The outer sides of each of these dorsal extensions abuts against the first adambulacral below and the second adambulacral above. The upper end as mentioned above rests against the lower end of the elongate, narrow, vertical interradial plate. (Pl. 4, fig. 1*a*.)

Type.—Cat. No. E. 1415, U.S.N.M.

Type-locality.—Station 3342, off British Columbia (52° 39′ 30″ N., 132° 38′ W.); 1,588 fathoms, gray ooze and coarse sand; bottom temperature, 35.3° F.; 12 specimens. Taken also at station 4537, 7 miles northeast of Point Pinos, Calif., 1,062 to 861 fathoms, hard sand, mud; bottom temperature, 38.5° F.; one specimen.

Distribution.—British Columbia to central California, 861 to 1,588 fathoms, mud and sand; temperature range, 35.3 to 38.5° F.

Remarks.—I have examined a ray of *Freyella propinqua* Ludwig and a ray of *F. pacifica* Ludwig. These two, as well as *F. elegans* Verrill, have the same type of adambulacral armature, namely, one subambulacral spine and one aboral furrow spinelet, and in this respect agree with *F. microplax.* But *microplax* differs from these three species in having much more numerous and smaller plates on the genital region of the ray, and as compared with *elegans* much more numerous and smaller disk plates. The spinelets of the disk and rays of *microplax* are much smaller—very small, in fact—and as the plates are diminutive, so the groups of spinelets are also smaller, much closer together, and correspondingly very much more numerous.

FREYELLA INSIGNIS Ludwig

Plate 3, Figure 2; Plate 4, Figure 2, 2*a*; Plate 8, Figure 1

Freyella insignis Ludwig, Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 272, pl. 32, figs. 188, 189.

Diagnosis.—Rays 11 (to 13 in typical form); in California specimen, R 104 mm., r 5.5 mm., R = 19 r. (Ludwig gives R = 20 r and R = 17.6 r.) Disk thickly covered with fairly close-set sharp spinelets, two, three, or even more to a plate; genital region of ray about 3 r in length, covered with relatively large, closely fitted, roundish or irregularly elliptical plates bearing 7 to 20 spinelets (only three or four in the California example) which form transversely oriented groups; lateral spines slender, opposite alternate adambulacral plates, beginning with the fifth; adambulacral armature: one or sometimes two aboral furrow spinelets (regularly two in California variety) and one subambulacral spine, those of the genital region modified, with a more or less spatulate tip ending in two to four points or prongs; mouth plates with two spinelets at mouth of furrow and one adjacent to first adambulacral plate; suboral, one, rather short and pointed; gonads two to each ray, each with a single aperture on the side of ray 1 r from base.

Description.—Disk firmly plated, with two, three, or sometimes even more, relatively conspicuous, sharp, slender spinelets to each plate. The spinelets are fairly close-set and often bear a relatively large pedicellaria.

Genital region of ray about 3 r in length, only slightly swollen, and covered with relatively large closely fitting spiniferous plates, the spinelets forming spaced groups, transversely oriented, of three or four spinelets to a plate. The spinelets are relatively large, being 0.4 to 0.5 mm. long. They tend to form interrupted lines crosswise to the ray, and at the distal end of the genital region the plates are more or less independent, forming one or two poorly defined, independent arches. On the sides of the ray just above the adambulacral plates the integument is bare except for rudimentary arches reaching alternate adambulacral plates. This is probably due to the immaturity of the specimen. Beyond the genital region the ray is crossed by a broad band of pedicellariae opposite each adambulacral plate.

First lateral spine attached to upper border of the fifth adambulacral plate. The first spine is short, as usually the case; the second equals 2.5 adambulacral plates in length; the third equals 3; the fifth equals 3.5; at about the middle of ray the spine equals 5 plates in length. It is covered with a sheath closely beset with minute pedicellariae.

Adambulacral plates rather slender, longer than broad. Armature consists of two furrow spinelets at the aboral end of the plate, on the distal apophysis, the proximal spinelet usually a little the longer and about equal to the length of the plate measured on the actinal surface. A little aboral to the middle of the plate is the subambulacral spine which on the first nine plates has a broadened two or three pronged tip. These modified spines are about two adambulacral plates in length, while the sharp ones are a trifle longer. A few plates have a second shorter subambulacral near the first but it is not normal. On the distal attenuate portion of the ray where the ambulacral furrow is very narrow, the furrow spinelets are lacking. Both subambulacral and furrow spines are liberally supplied with pedicellariae, those on the furrow and proximal half of the subambulacral are conspicuously larger than the pedicellariae of the lateral spines and distal half of the subambulacral spines. Ludwig states that the adambulacral plates of his specimen of *insignis* have a single furrow spinelet. I have a specimen from station 3381, Gulf of Panama, one of the four which he lists, in which a considerable number of the plates have two aboral furrow spinelets.

Mouth plates small, with wide median suture, and very little modified from a pair of adambulacral plates. Armature consists of two spinelets on actinostomial-furrow corner of the plate (sometimes three) and one spinelet on the distal furrow corner, all provided with good-sized pedicellariae. There is a single slender, blunt suboral spine about two adambulacral plates in length.

The apex of the interbrachial angle nearly touches the mouth plates, and is bounded by the first adambulacral plates, above which there are no prominent marginal plates as in *Freyellaster*. The proximal ends of the first pair of adambulacral plates in each interbrachium touch, but the plates are not joined by their lateral faces as in *Freyellaster*.

Types.—In U. S. National Museum.

Type-locality.—Gulf of Panama.

Distribution.—Gulf of Panama to southern California; 1,772 to 2,228 fathoms on gray mud, green mud, brown mud, and globigerina ooze; temperature range, 35° to 36° F.

Specimens examined.—Station 4397, off Santa Catalina Island, Calif. (33° 10′ 15″ N., 121° 42′ 15″ W.); 2,196 to 2,228 fathoms, gray mud; bottom temperature, 35° F.; one specimen.

Station 3381, Gulf of Panama; 1,772 fathoms, green mud; bottom temperature, 35.8° F.; one specimen.

Remarks.—The single Californian specimen is small and presents slight differences from the typical form from off Panama. There are regularly two aboral furrow spinelets, instead of usually one (occasionally two), and the disk spinelets are not so densely placed, nor are there so many spinelets on the abactinal arm plates. But the California specimen is immature, which would account for the fewer disk spinelets and fewer spinelets on the abactinal plates of the ray. It is not possible to determine whether this specimen represents a distinct northern race. It lives in somewhat deeper water than the southern form.

Genus ASTROCLES Fisher

Astrocles Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 20, 1917, pp. 426, 430. Type *A. actinodetus* Fisher; Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 504.

Diagnosis.—Related to *Freyella* but plates of ray localized in transverse arches separated by intervals without plates; plates flat, not forming prominent carinate costae as in *Brisinga*; gonads two to each ray, opening each by a single aperture on side of ray a little less than 1 r from the disk; furrow spinelet and proximal subambulacral spines with expanded modified tips; in interbrachial angle first pair of adjacent adambulacral plates joined only at proximal end, not for their whole length as in typical *Freyellaster;* no prominent pair of first marginal plates directly above the first pair of adambulacrals; touching the lower end of the slender interradial plate is a pair of small plates. These are the outer ends of the mouth plates which project dorsally behind the proximal ends of the first pair of adambulacral plates, as in *Freyella.* The adambulacral plates segregate this dorsal part of the mouth plates from the actinal spine-bearing portion; first and second adambulacral plates as well as the upper part of the second and third ambulacrals joined by a normal muscular symphysis; no syzygy present.

Remarks.—This curious genus agrees with *Freyella* in certain important features—the absence of a proximal adambulacral syzygy, absence of marginal plates above the first few adambulacral plates, and presence of only two gonads to each ray. I think the independent abactinal skeletal arches of the ray have nothing to do with those of *Brisinga.* The plates are flattish and resemble more nearly segregated abactinal plates of *Freyella* than they do the slender compressed costal plates of *Brisinga* and near allies.

ASTROCLES ACTINODETUS Fisher

Plate 4, Figures 3, 3*a*–3*b*; Plate 5; Plate 11; Plate 12, Figure 2

Astrocles actinodetus Fisher, Ann. and Mag. Nat. Hist., ser. 8, vol. 20, 1917, p. 430.

Diagnosis.—Rays 11, not very deciduous; disk fairly large, covered with circular plates bearing one to three spinelets; genital region of ray 3.5 to 4 r in length, or about one-sixth total length of ray, and crossed by 25 to 27 pretty regular transverse arches of depressed elliptical, crenulate plates covered with a felting of minute pedicellariae and bearing small spinelets in transverse series; intervals between arches without plates or pedicellariae; lateral spine opposite alternate adambulacrals, very slender and delicate; adambulacral armature consisting of one aboral furrow spinelet with tip greatly broadened and subtriangular in form, and one subambulacral spine, those on proximal half or two-thirds of genital region with an enlarged bifid tip; mouth plates with three actinostomial spines, expanded flattened and more or less irregular in form, one aboral, modified, furrow spinelet and one suboral pointed spine; in interbrachium the first pair of adjacent adambulacral plates touch or join only at their proximal ends—are not fused the whole extent of their interradial faces, nor is there directly above them a prominent pair of first marginal plates as in *Brisinga.*

Description.—The disk is only very slightly elevated above the level of the base of rays, and the latter slopes upward to the disk without any abrupt shoulder. Surface of disk fairly plane. Disk plates circular, slightly elevated at middle for articulation of one to three spinelets, these larger plates surrounded by a variable number of much smaller secondary platelets which do not bear spinelets and are entirely concealed by skin until the specimen is dried. In a specimen with R 12 mm. these platelets are numerous everywhere among the primary plates, but in an example with R 10.5 mm. the primary plates are separated by bare integument, and the secondary plates are beginning to appear here and there in this integument. Ordinarily there are one to three delicate sharp spinelets, about 1 mm. long, to each plate, these appearing blunt before being dried on account of the membranous investment. The groups of spinelets are spaced 0.5 to 1.5 mm. apart and about 25 to 28 of these groups can be counted from one side of the disk to the other. In some specimens half the primary plates, or even more, have but a single spinelet. The spinelets as a consequence appear to be less numerous and more widely spaced. Attached to the plates and sometimes to the base of the spines are one to five minute pedicellariae. Madreporic body on edge of disk small, prominent, with a very few deep striae.

Rays with short, swollen genital region, the length of which is about 3.5 to 4 r, or on one perfect ray about one-third the length of ray. The disk plating continues upon the radial region of the ray as far as the fourth adambulacral, beyond which the plates are in pretty regular transverse arches, covered with an even felting of minute pedicellariae. The plates are irregularly elliptical, oriented transversely, the edges more or less crenulate in old specimens, and the plates are broadest on the abactinal surface, narrowing conspicuously upon the sides of ray. The interval of bare skin is therefore wider (1.5 mm.) on the sides of the ray, than at the crest of the arches (0.5 to 1. mm.). The plates seem to increase in size with age, the arches being relatively broadest in the largest specimens. The arches taper to a point where they join the small lateral plates, and alternate arches end before reaching the corresponding adambulacral, as there is no lateral plate for them to meet. The plates are thin and almost flush with the general surface, except along the middle line where there is a row of two to five sharp, small, spinelets articulated to an incipient ridge in old specimens. The arches do not form such prominent costae or ribs as are commonly found in *Brisinga*. Beyond the costal area the ray is crossed by fairly broad, frequent bands of minute pedicellariae, one opposite each adambulacral plate.

Lateral plates small, situated opposite alternate adambulacral plates, beginning with the fifth to seventh. Lateral spines very slender and fragile, and on the outer part of ray attain a length of 21 mm., or about the length of 10 adambulacral plates, but on the genital region they are short. The first spine is about one plate long, and the seventh about 3.5 plates (6.5 mm.).

Adambulacral plates rather short with deeply excavated furrow margin. Armature consists of one aboral furrow spinelet and one subambulacral spine. The former extends half-way across ray and has a very unique form. The end of the spinelet flares so as to form a flattish triangluar plate, or else it is two-pronged. This tip fits snugly against that of the opposite spinelet, and at the same time the tips of the spines of the same series nearly meet on account of the flaring end. As a result the ends of the spinelets form a series of valves which completely or nearly completely fill in the spaces around the tube-feet, almost as if they had been poured in and allowed to harden. This applies to the genital region, beyond which the curiously modified tip becomes less prominent as one proceeds along the ray, until on the outer attenuate portion the spinelets are normal or only slightly clavate, or spatulate. Sometimes far along ray there are two aboral furrow spinelets. The first 12 or 15 subambulacral spines have a variably modified spatulate truncate, grooved, or incipiently bifid tip, most pronounced on the third to the ninth or tenth, beyond which as the spines lengthen the tip becomes rapidly smaller. From the twelfth to about the twenty-fifth the spines are merely slightly and decreasingly capitate. On the genital region the subambulacral spines are about 2.5 to 3 plates in length. On the outer part of the ray those on plates to which a lateral plate and spine are fastened are short and slender (1.5 to 2 plates long) while on alternate plates the subambulacral is fastened slightly more upon the actino-lateral face of the plate and measures 3.5 to 4 plates in length (as compared to the lateral spine which equals 9 or 10 plates).

The rays are separated nearly to the mouth plates; only the proximal ends of the first adambulacral plates are in contact. The outer part of the mouth plates does not separate the first pair of adjacent adambulacrals but extends upward behind the joined inner ends of the adambulacral plates to meet the lower end of the interradial plate. These upper ends resemble a pair of independent plates.

Mouth plates with a modified spinelet, like the adambulacral furrow spinelets, at the outer furrow end of plate, and another at the inner actinostomial end, the two enclosing the first tube-foot. Forming a series with the latter spinelet on the actinostomial margin are two others, variously expanded and leaflike in form, but bent sharply toward the furrow mouth. The innermost is near the median suture and is sometimes quite small. The second is intermediate in size and lies parallel to that which guards the mouth of the furrow. The amount of expansion of these curious spinelets varies a good deal and their form is often irregular and bizarre. On the outer half of each plate is a tapering, pointed, suboral spine equal to the first 3 or 3.5 adambulacral plates in length.

The articulation surface of the ambulacral plates (second pair), where the ray has been broken off from the disk, is small, deeply notched above and below. The articulation surface is not sharply marked off from the two processes below, as in *Brisinga*.

Gonads: The ovaries are each a single slender sac about 2 r in length which opens by the proximal end on the side of the ray, nearly 1 r from the interbrachium. There are two ovaries to each ray. The testes, two to a ray, are many-lobed bodies which have a single opening about 1 r from the interbrachium.

Type.—Cat. No. E. 1416, U.S.N.M.

Type-locality.—Station 2859, off British Columbia (55′ 20″ N., 136′ 20″ W.); 1,569 fathoms, gray ooze; bottom temperature, 34.9 F.; 13 specimens.

Suborder ASTERIADINA Fisher

Family ZOROASTERIDAE Sladen

Zoroasteridae Sladen, Challenger Asteroidea, 1889, p. 416.—Fisher, Ann. Mag. Nat. Hist., ser. 9, vol. 3, 1919, p. 387; Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 470.—Clark, Mem. Mus. Comp. Zoöl., vol. 39, No. 3, 1920, p. 94.

Deep-water Forcipulata having a small disk and slender, subcylindrical, often long rays, the plates of which are disposed in regular, usually closely juxtaposed, longiseries; pedicellariae of the straight sort only, the crossed being absent; spinelets delicate and slender, usually in regular longiseries, sometimes absent; alternate adambulacral plates (in one genus, all) with a prominent spiniferous projection into furrow.

Starfishes of the Zoroasteridae are abundant on muddy bottom in deep water off the west coast of the United States, and form a very characteristic element of the fauna. While the species are not numerous, individuals swarm in some localities, judging by the results of dredge hauls.

Further study of *Myxoderma*, first proposed as a subgenus, has shown it to be very distinct from *Zoroaster*. The capture of large examples of *Cnemidaster wyvilli*[9] in the Gulf of Tomini, Celebes, not a great distance from the type-locality, has thrown a new light upon a genus which was based upon a young and inadequate specimen.

Mammaster is closely related to *Cnemidaster*. Clark (1920, p. 96) has found that in *Mammaster* the first carinal plate, just distal to the primary radial is conspicuously enlarged and is larger than the adjoining second marginals. *Mammaster* also lacks adradial plates. The genus is monotypic and is found in the West Indies and Gulf of Mexico.

Clark (1920, p. 100) has prepared a very useful synopsis of the species of *Zoroaster*. This paper, furthermore, contains a good review of the family.

SYNOPSIS OF THE KNOWN GENERA OF ZOROASTERIDAE

a^1. Dorsal surface not devoid of spines and not covered with a smooth tough membrance in sharp contrast to the spiniferous of squamiferous actinolateral regions.

b^1. Superambulacral plates absent, no conspicuous buttress extending from the upper enlarged end of the first two pairs of ambulacral plates to the body-wall at the interradial angle.

c^1. All adambulacral plates carinate on the furrow face. Genotype, *Prognaster grimaldii* Perrier ---------- *Prognaster*[10] Perrier.

c^2. Adambulacral plates alternately carinate and noncarinate.

d^1. Rays long, slender; disk small; abactinal, marginal, and actinolateral plates arranged in regular longitudinal lines along ray, a series of adradial plates being always present; all but the median radial or carinal, which are larger, form also transverse series; plates are covered with small, papilliform, skin-covered spinelets, and most of them bear an enlarged spine; papular areas generally very small but sometimes nearly as large as plates; straight pedicellariae present; actinolateral plates in three to five series, the upper subequal to the inferomarginal plates; superomarginal plates not conspicuously larger than the inferomarginal plates. Genotype, *Zoroaster fulgens* Thomson. *Zoroaster* Thomson.

d^2. Plates of ray arranged in regular longitudinal series, the carinal plates the largest; abactinal and marginal plates armed with fairly large, skin-covered scales which mask all plates except some of the disk-plates and the carinal series along ray; no pedicellariae; actinolateral plates, in two or three series, much smaller than inferomarginals; superomarginal plates much larger than inferomarginal plates. Genotype, *Pholidaster squamatus* Sladen ---------- *Pholidaster* Sladen.

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[9] Fisher, Bull. U. S. Nat. Mus., 100, vol. 3, 1919, p. 480.—Clark, Mem. Mus. Comp. Zoöl., vol. 39, No. 3, 1920, p. 97.

[10] *Prognaster* Perrier, "Comptes rendus," vol. 112, 21, No. May 5, 1891, p. 1226. Type, *P. grimaldii*. Also "Resultats des campagnes scientifiques du Prince de Monaco," fasc. 11, 1896, p. 22, pl. 2, figs. 1, 1*a*–*b*. In the meantime, Perrier described *Prognaster* as a new genus with *P. longicauda*, new species, ostensibly as type (Expéd. scientif. du "Travailleur" at du "Talisman," 1894, p. 119). This species does not seem to be congeneric with *grimaldii*, which, of course, is the genuine genotype.

b^2. Superambulacral plates present; a conspicuous buttress, the specialized first superambulacral plate connects the upper end of the first two ambulacral plates with the bodywall at interradial angle.

c^1. Adradial plates present; two series of papular areas between the carinal and superomarginal plates, the latter never conspicuously enlarged nor overlapping the carinals. Genotype, *Zoroaster sacculatus* Fisher-------------------------------*Myxoderma* Fisher.

c^2. No adradial plates; one series of very small adradial papular pores; superomarginal plates of two sizes, alternately larger and smaller, overlapping the carinals strongly and dominating these plates, which are sunken below the level of the superomarginals. Genotype, *Bythiolophus acanthinus* Fisher-------------------*Bythiolophus*[11] Fisher.

a^2. Abactinal plates of disk, the carinals, adradials (when present), marginals, and sometimes one series of actinolateral plates devoid of spines or any conspicuous armature, but mostly smooth and covered with a tough membrane of variable thickness, often partly obscuring the plates; two to four lower series of actinolateral plates covered with squamiform fleshy spinelets and sometimes a conspicuous appressed spine; superambulacral plates present, the first conspicuously enlarged into a buttress connecting the upper end of the first two ambulacral ossicles with the body wall.

b^1. With a series of adradial plates more or less well developed; first carinal scarcely or not at all larger than the first marginals which are evidently larger than the second; four or five series of actinolateral plates. Genotype, *Cnemidaster wyvilli* Sladen-*Cnemidaster* Sladen.

b^2. Adradial plates absent, the inner lobe of the superomarginal plates overlapping the carinal plates; first carinal plate, just distad to primary radial, conspicuously enlarged, larger than the adjoining *second* marginals which are very much larger than the first ones; three series of actinolateral plates with rudimentary fourth series in large specimens. Genotype, *Zoroaster sigsbeei* Perrier------------------------------*Mammaster* Perrier.

Genus ZOROASTER Wyville Thomson

Zoroaster WYVILLE THOMSON, The Depths of the Sea, 1873, p. 154. Type, *Z. fulgens* Thomson. For key to species: Clark, Mem. Mus. Comp. Zoöl., vol. 39, No. 3, 1920, p. 100.

Diagnosis.—Zoroasteridae lacking superambulacral plates, with small disk, composed chiefly of primary apical plates, and long slender rays made up of a carinal series of four to six lobed plates, overlapping on either side a regular adradial series, these followed by two regular series of four-lobed or lozenge-shaped marginals and three or four series of subsimilar actinolateral plates, imbricating so that the lower and the adoral margins, or lobes, are free and overlap the aboral and upper margins of neighboring plates; adradials, marginals and actinolaterals also forming transverse series; most of the plates normally with a central spine, and spinelets; papular areas very small, in the junction between four plates; adambulacral plates short, band-like, of two sorts: (1) prominent plates projecting into furrow forming a sort of carina bearing a transverse series of three to six spines, the inner one or two frequently bearing pedicellariae, sometimes quite large; (2) alternating with these prominent plates are much narrower noncarinate plates bearing one or two transverse series of two spines each, or a group of three with or more often without pedicellariae; pedicellariae usually present on abactional and lateral plates; tube feet in four series

[11] Proc. Biol. Soc., Washington, vol. 219, 1916, p. 31. Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 484, pl. 135, figs. 1, 1a–c; pl. 139 figs. 1, 2. In the description adradial plates should read superomarginal. The corrected diagnosis is as follows: In general structure resembling *Zoroaster*, except in the absence of adradial plates; in presence of superambulacral plates; in the specialization of the first superambulacral plate as a conspicuous buttress running from the body wall at the interradius to the upper end of the first ambulacral ossicle, and in the arrangement of the abactinal skeleton. The superomarginal series is more prominent than the carinal consisting of alternately larger and smaller, transversely elongated plates, the larger of which overlie the lateral third of the carinals; both sorts strongly overlap the upper end of the inferomarginals. Two series of marginal and five series of actinolateral plates. Adambulacral plates as in *Zoroaster*.

proximally, usually becoming two distally; ampullae when deflated with two lobes; gonads two to a ray, attached a little distance from interradial angle on level with marginal plates.

KEY TO THE SPECIES AND SUBSPECIES OF ZOROASTER HEREIN DESCRIBED

a^1. With four series of actinolateral plates on proximal part of ray; dorsolateral and intermarginal papular areas very small with normally one papula each; inferomarginal and actinolateral spines slender, closely appressed.

b^1. Superomarginal spines very slender, appressed; no adradial spines; 10 carinal plates correspond to 14 adradial and 14 superomarginal plates; fourth or lowest actinolateral series extending far along ray; plates of first two actinolateral series as broad as inferomarginals; adradial plates broadly overlapped by adjacent series------- *ophiurus* Fisher

b^2. Superomarginal spines more robust, often bristling; an incomplete series of adradial spines; 10 carinal plates correspond to 19 adradial and 19 superomarginal plates; fourth or lowest actinolateral series short (one-sixth length of ray); plates of first actinolateral series, only, as broad as the inferomarginals; adradial plates exposed (about 50 per cent broader) -- *actinocles* Fisher.

a^2. With three series of actinolateral plates; the two dorsolateral and the intermarginal series of papular areas with two to four papulae, the areas rather large; all spines rather long and bristling.

b^1. No large pedicellaria regularly on the second spine of prominent adambulacral plates -- *evermanni* Fisher.

b^2. A large pedicellaria regularly present on the second spine of prominent adambulacral plates -- *mordax* Fisher.

ZOROASTER OPHIURUS Fisher

Plate 13, Figures 1, 1*a*–1*c*; Plate 17; Plate 18, Figures 2, 3

Zoroaster ophiurus Fisher, Bull. Bureau Fisheries, 1904, vol. 24, June 10, 1905, p. 315; Ann. and Mag. Nat. Hist., ser. 9, vol. 3, 1919, p. 390.—H. L. Clark, Bull Amer. Mus. Nat. Hist., vol. 32, art. 8, July 9, 1913, p. 199; vol. 48, art. 6, 1923, p. 152; Mem. Mus. Comp. Zoöl., vol. 39, No. 3, 1920, p. 102.

Diagnosis.—Belonging to the slender-rayed relatively delicate *carinatus* group. Rays five. R 140 mm.; r 10 mm.; R = 14 r. Breadth of ray at base, 11 mm. Disk small and convex; rays very long and slender, tapering from a narrow base to an attenuate extremity. Abactinal surface of rays strongly convex, with a fairly prominent median radial ridge. Adradial plates sunken, rather inconspicuous, nearly covered by adjacent series; four series of actinolateral plates; marginals and actinolaterals each with a very slender needle-like spine; numerous prominent pedicellariae; miliary spinelets slender, curved, spaced, not so long on rays as the pedicellariae; carinal plates with a short blunt, subtruncate tubercular spine, much heavier than the lateral spines and usually more or less grooved or scored at the end.

Description.—Plates of abactinal surface of disk rather convex, the primary radials and basals being most prominent. They are covered with delicate and slender sharp spinelets, about 1 mm. in length, distinctly spaced, among which are scattered numerous straight pedicellariae, larger than the spinelets, and, of course, much more robust. The median radial series of plates is more prominent than the rest, and each bears, on a central prominence, a thimble-shaped tubercle. The abactinal and lateral faces of the ray are gradually confluent by a well-rounded margin, the superomarginal plates not being prominent in any way. Between the superomarginal and adambulacral plates are five longitudinal series of exactly similar plates—an inferomarginal and four actinolateral series—and all are precisely similar to the superomarginals. On the outer portion of ray the actinolateral series are successively reduced to three, two, and finally at end of ray to one. Each of these plates, including the marginals, bears a very slender, delicate, sharp spinule, which increases in length toward the furrow, that on the proximal superomarginals being 2 mm. in length, and that nearest the furrow in the same transverse series, nearly 4 mm. The general surface of the plates is covered with very delicate, short, spaced, often curved spinelets, and there are one or two rather prominent pedicellariae to each plate, forming fairly regular longiseries along the ray, between successive series of plates. The median radial plates bear two to five pedicellariae each. Papulae inconspicuous, one or two to the pore, usually one. Papular areas *very small.*

The prominent adambulacral plates bear a transverse series of three to five spinelets. The inner two are short, stout, and pointed, and are borne on the furrow projection. The inner has a terminal membranous expansion bearing six or eight pedicellariae of graduated sizes. The second bears one similar much larger pedicellaria or occasionally two, near the base of the spinelet. The next or first subambulacral spinelet is larger, and is slender and pointed, the two following being successively shorter. On the outer part of ray, only two subambulacral spinelets are commonly present, and the second furrow spinelet is often missing. The alternate, nonprominent, plates have a small furrow spinelet, bearing one or two small pedicellariae, situated near the adoral edge, and on the actinal surface a transverse row of two spinelets very similar to those of the prominent plates. A large pedicellaria sometimes stands at the outer end of the series.

Madreporic body convex, subtubercular, circular, situated 7 mm. from center of disk.

Anatomical notes.—There is an incipient dorsal stomach pentagonal in outline, and a saccular stomach proper with a short rounded lobe in each ray. From the corners of the dorsal division depart the two slender hepatic coeca which extend 0.6 the length of ray. Interradially, between the points of departure of the hepatic coeca, the dorsal stomach is outlined by a prominent fold. The radial sacs of the ventral stomach are attached to the prominent knob of the first two pairs of ambulacral ossicles by numerous strands. Intestinal caecum consists of three tubular structures, 10 to 15 mm. long, springing from a common center. The opening from this small central chamber into stomach is prominent. Gonad long tubular with a few irregular lateral branches; it opens intermarginally at base of ray a short distance from the interradius. Interradial septum rudimentary, membranous. Ampullae double; that is, consisting of two divergent divisions springing from the central portion of the pore. No Polian vesicles; Tiedmann's bodies present. No superambulacral ossicles present. (Specimen from station 2919 examined.)

Variations.—The largest specimen from station 2919 is only slightly bigger than the type, but the rays are noticeably broader and the adradial series of plates is not quite so much encroached upon by the neighboring series as in the type. The lobes of the superomarginal and carinal plates do not come within 0.8 to 1 mm. of touching. R 155 mm., r 12 mm.; breadth of ray slightly beyond base, 12 mm.

The example from station 4765 has the following large dimensions: R 178 mm., r 11 mm. R = 16 r; breadth of ray, a little beyond base, 14 mm. This specimen is fairly typical with the exception that there are fewer adambulacral pedicellariae than in California examples; particularly the big pedicellaria on the *second* furrow spine is wanting except on a relatively few plates at the base of the ray. Rarely spine two carries a group of three or four small pedicellariae like those (four to six in number) on the first or innermost spine. Except at the very base of ray, the tube feet are two-ranked. The marginal and actinolateral spines are delicate, slender and sharp as in the type, 4 to 6 mm. long at base of ray and increase in diameter as the furrow is approached, those of the lowermost two rows being at the base about twice as thick as the marginal spines, as well as about 1 to 1.50 mm. larger. The carinal tubercles are coarse, 1 to 1.25 mm. long, slightly swollen above the base (about 0.75 mm. in diameter), truncate or blunt, the end sometimes finely striated longitudinally. The carinal plates form a prominent angular ridge, and the adradials are appreciably sunken. The lobes of the superomarginal and carinal plates broadly overlap the adradials and are separated by 0.75 to 1.25 mm. space at the base of the ray. The pedicellariae slightly exceed the miliary spinelets in length, and are conspciuous, being about 1.25 to 1.50 mm. long; but owing to the investment of the spinelets being a little thicker than in southern specimens the pedicellariae do not appear to be quite so prominent. The spinelets are slender, delicate, curved at the base , and slightly compressed so that they appear to be saber-shaped in many cases. They average slightly over a millimeter in length. The papular areas of the dorsolateral surface frequently have two papulae; those of the four lateral series, one each.

Type.—Cat. No. 22,345, U.S.N.M.

Type-locality.—Station 4387, off San Diego, Calif.; longitude of Point Conception, 32° 32′ 40″ N., 118° 04′ 20″ W.; 1,059 fathoms, green mud. (*Albatross*, 1904.)

Distribution.—From Bering Sea and off southern California; 989 to 1,217 fathoms, mud and fine black sand. Temperature range, 35.2° to 38° F. Recorded by Clark (1913) from 879 to 1,101 fathoms off Ballenas Bay and San Rosario Bay, Lower California; bottom temperature, 37.3° and 38.1°.

Specimens examined.—Six; one from type-locality:

Station 2919, 32° 17′ N., 119° 17′ W. (off San Diego, Calif.); 984 fathoms, gray mud; bottom temperature, 38° F. (Coll. U.S.N.M.); four specimens.

Station 4765, 53° 12′ N., 171° 37′ W. (43.5 miles northwest of west point of Yunaska Island, Aleutian Islands); 1,217 fathoms, fine black sand; bottom temperature, 35.2° F. (*Albatross*, 1906); one specimen.

Remarks.—*Zoroaster ophiurus* belongs to the *carinatus* group of species, in which the rays are very slender, long, and pointed; the carinal series of plates is prominent and more or less carinate; and, particularly, the adradial series is inconspicuous, much narrower than either the carinal or the superomarginal and is strongly encroached upon by both. No matter how large the specimen becomes, the adradials do not equal the size of the superomarginals. The reduction of the adradials is more pronounced in *Z. ophiurus* and in *Z. carinatus philippinensis* than in *Z. spinulosus* of the Hawaiian Islands.

Z. ophiurus differs from *Z. spinulosus* in having the adradial series of plates so nearly covered by the carinals and superomarginals that the lobes of the two latter series nearly touch, and, in fact, are in contact in the type. In *ophiurus* the pedicellariae of the general body wall and disk are twice as large as in *spinulosus*, more numerous, and the miliary, or secondary, spinelets are conspicuously longer. Even the primary spinules are longer, but the difference is less well marked. *Z. carinatus philippinensis* lacks the carinal series of tubercles, and the slender acicular supero and infero marginal spines. The miliary spinelets of the Philippine species are more numerous, more compactly placed, and are appressed to the plates. They are less slender and more squamiferous than in *ophiurus*. The body pedicellariae are inconspicuous

Two species from the Pacific Ocean south of the United States must be compared with *ophiurus*; these are *Z. hirsutus* Ludwig,[12] station 3415, south of Acapulco, Mexico 1,879 fathoms, and *Z. magnificus* [13] Ludwig, station 3360, Gulf of Panama, 1,672 fathoms. Although Ludwig separates these species in his text by the description of *Z.* (= *Cnemidaster*) *nudus*, the two are very similar in appearance. Both have the long slender rays of the *carinatus* type, but the adradial plates are not sunken, or subservient to the carinal and superomarginal series, although the latter slightly overlaps them. In Figure 146 [14] the adradials are shown as being slightly smaller than the superomarginals. In a ray of the cotype which I have, they are more often slightly larger on the basal part of the ray. Figure 168 [15] shows the arrangement of plates in *Z. hirsutus*. These two species constitute a *magnificus* type, differing from the *carinatus* type in the greater size of the adradial plates, although in general form and in the small size of the papular areas resembling the *carinatus* type. *Z. magnificus* differs from *hirsutus* in having a few relatively large (2 mm.) abactinal and lateral pedicellariae and three series of actinal intermediate plates. In *hirsutus* there are four series of plates between the inferomarginal and adambulacral plates, and numerous small pedicellariae.

Z. ophiurus differs from these two species in respect to the adradial plates, which, as noted above, are much less conspicuous. In addition it is separable from *magnificus* by reason of the presence of a fourth actinal series of plates and the absence of the particularly large pedicellariae, relatively few in number. On the other hand, the pedicellariae are larger and more numerous than those of *hirsutus*, the carinal plates are more prominent and have longer lateral lobes.

ZOROASTER ACTINOCLES Fisher

Plate 13, Figures 2, 2*a*–2*c*; Plate 18, Figure 1; Plate 20, Figure 1

Zoroaster actinocles Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 3, 1919, p. 390.—Clark, Mem. Mus. Comp. Zoöl., vol. 39, No. 3, p. 101.

Diagnosis.—Rays five. R 161 mm., r 11 mm., R = 14.6 r; breadth of ray at base, 13 mm. Rays *slender*, evenly tapered to the extremity, which is capped by a relatively large terminal plate; disk elevated at center; carinal ridge rather prominent. Resembling a slender-rayed *Z. fulgens* but differing in having the plates of the second, third, and fourth actinolateral series smaller, the fourth series being rudimentary; in having slenderer superomarginal spines (decidely slenderer than the carinal spines), fleshier spinelets, relatively larger carinal plates, never but one actinolateral

[12] Ludwig, Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 172, pl. 28, fig. 161, 162; pl. 29, fig. 168.
[13] Ludwig, idem, p. 159, pl. 26, figs. 146–148, pl. 27, figs. 149, 150.
[14] Ludwig, idem, vol. 32, 1905.
[15] Ludwig, idem, vol. 32, 1905.

spine to a plate; in having a decidedly larger terminal plate, and a large pedicellaria on the second (from furrow) adambulacral spine.

Description.—The carinal ridge is carried to center of disk, the central, radial, and basal plates of which bear a stout spine similar to those on the ray. All the plates are perceptibly convex and are covered closely with papilliform blunt pulpy spinelets like those of the rays. The pedicellariae are few and only a trifle longer than the spinelets. Papular pores and papulae (single) very inconspicuous.

The ray slopes off rather steeply from the carinal ridge like the roof of a house; there is a perceptible angle between this dorsolateral surface and the slightly convex or rounded lateral surface. Each carinal plate is convex, and the series as a whole forms a ridge rising above the general level. Carinal spines robust, somewhat swollen and furrowed, bluntly pointed to subtruncate. The adradial plates are fairly well exposed and a few at the base of the ray bear a conical spine 2.5 mm. long. Superomarginal spines robust but slenderer than the carinals, tapering, pointed, about 2.5 to 3 mm. long, normally bristling as in *fulgens*. Below these is a longitudinal series of similar inferomarginal spines, then four series of sharp actinolateral spines, those of the two upper series being the longest. The fourth series extends only a short distance; over the greater part of the ray there are either three or two series only. The general surface of the plates is covered with close-set pulpy papilliform spinelets which are contiguous and completely hide the surface of the plates. These are much thicker than the sheathed spinelets of *Z. ophiurus* from the same station and show evidence of having been slimy in life. When dried, the calcareous part is seen to be very delicate and sharp and 0.6 to 1 mm. long. The spinelets then appear to be well spaced. The carinal plates carry upward of 50 and the adradials about 15. The pedicellariae are fairly slender, evenly tapered, a trifle longer than the spinelets, rather few and inconspicuous. They stand near the single papulae, on both dorsal and lateral surfaces.

The skeleton of the ray is very compact and is characterized by exposed adradials, smaller than the superomarginals. (See pl. 13, fig. 2.) The carinals are rather long with two short rounded lobes on each side. To 10 carinals at base of ray there are 19 adradials and 19 superomarginals (=35 mm.). In a specimen of *Z. ophiurus* from the same station, to 10 carinals there are 14 adradials and 14 superomarginals (=26 mm.). The carinals are thus bigger in *actinocles,* for in a space of 35 mm. in *ophiurus* there are exactly the same number of adradials and superomarginals as in *actinocles*. In the latter the adradials are much more exposed and thus appear to be larger than in *ophiurus*. In *actinocles* the lowest or fourth series of actinolateral plates extends only a short distance (about 22 mm., or one-sixth the length of ray), whereas in *ophiurus* they extend upon the outer part of the ray and bear spines. In *actinocles* the third series extends two-thirds the length of ray, and the second series to within about 20 mm. of the tip. If a cleaned ray of *actinocles* is compared with one of *ophiurus* of the same size, the larger actinolateral field of the latter is at once very evident. At the base of the ray in *ophiurus* the plates of the first two actinolateral series are quite as large as the inferomarginal plates while those of the third series are about two-thirds as large. In *actinocles* only the plates of the upper, or first, row are as large as the inferomarginals, and that only at the very base of the ray, for after the sixth or seventh plate of the series they become smaller than the inferomarginals. The combined breadth of the second, third, and fourth series is only a trifle greater than the width of the first series alone. As mentioned above, after the first sixth of the ray is passed, only three actinolateral series remain. The terminal plate is relatively large, broadly elliptical, and rounded-truncate. It lacks the characteristic notch on the proximal side, or has but a slight indication of it. The plate is 4 mm. long (or the length of the last four carinal plates) and a trifle over 2.5 mm. broad. In the large specimen of *ophiurus* from the same station, the terminal plate is small subglobose or subquadrate, about 2 mm. long by 2 broad, the proximal margin broadly notched for a third of its length; it is about as long as the last four carinal plates, which are therefore very small.

Papular pores small; there are five regular longitudinal series, with the beginnings of a sixth at the base of ray, and they also form regular transverse series. There are two dorsolateral, one intermarginal, and two actinolateral series, plus one rudimentary series. In *ophiurus* there are three actinolateral series plus a few pores of a fourth. Papulae solitary and small.

Prominent adambulacral plates with a transverse series of five spines. The first is deep in the furrow on the apex of the projection, is slightly compressed, and has a terminal flap of tissue carrying upwards of eight small unequal tapered pedicellariae. The second is about the same length, slightly compressed, and usually carries a pedicellaria about 1.5 mm. long attached to its base. The third is tapered, bluntly pointed, and a little longer than the second, or about 2.5 mm. The fourth and fifth (and sometimes a sixth) are very delicate, similar to the actinolateral spinelets, and about 1.5 mm. long; No. 5 may be lacking. The nonprominent alternate plates have a transverse series of four or five spinules, the innermost small and situated adorad out of line with the others. The second is commonly enlarged, about 1.75 mm. long, and corresponds to No. 3 of the prominent plates. The outer one or two spinelets are delicate. All spines, and particularly spinelets, are sheathed with pulpy soft membrane so that they appear unnaturally robust. The mouth plates have three actinostomial and two suboral spines. Ambulacral furrows rather narrow; tube feet in four series, crowded.

No superambulacral plates. Ampullae, when empty, with two subequal lobes. Gonads two to each ray.

Madreporic body quite small, situated 7 mm. from center.

Type.—Cat. No. 37039, U.S.N.M.

Type-locality.—Station 4765, 53° 12′ N., 171° 37′ W., 43.5 miles northwest of west point of Yunaska Island, Aleutian Islands; 1,217 fathoms, fine black sand; bottom temperature, 35.2° F. (*Albatross*, 1906.)

Distribution.—Known only from the type-locality.

Remarks.—As nearly as can be determined, this species is a north Pacific representative of *Zoroaster fulgens*, from which it differs, however, in rather fundamental ways, as enumerated in the diagnosis. Sladen is quite explicit in his description with regard to the size and armature of the actinolateral plates—the plates of the uppermost series being broader than those of the three lower (as in *actinocles*) but the plates of the three lower series have "usually one to three spinelets much longer and more robust than the accompanying miliary spinelets. These are naked, delicate, cylindrical, and taper to a fine extremity, and are generally arranged in slightly oblique lines with the middle spine often more forward, and longest when three are present, near the lower margin of the plate." (Sladen, 1889, p. 419.) In *actinocles*, the surface of two lowest series is sufficient to carry but one major spine. In *actinocles*, the prominent longer series of adradial spines of *fulgens*, is represented by only a few sporadic spines.

I have been able to compare *actinocles* directly with examples of *Z. diomedeae* Verrill from 1,300 to 1,500 fathoms off Marthas Vineyard. *Z. diomedeae* is a western Atlantic representative of *Z. fulgens*, which it greatly resembles. As compared with *actinocles*, *diomedeae* has broader rays which are noticeably swollen proximally; stouter and more rigid superomarginal spines; the fourth actinolateral series of plates extends over half the length of the ray; while at the base there is a rudimentary fifth series of actinolateral plates; there are 17 adradial and 17 superomarginal plates to 10 cardinals at the base of ray (15 in Sladen's figure of *fulgens*); the second adambulacral spine of prominent plates lacks a large pedicellaria; the rays are much shorter (R = about 12 r), and the terminal plate, much smaller and deeply emarginate on proximal border; some of the proximal carinal plates have three and four spines.

Both *Zoroaster hirsutus* and *Z. magnificus* Ludwig, mentioned in comparison with *Z. ophiurus*, are of a more delicate build, with much longer and still slenderer rays, more delicate abactinal spines, fine capillary spinelets with scarcely any sheath, carinal plates only slightly convex. *Z. magnificus* has very large pedicellariae.

ZOROASTER EVERMANNI Fisher

Plate 13, Figure 3; Plate 14, Figures 1, 1*a*, 1*b*, Plate 18, Figure 4; Plate 19, Figure 1; Plate 20, Figures 3, 4.

Zoroaster (*Myxoderma*) *evermanni* Fisher, Bull. Bureau Fisheries, 1904, vol. 24, June 10, 1905, p. 317; not Clark, Bull. Amer. Mus. Nat. Hist., vol. 32, art. 8, July 9, 1913, p. 198 (= *Myxoderma sacculatum*).

Zoroaster evermanni Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 3, 1919, p. 390.—Clark Mem. Mus. Comp. Zoöl., vol. 39, 1920, p. 100; Bull. Amer. Mus. Nat. Hist., vol. 48, art. 6, 1923, p. 152.

Diagnosis.—Rays, five. R. 140 mm.; r 10 mm.; R = 14 r; breadth of ray at base, 11 mm. Rays long, gradually tapering from a narrow base to a pointed extremity which is capped by a small terminal plate; dorsal surface sloping like a roof from the carinate radial series of plates to the superomarginal series, which marks boundary between the dorsolateral and the slightly bulging lateral face of ray; disk convex, the abactinal surface considerably higher than carinal ridge of ray; interbrachial angles very acute, the rays being slightly constricted at base. Characterized by irregularly lobed, exposed, adradial plates, relatively large papular areas dorsally, very prominent carinals and marginals, prominent, bristling, acicular spines (one to a plate except adradials), numerous capillary spinelets invested in life by a soft, thick, pulpy sheath, and long bristling adambulacral spines.

Description.—The primary radial, basal and central plates of the disk are stellate with five, six, or seven prominent rounded lobes, and bear a central, prominent, rather stout sharp spine about 2.5 mm. long, articulated to a prominent boss on the plate, and the general surface of these and the other smaller disk plates is beset with distinctly spaced spinelets, 0.75 to 1.25 mm. long, some of which are pointed others are flattened and broad at the ends. On the larger plates there are one or two pedicellariae from 0.75 mm. to 1.5 mm. in length. Although the spinelets themselves are spaced and slender, owing to the thick skin which invests them and the surface of the plate, they appear to be rather crowded. In alcoholic specimens the spinelets are thick, pulpy, subconical or slenderly ovoid, and touch one another. The sheath is rather thick also on the basal portion of the primary spines.

The median radial series of plates is prominent, as is also the superomarginal series, and each bears a slender tapering sharp erect spine, about 3.5 or 4 mm. long, articulated to a prominent elevation of the plate. The superomarginals clearly mark the boundary between the sloping abactinal and the rounded lateral faces of the ray. Below the bristling superomarginal spines there are at the base of ray four (further along three, and finally two) longiseries of slender, subequal, bristling, sharp spines which also form transverse series. As on the disk, the general surface is beset with spaced, very delicate, almost capillary spinelets, about 1 mm. long, which in life are sheathed with pulpy membrane that makes them appear robust, papilliform, and fairly crowded on their own plate. Pedicellariae (0.75 to 1.50 mm.) occur rather commonly near the papular areas, or actinally on the membrane of the area, more abundantly on the abactinal than on the lateral surfaces. There are about two zones of them between the midradial and superomarginal angles, while on the sides of the ray they occur between the rows of spines.

There are two dorsolateral, one intermarginal, and at base of ray 3 (further along 2, 1, and 0) actinolateral series of papular areas. In the dorsolateral areas there are usually three or four papulae (two or three on the outer part of ray); in the intermarginal areas, three or two proximally, and in the actinolateral areas generally one, but sometimes two on the proximal part of ray.

The carinal plates usually have two prominent rounded lobes laterally (sometimes one) which overlap the smaller, very irregularly lobed adradial plates. These, as shown in Plate 13, Figure 3, are a bit smaller than the mostly four-lobed superomarginal plates. The lobes of the latter do not touch those of the carinal plates. The adradials do not bear a primary central spine (and are not visible in alcoholic specimens) but have an irregular group of upwards of 10 secondary spinelets. The other plates are four-lobed, and as the furrow is approached the plates are narrowed, and the transverse lobes are gradually shortened. In a specimen from station 4423 to 10 carinal plates at the base of ray (measuring 28 mm.) there are 15 to 17 adradial plates and 13 superomarginals.

The adambulacral armature partakes of the bristling character of the general body armature. The prominent plates have a rather slighter keel or ridge into the furrow than usual. This bears a single vertical series of 4 slender terete tapering sharp spines plus one much smaller spinule at the outer end. Spine one (directed into or across furrow) carries a subterminal or terminal cluster of two to five small pedicellariae, or sometimes one fairly large and one or more small ones. Number two is a trifle larger; spines three and four are successively longer, four attaining 3.5 mm. at base of ray in some cases; or spine three may be the longest. The alternating nonprominent plates have a small spinelet on the furrow margin near the adoral border, and on the median transverse line of plate, a spine about equal to (or a bit longer than) spine four of the prominent plates, and standing almost exactly in line with it. Outside of this is a slender spinelet similar to that of the prominent plates and in line with it.

Ambulacral furrow narrow; tube-feet rather crowded, at base of ray arranged in two zigzag (or four) series, but in two series on outer half of ray. Tube-feet rather slender, with a small sucking disk.

Mouth plates very short, pretty well hidden on account of the upward bend of the base of arms which carries the furrow dorsad. There are two sharp slender suboral spines and two spines at the narrow mouth of the furrow. One extends about halfway across and bears several pedicellariae; another much shorter, also bearing one or two small pedicellariae, extends over the actinostome.

Madreporic body, 2.75 mm. in diameter, is convex, and its center is 7 mm. from the center of disk.

Anatomical notes.—The single stomach occupies the entire disk and sends a short rounded lobe into each ray. From the dorsal surface of this diverticulum (which is as broad as the inside of the ray) two hepatic coeca arise close together and extend three-fourths the length of ray. From the sides of the central tube branch off, in regular pinnate fashion, numerous small lobulated saccules, the whole gland being narrow to conform to the tenuity of the coelom. The inner surface of the stomach is very finely wrinkled and the walls are thrown into shallow folds. No dorsal stomach. Into the tiny intestine empties a conspicuous coecum, consisting in the specimen examined of two slender branches, one 15 mm. long, the other 3 mm. The large branch, tubular in form, lies on the dorsal part of one ray. The gonads are two to each ray, and open upon the side of the ray about 4 mm. from the interradial angle. The gonads consist of a single axis from which depart numerous lobulated branches. Interbrachial septum very small, rudimentary, membranous. Ampullae single, but distal end expanded, and if not inflated would appear to be somewhat fan-shaped. No Polian vesicles. No trace of superambulacral plates.

Young.—The smallest specimen, from station 4400, has R 10 mm., and r 2.25 mm. It would be impossible to identify this correctly if it were unaccompanied by adults. The rays are already very slender, about 2 mm. in diameter at the base. There are present the carinal series, the beginning of the adradial series, the supero and infero marginal series, but no actinolateral plates. Except for the adradials, these and the large disk plates bear a relatively long central sharp spine, stoutest on the carinal series, and a few delicate spinelets. There are a very few relatively large pedicellariae, which, like the spines, are larger in proportion to the size of the plates than in the adult. There is one papula to each area. The adambulacral plates do not show any differentiations, there being a transverse series of three very delicate, long, sharp spines. Tube-feet in two series. The mouth plates are relatively large, not sunken, and separate entirely the first adambulacral plates of adjacent rays. (In the adult three pairs of adjacent adambulacral plates meet by their outer ends on the interradial line back of the mouth plates.) Like the adambulacrals, the mouth plates have a single series of three sharp spines, that at the inner end of the plates being quite small. The terminal plate is relatively prominent and bears six prominent sharp spines, four horizontally directed (two from end, and one on each side) and two on the ventral surface. From above the proximal end of the plate is notched or emarginate for about half its length. The distal end is rounded. This tiny star is decidedly phanerozoniate in appearance and has not become a *Zoroaster*. At this particular immature stage it does not belong to any known genus.

There are a number of half grown specimens with R 65 mm., which closely resemble the adult but have only two series of actinolateral plates.

Type.—Cat. No. 22347, U.S.N.M.

Type-locality.—Station 4400, 32° 50′ 20″ N., 118° 03′ 30″ W. (between San Diego and San Clemente Island), 500 to 507 fathoms, green mud; bottom temperature, 40.2 F.

Distribution.—The typical form is found off southern California, from San Diego to Santa Cruz Island, in 216 to 510 fathoms; including the following race, *mordax*, the species ranges to Washington and to 603 fathoms off southern California and 760 off Washington.

Specimens examined.—Forty-two.

Specimens of Zoroaster evermanni examined

Station	Locality	Depth	Nature of bottom	Bottom temperature	Number of species	Collection
2936	Off southern California, 32° 49′ N., 117° 27′ 30″ W	359	Mud	49	3	U.S.N.M.
2937	Off southern California, 33° 04′ 30″ N., 117° 42″ W	464	Green mud	46.5	7	Do.
4317	11 miles southwest of Point Loma, San Diego	161–510	Green mud, fine sand		1	Albatross, 1904.
4400	Between San Diego and San Clemente Island	500–507	Green mud	40.2	5	Do.
4423	Between Santa Barbara and San Nicholas Island	539–216	Gray sand, black pebbles, shells.		7	Do.
4427	Off Santa Cruz Island	447–510	Black mud, rocks		19	Do.

ZOROASTER EVERMANNI MORDAX Fisher

Plate 13, Figure 4; Plate 14, Figure 2; Plate 19, Figure 2

Zoroaster evermanni mordax FISHER, Ann. and Mag. Nat. Hist., ser. 9, vol. 3, 1919, p. 391,

Diagnosis.—Closely resembling *Z. evermanni* but differing in having more robust primary spines (which are typically also a little shorter actinolaterally), and in having on the second from inner spine of prominent adambulacral plates a large pedicellaria (or sometimes two), from 1.5 to 2.5 mm. long, and conspicuously bigger than the cluster of small pedicellariae on the furrow spine. R, 153 mm.; r, 10+ mm. R = 15 r.

Description.—This race is so closely similar to the type race in most respects that a description is superfluous. In a very large specimen from the type-locality the skeleton is more open, the papular areas being larger. There are 20 or 21 adradial plates and 15 superomarginal plates to 10 carinal plates. A very few adradials bear a major spine proximally, but this can not be considered a reliable character. Rather, I think, it is due to age.

The prominent adambulacral plates have a transverse series of four or five spines shorter than in typical *evermanni*. On the furrow spine is a prominent cluster of four to eight small unequal pedicellariae (sometimes one or two enlarged); spine two is short and carries on the side a large pedicellaria resembling a miniature ibis head, the jaws being generally curved at the tip. The nonprominent plates carry a small furrow spine and a larger actinal spine, with sometimes a third smaller spinule external to the latter.

Type.—Cat. No. 37040, U.S.N.M.

Type-locality.—Station 3073, off Washington, 47° 28′ N., 125° 15′ W.; 477 fathoms, green mud; bottom temperature, 49.2° (?) 5 specimens.

Distribution.—From off Washington to southern California, 239 to 760 fathoms; in south only in over 600 fathoms.

Specimens examined.—Station 3069, off Washington, 47° 25′ 30″ N., 125° 42′ W.; green mud, 760 fathoms; bottom temperature, 37.6° F.; one specimen.

Station 3349, off northern California 38° 57′ 45″ N., 124° 03′ 05″ W.; 239 fathoms, black sand; bottom temperature, 44.1° F.; one specimen.

Station 2980, off southern California, 33° 49′ 45″ N., 119° 24′ 30″ W.; 603 fathoms, green mud; bottom temperature, 38.9° F.; 33 specimens.

No locality, 11 specimens (label lost during earthquake, 1906).

Remarks.—Although the differences which separate this race are not great, they are constant as regards the pedicellariae; the spines fluctuate a little and the distinction is not very evident except on direct comparison. In the southern California examples the spines are scarcely heavier than in the typical form from shallower water, but the pedicellariae are very well developed.

It is interesting that this race, or at least the differences which characterize the race, are found in specimens from 603 fathoms off Anacapa Island, southern California, bottom temperature 38.9°. It is probable that the high bottom temperature of 49.2° recorded for station 3073 is a misprint or a mistake; it is more likely between 38° and 39°, judging from records of neighboring stations.

Genus MYXODERMA Fisher

Myxoderma Fisher, subgenus, Bull. Bur. Fisheries, 1904, vol. 24, June 10, 1905, p. 316. Type, *Zoroaster* (*Myxoderma*) *sacculatus* Fisher; Ann. and Mag. Nat. Hist., ser. 9, vol. 3, 1919, pp. 389, 391 (genus).—Clark, Mem. Mus. Comp. Zoöl., vol. 39, no. 3, 1920, p. 99.

Diagnosis.—Zoroasteridae resembling *Zoroaster* more closely than any other genus, yet differing in having a more open abactinal skeleton with relatively smaller carinal plates and smaller, usually trilobate, irregularly oriented adradial plates bounding good-sized papular areas often irregular in contour; differing absolutely in the possession of well-developed superambulacral ossicles, and especially in the development of the first superambulacral ossicle into a heavy buttress or bridge, uniting the enlarged upper end of the first ambulacral ossicle with the body wall at the interradius; gonads two to each ray and attached to side of the ray close to interbrachial angle; ampullae single, with a very rudimentary second lobe; ambulacral furrow wide proximally; tube-feet four-ranked; three actinolateral series of plates below inferomarginals.

Remarks.—Originally I included *Zoroaster evermanni* in the subgenus *Myxoderma*. A further study of more extensive material, as well as the subsequent description of a new species, *Zoroaster platyacanthus* H. L. Clark, has provided additional means of testing the naturalness of this group. I have greatly emended the original description by the addition of the features which sharply demark *Myxoderma* from *Zoroaster*, namely, the possession of superambulacral plates, and the specialization of the first superambulacral ossicle into a sort of flying buttress between the enlarged upper end of the first pair of ambulacral ossicles and the body wall. This forms in effect an inner accessory actinostomial ring and is not found at all in true *Zoroaster*.

Zoroaster evermanni does not possess these specialized stays, nor other superambulacral plates, and its adradial plates are more nearly like those of *Zoroaster* than those of *Myxoderma*.

M. platyacanthum is a very distinct form and the membrane is not so thick and pulpy as in *sacculatum*, nor is there evidence that it was slimy in life. The name *Myxoderma* is therefore in part a misnomer, although highly descriptive of the type species, *sacculatum*.

KEY TO THE KNOWN SPECIES AND SUBSPECIES OF MYXODERMA

a^1. Size large (R, 200 mm.), the plates and spines invested in a thick pulpy membrane, slimy in life; abactinal papular areas large, the dorsal skeleton being open and rather irregularly reticulate at base of ray; abactinal plates without accessory spinelets to any extent; actinolateral spines pointed, tapered, sometimes somewhat flattened but never spatulate; terminal plate large, ovoid, especially conspicuous in young specimens; rays alternate distally.

b^1. Rays thicker and skeleton stouter; third or lowest series of actinolateral plates extending five-eighths the length of the ray; abactinal spines robust and stubby; abactinal pedicellariae smaller and less numerous. Bering Sea to central California..*sacculatum* Fisher.

b^2. Rays longer and slenderer, the third or lowest actinolateral series of plates extending along only the proximal third of ray; spines rather slenderer, and abactinal pedicellariae larger and more numerous. California south of Point Conception..............*ectenes* Fisher.

a^2. Size medium, the plates and spines not especially sacculate or slimy—about as in *Zoroaster;* abactinal papular areas with one or two papulae which do not occupy all the area; adradial plates small, more or less overlapped by the carinals and superomarginals; abactinal plates with numerous accessory miliary spinelets; actinolateral spines broad, flat, and more or less truncate; terminal plate small; rays not alternate distally.

b^1. Rays slenderer and longer, disk smaller; plates, especially the carinal and marginal, not broader than long; superomarginals not noticeably prominent; spines slenderer; pedicellariae larger. Southern California (south of Point Conception) and Lower California...*platyacanthum* (Clark).

b^2. Rays broader and shorter, disk slightly larger; plates, especially the carinal and marginal, broader than long; superomarginals noticeably prominent, at least distally; spines more robust; pedicellariae shorter. Oregon to Central California...........*rhomaleum* Fisher

MYXODERMA SACCULATUM Fisher

Plate 14, Figure 5; Plate 15, Figures 1, 1*a*–1*c*; Plate 20, Figure 2; Plate 21, Figures 2, 3; Plate 22, Figures 2, 3; Plate 25, Figure 4

Zoroaster (*Myxoderma*) *sacculatus* Fisher, Bull. Bureau Fisheries, 1904, vol. 24, June 10, 1905, p. 316.

Zoroaster evermanni Clark (not Fisher), Bull. Amer. Mus. Nat. Hist., vol. 32, art. 8, July 9, 1913, p. 198.

Myxoderma sacculatum Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 3, 1919, p. 392.—Clark, Mem. Mus. Comp. Zoöl., vol. 39, No. 3, p. 99; Bull. Amer. Mus. Nat. Hist., art. 6, 1923, p. 152.

Diagnosis.—Rays five. R 200 mm., r 17 mm., R = 11.7 r; breadth of ray at base, 22 mm. Disk convex, fairly high; rays subcylindrical, stout but slender, the base being slightly inflated, tapering thence evenly to an attenuate extremity capped by a swollen conspicuous terminal plate; rays not carinate except on outer portion, the dorsal surface proximally being evenly arched. Abactinal skeleton very open, with large papular areas containing several papulae; all plates with a short stout spine (on disk upwards of eight) which increases in size on the ventrolateral region; abactinal plates without miliary spinelets, which are numerous on side of ray; pedicellariae fairly numerous on abactinal surface, not particularly conspicuous. Membranous investment of spines, spinelets, and plates, thick and saccular in life, and extremely slimy. In dried specimens it is rather insignificant.

Description.—On the disk and proximal third of the rays the abactinal skeleton is open and reticulate and unlike that of *Zoroaster*. The plates have usually four prominent lobes on the rays by which they articulate with neighboring plates, leaving extensive subquadrate papular areas; but on the sides and ventrolateral regions of the ray the plates are more compactly placed and the papular areas are consequently smaller.

The disk of large specimens is evenly convex and higher than the rays. The principal plates are a cycle of five large six and seven lobed primary radial plates, farthest from center; a cycle of six-lobed primary basal or interradial plates, not quite so far. These 10 plates form a pentagon of which the radials are the corners. There is a good-sized stellate central plate, and connecting it with the radial plate, a smaller four-lobed plate whose lateral processes imbricate with the basal plate. These five plates plus the five basals make up a pentagon (usually interrupted or incomplete) within the first pentagon, the basals being the corners. The papular areas of disk are larger than those of the ray and are three and four sided. A circle of typically five immediately surrounding the central plate are the largest (7 to 10 papulae) and are somewhat broadly lozenge-shaped or kite-shaped. Outside of these are typically 10 smaller triangular meshes with five or six papulae. Outside of these a cycle of 10 triangular meshes (with five to eight papulae), a trifle larger than the foregoing cycle of 10.

The carinal series of plates is fairly regular; the plates are usually four-lobed, rarely six-lobed, and are a trifle larger than the superomarginals, which are also four-lobed. Between the carinal and superomarginal series is a very irregular series of much smaller three and four lobed plates which imbricate with the processes of the carinal and superomarginal plates either directly or by means of a small intermediate ossicle. The characteristic large, irregular papular areas of the proximal abactinal surface result from these irregular adradial plates. The superomarginal series is perfectly regular and proximally the cruciform plates are a little wider than long. Below these is a regular series of subequal inferomarginal plates with slightly broader lobes. Then follow, at the base of ray, three actinolateral series, which are soon reduced to two and finally to one on outer part of ray, these forming regular transverse series with the marginals. The plates imbricate more and more as they near the furrow (especially in small examples) so that the papular areas are reduced in size, those below the inferomarginals (three series in big specimens) being smaller than adjacent plates. In very large specimens a fourth series of rudimentary actinolateral plates is sometimes present for a very short distance at the very base of ray. On the outer portion of ray the extreme open character of the abactinal skeleton is largely lost, the adradial plates becoming more regular as the ray increases in tenuity. (For details of skeleton, see pl. 15, fig. 1*a*.)

The primary plates of the disk bear upward of six or eight short, stout, subconical usually pointed spinules about 2 to 2.5 mm. long, and a very few smaller spinelets are to be found on the abactinal surface. All the plates of the ray bear a prominent central or subcentral, stout, tapered spine, about 2 to 2.5 mm. long on the carinal plates, a little less on the adradial, 2 to 2.5 mm. on the superomarginal, about 3.5 mm. on the inferomarginal, and 5 to 6.5 mm. on the actinolateral plates. The carinal spines are generally blunt, and an accessory spinule is sometimes present. The adradial and marginal spines are a little sharper, while the actinolateral spines are quite sharp and acicular. The general surface of the abactinal plates is beset with scattered small granules and granuliform spinelets (invisible until specimen is dried) but on the superomarginal plates spinelets begin to appear, which increase in number and in length toward the furrow, attaining a length of 2 mm. on the actinolateral plates. They are very slender, terete, and delicate. The whole surface of the plates, granules, spines, and spinelets is covered and incased by a fleshy rather jellylike membrane which is decidedly slimy in life. Especially on the spinelets is the sheath conspicuous. Each spinelet has a thick clavate, saccular sheath with a rounded tip, entirely obscuring the slender spinelet within. On account of the size of this pulpy sheath the actinolateral spinelets appear to be closely crowded. The primary spines are also similarly invested but the sheath is not proportionally so thick; they appear heavy, and on the actinolateral plates, flattened. This membrane shrinks rapidly with drying and in dried specimens almost disappears abactinally.

Fair-sized pedicellariae (1.5 to 1.75 mm. long) are numerous on the abactinal surface, but decrease greatly in numbers on the actinolateral plates. They are found on the borders of the papular areas, usually at least one, sometimes two or three to an area.

Papulae numerous, vermiform, large, usually longer than the spines. There are four or five, proximally in each of the abactinal areas (four series), finally diminishing in number to one on outer part of ray. On the sides of the ray, in the four series, there are one or two papulae. Distally there are but three lateral series of papulae, then two, then one and finally at the tip, none.

The terminal plate is very prominent, cordate, with a deep sulcus on the proximal side, and it is broader than the terminal, attenuate portion of the ray immediately adjacent to it. It measures 4.5 mm. to 5.5 mm. long by 3.5 mm. to 4 mm. broad in fully grown specimens.

The prominent adambulacral plates have a conspicuous furrow keel. Their armature is as follows: (1) On the tip of the furrow projection is a short terete spine, often curved a little furrowwards at the end, which bears a large pedicellaria (2 mm.), with curved jaws, and two or three smaller companions. The latter are sometimes absent. (2) Following this is a transverse series of three or four slightly curved, tapered pointed spines, which diminish in size as they proceed outward. The inner two are subequal, 2.5 to 3 mm. long, tapered and pointed; the outer two are about the size of the spinelets of the adjacent plates. Adorad to them is a transverse series of two similar spinelets. The alternating nonprominent plates have a small spinelet on the margin bearing a pedicellaria or sometimes two or three, and on the actinal surface four spines in two transverse series, about equal to the smaller spines of the prominent plates. The actinal spines and spinelets are sheathed by the characteristic pulpy membrane which, owing to pressure, may form a rather prominent flange along either side of the spine which takes on a blunt, lanceolate, squamiform appearance.

Ambulacral furrow broad; tube-feet crowded, four-ranked, except on the outermost attenuate portion of the ray.

Mouth plates small but brisingoid in shape—that is, with the actinostomial margin broadened fanwise—and bearing two short marginal spines, loaded with pedicellariae. Suboral spines two, tapering, bluntly pointed, in a longitudinal series.

Madreporic body small, convex, situated near entrance to interbrachial sulcus 12 mm. from center. Anal aperture considerably to one side of center.

Color in life, buffy "salmon" pink.

Anatomical notes.—Specimen from station 4517. The stomach is a depressed subspherical sac filling the coelom of the disk but not extending into the rays. There is no separate dorsal stomach, nor even a fold of the wall to indicate a dorsal division of the cavity. The hepatic coeca are rather thick and extend about one-third the length of the ray; their lateral branches have very numerous, crowded, short irregular lobules. The two coeca open independently side by side into each radial area of the stomach. Sometimes the first branch of each coecum opens independently, just dorsad to the main tube, into the stomach. The hepatic coeca and the gonads completely fill up the proximal third of the coelom of the ray. From the middle of the dorsal side of the stomach departs the extremely short intestine into which open two digitiform coeca (one forked) about 10 mm. long. These two really unite into a common base before joining the intestine. The dorsal wall of the stomach is thrown into folds, which from the inside consist of radiating, ramified grooves separated by thickened glandular spaces; from the outside these grooves are raised, and the glandular parts depressed. Gonads massive, branched, two to each way. The gonoduct is attached to the wall close to the outer end of the first enlarged superambulacral buttress (see below) and on a level with the upper border of the inferomarginal plates.

Interbrachial septum narrow, thin, and membranous; the attached outer interbrachial border is in the angle formed by two buttresses (which join the conspicuous knob-like proximal end of the ambulacral ridge to the interbrachial angle of the body wall). These buttresses (pl. 14, fig. 5) are really very much enlarged superambulacral ossicles, are compressed, and each consists of usually two large and several small pieces closely united. In each interradius a pair of these stays forms an acute angle inclosing the interbrachial septum, and (on either side of the base of the latter) a tube-foot (two in all). The superambulacral ossicles are conspicuous on the proximal part of the ray and are usually in pairs to each (lowest) actinolateral plate (one to each ambulacral plate). No Polian vesicles; Tiedmann's bodies small, spaced; ampullae single; when deflated they have a long terminally curved division toward the ambulacral ridge, and a short outer incipient lobe. Tube-feet large with a very small button or disk.

Young.—The smallest specimen of the northern race measures R 58 mm., r 9 mm., R = 6.4 r; breadth of ray at the base, 11 mm. The abactinal and marginal spines are from 2 to 3.5 mm. long and hence relatively more conspicuous than in large specimens. The abactinal papular areas contain one or two papulae; the adradial spines are relatively small; pedicellariæ of abactinal surface few and small; the third actinolateral series of plates just starting at the base of ray; the first does not reach the end of ray by 10 mm., and the second series stops nearly 20 mm. short of the end. The terminal plate is very swollen and conspicuous. The large pedicellaria on the furrow spine is conspicuous.

Variations.—Of two large specimens from station 4775, Bering Sea, one measures as follows: R 160 mm.; r 17 mm.; R = 9.4 + r; breadth of ray at base, 20 mm. The other measures R 147 mm.; r 15 mm.; R = 9.1 r; breadth of ray at base, 21 mm. In this example the base of ray is much more swollen than in the other. In both the the ray is shorter than in typical examples from central California and the spines generally are shorter and stubbier. The proximal abactinal papular areas contain only two or three vermiform papulae instead of the typical four or five of big Californian examples. These northern examples show an accentuation of the differences which separate the Monterey Bay and northern California examples from the southern race I have called *ectenes*. If typical *ectenes* is compared with the Bering Sea specimens, the difference is very striking.

Type.—Cat. No. 22346, U.S.N.M.

Type-locality.—Station 4517, 9 miles off Point Pinos, Monterey Bay, Calif.; 766 to 750 fathoms, green mud and sand; five specimens.

Distribution.—Bowers Bank, Bering Sea, and off central California, undoubtedly intergrading with the southern form from off southern California. Bathymetric range from about 550 to 766 fathoms.

Specimens examined.—Ten from the following localities:

Station 3670, off Monterey Bay; 581 fathoms, green mud and sand; bottom temperature, 57.8° F.; two specimens.

Station 4517, 9 miles off Point Pinos, Monterey Bay; 766 to 750 fathoms, green mud, sand; two specimens.

Station 4540, 11.2 miles northwest Point Pinos, Monterey Bay; 551 to 389 fathoms, green mud; one specimen.

Station 4565, off Farallone Islands, San Francisco entrance; 587 to 495 fathoms, blue and green mud; three specimens.

Station 4775, Bowers Bank, Bering Sea (54° 33′ 30″ W., 178° 44′ E.); 584 fathoms, green mud, black specks, foraminifera; two specimens.

Recorded by H. L. Clark from Monterey Bay region, 475 to 659 fathoms, 37.9° to 39.9° F.

Remarks.—The stomach of one specimen contained a shrimp.

MYXODERMA SACCULATUM ECTENES Fisher

Plate 14, Figures 4, 4*a*, 4*b*; Plate 21, Figure 1; Plate 22, Figure 1; Plate 25, Figures 5–12

Myxoderma sacculatum ectenes FISHER, Ann. and Mag. Nat. Hist., ser. 9, vol. 3, 1919, p. 392.
Zoroaster evermanni part, CLARK (not Fisher), Bull. Amer. Mus. Nat. Hist., vol. 32, art. 8, July 9, 1913, p. 198.

Diagnosis.—Differing from typical *M. sacculatum* in having slenderer and longer rays; the third or lowest actinolateral series of plates is present on only a small proximal portion (about a third) of each ray; abactinal spines rather slenderer generally; abactinal pedicellariae larger and more numerous. R 210 mm.; r 16 mm.; R = 13 r; breadth of ray at base, 19 mm.

Description.—The differences between this southern race and the northern typical form are analogous to those existing between the two subspecies of *Myxoderma* *platyacanthum*. The most evident distinctions are the slenderer rays and more delicate structure generally of the southern form. The third or lowermost row of actinolateral plates, even in the very long rayed type-specimen, extend only a third the length of the ray, and fully half of these plates are inconspicuous, being very largely covered by plates of the second row. In a comparable specimen of *sacculatum* from the type-locality which has been cleaned and dried the third series extends five-eighths the length of the ray or about twice as far as in *ectenes*, and there is a very rudimentary fourth series, also, for a short distance beyond the interbrachial angle. The abactinal skeleton is much less rigid in very large specimens (but in medium-sized examples the difference is negligible), the adradial plates being smaller and more loosely articulated with the relatively slightly smaller superomarginal and carinal plates. The adradial papular areas contain proximally two to four papulae, mostly the higher number. The abactinal pedicellariae are conspicuous, 2 to 2.75 mm. long, and are sometimes longer than the conical spinules, which are relatively to their length much thicker than in medium-sized examples. In the latter the pedicellariae are much thicker than the spinules, and these are in turn much slenderer than in medium-sized examples of true *sacculatum*. In other words, the spine differences are more marked in smaller specimens. In the type the lateral spines are decidedly flattened and the longest are about 5 to 6 mm. They do not occur on every plate, certain plates being skipped (as in *sacculatum*). The spines have a thick sheath. On the abactinal surface the spines, pedicellariae, and papulae are so nearly of the same length that the surface seems to be covered with nearly uniform close-set papillae.

The pedicellaria on the furrow spine reaches a length of 3 mm., has unequal jaws, the ends being bent so as to greatly resemble a miniature bird's head with an unusually large ibis-like beak.

Young.—There is a very complete series of young mostly from station 4425, ranging from R 11 mm. (Pl. 25, figs. 5–12.) The most conspicuous feature is the relatively huge terminal plate, of a rather broadly oval contour, deeply notched adcentrally, and bearing on the ambitus eight radiating sharp relatively long spines (usually broken). This plate is 3 mm. long (R 11 mm.) or one-third the length of ray measured on the side, and 2.25 mm. in diameter; the longest terminal spine is about 2 mm. Relative to length of ray, the marginal and carinal spines are much longer than in the adult, and relatively large pedicellariae are already numerous. There is one actinolateral series of plates. The adradial plates are largely covered by the two adjacent series. The adambulacral plates are not yet differentiated into two sorts, and they carry a transverse comb of four or five relatively long spinules, the series alongside of the furrow reminding one of the subambulacral combs of *Solaster*. Tube-feet in two series and with relatively much larger disks than in adults.

In a specimen with R only 18 mm., differentiation of adambulacral plates is progressing, and relatively large pedicellariae have appeared on the furrow spines. A second series of actinolaterals is present and the numerous abactinal pedicellariae are relatively very large.

An example of the size of R 80 mm. is notable for its numerous large pedicellariae, relatively much slenderer spines than in typical *sacculatum*, and for already having papular areas big enough to contain three papulae, proximally. There are three series of actinolateral plates proximally.

Type.—Cat. No. E. 1417, U.S.N.M.

Type-locality.—Station 5694, southwest of Santa Cruz Island, Calif., 640 fathoms.

Distribution.—Off southern California, from the vicinity of Santa Cruz Island to Los Coronados Islands, and from about 500 to 1,100 fathoms; bottom temperature, 38° to 38.9° F.

Specimens examined.—Seventy-two.

Specimens of Myxoderma sacculatum ectenes examined

Station	Locality	Depth	Nature of bottom	Bottom temperature	Number of specimens	Collection
2919	Off San Diego, Calif.	984	Gray mud	38°	1	U.S.N.M.
2923	do	822	Green mud	39°	7	Do.
2929	do	623	do		1	Do.
2980	Southeast of Santa Cruz Island	603	do	38.9°	1	Do.
4380	Off Los Coronados Island	530–618	Green mud, gray sand		1	Albatross, 1904
4425	Between Santa Barbara and San Nicholas Island	1,100–1,084	Green mud, fine sand, globogerina.		53	Do.
4427	Off Santa Cruz Island	447–510	Black mud		1	Do.
4428	do	764–981	Green mud		5	Do.
5694	Southwest of Santa Cruz Island	640			1	Albatross, 1911.
5695	do	534		38.9°	1	Do.

Remarks.—A species which is related to this form is *Myxoderma longispinum* (Ludwig),[16] the type of which was dredged at station 3435, Gulf of California, 859 fathoms, brown mud, bottom temperature, 37.3° F. Other specimens were taken east of the Galapagos Islands and from the Gulf of Panama, 782 to 1,322 fathoms. The largest specimen examined by Ludwig had R 29 mm.

I have before me a specimen from the type-locality with R equal to 28 mm. I have also examined the type. All the specimens are, of course, very immature and no new species should have been founded upon such young material. I have examined the cotype for the superambulacral plates and find them present, the first large superambulacral buttress being well developed.

M. longispinum is not at all the same species as *M. sacculatum ectenes.* I have compared specimens side by side and the following differences are readily detected: *longispinum* has still slenderer rays (see Ludwig, pl. 14) capped by a much smaller terminal plate which has a deeper adcentral notch and is about half as broad and a fourth shorter than that of *ectenes.* The abactinal pedicellariae are few and less than half as large as those of *ectenes,* while the median radial plates are more carinate and their spines fully twice as long as the carinal spines of *ectenes.* The furrow pedicellaria is smaller than in *ectenes.* The narrowness of the outer half of ray is expecially noticeable.

[16] *Zoroaster longispinus* Ludwig, Mem. Mus. Comp. Zoöl., vol. 32, July 17, 1905, p. 180, pl. 14, figs. 71-74; pl. 29, figs. 169-170.

The young of *M. platyacanthum* of comparable size have much thicker rays, shorter spines, numerous abactinal miliary spinelets, broader furrows, and four-ranked tube-feet.

MYXODERMA PLATYACANTHUM (H. L. Clark)

Plate 15, Figure 3; Plate 16, Figures 2, 2*a*; Plate 23, Figure 2; Plate 24, Figure 1; Plate 25, Figures 1, 2

Zoroaster platyacanthus H. L. Clark, Bull. Amer. Mus. Nat. Hist., vol. 32, art. 8, July 9, 1913, p. 199, pl. 44, figs. 1 and 2.

Myxoderma platyacanthum Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 3, 1919, p. 392.—Clark, Mem. Mus. Comp. Zoöl., vol. 39, No. 3, 1920, p. 99; Bull. Amer. Mus. Nat. Hist., vol. 48, art. 6, 1923, p. 152.

Diagnosis.—Rays five. R 96 mm.; r 10.5 mm.; R = 9 r; breadth of ray at base, 12 mm. (Specimen from station 4321; the type measures R 67 mm.; r 9.5 mm.; r = 7 r.) Disk small, usually flat-topped or slightly sunken in middle; rays convex, without a carinal ridge, so that the dorsum has a somewhat flattened appearance; rays slender, nearly parallel-sided to near the end which is not attenuate; abactinal spines and spinelets sharp, rough, bristling, rather short; actinolateral spines bristling, broad, and flat; especially characterized by open skeleton, large papular areas, small adradial plates, flattened actinolateral spines, an adradial series of primary spines, broad furrows, four-ranked tube-feet throughout, and superambulacral plates.

Description.—Primary plates of disk not especially conspicuous, stellate, the skeleton coarse with relatively large meshes containing one or two large papulae which do not occupy all the area. Spines, spinelets, and pedicellariae as on rays.

Dorsal surface of ray not carinate, nor are the median radial series of spines different from the others. Carinal plates with four or six lobes, and only a little larger than the four-lobed marginal plates. There are three series of four-lobed actinolateral plates, the lowermost plates being much longer than wide owing to a shortening of the transverse processes. Between the carinal and superomarginal plates is a series of mostly three-lobed (sometimes only two-lobed) adradial plates, which are very inconspicuous in all but the largest specimens (where they bear primary spines) owing to encroachment of the adjacent series. These plates extend to the end of the ray but distally are quite small, rather irregular, and pretty completely hidden by the lobes of neighboring plates. The whole skeleton is very open-meshed for a member of this family, and resembles that of a *Pedicellaster*. (For details of skeleton, see pl. 16, fig. 2*a*.)

There are two series of papular areas between the carinal and superomarginal plates, and four lateral series, each with a large, swollen papula (or rarely two), which does not occupy the whole area.

In fully grown specimens each carinal, marginal, actinolateral, and a variable number of *adradial* plates carries a central stout, tough spine. Those on the carinal, adradial, and marginal plates are conical, usually sharp, and about 2 mm. long in the largest specimen. The spines of the upper actinolateral series are a little longer than the inferomarginal, usually slightly flattened toward the tip, which is broader and blunter than that of the marginal spines. The second row has the longest spines (3 to 4 mm.). These are much flattened and widened, truncate, or lanceolate-subacute, often broadly grooved, and incipiently bifid in extreme cases. The lowest actinolateral spines are a little shorter, somewhat slenderer, but are often grooved. There is considerable variation in the shape of these actinolateral spines but the essential feature is that they are flattened, broadened, and when fully developed, spatulate. The spines and spinelets are borne on unusually prominent bosses or condyles, which are more prominent than in any member of this family. Each plate carries a number of spaced, slender, often basally curved, sharp, miliary spinelets 0.5 to 0.75 mm. long. These are rough, sometimes more or less flattened at the tip, and are sheathed in life by a soft, not very thick skin which also covers the plates and bases of the large spines.. Proximally the carinal plates carry 10 or 12 of these spinelets; an adradial plate 3 or 4; a superomarginal plate about 7 or 8; the actinolateral plates, about 6.

Pedicellariae numerous but not especially conspicuous. They are longer than the spinelets but shorter than the spines, have round-tipped, subspatulate jaws, or sometimes slenderer ones, and are variable as to numbers but stand on the edge of the plates so as to be close to the papulae; each papular area has one or two of them as a rule. For exact form see Plate 15, Figure 3.

Ambulacral furrow wide; tube-feet four ranked the entire length of furrow. Ambulacral pores in four distinct alternating series. Adambulacral plates short separated by muscular spaces about as long as the surface of plates. Prominent plates with a transverse series of four or five, rarely six, slender spines of which the first is well in the furrow and bears a terminal cluster of a few small pedicellariae or one large one. The second and third are usually increasingly longer, reaching a length of 3.5 mm. at base of ray; the fourth and fifth are short spinelets; sometimes the fourth is about half to three-fourths the length of three. On the nonprominent plates of the type are two or three spines. In a large specimen from station 4321 there are four and sometimes five, the outer two or three being spinelets; the second is about the same size as the third spine of prominent plates, while the furrow spine is shorter and often carries a fair-sized pedicellaria. "In the interradial angles are a very few pedicellariae larger than elsewhere, and these may be 2 mm. long. Oral plates short (as usual in *Zoroaster*) each with two marginal and two suboral spines, 1 to 2 mm. long; the distal marginal spine carries a cluster of three or four small pedicellariae." (Clark.)

Madreporic plate subcircular, convex, about 2 mm. in diameter and situated about halfway between center of disk and margin.

Color of alcoholic material brown and brownish yellow; small specimens from stations 4432 and 4433 were bleached vermilion when first received; later this color disappeared entirely. In life they were probably bright red (which in the deep sea is equivalent to no color).

Anatomical notes.—This species has well-developed superambulacral plates. As six fully grown examples of the northern race are available, notes on the soft anatomy will be found below under *Myxoderma platyacanthum rhomaleum.*

Young.—The smallest example (station 2960) has R 5.5 mm. and relatively long slender spines. The adambulacral plates are as yet undifferentiated. A specimen with R 20 mm. has the differentiation of the adambulacral plates well started, but the actinolateral spines are still slender. An example from station 3201 with R 14 mm., when compared with a specimen with R 15 mm. from station 3112, and of the northern race, is notable for its slenderer rays and relatively smaller disk, characteristics of the adults. Both have a complete series of adradial plates.

Specimens with R between 40 and 50 mm. are very numerous, while those with R over 50 are rare. These small examples are sexually mature; in fact, fairly well-developed gonads were found in a specimen only 22 mm. major radius.

These smaller specimens differ from the largest chiefly in having relatively shorter rays, an incomplete third actinolateral series of plates, usually few adradial spines (or sometimes none), fewer miliary spinelets (but not always), less extremely flattened actinolateral spines, and two or three spinelets on the nonprominent adambulacral plates. The ambulacral pores and feet are in four series and the pedicellariae are generally fairly numerous and in size relatively as large as in the big specimens.

Type.—Cat. No. 31640, U.S.N.M.

Type-locality.—Station 5675, southwest of San Cristobal Bay, west coast of Lower California; 284 fathoms; bottom temperature, 44.6° F.

Distribution.—From Point Conception, Calif., to San Cristobal Bay, Lower California, in 205 to 287 fathoms, green mud.

Specimens examined.—Seven hundred and fifty-one.

Specimens of Myxoderma platyacanthum examined

Station	Locality	Depth	Nature of bottom	Bottom temperature	Number of specimens	Collection
2909	Santa Barbara Channel, 34° 22′ N., 120° 08′ 30″ W	205	Green mud	45.2	118	U.S.N.M.
2960	Santa Barbara Channel, 34° 10′ 45″ N., 120° 16′ 45″ W	267	do	48	158	Do.
3200	Santa Barbara Channel	265	do	43.1	46	Do.
3201	do	280	do	42.9	141	Do.
[1]4321	Off San Diego, Calif.	206	Dark green mud	58	2	Albatross, 1904
4432	Off Santa Rosa Island	272	Green mud		134	Do.
4433	do	265–243	do		12	Do.
4435	Off San Miguel Island	287–274	do		22	Do.
4436	do	271–264	do		8	Do.
	No locality				65	U. S. N. M.
[2]2891	Off Point Conception	233	Mud	45.1	45	Do.

[1] Adult specimens; all the others are either small or medium-sized examples.
[2] Some specimens intermediate with *rhomaleum.*

MYXODERMA PLATYACANTHUM RHOMALEUM Fisher

Plate 14, Figures 3, 3*a*; Plate 15, Figure 2; Plate 16, Figure 1; Plate 23, Figure 1; Plate 24, Figure 2; Plate 25, Figure 3

Myxoderma platyacanthum rhomaleum FISHER, Ann. and Mag. Nat. Hist., ser. 9, vol. 3, 1919, p. 393.

Diagnosis.—Differing from *M. platyacanthum* in having constantly broader and slightly shorter rays, slightly larger disk, much heavier abactinal and marginal spines, slightly shorter and decidedly heavier actinolateral spines, and shorter abactinal pedicellariae. R 100 mm.; r 12.5 mm.; R = 8 r; breadth of ray at base, 13 mm.; at a little beyond base, 15.5 mm. Disk elevated, dome shaped; rays very gradually tapered, but not attenuate distally.

Description.—The features which characterize this northern race are more readily appreciated from a comparison of figures. The difference in the width of the ray, for instance, is not great but it is constant even for small specimens and gives the animal a stockier, more robust appearance. In the example of *platyacanthum* from station 4321 having R 96 mm., a carinal spine at the base of the ray is a trifle over 2 mm. long and 0.5 mm. in diameter at the base. A similar spine in *rhomaleum* measures about the same length (1.75 to 2.2 mm.) and is 0.65 to 0.75 mm. in diameter, and is a bit swollen and thick up to the blunt tip instead of being regularly tapered and sharp. In the southern form the abactinal pedicellariae are 1 to 1.50 mm. in length and very appreciably longer than the miliary spinelets; in the northern race they are shorter than or subequal to the spinelets and 0.6 to 0.8 mm. long. The membranous investment of the spinelets is a little thicker than in the southern form but it is rather too slight to be tangible.

The specimens from off Pigeon Point, north of Monterey Bay, while less extreme in the racial characters than the specimens from the type locality, belong to the northern form. I think there can be scarcely a doubt that the two races intergrade between Santa Barbara Channel and Monterey Bay.

In large well-developed specimens the internal intermarginal ossicles are sometimes visible from the exterior. These are oblong ossicles which bind together adjacent transverse lobes of the supero and infero marginal plates. They are present also for a short distance between the inferomarginals and first actinolateral series.

Young.—As noted before, the difference in robustness can be distinguished in small specimens. In an example of the southern form with R 15 mm., r is 2.5 mm., and the breadth of the ray at base, 2. 75 mm. In a specimen of the northern form with R 14 mm., r is 3 mm., or 20 per cent greater, and the breadth of the ray at base is 3.5 mm., or a little over 20 per cent greater, allowing for error in measurement. In the case of specimens of the average size, say with R above 30 mm. and under 50 mm., the differences can be readily seen on comparison of specimens. An example from station 2960 (southern form) has more delicate spines generally than are present on an equal-sized example from 3112. (There are no small examples from Oregon.) The difference in width of ray is slight, but is less in the southern example if R is equal.

Anatomical notes.—The stomach fills the disk and is single-chambered, there being short lobes extending into the base of each ray. Through the dorsal surface of these lobes empty two hepatic coeca which extend far along the ray. The intestinal coecum is a trilobate, rather irregular sac, about 20 mm. long, proximally narrow, distally expanded. The gonads form a multilobed mass opening on a level with the inferomarginal plates 2 mm. from the interradial line.

The prominent knob-like upper end of the first pair of ambulacral plates is connected with the interradial angle by a heavy calcareous buttress or bridge which is really the very much enlarged first superambulacral ossicle. (Pl. 14, figs. 3, 3*a*.) Between the outer ends of these ossicles, which are compressed and rather thick dorsoventrally, there extends centrally the narrow membranous interradial septum, with a long dorsoventral free edge impinging upon the stomach. In the angle formed by the superambulacral buttress (the apex of which is at the interbrachial line) there is a slight depression bisected by the interradial septum, on either side of which there is an ampulla. Viewed from above, the buttresses plus the enlarged ambulacral knobs form a raised pentagonal frame for the subcircular actinostome. The ambulacral ridge is permanently bent upward at the base, which causes the actinostome from the outside to appear sunken. Ampullae really single, somewhat triangular in form when inflated; when deflated there appears to be an indication of an incipient external lobe; no Polian vesicles; two Tiedemann organs. The superambulacral ossicles are slender and one to each ambulacral plate; two or three consecutive plates converge to attach themselves to the lower ends of the second series of actinolateral plates.

Type.—Cat. No. 37041, U.S.N.M.

Type-locality.—Station 2890, off Oregon (43° 46′ N., 124° 57′ W.); 277 fathoms, gray sand; bottom temperature, 42.2° F.; six specimens.

Distribution.—Known from off Oregon and central California; 277 to 296 fathoms, gray sand; 41.8° to 42.2° F.

Specimens examined.—One hundred sixty-eight, in addition to six from type-locality.

Station 3112, off Pigeon Point, north of Monterey Bay, Calif. (37° 08′ N., 122° 47′W.); 296 fathoms, fine gray sand; bottom temperature, 41.8° F.; 179 specimens.

Station 3145, off San Luis Obispo County, Calif., 35° 14′ N., 121° 07′ W.; 252 fathoms, green mud; bottom temperature, 43.2° F., nine specimens; bottle broken during earthquake, 1906; locality reasonably certain; specimens not typical, intermediate with *platyacanthum*.

Family ASTERIIDAE Gray, emended

Asteriidae Gray, Ann. Mag. Nat. Hist., vol. 6, 1840, p. 178.

A polyphyletic aggregation of genera, some probably very ancient, which have been placed for convenience under the aegis of *Asterias*. They have the common characteristic of not belonging in the other families of Asteriadina. (See synopsis, p. 4.)

SYNOPSIS OF THE SUBFAMILIES OF ASTERIIDAE

a^1. No marked adoral carina, the first pair of postoral adambulacral plates separated interradially (or in contact only along the adoral part of the interradial margin) in combination with inferomarginals having never more than one prominent spine. Rays five or six; skeleton an open network composed of mostly small cruciform or trilobate plates; spinelets small; crossed pedicellariae scattered, never in circlets about spinelets; straight pedicellariae present; no adambulacral spine pedicellariae; tube-feet biserial or quadriserial on proximal part of ray---------- *Pedicellasterinae* Fisher.

a^2. An adoral carina; i. e., at least one, but usually several, pairs of postoral adambulacral plates in contact by their interradial margins; tube-feet quadriserial at least proximally.

b^1. Adambulacral spines without attached pedicellariae, singly or in clusters, although these may occur on the oral spines.

c^1. Primary apical plates conspicuously enlarged; abactinal and marginal plates subhexagonal, closely imbricated in seven regular longiseries (resembling *Zoroaster*), sparsely granulated; actinal plates with short spinelets---------- *Neomorphasterinae* Fisher.

c^2. Primary apical plates not conspicuously enlarged; rays not resembling those of *Zoroaster*.

d^1. Rays numerous, long, slender, in combination with only one inferomarginal spine (on each plate) carrying a prominent wreath of crossed pedicellariae. No actinal plates; abactinal skeleton either very open with large squarish meshes or else abortive with scattered independent plates; crossed pedicellariae in abactinal spinal wreaths or thick ruffs---------- *Labidiasterinae* Verrill.

d^2. Rays five to many; in combination with two inferomarginal spines, heavily sheathed, and an abortive abactinal skeleton and no actinal plates; abactinal spines bearing prominent wreaths of crossed pedicellariae------------------*Pycnopodiinae* Verrill.

d^3. Rays five to many; with a well-developed abactinal skeleton, two sheathed inferomarginal spines and one series of actinal plates. Carinals, marginals, actinals and often dorsolaterals in definite longiseries; abactinal, marginal, and actinal spines (when present) prominent, spaced, styliform or acicular, normally one to a plate except inferomarginals), wreathed with pedicellariae and often in evident longiseries--------------------------------------*Coscinasteriinae* Fisher.

d^4. Rays five, in connection with peculiar macrocephalous crossed pedicellariae and abactinal spines lacking (or with only rudimentary) wreaths of pedicellariae; carinal and marginal plates prominent with prominent spine (inferomarginals in one case with two); actinal plates wanting or in one series. Arctic and Antarctic. *Notasteriinae* Fisher.

$b.^2$ Adambulacral spines carry pedicellariae singly or in clusters, or are entirely without attached pedicellariae; abactinal spines not as a rule prominent, styliform, or acicular and more or less spaced and isolated, but short, slender to stout, conical, tubercular-subglobose, variously granuliform, sharp to capitate, single or in groups; abactinal plates in more or less definite longiseries or irregularly reticulate, sometimes abortive; actinal area sometimes broad, with upwards of five longiseries of plates, sometimes without any actinal plates; gonads opening dorsally, laterally, or ventrally--*Asteriinae.*

Subfamily Pedicellasterinae Fisher

Pedicellasterinae Fisher, Ann. Mag. Nat. Hist., ser 9, vol. 2, 1918, p. 108; vol. 12, 1923, p. 249.

Asteriidae without an adoral carina (the first pair of postoral adambulacral plates separated interradially by a muscular symphysis or in contact only along the adoral part of interradial margin); skeleton an open network composed mostly of small cruciform or trilobate plates, the dorsolaterals in irregular, the carinal and marginal plates in regular longiseries; abactinal spinelets small, generally one to a plate; never more than one prominent inferomarginal spine; crossed pedicellariae scattered, never in circlets about spinelets; straight pedicellariae present; no adambulacral spine pedicellariae; rays five or six.

Key to the known genera of Pedicellasterinae

a^1. Inferomarginal spines *not* conspicuously larger than the superomarginals, nor forming a prominent longiseries external to the adambulacral spines; the latter are the longest on ray, in transverse combs of two to five; no quartet of enlarged or especially strong plates in each interbrachium; tube-feet biserial; first postoral pair of adambulacral plates widely separated interradially.

b^1. Actinal plates present. Crossed pedicellariae with one or more enlarged teeth on the distal portion of the jaw.

c^1. Straight pedicellariae not unusually large, nor spatulate-unguiculate; gonads opening ventrally; actinal plates of large specimens in closely imbricated transverse series, the number of plates per series (in some species) increasing on middle third of ray instead of decreasing; *crossed pedicellariae of two sorts*, the larger with slenderer jaws and four large claw-like terminal teeth and one to four conspicuous teeth on the shank, below the terminal; the smaller (abactinal) pedicellariae have numerous small terminal teeth, none conspicuously enlarged---*Pedicellaster* Sars.

c^2. With very large spatulate-unguiculate straight pedicellariae; gonads opening dorsally; actinal plates in two simple longiseries; crossed pedicellariae, not obviously of two different sorts, have one or two enlarged lateral terminal teeth and numerous small ones. *Peranaster* Fisher.

b^2. Actinal plates present; crossed pedicellariae with the numerous terminal teeth uniformly tiny; gonads opening ventrally; actinal plates in one or two longiseries; prominent unguiculate straight pedicellariae in some species--------------------*Anteliaster* Fisher.

b^3. Actinal plates absent, the inferomarginals juxtaposed to the adambulacrals; inferomarginal spinelets small; crossed pedicellariae all of one kind, small, with numerous small uniform terminal teeth; gonads opening on extreme edge of abactinal area---*Hydrasterias* Sladen.

a^2. External to the adambulacral spines is a longitudinal series of prominent inferomarginal spines conspicuously larger than the superomarginals (which are subequal to the abactinal spinelets); no actinal plates; a quartet of strong interbrachial marginal plates; first pair of postoral adambulacral plates narrowly separated or touching by the adoral corners.

b^1. Straight pedicellariae not unguiculate nor broadly spatulate; an accessory inferomarginal spinelet above the major spine (at least proximally); adambulacral plates diplacanthid or diplacanthid and monacanthid; interbrachial marginals not much enlarged; superomarginals regularly four-lobed (not warped or irregular, nor three-lobed)--*Tarsaster* Sladen.

b^2. Straight pedicellariae unguiculate, often also strongly spatulate; no accessory inferomarginal spinelet or tubercle; adambulacral plates predominantly monacanthid (a few plates may be diplacanthid); two enlarged interbrachial superomarginals overlap two corresponding, sometimes enlarged inferomarginals; superomarginals often three-lobed or irregularly four-lobed (proximal plates generally fairly regular)------------------*Ampheraster* Fisher.

Genus PEDICELLASTER Sars

Pedicellaster Sars, Översigt af Norges Echinodermer, Christinania, 1861, p. 77. Type *P. typicus* Sars.—Fisher, 1923, p. 251.

Diagnosis.—Crossed pedicellariae of two kinds: larger, with slender jaws having usually four curved prominent terminal teeth, and below these on the slender shank, one to five slender thornlike teeth; the smaller pedicellariae of the usual Asteriid type; actinal plates well developed, in transverse series, the number of plates in series in the adults of some species increasing toward the middle third of ray and decreasing in the distal third; young specimens with one or two longitudinal series; skeleton of the quadrate-mesh type, often delicate, of ✚-and Y-form plates, the intervals medium sized to large; dorsolateral skeleton irregular; spinelets small, the inferomarginal not conspicuously larger than the rest; the first postoral pair of adambulacral plates widely separated interradially; furrow narrow, tube-feet biserial; gonads normally opening laterally at a slight distance from disk.

Remarks.—The characteristic structure of the actinal skeleton is not attained until specimens have reached some size. It is, however, fundamentally different from that in large examples of *Anteliaster*, where the actinal plates are in one or two simple longiseries, the outer extending farther long the ray than the inner. Young *Pedicellaster* passes through this stage, and, so far as the actinal plates are concerned, is then not different from *Anteliaster*. Later, in *magister, megalabis, and orientalis*, additional plates are added more numerously in the middle third of the ray than at either the base or distal portion, and the arrangement in longiseries is consequently lost. The plates become closely imbricated in transverse series, and the transverse series tend to become less well connected with their neighbors.

Young examples of *Pedicellaster* may be recognized by the presence of two sorts of crossed pedicellariae, of which the larger, ventral, sort have slenderer jaws with only four terminal teeth. None of the other nearly related genera have this type of pedicellaria, the terminal teeth in all cases being uniformly small and the jaws relatively shorter and stouter.

Koehler, 1920 (p. 109), gives a list of the nominal forms of *Pedicellaster*:

antarcticus Ludwig.
atratus Alcock.
formatus Koehler.
hypernotius Sladen.
hyperoncus Clark (*Ampheraster*).
improvisus Ludwig (*Hydrasterias*).
octoradiatus Studer.
palaeocrystallus Duncan and Sladen.
parvulus Perrier.
pourtalesii Perrier.
reticulatus H. L. Clark.
sarsi Studer.
scaber Smith.
sexradiatus Perrier (*Hydrasterias*).
typicus Sars.

Of these *antarcticus*, *formatus*, possibly *hypernotius*, *pourtalesii*, and *typicus* (including *palaeocrystallus*) are true *Pedicellaster*. I have examined specimens of *P. pourtalesii*, loaned by Dr. H. L. Clark. They are too small to show the characteristic actinal structure, but the larger pedicellariae are of the characteristic fanged type. *Atratus* is possibly a true *Pedicellaster*. Alcock mentions large pedicellariae which is a characteristic of *Pedicellaster* as contrasted with *Anteliaster* or *Hydrasterias*. He also says that there are 14 longitudinal rows of plates (probably either 13 or 15) which seems to indicate about three series of actinals. *P. octoradiatus* Studer is probably not a *Pedicellaster*. *P. parvulus* is a young *Sclerasterias*, judging by one of Perrier's specimens which I have examined.

PEDICELLASTER MAGISTER Fisher

Plate 16, Figure 3; Plate 26, Figures 2, 2*a*–2*f*; Plate 27, Figures 2, 2*a*–2*d*; 6, 6*a*, 6*b*; Plate 28, Figures 1, 1*a*–1*b*; Plate 33; Plate 34, Figure 1; Plate 36, Figure 2

Pedicellaster magister Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 251.

Diagnosis.—Differing from *typicus* in regularly attaining a relatively gigantic size, with extensive dorsolateral region and a conspicuous actinal area crossed by transverse series of imbricating, four-lobed plates which increase in number for each series toward the middle third of the ray, and decrease slowly in the final third; in having differently formed, slenderer-jawed, major crossed pedicellariae, as well as differently shaped minor ones. Type, R 85 mm.; r 12 mm.; R = 7 r; breadth of ray at base, 13 mm. Paratype, station 4792, R 70 mm.; r 11 mm.; R = 6.4 r. Breadth of ray at base, 14 mm. Rays slender, flexible, slightly inflated above base, very gradually tapered to a bluntly pointed extremity.

Description.—The following description applies particularly to the full-grown large specimens from stations 3223, 3224, 3257, 3258, 3675, 4786, 4791, 4792: In alcoholic specimens the rays are flexible and the body wall rather thin. The arrangement of the plates is not at all visible, since the entire surface is thickly covered with small uniform spinelets 0.5 to 0.6 mm. long, their true size augmented somewhat by a pulpy sheath. Between the spinelets are numerous pedicellariae, shorter than the spinelets, appearing as smaller pulpy papillae, while interspersed among these are the papulae—numerous in the aggregate, but only a few to each area. No spinelets are conspicuous by superior size until the double row along the furrow margin is reached. Along the sides and actinal surface of the ray the larger of the two sorts of pedicellariae are very numerous, so closely placed as to touch one another by the investing sheaths.

In prepared specimens: The carinal marginal and actinal plates are regularly four-lobed. The carinals are distinguishable from the dorsolaterals mainly by reason of regularity, the latter (as seen in the figures) being irregularly arranged and not symmetrical in form. New plates are continually being added to the dorsolaterals. In very small specimens there is a single row. I have none small enough to demonstrate their absence. A specimen of true *typicus* with R only 8 mm. has a single series of three-lobed dorsolaterals. In big specimens the marginal plates are lateral and bend upward a little at the interbrachium. The superomarginals form a sharp line of demarcation between the irregular dorsolaterals and the regular transverse ranks of actinals-plus-marginals which are characteristic of very large specimens of this genus. The plates strongly overlap as shown in Plate 28, Figures 1, 1*a*, and 1*b*. There are 4 or 5 actinals in each transverse series at the base of the ray, increasing to 8 to 11 at about the middle, and then decreasing again near the tip. The actinal plates do not, therefore, stand in regular longitudinal series on account of this highly peculiar arrangement. The actinals are rather thin around the edges. In a great mass of small plates it is sometimes difficult to be sure of the marginal series, and it is essential to be certain. The superomarginals, in addition to standing at the upper end of the transverse rows, have both their transversely oriented lobes overlapping those of their neighbors.

The plates usually bear a single spinelet only, except the carinals and the larger dorsolaterals, which commonly carry two or three. Over the disk the spinelets are rather thickly placed, most of the larger plates having two or three, and I find some specimens in which the proximal superomarginals have one or two smaller accessory spinelets. The spinelets, averaging 0.45 to 0.6 mm. long, end in three to several sharp divergent points, except the smaller secondaries which may have but 1. (Pl. 27, figs. 6, 6*a*, 6*b*.)

The adambulacral spines, two to a plate in an oblique transverse row, form two regular series on the edge of the furrow. The inner spine is slender, slightly tapered and pointed; the outer is a little stouter and longer, sometimes slightly tapered and pointed, sometimes somewhat clavate and blunt. Occasionally there are three spines to a plate either in a regular transverse series, or two are rather obviously smaller, furrow, spines and the third a heavier subambulacral. The first pair of adambulacral plates do not meet in the interradial line back of the mouth plates. A very few small blunt ovate straight pedicellariae (0.25 to 0.27 mm. long and about 0.18 broad) occur here and there along the inside of the furrow.

The mouth plates, the form and armature of which are best appreciated from the figure, usually have a longitudinal series of four fairly long spines and at the inner end of the plate, one, two, or three smaller actinostomial teeth, with, occasionally, a tiny ovate straight pedicellaria, 0.25 mm. long.

The papulae, usually one to an area, are small and in alcoholic specimens rather hard to distinguish.

The crossed pedicellariae are of two sorts and are of definite diagnostic value. The larger kind (pl. 26. figs. 2, 2*a*–2*e*) are very abundant on the actinal and lateral surfaces, and sometimes in big examples (station 4792) on the dorsolateral regions also. In small specimens they are restricted to the lateral and actinal regions, the latter, of course, very narrow. The smaller sort are found on the abactinal surface very plentifully on the marginal plates, and sparingly on the actinal area. The larger kind have slenderer jaws with two pairs of prominent terminal teeth and on the inside of each jaw two, less often three, slender sharp thorns. The largest measured, from a huge specimen, was 0.6 mm. long, but this is exceptional; 0.45 to 0.55 mm. is the average largest on big specimens. Small examples have the same sort, only smaller—about 0.28 to 0.3 mm. in an example with R 12 mm. (See pl. 27, fig. 2*b*, magnified 200 times, twice that of the figures 2, 2*a*. Pl. 26, figs. 1, 1*a*, 1*b*, 1*c*, are from very small *typicus*, enlarged x200; 1*c* is abactinal.) The smaller pedicellariae (pl. 26, fig. 2*f*) are much shorter and relatively broader, with a broad, many-toothed terminal portion, similar to that of the usual type of small crossed pedicellaria.

Both kinds differ from the corresponding ones of true *typicus* (of which a specimen, probably from Norway, was loaned by Dr. H. L. Clark). Compare Plate 26, Figures 1–1*b*, showing the larger pedicellariae of *typicus* magnified 200 times, with Plate 27, Figure 2*b*, showing those of a small specimen of *magister* from station 4792, same enlargement. Figures 2 and 2*a* are enlarged only 100 times. The jaws of the pedicellariae from *typicus* are much heavier and have four to six median teeth. The smaller sort (pl. 26, fig. 1*c*), distinguishable by the many toothed terminal margin, is also different, having more numerous teeth on the cutting edge of the jaw, as well as a somewhat different form.

The straight pedicellariae are absent in some specimens; in others a very few tiny ovate ones, sometimes blunter than the figure, occur sporadically along the margin of furrow and at the base of the innermost oral spine—in the last position, always singly. (Length, 0.25 to 0.27 mm.)

Madreporic body inconspicuous, often irregular, one-third to one-fourth distance from margin to center.

Young specimens.—These have slender rays and the skeleton is characterized by a restriction of the dorsolateral plates to one or two series, while the actinals are in one or two longitudinal series (one series in a specimen with R 12 mm.). It is curious that these very small specimens do not show the arrangement in transverse series which is so characteristic of mature individuals. A specimen from station 4243 with R 28 mm. does not exhibit any multiplication of the distal actinal plates (one longiseries beyond middle of ray). However, another from station 4792, with R 30 mm., has four or five actinal plates in each transverse series and is constructed like one of the very large examples. One of the generic characters, therefore, is not found in very small specimens and may not appear until R is about 30 mm. In lieu of the actinal plates, the terminal claws of the crossed pedicellariae will suffice to distinguish young *Pedicellaster* from young *Anteliaster*.

It is noticeable that the plates of the young have stout lobes like those of the adult. The immature stage can be readily separated from those of *megalabis* on plate as well as pedicellarian characters.

The spinelets are relatively slenderer than in the big specimens with R 60 to 85 mm.; there is usually one to a plate, and the pedicellariae are less crowded.

Anatomical notes.—The gonads form each a bushy tuft of branched tubules and open 3 to 5 mm. from the interbrachial angle (R 70 mm.), on the side of the ray in a variable relation to the plates—sometimes between the inferomarginal and actinal plates, and in one case just above the superomarginal series.

The stomach is very spacious, filling the entire disk and reaching into the base of the rays. It has a single chamber, the hepatic coeca entering the dorsal part of each lobe. The intestinal coecum consists of two short thick lobes. The food is evidently ingested entire, as the stomach was full of small gasteropods. The ampullae are rather large, strictly simple, not bilobed, and the tube-feet are biserial. The radial nerve fold and circumoral pentagon are rather thick.

Type.—Cat. No. E, 1418, U.S.N.M.

Type-locality.—Station 4792, off Cape Monati, Bering Island; 72 fathoms, pebbles.

Distribution.—Southern Bering Sea, from the Commander Islands to Unimak, and north to 57°; south along the Alaskan coast to Kasaan Bay, Prince of Wales Island; 42 to 121 fathoms, on gravel, black and gray sand and green mud. Temperature range typically 37.3° to 39.8° (an exception station 4292).

Specimens examined.—Thirty-eight.

Specimens of Pedicellaster magister examined

Station	Locality	Depth	Nature of bottom	Bottom temperature	Number of specimen	Collection
3223	Between Unalaska and Unimak	56	Black pebbles	39	4	U. S. Nat. Mus.
3224	do	121	Black sand; gravel	38.7	1	Do.
3257	North of Unimak Island	81	Gray sand; gravel	39	1	Do.
3258	do	70	Black sand; gravel	39	1	Do.
3488	Bering Sea, 57° 05′ N., 173° 47′ W	106	Green mud; gray sand	37.3	1	Do.
3500	Bering Sea, 56° 02′ N., 169° 30′ W	121	Fine gray sand; gravel	38.6	4	Do.
3675	Off Karluk, Kadiak	110	Green mud	39	2	Do.
4243	Kasaan Bay, Prince of Wales Island, Alaska	42–47	do	49.1	1	Albatross, 1903.
4292	Shelikof Strait, Alaska	102–94	Mud; fine sand	39.8	1	Do.
4786	Off Medni, Commander Islands	54	Green sand		1	Albatross, 1906.
4791	Off Cape Monati, Bering Island	76	Rocky		3	Do.
4792	do	72	Pebbles		18	Do.

Remarks.—*Pedicellaster typicus*, from the northern part of the North Atlantic and adjacent Arctic Ocean seems to be rather further removed from *magister* than are either of the Pacific subspecies. It is a small form, the largest specimen recorded by Danielssen and Koren [17] being but 42 mm. in diameter, while most of their specimens ranged from 10 to 23 mm. in diameter. The type of *magister* is 170 mm., and many are over 100 mm. in diameter. According to Danielssen and Koren, true *typicus* is an Arctic form which extends southward on the European coast to Sognefjord, Norway. It is found on the Murman coast; at Nova Zembla, Spitzbergen, Jan Mayen; in Barents Sea; Kara Sea; on the west side of the Taimur Peninsula (the northeast border of the known range). On the American side it has been taken as far south as 42° (Verrill, 1895), and north through Davis Strait as far as Discovery Bay in Grinnell Land, 81° 41′ north latitude (Duncan and Sladen).

Verrill, 1914 (p. 203), has recorded a small example from Icy Cape, Alaska, well within the Arctic Ocean. This specimen (No. 6123, U.S.N.M., 10 to 15 fathoms, mud and sand, W. H. Dall, 1874) can not now be found. If it is true *typicus* (and not a young specimen of *magister*), the range is therefore circumpolar, and intergradation

[17] Asteroidea (Norwegian North Atlantic Expedition, 1876–1878), 1884, p. 38.

with *magister*, if it occurs at all, must take place between Icy Cape and southern Bering Sea.

After examination of the type of *typicus*, Danielssen and Koren call attention to the fact (1884, p. 37) that the original figures and description of the pedicellariae given by Sars are not quite correct. They state that in the type the pedicellariae are exactly like the figure given by Duncan and Sladen (1881, pl. 2, fig. 26).

I have carefully examined pedicellariae of a specimen of *typicus*, believed to have come from Norway, and find more numerous teeth on the shaft. The pedicellaria figured by Duncan and Sladen is not in all probability a typical ventral one, as the terminal teeth appear to be more like those of the dorsal pedicellariae, or of an intergrade between the two sorts.

Although *magister* has much the same appearance as *typicus* the characters offered by the very numerous major crossed pedicellariae are diagnostic, while the extraordinary development of the actinal plates, in transverse series, is not found in *typicus*, although undoubtedly latent there. As mentioned below, *typicus* may not be even closely related to *magister*.

The specimen from station 4243, Kasaan Bay, Prince of Wales Island, Alaska, belongs quite evidently to the Alaskan rather than to the southern race of the species. The major crossed pedicellariae are smaller than in *megalabis*, especially contrasting with the Washington example of the latter, which, however, is not precisely typical. The minor pedicellariae have the fewer proximal shank teeth of the northern form.

Some light is thrown upon the relationship of *magister* and *typicus* by two Antarctic species, *P. antarcticus* Ludwig and *P. formatus* Koehler, both of which appear to be more closely related to *magister* than is *typicus*.

P. formatus Koehler (1920, p. 106, pl. 16, figs. 1, 9, 10; pl. 17, figs. 6, 7; pl. 58, fig. 4) from latitude 66° 8′ S., longitude 94° 17′ E., 120 fathoms, has a robust skeleton and there are proximally four plates in each transverse actinal series; three further along the ray. R varies from 38 to 40 mm. The plates are stouter even than in *P. magister*, but the major crossed pedicellariae are closely similar in form although they are somewhat larger in size (averaging 0.6 mm.) There are one or two teeth below the terminal set of four. Koehler describes the straight pedicellariae (pl. 58, fig. 4*b*) as occuring in the ambulacral furrow. They are very rare in *magister*; occasionally a small one, very similar to those of *formatus*, is found on the oral plates, less often at wide intervals in the furrow. In fact they may be described as absent from the furrow, since their presence there is so rare as to have little significance.

P. antarcticus Ludwig (1903, p. 35, pl. 4, figs. 32–38) from between 70° and 73° south, and 82° and 87° west, 450 meters, has a skeleton which is much more delicate and is analogous to that of *megalabis*. The major crossed pedicellariae are smaller however (0.35 to 0.43 mm. high) and in form a little stouter than those of *megalabis* especially as regards the three or four median teeth. The size of the pedicellariae is nearer that of the major crossed pedicellariae of *orientalis*. The straight pedicellariae of *antarcticus* are 0.16 to 0.22 mm. long, those of *megalabis* more than twice that and of a different form.

The presence in the Antarctic seas of two species so similar to three North Pacific forms is of great interest, and is a bit of evidence in favor of the Antarctic origin of the cold water of intermediate depths of the North Pacific. In time we shall doubtless find a chain of closely related forms connecting *antarcticus* with *megalabis*, just as we are pretty certain that there is a continuous distribution of Pedicellasters from southern California to Japan. Clark [18] has stated the case for *Florometra*, where the greater number of species furnishes more striking evidence. I think it not unlikely that *P. typicus* is derived from a distinct line of forms via the South Atlantic and is not at all a small offshoot of *magister* as might at first sight seem probable. The major crossed pedicellariae, although keeping the characteristic generic form, are rather more different from those of *magister* than are the homologous pedicellariae of *formatus*. *Pedicellaster pourtalesii* Perrier is one of the forms of the Atlantic cycle.

The stomach of a specimen from station 4786 was full of gastropods, the largest 7 mm. in diameter.

PEDICELLASTER MAGISTER MEGALABIS, new subspecies

Plate 16, Figure 4; Plate 26, Figures 3, 3*a*–3*e*; Plate 27, Figures 4, 4*a*; Plate 28, Figure 2; Plate 34, Figures 2, 3

Diagnosis.—Differing from *Pedicellaster magister* in smaller size, decidedly more delicate plates, and more open skeleton; in the larger size of the crossed pedicellariae and in the presence of numerous much larger adambulacral straight pedicellariae proximally, as well as in the greater distance of the gonads from interbrachial angle. Type: R 43 mm., r 6 mm., $R=7+r$; breadth of ray at base, 6.5 mm. Rays slightly swollen above base, slender, gradually tapered to a bluntly pointed extremity; body wall weak; plates and spines invested by a thin membrane.

Description.—None of the specimens of this race are so large as the maximum of *magister*. The largest example from station 3347 has R 48 mm. and another from 4427 has R 40 mm. Alcoholic specimens can generally be recognized by the much larger meshes of the skeleton and the thinner membranes covering the plates, while if two equal sized specimens are placed side by side the actinal major pedicellariae of the southern form are seen to be much larger.

The skeleton is arranged as in the northern race but is much more delicate, as can be best seen from the figures. The difference is as well marked in young as in adults and is probably correlated with the greater depth of the habitat. The skeleton may be described as open and more loosely joined than in *magister*. The actinal plates form similar transverse series, a maximum of six plates occurring in the largest specimens. The plates bear a single, generally three-pronged spinelet, about 0.5 mm. long, and averaging a little slenderer than those of *magister*, as would be expected from the more delicate skeleton.

There are two very slender, tapered, sharp adambulacral spines in an oblique transverse row, the furrow spine a little aboral to the other and a trifle shorter and slenderer. On the furrow face of the proximal plates is a broadly lanceolate, small pointed straight pedicellaria (0.45 to 0.48 mm. long). The oral plates generally carry a row of three sometimes four slender spines, and on the surface of the plates one to three straight pedicellariae like those of the adambulacrals.

Papulae are one, occasionally two, to each skeletal mesh.

The crossed pedicellariae are of two kinds, both of which are very similar to those of the northern race yet differ in respect to size and details. The minor pedicellariae

[18] A. H. Clark. The Circulation of the Abyssal Waters of the Oceans, as indicated by the Geographical and Bathymetrical Distribution of Recent Crinoids. Bull. Inst. océanographique, No. 285, February, 1914.

are distinctly larger even in specimens half the size of the big examples of *magister*, and have five or six median teeth in the vertical row in place of the usual four of *magister*. These pedicellariae are about 0.3 to 0.35 mm. long. The larger sort are also distinctly bigger, ranging in length of jaw, in the largest specimens, from 0.55 to 0.65 mm., the latter from the largest specimen, R 50 mm. (station 3347). Comparable specimens of *magister* have the larger pedicellariae 0.37 0.45 If two approximately equal-sized specimens are placed side by side the conspicuously larger pedicellariae of the southern form can easily be seen with an ordinary glass. Specimens from the southern extremity of the known range frequently have three or four unpaired median teeth as against two or three in the Washington specimen, and two in most examples of *magister* (but sometimes three). The madreporic body is small and near the margin.

Anatomical notes.—The gonads, similar in form to those of *magister*, have slender branched lobes, and form a tuft which opens just under the inferomarginals at a conspicuous distance from the interbrachium—about 1.5 r, or about one-fifth of R. This is much farther out relatively than the opening in *magister*.

Young.—The young exhibit the same differences from the adult as characterize *magister*, namely, the reduction of the actinal and dorsolateral regions. The plates are consistently more delicate than in the young of *magister* (compare pl. 28, fig. 1*b* with pl. 28, fig. 2*a*); while the pedicellariae are larger.

Type.—Cat. No. E. 1419, U.S.N.M.

Type-locality.—Station 4335, off San Diego, Calif., 14 miles southwest Point Loma Light, 500 to 530 fathoms, green mud, fine sand; bottom temperature, 39.5° F.

Distribution.—From the vicinity of San Diego, Calif., to Washington (45° N. lat.) in 284 to 530 fathoms, green and yellow mud or black sand. Temperature range, 39.5° to 44.1° F.

Specimens examined.—Twenty-three.

Specimens of Pedicellaster magister megalabis examined

Station	Locality	Depth	Nature of bottom	Bottom temperature	Number of specimens	Collection
2892	Off southern California, 34° 15′ N., 120° 36′ W	284	Yellow mud	44.1	8	U.S.N.M.
2925	Off southern California, 32° 32′ 30″ N., 117° 24′ W	339	Mud	42.9	1	Do.
2928	Off southern California, 32° 47′ 30″ N., 118° 10′ W	417	Black sand, gravel	41	3	Do.
3347	Off Washington, 45° 09′ 35″ N., 124° 45′ W	345	Mud	40.9	2	Do.
4333	Off San Diego, Calif	301–487	Green mud	41.7	4	Albatross, 1904.
4334	do	525–541	Green mud, fine sand	40	1	Do.
4335	do	500–530	do	39.5	3	Do.
4351	do	423–488	Soft green mud		1	Do.

Remarks.—There are no specimens available between station 4243, the southernmost record of *magister*, and station 3347, off Washington, the northernmost for *megalabis*. Intergradation therefore has not been proved, but the southern form seems to be quite evidently a deep-water representative of *magister*.

It is noteworthy that while the major crossed pedicellariae of *megalabis* are larger than those of *magister*, the reverse is true of the race from the sea of Japan.

A specimen from station 4427 and another from station 4334 contain each a good sized parasitic *Dendrogaster*, probably *D. arbusculus* [19] as the general external form is the same as in the type of that species.

PEDICELLASTER MAGISTER ORIENTALIS, new subspecies

Plate 16, Figure 5; Plate 27, Figures 1, 1*a*–1*c*, 5; Plate 28, Figure 3; Plate 34, Figure 5

Diagnosis.—Similar in general appearance to *Pedicellaster magister* but differing in the following respects: Major crossed pedicellariae slightly smaller, with four or five teeth in the median vertical series, instead of two; small ovoid straight pedicellariae numerous on mouth plates; actinal plates fewer in each transverse series. Rays slender, subterete, slightly swollen proximally, very gradually tapered to a blunt point; disk small. R 52 mm., r 7 mm., R = 7.4 + r; breadth of ray at base, 7 or 8 mm.

Description.—In alcoholic specimens: The surface is covered by small, spaced, uniform, pulpy papillae—the spinelets—which are very inconspicuous, being 0.5 to 0.7 mm. long, interspersed with numerous sheathed pedicellariae that increase in number and size on the sides and actinal surface. The papulae are small and not easily distinguished. The surface of the rays has a soft, almost downy, appearance owing to the small size of the spinelets and pedicellariae, and is much the same as in alcoholic examples of *magister*. The furrow is bordered by a double row of pulpy spinelets.

The arrangement of the plates is essentially like that of *magister*, the dorsolaterals and carinals being, if anything, a trifle broader lobed, but this feature is undoubtedly variable. In a specimen with R 49 mm. there is a maximum of three actinal plates to a transverse series in the median third of the ray. An equal-sized specimen of *megalabis* has five or six plates to a series, and one of *magister* from station 4791 as many as 10. It is perhaps a matter of age, rather than size, and I do not know whether the smaller number in *orientalis* is constant. I think it probably is, as the ray is more attenuate than in *magister*.

In a dried specimen the abactinal spinelets, which are tipped by three to several rather divergent hyaline points, reveal themselves in lines or groups of two, three, four, and rarely five to a plate, the latter number occurring on the carinals. In the type, however, the plates carry generally only one or two. The superomarginals have one spine with sometimes one or rarely two smaller accessory spinelets, and the actinals carry a single small spinelet.

Adambulacral spines, two to a plate, similar to those of *magister*. The mouth plates carry four or five slender spines, in a longitudinal, curved series, increasing slightly in length from the inner to the outer. When there are five spines the two outer form a transverse series. The mouth plates carry rather numerous, small, straight pedicellariae, oval, blunt, and much smaller than in *megalabis*. (Compare pl. 16, figs. 4 and 5.)

The major crossed pedicellariae occur on the marginal and actinal plates very abundantly; the smaller sort, on the abactinal and superomarginal plates, but not on the actinal plates. The major variety are smaller on the average than in *magister*,

[19] Fisher, Bull. 76, U. S. Nat. Mus., 1911, p. 404, pl. 3, fig. 1.

the largest being 0.34 to 0.39 mm. long. But the main difference is in the structure and in the presence of more numerous teeth (four or five, less often six) in the vertical series of each jaw. Compare figures. The presence of numerous small oral straight pedicellariae (pl. 16, fig. 5) is a feature not found in *magister*, except sporadically in rather small specimens (station 3500) when only one or two are present.

Madreporic body very small, situated variably in the outer half of r.

The gonads, similar to those of *magister*, open just under the inferomarginals a little less than the length of r from the interbrachium.

Type.—Cat. No. E. 1420, U.S.N.M.

Type-locality.—Station 4867, off east coast of Korea, 36° 31′ N., 129° 46′ E.; 150 fathoms, green mud, fine gray sand; bottom temperature 33.4 F.; five specimens.

Distribution.—This race is probably found throughout the cold western part of the Sea of Japan.

Remarks.—This form is well marked on account of pedicellarian characters alone. The slighter development of the actinal areas may prove to be a fundamental difference. The skeleton, if anything, is closer knit than in *magister*. The lobes of the abactinal plates are broader and the spinelets have rather more numerous terminal points.

Genus PERANASTER Fisher

Peranaster Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 252. Type *Pedicellaster chirophorus* Fisher (Celebes).

Diagnosis.—Pedicellasterinae resembling *Pedicellaster* but differing in having spatulate unguiculate straight pedicellariae; only one sort of crossed pedicellariae; the gonads opening dorsally, and the actinal plates in normal longiseries (not reaching and of ray). Carinals, marginals, and actinals + form, monacanthid, in regular longiseries; dorsolaterals Y form in a zigzag longiseries; papular areas in two dorsolateral, one intermarginal, and two actinal series for each side; adambulacrals triplacanthid and diplacanthid (the spinelets longer than the marginals); oral plates relatively large with a longitudinal series of four or five spinelets; postoral pair of adambulacral plates separated interradially; tube-feet biserial; gonads opening dorsally.

Remarks.—This group resembles *Anteliaster* in having the actinal plates arranged in longiseries, and in the form of the straight pedicellariae; but differs in having the gonads opening dorsally at the margin of the abactinal area, and in the different form of the crossed pedicellariae. These have an enlarged tooth on one side of the expanded terminal portion of the jaw. They resemble some of the pedicellariae intermediate between the two types characteristic of *Pedicellaster*, s. s.

Hydrasterias has no actinal plates on the ray and the crossed pedicellariae are more nearly like those of *Anteliaster*.

The genus is known only from the type, taken at station 5656, Gulf of Boni, Celebes, 484 fathoms.

Genus HYDRASTERIAS Sladen

Plate 27, Figures 7, 8

Hydrasterias SLADEN (subgenus), Challenger Asteroidea, 1889, p. 581. Type *Asterias* (*Hydrasterias*) *ophidion* Sladen.—FISHER, 1923, p. 251.

Pedicellaster part PERRIER, Exp. Sci. Travailleur et Talisman, 1894, p. 100.—LUDWIG, Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 216.

Diagnosis.—Typical Pedicellasterinae differing from *Pedicellaster* in the entire absence of actinal plates and in having only one kind of crossed pedicellariae. Inferomarginal plates juxtaposed to adambulacral plates; inferomarginal spinelet not conspicuously larger than the superomarginal and abactinal spinelets which are small, slender, sharp, and isolated; carinal and superomarginal plates + form; inferomarginals same, but with ventral lobe more or less suppressed; dorsolateral skeleton somewhat irregular, as a rule, with two or three longiseries of large meshes, the plates either three or four lobed, and in well-grown specimens connected by slender, elliptical oblong secondary ossicles; first pair of postoral adambulacral plates entirely separated interradially; adambulacral spines two or three in a transverse series; crossed pedicellariae rather thickly scattered over papular areas and on plates but not on spines, all of one kind, without enlarged terminal teeth as in *Pedicellaster*; straight pedicellariae small and confined to adambulacral and mouth plates; or larger, blunt, spatulate denticulate ones may be present in axillary region; gonads[20] open on side of ray just above the superomarginals and hence on lower edge of the abactinal region.

Remarks.—*Hydrasterias* was first described by Sladen in 1889 as a subgenus of *Asterias*. Apparently its true relationship has not been suspected, because all species subsequently assigned to the group are in no way closely related. *Hydrasterias diomedeae* Ludwig[21] is the six-rayed fissiparous young stage of *Sclerasterias alexandri* His *Hydrasterias* species is a young stage of the same, or another *Sclerasterias*. *Hydrasterias richardi* Perrier,[22] the specimens of which are very small, is probably also a six-rayed stage of a five-rayed adult asteriid.

The history as shown by *Sclerasterias alexandri* and *S. euplecta* (Fisher) is briefly this: The young at first develop six rays. They divide into two halves of three rays each. Three new rays are regenerated. There is evidence that a second division may take place nearly at right angles to the first (since a resulting animal has one long and two short rays, while another in the same haul has two long and one short). After the last division, when the animal is still small, regeneration produces a five-rayed condition, which results in a symmetrical five-rayed adult.

This is a case of asexual reproduction inasmuch as one egg may give rise to a number of adults, as in *Aurelia*.

Hydrasterias verrilli Fisher[23] although superficially resembling *Hydrasterias ophidion* has four rows of tube-feet, a narrow oral angle, with several small pairs of postoral adambulacral plates in contact interradially, and apparently belongs in the Asteriinae. It is now the type of *Tarsastrocles* Fisher.

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[20] In *H. sexradiata* (Perrier) and *H. improvisa* (Ludwig) which I have examined, males in both cases.

[21] Mem. Mus. Comp. Zoöl., 1905, p. 242, pl. 34, fig. 204; pl. 35, fig. 206.

[22] Exp. Sci. Travailleur et Talesman, 1894, p. 109, pl. 9, fig. 4.

[23] Starfishes of the Hawaiian Islands, 1906, p. 1106, pl. 41, figs. 3, 3*a*, *b*.

I had already set aside *Pedicellaster sexradiatus* Perrier and *P. improvisus* Ludwig as a generic group quite distinct from *Pedicellaster*, when the similarity of the first species to *Hydrasterias ophidion* Sladen occurred to me. At my request Dr. R. Kirkpatrick, of the British Museum (to whom I have been indebted repeatedly for information concerning types then under his care), examined the oral region of the unique specimen of *Hydrasterias ophidion*, made excellent photographs and sent a small piece of the dorsolateral integument with numerous pedicellariae.

Doctor Kirkpatrick's observations and photographs prove, as I suspected, that the first pair of postoral adambulacral plates are widely separated as in *Pedicellaster*. Indeed the alliance of *Hydrasterias* with *Pedicellaster* might be inferred from Sladen's figure, showing clearly the biserial tube-feet and wide-meshed delicate skeleton. But it could not be satisfactorily established without knowledge of the structure of the oral angle.

The relationship of *Hydrasterias ophidion* to *H. sexradiata* remains to be worked out. They are probably races of the same species, or may be the same species. Specimens of *H. sexradiata* from latitude 37° north, longitude 27° west, 1,600 meters, however, have good sized spatulate, denticulate straight pedicellariae in the interradial region. The crossed pedicellariae of *sexradiata* are closely similar to those of *ophidion* which are figured herewith. (Pl. 27, fig. 8.)

Hydrasterias improvisa (Ludwig)[24] was dredged by the *Albatross* at stations 3362, 3400, and 3407, east of Cocos Island and near the Galapagos Islands, in 1,175, 1,322, and 885 fathoms. It is a five-rayed form with quite distinct crossed pedicellariae, which, however, are of the same type as those of *ophidion*. (Pl. 27, fig. 7.)

Clark's[25] record of *improvisa* from station 5675, 284 fathoms, southwest of San Cristobal Bay, Lower California, is based upon a specimen which is described in this work as *Anteliaster coscinactis megatretus*.

Genus ANTELIASTER Fisher

Anteliaster Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 252. Type *A. coscinactis* Fisher.

Diagnosis.—Differing from *Pedicellaster* in the arrangement of the actinal plates, which are in one to three normal longitudinal series (not in transverse series with more numerous plates to a series distally than proximally), and in lacking prominent terminal claws on the jaws of the crossed pedicellariae; adambulacral armature, a transverse comb of two to five slender spinelets, conspicuously longer than any of the others, except the oral spinelets (which form a longitudinal series on each plate); large, spatulate, sometimes unguiculate straight pedicellariae may be present. Gonads opening ventrally.

KEY TO KNOWN SPECIES OF ANTELIASTER

a^1. Abactinal papulae on rays; mouth plates larger.
  b^1. Large hand-shaped unguiculate, straight pedicellariae; skeleton with three dorsolateral and two actinal series of meshes; spinelets with numerous terminal thornlets---*coscinactis* Fisher.
  b^2. No straight pedicellariae; skeleton very open, with two dorsolateral and three actinal series of meshes; spinelets with three or four terminal thornlets------------------*megatretus* Fisher.

[24] Mem. Mus. Comp. Zoöl. vol. 32, 1905, p. 216.

[25] Bull. Amer. Mus. Nat. Hist., vol. 32, 1913, p. 202.

a^2. No abactinal papulae on rays; mouth plates smaller.

b^1. Adambulacral combs with proximally five spines; no straight pedicellariae. *microgenys* Fisher.

b^2. Adambulacral combs with two or three spines; spatulate oral straight pedicellariae. *nannodes* Fisher.

ANTELIASTER COSCINACTIS Fisher

Plate 29, Figures 1, 1*a*–1*e*; Plate 35, Figure 6; Plate 36, Figure 4; Plate 37, Figure 3

Anteliaster coscinactis Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 252.

Diagnosis.—Rays five, long, slender, flexible, very gradually tapered to a bluntly pointed extremity; disk small; body wall rather thin; spinelets very small, close-set alternating, on the rather large meshed skeleton, with small crossed pedicellariae; abactinal papular areas irregular (in equivalent of about three series); about three actinolateral series of regular, subquadrate meshes; two series of actinal plates; adambulacral spinelets longer than any of the others, proximally four or three, then two, in transverse series; large hand-shaped, unguiculate straight pedicellariae. R 63 mm.; r 9mm.; R=7r; breadth of ray at base, 7.5 to 10 mm.

Description.—The abactinal surface has somewhat the appearance of that of a deep-water *Henricia*, the pedicellariae and small spinelets standing in single file on the narrow, very irregular skeletal ridges. The meshes are large, not at all uniform in size, very irregular in form, and contain three to six papulae. The spinelets are quite delicate, 0.4 to 0.5 mm. long, while the interspersed crossed pedicellariae are 0.27 to 0.3 mm. long. Usually there is but one spinelet to a plate, but since the plates themselves are small, the spinelets stand less than their own length apart, with usually one or two pedicellariae between. The form of the spinelets is best appreciated from figures. Both the marginal and actinal spines and pedicellariae are a little larger than the abactinal, and the spines are tapered and pointed. In contrast to the abactinal, the lateral and actinal papular areas form three (or two in smaller specimens) regular longitudinal series, broken here and there by slight irregularity, like that of a clumsily mended net.

An analysis of the skeleton, of great importance for identification, reveals a very irregular carinal series of three, four, or even five lobed plates, joined by one to three intermediate ossicles. There are the equivalent of two dorsolateral series of + or Y shaped plates, joined by elliptical intermediate ossicles, forming the very irregular reticulum alluded to above. Then comes two series of +-shaped marginal plates, the inferomarginals the more regular of the two, and between these and the adambulacrals are two series of actinals, the inner not fully developed. Transverse, elliptical ossicles join the three outer of these four series as shown in the figure. The outer series of actinals continue to within 10 mm. of the end of ray, and the inner series, varying on different rays, to well beyond the middle.

The relatively long, slender, tapered, pointed adambulacral spines form a bristling cheveux-de-frise on the furrow margin. The spines stand in transverse combs, four on the first four or five plates, then three on the following six plates, then two for the remainder of the ray. Of these, the inner is a little shorter and slenderer than the outer, which is 2.5 to 3 mm. long. The second spine is slightly the longest, in the combs of three and four. The external end of the first adambulacral plate is rather widely separated from its vis-à-vis across the interradial angle. There are no small straight pedicellariae on the adambulacral plates, but occasionally a large spatulate unguiculate pedicellaria stands on the actinal surface of the proximal plates.

The mouth plates (pl. 29, fig. 1) have the usual form and carry a longitudinal series of five slender spines, of which the two inner (actinostomial) are the shortest; and the outermost (just external to middle of plate) is subequal to the longest adjacent subambulacral. A short sixth spinelet stands on the furrow margin in a transverse direction to the outermost suboral. There is no trace of small straight pedicellariae on the mouth plates, but in one mouth-angle each plate carries a large unguiculate spatulate pedicellaria.

The crossed pedicellariae are numerous and alternate with the spinelets on the skeletal net. Occasionally two stand between a pair of spinelets, and one to three are found on the membrane of most of the papular areas. They range in length from 0.27 to 0.4 mm., the largest being actinal, and are characterized by numerous teeth (about 10) on the vertical series of each jaw. (Pl. 29, figs. 1*c*, 1*d*.)

Straight pedicellariae: On the actinal plates near the interbrachial angle there is usually a single large spatulate pedicellaria with three or four long curved teeth. It resembles in miniature a pair of clasped hands and is 0.9 to 1 mm. long. Several of the same sort, but narrower and with sometimes only two teeth, stand on the proximal adambulacral plates or on the outer end of the oral plates. There are no small lanceolate straight pedicellariae. (Pl. 29, fig. 1*a*.)

Madreporic body fairly large, near margin.

Anatomical notes.—The gonads open in the interval between the inferomarginal and the actinal plates, about 6 mm. from the interbrachial angle. Each gonad consists of several small branched tufts, the lobules being irregular in form and unequal in length. The ampullae are rather large, not divided, and the tube-feet are in two series. A peculiarity of the species seems to be the entire absence of an interbrachial septum. There is no membrane nor continuation inward of the interbrachial skeleton. There is therefore a free space interradially between the interbrachial ridge and the inner border of the actinostome.

Type.—Cat. No. E. 1421, U.S.N.M.

Type-locality.—Station 4427, 7 miles southwest of Point San Pedro, Santa Cruz Island, Calif.: 447 to 510 fathoms, black mud, rocks; April 14, 1904.

Distribution.—Known only from the type-locality.

ANTELIASTER COSCINACTIS MEGATRETUS, new subspecies

Plate 29, Figures 2, 2*a*, 2*b*; Plate 35, Figures 5, 5*a*

Pedicellaster improvisus Clark, not Ludwig, Bull. Amer. Mus. Nat. Hist., vol. 32, 1913, p. 202.

Diagnosis.—Rays 5. R 77 mm. (longest ray); r 9 mm.; R = 8.5 + r; disk small; rays slender, weak, flexible. Differing from *A. coscinactis* in lacking straight pedicellariae, in having a more open skeleton with larger meshes (two dorsolateral series) slenderer plates, more delicate spinelets (with fewer terminal thornlets), and slenderer crossed pedicellariae.

Description.—The skeleton is more open than in *coscinactis*. Along the side of the ray there are four longiseries of large quadrilateral meshes which are normally regular, although on some rays the longitudinal trabeculae disappear so that two or more meshes merge in a transverse way forming a very wide interval, extending occasionally from the superomarginal to the adambulacral plates. Bounding the four longiseries of meshes there are two series of slender, four-lobed marginal and three of actinal plates. These plates are connected, in transverse series, by a slender intermediate ossicle between the superomarginal and inferomarginal plates, between the latter and the first actinals, and sometimes between the first and second actinals. Intermediate ossicles appear sporadically in the longitudinal series, but not regularly and they all tend to disappear on the outer part of ray. There is an irregular series of slender-lobed, +-form carinals, and between these and the similar superomarginal plates are two series of very large dorsolateral skeletal meshes, separated by an irregular series of largely three-lobed plates. (Owing to the condition of the type, it is not possible to ascertain the constancy of this arrangement for all the rays.) These dorsolateral plates are connected with the carinals and superomarginals by slender intermediate ossicles. The primary plates and most of the intermediate ossicles bear a very small spinelet (pl. 29, fig. 2*b*) with three or four terminal points, 0.4 to 0.5 mm. long. These are a little more delicate and have fewer terminal points than those of *coscinactis*. The skeleton differs from that of *coscinactis* in having larger meshes, with slenderer lobes to the plates; two rather than three dorsolateral series of meshes; proximally three series of actinal plates (and papular areas).

The dorsolateral and intermarginal papular areas have three to five papulae; the others, one or two.

First 8 or 10 adambulacral plates carry a transverse comb of three, rarely four, very slender spines, the other plates two, equal in length to about four consecutive plates. They are similar to those of *coscinactis* but are slenderer.

Each mouth plate carries five or six spines; one or two on the actinostomial end; a row of three or four in line with the larger actinostomial spine, reaches nearly to the outer end of the plate; sometimes there is a small spine as in *coscinactis*, on the margin and near middle of plate. The plates are not very different from those of *coscinactis*.

There are no straight pedicellariae. The crossed pedicellariae are more tapered than those of *coscinactis* as viewed in profile, the exact difference being best appreciated by comparison of figures. (Pl. 29, fig. 2, 2*a*.) The largest ventral pedicellariae measure 0.45 mm. long; the dorsal 0.27 to 0.32 mm.

Madreporic body very small, circular. Furrow narrow; tube-feet strictly biserial.

Type.—No. 32477, U.S.N.M.

Type-locality.—Station 5675, off San Pablo Point, Lower California (27° 07′ 08″ N., 114° 33′ 10″ W.); 284 fathoms, green mud, fine sand; bottom temperature, 44.6° F. (March 15, 1911).

Distribution.—Known only from type-locality.

Remarks.—The type specimen, recorded by Clark (1913, p. 202) as *Pedicellaster improvisus* Ludwig, is larger than the type of *coscinactis* and has conspicuously larger skeletal meshes. The superomarginals are much nearer to the carinals than to the adambulacral plates. On the ray that is best preserved and most regular there are large subquadrate meshes between the carinals and adambulacrals; four of these series are between the superomarginal and adambulacral plates. It is not possible, of course, to ascertain how constant the differential characters will prove to be.

Although this species resembles a large *Hydrasterias improvisa* (Ludwig), the latter lacks entirely the actinal plates which characterize even quite small *Anteliaster*. *Improvisa* has numerous small straight pedicellariae on the furrow face of the adambulacrals. These are not found in any of the known forms of *Anteliaster*.

ANTELIASTER MICROGENYS, new species

Plate 30, Figures 1, 1*a*–1*e*; Plate 35, Figure 3; Plate 36, Figure 1

Diagnosis.—Rays 5, rather short, strongly inflated at base, bluntly pointed, recurved; disk fairly large; abactinal skeleton irregular with two rows of meshes, the outer rather elongate transversely; superomarginal and inferomarginal plates well spaced, with slender connecting ossicles between the two series; one series of actinal plates, mouth plates small, with two actinostomial and four larger superficial spines; adambulacrals with proximally five, distally three spines in transverse comb. No straight pedicellariae. R 30 mm ±; r 7 mm.; R = 4.3 r; breadth of ray at base, 7 mm.; just beyond base, at widest part, 9 mm.

Description.—The abactinal surface might be described as of an indifferent *Pedicellaster* type, with the usual irregular skeleton, having, however, large transversely elongated meshes mostly devoid of papulae, except on disk. The spinelets, generally one to a plate, are a little thicker than usual, about 0.5 mm. long, somewhat tapered, and terminated by several points. (Pl. 30, fig. 1*a*.) Alternating with the spinelets, and occurring also on the membrane of the meshes, are numerous small pedicellariae about 0.3 mm. long. In alcohol, the spinelets and skeleton were covered by a thickish membrane. The sides of the rays are characterized by the regular, rather widely separated marginal series, each plate bearing a single tapered spinelet slightly larger than the abactinal spinelets, and in addition most of the long intermarginal ossicles of the proximal half of the ray carry also a small spinelet. A row of actinal spinelets, a trifle bigger than the inferomarginal spinelets, extends two-thirds to three-fourths the length of ray. Each intermarginal and actinal mesh (except near end of each series) has a papula.

An analysis of the skeleton shows an irregular carinal series of four-lobed plates; proximally two dorsolateral longiseries of alternately ⅄ and Y shaped plates joined in series by the arms. The handle is connected, respectively, to the carinals and supermarginals, usually by means of one or more slender ossicles. The superomarginals are joined to the corresponding inferomarginal by a slender, long ossicle, and the first few inferomarginals are similarly connected to the corresponding actinals by a short intermediate ossicle. (Pl. 30, fig. 1.)

The adambulacral spinelets, 1.5 to 2. mm. long, are proximally five to a plate, in a transverse slightly curved comb. Beyond the basal third of the ray the number is quickly reduced to three which is maintained to the end. On one ray four is more usual than three. There is not much difference in the length of the spines of a comb; the median of three is likely to be the longest, and when there are four or five, the outermost but one is often the longest.

The mouth plates are smaller than in *coscinactis*, and normally the spines cover the surface, overlying the first adambulacral comb, as that overlies the succeeding. The surface of the plates slopes sharply toward the mouth so that the two small actinostomial spinelets are directed fairly into it, or else across the mouth of the furrow.

The four suboral spines, similar in all respects to the adambulacrals, are close to the furrow margin in a sort of arcuate series. (Pl. 30, fig. 1*b*.)

I can find no straight pedicellariae. The crossed pedicellariae (pl. 30, figs. 1*d*, 1*e*) are from 0.28 to 0.34 mm. long and are similar in general form to those of *coscinactis* but have usually fewer teeth in the vertical series of each jaw (six to eight as a rule). The adambulacral and oral plates and spines are entirely devoid of pedicellariae.

Madreporic body small, about two-thirds distance from center of disk to superomarginals at interradius.

Anatomical notes.—The gonads open just ventral to the inferomarginal plates, 2.5 mm. from the interradial angle. Each ovary is a small globular mass. The skeleton of each interradial angle is continued internally as a slight septum or buttress. The ampullae are single and the tube-feet strictly biserial.

Type.—Cat. No. E. 1422, U.S.N.M.

Type-locality.—Station 2951, south of Santa Cruz Island, Calif., 33° 55′ 30″ N., 119° 55′ W.; 48 fathoms, fine gray sand; 1 specimen.

Distribution.—Known only from the type-locality.

Remarks.—This species is readily separable from *coscinactis* by reason of the notably smaller mouth plates, larger combs of adambulacral spines, absence of straight pedicellariae, wider intermarginal space, and the presence of incipient interbrachial septa. The crossed pedicellariae have slightly fewer teeth in the vertical series of each jaw. The rays are considerably stockier than in *coscinactis*. Whether the absence of abactinal papulae from the rays is really characteristic of the species or only a specimen peculiarity can not be determined. Since the same peculiarity is found in *nannodes*, I believe it is an important character.

The station number may not be correct, as the depth recorded is much less than usual for this genus.

ANTELIASTER MICROGENYS NANNODES, new subspecies

Plate 29, Figures 3, 3*a*–3*d*; Plate 35, Figure 4

Diagnosis.—Differing from *A. microgenys* in having fewer, slenderer adambulacral spinelets, slightly different crossed pedicellariae, and in having, sometimes, oral, spatulate straight pedicellariae of conspicuous size. R 17 mm.; r 3.5 mm.; breadth of ray at widest part, 4 mm.; R = 4.8 + r.

Description.—The skeleton is very similar to that of *microgenys*, but on account of the small size of the specimen the intervals are smaller. There are two more or less interrupted dorsolateral series of meshes separated by the ⅄ and Y dorsolateral plates, but very few intermediate ossicles are present. As in *microgenys* there are no dorsal papulae except a few on disk. The intermarginal ossicles are developed proximally so that even in such small specimens the two series of marginal plates are well separated. A single longiseries of actinal plates, and above them one of papular areas, extend nearly to the middle of ray. Each intermarginal and actinal area contains one papula.

The spinelets are very small, rather thick, tapered, and end usually in three or four points. They stand one to a plate, are 0.26 to 0.35 mm. long, and are well spaced, but the intervals are filled with pedicellariae which resemble those of *micro-*

genys. The teeth of the vertical series are usually less well developed, and the pedicellariae are, of course, smaller (0.18 to 0.22 mm. long; see pl. 29, figs. 3*c*, 3*d*, 3*e*).

The first two or three adambulacral plates have three slender spinelets, the rest only two, conspicuously longer than the actinals and inferomarginals, which in turn are a trifle longer than the abactinal. The small oral plates each carry three or four spinelets in a series, and the type also has on the outer part of each pair (except one) a large spatulate straight pedicellaria with irregularly denticulate distal margin. These are not present in the other specimen. The spinelets are sheathed in a delicate watery membrane which almost disappears on drying.

Madreporic body small, at the top of interbrachial sulcus.

The gonads of the type, a male, are large lobulated organs which open a short distance from the interbrachial angle, just below an inferomarginal plate. The lobes of the gonad extend to the middle of the ray, and fill most of the proximal half of the ray coelom.

Type.—Cat. No. E. 1423, U.S.N.M.

Type-locality.—Station 4770, Bowers Bank, Bering Sea, 54° 31′ N., 179° 15′ E.; 247 fathoms; June 3, 1906; bottom not recorded. The bottom temperature at station 4769, very close to this locality, 244 fathoms, is 38.5° F.; gray sand, green mud.

Distribution.—Known only from the type-locality.

Remarks.—Two small specimens are a hazardous basis for a new subspecies, but they must be treated more formally than variants of the Californian species. Their relationship with *microgenys* was not at first appreciated, since the presence of large spatulate pedicellariae in one example suggested, rather, *coscinactis*. The structure of the dorsolateral and marginal skeleton, the form of the spinelets and crossed pedicellariae, and the small size of the oral plates are all more like *microgenys* than *coscinactis*. The absence of abactinal papulæ on the rays, although not surprising in such small examples, is nevertheless a characteristic also of *microgenys*. In *coscinactis* the abactinal papulæ extend up to the tip of the ray.

While the fewer adambulacral spinelets is the most tangible difference separating *nannodes* from *microgenys*, the presence of spatulate straight pedicellariae is also probably of value, although these may be present on some specimens of *microgenys*. The crossed pedicellariae have rather fewer teeth in the vertical series of each jaw and the two or three distalmost are more strongly developed than in *microgenys*.

Genus TARSASTER Sladen

Plate 30, Figures 2, 3; Plate 31, Figures 1, 1*a*; Plate 37, Figures 1, 1*a*

Tarsaster Sladen, Challenger Asteroidea, 1889, p. 439. Type *T. stoichodes* Sladen.—Fisher, 1923, p. 252.

Diagnosis.—Rays 5, slender, tapering, subterete, constricted adjacent to small disk; no actinal plates on ray; inferomarginal plates with a prominent spine heavier than the adambulacral spines and forming a longiseries just external to them; interbrachial marginals stout, firmly united but not especially enlarged; first pair of postoral adambulacral plates separated or else in partial contact on interradial line; adambulacral plates diplacanthid or both diplacanthid and monacanthid; straight pedicellariae lanceolate, not prominently spatulate or unguiculate; tube-feet quadriserial proximally, biserial distally. Skeleton a close reticulum of three and four lobed plates, rather irregular on dorsolateral area; carinals well marked, + form; superomarginals + form, regular (not warped); abactinal and superomarginal spinelets short, spaced, tubercular or mobile, one to several per plate; interbrachial septum small, almost wanting; gonads opening dorsally just above superomarginal plates.

Remarks.—*Tarsaster stoichodes*, the type of the genus, was described by Sladen in the *Challenger* report (1889, p. 440) and was based upon a single specimen taken north of the Admiralty Islands in 150 fathoms. It was classified in the now defunct Stichasteridae because the dorsal plates were arranged in longitudinal series. A second species, *T. distichopus* (differing in having unguiculate pedicellariae and biserial tube-feet), was described by the writer from the Straits of Macassar, 400 fathoms (1919, p. 590). In attempting to classify "*Sporasterias*" *mariana* Ludwig, *S. cocosana* Ludwig and *S. galapagensis* Ludwig from the Pacific coast of Mexico and Panamic area, it became apparent that they were perhaps generically the same as *Tarsaster distichopus* Fisher. I have had the advantage of making direct comparison of specimens. All these species have the first pair of postoral adambulacral plates separated interradially (or else in slight contact by the adoral corners) and thus resemble *Pedicellaster*, where the separation is always complete and conspicuous. They all differ from true *Pedicellaster* in having a prominent longiseries of inferomarginal spines external to the adambulacral.

Dr. R. Kirkpatrick, of the British Museum (Natural History), examined for me the type of *Tarsaster stoichodes* and made photographs of the oral angle. Doctor Kirkpatrick found, as shown by the photographs, that the first pair of postoral adambulacral plates are in partial contact; that is, they touch interradially by the adoral portion of the appropriate margin. In the other species which I have placed in this genus the plates are separated, but in *Ampheraster* an analogous condition exists; the plates may be either separated or in partial contact. In *Ampheraster marianus* the largest specimen has the plates in contact, the other smaller specimens have them separated.

It has seemed best to segregate in *Ampheraster* those species which, while resembling *Tarsaster*, have conspicuous unguiculate straight pedicellariae, a predominantly monacanthid adambulacral armature, enlarged interbrachial superomarginal plates, and no accessory inferomarginal spinelet or tubercle.

The latter, in the American species of *Tarsaster*, is a good recognition character and is constantly present in such distinct (perhaps subgenerically separable) species, as *alaskanus* and *cocosanus*. Sladen does not describe it in the type but in the photograph there appears to be an accessory inferomarginal spinelet above one of the major spines.

In *Tarsaster* as here limited the superomarginal plates do not exhibit the curious instability characteristic of *Ampheraster*. The plates are of the conventional four-lobed pattern and form regular longiseries. The distal plates are occasionally a trifle warped.

Tarsaster and *Ampheraster* are structurally in some respects intermediate between *Pedicellaster* and the simpler Asteriinae. The skeleton above the inferomarginals is very similar to that of typical Pedicellasterinae (which are now known to have sometimes unguiculate straight pedicellariae). The crowding of the tube-feet, in *Tarsaster*, into two zigzag rows, or into four distinct series, follows a multiplication and shortening of the ambulacral ossicles by which alternate pores are squeezed out of line. All degrees of these are found in the Asteriinae. In *Ampheraster*, two species have a biserial arrangement of tube-feet, even to the base of the ray; the other three have the tube-feet quadriserial in various degrees. In *Pedicellaster*, *Hydrasterias*, and *Peranaster* the tube-feet are strictly biserial. These three genera have a considerable gap between the interradial border of the first postoral pair of adambulacral plates, sometimes even to the intrusion between these plates of the outer end of the combined mouth plates. In *Tarsaster* and *Ampheraster* this first pair of plates is either separated by a muscular symphysis (sometimes fairly broad) or else the adoral corners are in close contact. In *Ampheraster marianus* only the largest specimen has the plates in contact; in others they are separated. In *A. atactus* the plates are obviously in contact. In the large *A. hyperoncus* the plates are well separated. This feature thus runs the gamut from the condition in *Pedicellaster* nearly to that of the least specialized Asteriinae, apparently in correlation with the structure of the ambulacral plates which are quite *Pedicellaster*-like in *A. hyperoncus* and not at all so in *marianus* and *atactus*.

KEY TO THE KNOWN SPECIES OF TARSASTER

a^1. Adambulacral plates diplacanthid, or the first few triplacanthid; abactinal crossed pedicellariae 0.26 to 0.32 mm. long.

b^1. Abactinal spinelets arranged in transverse series, the carinal and superomarginal plates with about 3 spinelets; oral plates each with 3 or more spinelets.

c^1. Spinelets cylindrico-conical, robust, erect; dorsolateral plates with 1 or 2 spinelets; adoral adambulacral plates touching by adoral corners; accessory inferomarginal spinelet not well developed; major inferomarginal spine lanceolate, flattened (150 fathoms, north of Admiralty Islands) ---------- *stoichodes* Sladen.

c^2. Spinelets rather slender, tapering, not erect and stubby; dorsolateral plates with more often two or three spinelets; adoral adambulacral plates separated, accessory inferomarginal spine well developed; major inferomarginal spine terete, clavate, in length equal to about 1.2 to 1.5 plates; minor inferomarginal spine equal to or larger than the superomarginal spines ---------- *alaskanus* Fisher.

b^2. Abactinal spinelets not in transverse series, the carinal and superomarginal plates with one spinelet each; oral plates with two spines each; major inferomarginal spine lanceolate, flattened (1.5 plates in length), the minor, slenderer, shorter, and sharper than the blunt superomarginal spinelets ---------- *galapagensis* [26] (Ludwig)

a^2. Adambulacral plates diplacanthid, sporadically monacanthid, distals largely monacanthid, abactinal crossed pedicellariae about 0.36 to 0.38 mm. long; major inferomarginal spine robust, tapered, blunt, very slightly flattened, in length equal to 1.2 to 1.5 plates; minor inferomarginal spine about two-thirds as long, blunt or pointed, larger than the two or three small subcylindrical or clavate superomarginal spinelets (in transseries); abactinal spinelets similar, small (0.55 to 0.65 mm.), subclavate, erect, stubby, one or two on dorsolaterals, three on carinals; dorsolaterals irregularly spaced, not in evident transseries. (Guadeloupe, West Indies) ---------- *fascicularis* [27] (Perrier)

a^3. Adambulacral plates monacanthid except first 9 or 10 which are diplacanthid; distal plates sporadically diplacanthid or rarely triplacanthid; abactinal crossed pedicellariae about 0.45 mm. long; abactinal and marginal spinelets short, very robust, tubercular, subcylindrical; the major inferomarginal spine sublanceolate, somewhat flattened (one plate in length); the minor spine, tubercular, rather smaller than the superomarginal spinelet. *cocosanus* [28] (Ludwig)

[26] *Sporasterias galapagensis* Ludwig, Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 240, pl. 34, figs. 202, 203; station 3404, south of Chatham Island, Galapagos Islands, 385 fathoms, rocks; bottom temperature 43.2 Fahr.

[27] *Asterias fascicularis* Perrier, Mém. sur les Étoiles de Mer ("Blake"), Nouv. Arch. Mus. d'Hist. Nat., ser. 2, vol. 6, 1884, p. 200, pl. 3, Guadeloupe, 309 fathoms. Data from type No. 1210. Mus. Comp. Zoöl.

[28] *Sporasterias cocosana* Ludwig, Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 235, pl. 33, fig. 199; pl. 34, figs. 200, 201; station 3370 off Cocos Island, 134 fathoms, rocks, shells; bottom temperature 51.8 F.

TARSASTER ALASKANUS, new species

Plate 30, Figures 4, *4a–4d*; Plate 36, Figure 3; Plate 37, Figure 4

Diagnosis.—Rays 5, slender, subterete, tapering gradually from a swollen base to a subacute tip; disk small marked off by a distinct constriction from ray; interbrachial angle sharp, closed; carinal plates forming a slight convex ridge; spinelets small, uniform, several to a plate, arranged (with numerous crossed pedicellariae) in transverse bands, between which are narrow transversely oriented papular areas; inferomarginal plates with two spines the upper uniform with the general spinulation, the lower enlarged, subclavate, obtuse, about 2 mm. long; adambulacral plates diplacanthid, except 8 or 10 proximal triplacanthid plates; oral plates with five spines, of which two stand on actinostomial margin; straight pedicellariae, small, broadly lanceolate, confined to oral and adambulacral plates; tube-feet proximally four-ranked distally biserial. Differing from *T. galapagensis* (Ludwig) in having several mobile spinelets on the abactinal plates; subterete, clavate, blunt major inferomarginal spines (instead of almond-shaped ones); five instead of two oral spines; and no straight pedicellariae on the abactinal and marginal plates. R 67 mm.; r 6.5 mm.; R = 10 r; breadth of ray at base, 8 mm.; at widest part, 12 mm.

Description.—The skin is relatively thick and completely obscures the outlines of the plates, which, however, are slightly indicated by shallow transverse depressions denoting the papular areas. The carinal plates form a rather broad, slightly convex ridge. The numerous small, slightly tapered, thorny tipped spinelets (about 0.8 to 1. mm. in length) are arranged in somewhat irregular consecutive transverse bands or ranks, which are separated by the transverse depressions noted above. The spinelets of the abactinal and superomarginal plates have the appearance of being of nearly uniform size, blunt, upward of three or four to a plate, and accompanied by numerous crossed pedicellariae, which, being largely absent from the papular areas, accentuate the transverse arrangement of the spinelets. The superomarginal plates are set off by a very slight longitudinal furrow on their upper margin and each plate carries about three spinelets in a vertical series, the consecutive series being rather close on account of the considerable overlapping of the plates.

The inferomarginal plates which closely join the adambulacral series (without any actinal plates between) carry usually two spines in a transverse series. The inner is heavy, clavate, blunt, about 2 mm. long, and situated close to the outer adambulacral spine. Occasionally two subequal slightly smaller spines take the place of the larger inner spine. The second spine is about half as long, much slenderer, and is similar to the lower superomarginal spinelet from which it is spaced a little more than its own length. This outer spinelet forms a longitudinal series separated from the superomarginals by a slight furrow and is in no other way differentiated from the general spinulation. The inner enlarged spine forms a prominent longiseries just external to the bristling adambulacral spines. On a number of plates a second accessory spinelet makes its appearance.

The skeleton is characterized by more compactness than that of other species, the skeletal meshes being smaller and the plates, especially the dorsolaterals, larger. The marginal plates are very firmly imbricated, the superomarginals being four-lobed, while in the inferomarginals, the ventral, or adambulacral, lobe is pretty much suppressed. The carinals are four-lobed and very firmly imbricated. The dorsolaterals are very irregular. There are about three series of dorsolateral skeletal meshes: A series of larger meshes (or alternating larger and smaller) adjacent to the carinals; a similar series adjacent to superomarginals; between these a very irregular series of quite small intervals.

Papulae numerous abactinally, arranged in transverse rows conforming to the trend of the skeletal intervals; intermarginal papular areas small, about one papula to an area.

First 10 or 12 adambulacral plates are triplacanthid, the rest diplacanthid, the spines, in close transverse series, being slender, terete, blunt, about 2 mm. long. The outer spine of the diplacanthid plates is commonly a shade longer and stouter than the inner, while that of the triplacanthid plates is slenderer, tapered, and sharp. The spines of the first 10 or 12 plates are a trifle longer and slenderer than the others. Rarely a proximal plate has a small fourth spinelet.

The mouth plates are rather broad and carry two slender actinostomial spines (the inner the longer and subequal to or a little longer than the median suture), and three longer, slender, suboral spines—two parallel to suture and one near outer furrow corner. There are sometimes one or two small, toothed, lanceolate or lanceolate-obtuse, narrow-jawed straight pedicellariae on actinostomial margin. The first postoral adambulacral plates are not joined by the interradial ends, but there is a rather conspicuous interval between them. (Pl. 30, fig. 4.)

Crossed pedicellariae numerous, similar to those of *T. galapagensis* (Ludwig) and much smaller than the pedicellariae of *T. cocosanus* (Ludwig); length about 0.3 mm. They are found on all plates except the oral and adambulacral, and tend to form transverse groups abactinally. They are generally absent from the papular areas. Small lanceolate straight pedicellariae (about 0.45 mm. long) occur along the furrow margin. The jaws are narrow and tapering. Larger ones with a few small terminal teeth occur on the oral plates sparingly. (See pl. 30, fig. 2, *stoichodes;* fig. 3, *cocosanus*; pl. 31, fig. 1, *galapagensis*.)

Madreporic body large (diameter 2.5 mm.) situated on the margin of the small disk.

Furrow rather narrow (3 mm.); tube-feet quadriserial along the proximal third of furrow, biserial distally. Ambulacral pores in two very zigzag series on proximal fourth of furrow, and, in this area, very narrow and slit-like; on remainder of ray they form two straight series and are more broadly elliptical.

Type.—Cat. No. E. 1424, U.S.N.M.

Type-locality.—Station 4230, off Indian Point, vicinity Naha Bay, Behm Canal, southeast Alaska; 240 to 108 fathoms, rocky; bottom temperature, 42.4° F.

Remarks.—*T. alaskanus* differs from *T. galapagensis* (Ludwig) in several important particulars. I have examined the type of *galapagensis* which is quite small (R 23 mm.). It has solitary, tubercular, heavy, abactinal and superomarginal spinelets like those of *T. cocosanus* (Ludwig), and its major inferomarginal spine is flattened and lanceolate, somewhat almond-form. The oral plates have but two spines, while the numerous abactinal and marginal straight pedicellariae are absent in *alaskanus*. Both species have diplacanthid adambulacral plates. In *galapagensis* a few of the proximal plates have a third smaller spinelet.

T. cocosanus, the types of which I have examined, differs from *alaskanus* in most of its details. The abactinal and superomarginal spinclets are short, tubercular, cylindrical and round-tipped; the crossed pedicellariae are much larger (0.38 to 0.45 mm. long); there are narrowly spatulate, small, toothed straight pedicellariae on the sides of the ray (and narrower-jawed ones on the furrow margin); the larger inferomarginal spine is somewhat flattened and lanceolate, while the smaller is subtubercular; the adambulacral plates are monacanthid, except about the first 10 and some near the tip of ray which are diplacanthid; the oral plates are diplacanthid.

T. fascicularis (Perrier) is a large species comparable in size with *alaskanus* (R 57 mm.; r 9 mm.). It differs in most of its details. The adambulacrals are diplacanthid and monacanthid, while the abactinal spinelets are shorter, stubbier, subclavate, erect (0.55 to 0.65 mm. long), and are not arranged in evident transverse lines except on the carinal and superomarginal plates. The abactinal crossed pedicellariae are about 0.36 to 0.38 mm. long.

Genus AMPHERASTER Fisher

Ampheraster FISHER, Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 253. Type, *Sporasterias mariana* Ludwig.

Diagnosis.—Rays five, slender; disk small; abactinally resembling *Pedicellaster*; closely related to *Tarsaster* but differing therefrom in having large, narrowly or broadly spatulate, prominently unguiculate, straight pedicellariae; an enlarged pair of interbrachial superomarginal plates overlapping a pair of firmly united sometimes enlarged, corresponding inferomarginals, the quartet forming a very firm interbrachial skeleton; no accessory inferomarginal spinelet; monacanthid adambulacrals (sometimes partly diplacanthid); more open skeleton with larger dorsal meshes; a tendency to warped, four-lobed superomarginals. Skeleton similar in essentials to that of *Tarsaster* but in some species the superomarginal plates are in part three-lobed and in part warped four-lobed, and there is a tendency to irregularity in the marginal skeleton; postoral adambulacrals well separated or in partial contact, both conditions being found sometimes in different ages of the same species; no actinal plates (except an interradial rudiment; gonads opening dorsally, just above superomarginal plates; tube-feet biserial throughout, quadriserial proximally, or quadriserial throughout.

Remarks.—The difficulties encountered in classifying the species of this genus have been indicated in the discussion of *Tarsaster*.

The differences between *marianus* with its strong quadriserial tube-feet and *hyperoncus* with biserial feet and pores may seem at first glance of generic value. But *A. chiroplus* has characteristics of both species. Its proximal tube-feet are quadriserial and its oral plates and first pair of adoral adambulacral plates are nearer those of *marianus*. Its abactinal skeleton and three-lobed marginals resemble those of *hyperoncus*. If these last characters are given precedence and *chiroplus* is ranged with *hyperoncus* in a special subgenus, difficulty arises because the mouth plates and enlarged first superomarginals of *chiroplus* are more like those of *marianus* (as are the tube-feet), while a further complication arises from *atactus* which is not at all like *hyperoncus* except in having three-lobed, and warped four-lobed, superomarginals.

The character of the marginal plates is therefore of value only when taken in combination with other features. It has been prominently used in the diagnosis and key because in dried specimens it is fairly easy to recognize. It must be used with caution because since the tendency to warping of distal superomarginals is apparent even in *Tarsaster* (and in other genera less closely related), the effect may be due to growth strains. In *chiroplus*, however, the curiously formed four-lobed plates are, at least sometimes, due to the fusion of two three-lobed ones.

The conspicuous, unguiculate, often spatulate hand-shaped pedicellariae and the enlarged interbrachial marginals of *Ampheraster* will serve as differentiating characters, while the absence of an accessory inferomarginal spinule will further aid in placing the species.

KEY TO THE KNOWN SPECIES OF AMPHERASTER

a^1. Adambulacral plates monacanthid to tip of ray.

b^1. Superomarginal plates normally four-lobed, + form (sometimes slightly warped), imbricated in a regular series; dorsolateral skeleton with three or four series of meshes on either side of the carinal plates; tube-feet strongly quadriserial__________*marianus* (Ludwig).

b^2. Superomarginals largely three-lobed (or, if four-lobed, warped), imbricated in a zigzag series; dorsolateral skeleton with two series of meshes on either side of the carinal plates.

c^1. Tube-feet biserial throughout the ray, the ambulacral pores broadly elliptical, in straight series; straight pedicellariae much compressed, large, unguiculate; mouth plates broad__________*hyperoncus* (Clark).

c^2. Tube-feet quadriserial on proximal half of ray, the ambulacral pores narrowly elliptical, in zigzag series proximally; straight pedicellariae very large, broadly spatulate, with three or four curved, interlocking tines; mouth plates narrow_______*chiroplus* Fisher.

a^2. Distal adambulacral plates diplacanthid; tube-feet quadriserial; marginal skeleton somewhat irregular, the superomarginals usually three-lobed, sometimes warped four-lobed; straight pedicellariae broadly spatulate with three or four coarse, curved, interlocking tines, spinelets conical, rough; dorsolateral skeleton with two series of skeletal meshes distally on either side of the carinal plates; proximally there may be three or four irregular meshes between carinals and superomarginals but not in serial order__________*atactus* Fisher.

a^3. The first six or eight adambulacral plates diplacanthid, the rest monacanthid; abactinal and marginal spinelets, one to a plate, slender, tapered; dorsolateral skeletal meshes in three longiseries proximally, two distally; superomarginals four-lobed more or less warped; tube-feet strictly biserial throughout the ray; oral plates with one actinostomial and two suboral spines; unguiculate straight pedicellariae (0.8 or 0.9 mm. long) on furrow margin and oral plates; (400 fathoms, Straits of Macassar)__________*distichopus* (Fisher).

AMPHERASTER MARIANUS (Ludwig)

Plate 31, Figure 2, 2*a*—2*f*; Plate 32, Figures 1, 1*a*; Plate 35, Figure 1; Plate 38, Figures 1, 2, 3, 4.

Sporasterias mariana Ludwig, Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 231, pl. 33, figs. 194–198.

Ampheraster marianus Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 253.

Diagnosis.—Rays five. R 76 mm.; r 10 mm.; R = 7.6 r; breadth of ray at base 10 mm. (slightly inflated beyond base); rays very gradually tapered to a pointed extremity; abactinal surface arched, actinal surface subplane, accentuated by the single series of acicular, usually horizontally directed inferomarginal spines; skeleton and spines covered by a thickish skin; skeleton open; about eight longitudinal series of abactinal meshes, subdivided by a straight series of carinal plates; spinelets mostly one to a plate, small, rough, conical; intermarginal papular areas rather large, subquadrate; adambulacrals monacanthid; numerous narrowly spatulate, unguiculate, straight pedicellariae; tube-feet four-ranked; furrows wide.

Description.—The carinal plates are easily distinguishable and are imbricated directly, that is, without intermediate ossicles, into a fairly straight series, which forms a slight ridge. The dorsolateral area is broad. In fully grown specimens the plates are so arranged that there is one longiseries of broad papular areas, or meshes, adjacent to the carinals and another adjacent to the superomarginals, while between the two there is a double row of much smaller irregular or lozenge-shaped areas, the meshes of each series of the four dorsolateral series alternating with those of adjacent series. (Pl. 32, fig. 1.) Ludwig[29] (pl. 33, fig. 195) indicates only three dorsolateral series of papular areas, but two of his cotypes which I have clearly show four at the base of ray (R 40 mm.). The dorsolateral plates are three or four lobed and are a little smaller than the carinals. The latter are a trifle smaller than the four-lobed superomarginals, which are strongly imbricated into a regular series, fairly low on the side of the ray. The distal superomarginals although four-lobed are "warped" out of shape so that the dorsal lobe is advanced further distad than the ventral, a feature often exaggerated in other species of this genus. The proximal plates do not as a rule show this very markedly. (Pl. 32, figs. 1, 1*a*.) The inferomarginals, also strongly imbricated, are a little larger than the superomarginals and are juxtaposed to the adambulacrals. There are a few inconspicuous intermarginal ossicles at the base of ray.

In the interbrachial angle the second superomarginal is conspicuously enlarged and is firmly joined to the second enlarged plate of the adjacent ray. The lower end of this pair of interbrachial plates overlaps a pair of similarly enlarged inferomarginals. The four constitute a very firm interbrachial skeleton. The joined pair of *first* superomarginals continue the interbrachial skeleton upward to the primary interradial plate of the disk.

The plates of ray have mostly one spine each. By reason of the open skeleton the spines are well spaced, and are short, stout, tapered, pointed, rough, and in length usually about half the greatest diameter of the plate. The superomarginal spines are scarcely different from the abactinal but are sometimes much blunter. In the largest specimen (station 2896) the abactinal spines are, relative to the plate, shorter than in small examples, and measure about 0.7 to 0.9 mm. long. The acicular, pointed, outwardly directed, inferomarginal spines stand on a prominent convexity of the plate and are as long as 2 or 2.5 inferomarginal plates, slender, but robust, in smaller specimens, heavier and slightly flattened in the large ones. A few of the proximal plates in the largest specimens may carry a second smaller spine above the first.

The large adradial papular areas contain five or six papulae proximally; the smaller intermediate, dorsolateral areas have about three; the supramarginal four or five, the intermarginal, four to six.

The adambulacral plates are small (30 to 32 corresponding to the first 10 spiniferous inferomarginals) and carry a slender, acicular spine equal to the length of about four consecutive plates. Behind the mouth plates the first pair of adambulacral plates is separated by a muscualr symphysis, fairly wide in small specimens, gradually narrowing with age, until in the largest specimen (station 2876) the plates touch by the corners nearest the mouth plates. In one of Ludwig's cotypes (station 3425), R 40 mm., the plates are separated by a space as wide as the length of the first adambulacral. In a slightly smaller specimen from station 2980 (southern Califorina)

[29] Mem. Mus. Comp. Zoöl., vol. 32, 1905.

the plates are separated about as widely, but in another (station 4427), a trifle larger, the symphysis is much narrower than the length of the first plate. I think there is a tendency for the northern specimens to have a slightly narrower symphysis than the southern. The structure of the first pair of adambulacral plates is of interest here, because in *Pedicellaster* and close allies (having five or six rays) the first adambulacrals are not in contact back of the mouth plates, whereas in the Asteriinae one pair at least, usually several, are in contact, forming the so-called adoral carina. In this species we really find a transition between the two types of structure.

The fairly large mouth plates carry, on the actinostomial margin, either one or two acicular spines and a straight pedicellaria with usually two teeth to the jaw. On the surface are one or two spines similar to the adambulacrals, and sometimes a pedicellaria. There may be, thus, two to four spines on each plate. (Pl. 31, figs. 2, 2*a*.)

The crossed pedicellariae are scattered on the skeletal meshes and are rather lacking in striking features. In profile the vertical series of teeth show usually about six or seven rather irregular dentations. Length, 0.32 to 0.36 mm. (Pl. 31, figs. 2*b*, 2*c*.) The pedicellariae of Ludwig's types agree in size and detail. The straight pedicellariae are of the narrow-spatulate, unguiculate type with generally two to four small curved teeth to each jaw tip. (Pl. 31, figs. 2*d*, 2*e*.) They are scattered over the surface of the body and along the furrow margin from the inner end of the oral plate to the end of the ray. The abactinal show greatest diversity in size and form and usually have four teeth; the furrow pedicellariae are relatively less spatulate, with two or three teeth, as a rule (0.9 to 1.25 mm.).

The furrow is broad (0.5 r), with rather crowded, four-ranked, tube-feet, which only at the end of the ray become two-ranked. The ambulacral pores are not at all in straight but in two distinctly zigzag series, which straighten out only at the end of the ray when the furrow narrows.

Madreporic body small, near the margin, and surrounded by a circle of spinelets.

Anatomical notes.—The gonads open dorsally near the upper margin of the second superomarginal plate (in the one specimen dissected). The ovary consists of four or five elongate lobes; eggs large. Stomach spacious, without distinct dorsal and ventral parts; coecum large, sac-like. Ampullae large, not bilobed. No Polian vesicles.

Type.—Cat. No. 34407, U.S.N.M.

Type-locality.—Station 3425, near Tres Marias Islands, Mexico, 21° 19′ N., 106° 24′ W.; 676 fathoms, gray sand; bottom temperature, 39° F.

Distribution.—From the Tres Marias Islands, Mexico, to Washington (47° 29′ 30″ N.), 277 to 676 fathoms; temperature range, 37.9° to 42.8° F.

Specimens examined.—Thirteen.

Specimens of Ampheraster marianus examined

Station	Locality	Depth	Nature of bottom	Bottom temperature	Number of specimens	Remarks
2890	Off Oregon, 43° 46′ N., 124° 57′ W	277	Gray sand	42.2	1	U.S.N.M.
2896	South of San Miguel Island, Calif	376	Yellow mud	42.8	1	Do.
2980	Southeast Santa Cruz Island, Calif	603	Green mud	38.9	1	Do.
3070	Off Washington, 47° 29′ 30″ N., 125° 43′ W	636	do	37.9	1	Do.
3425	Tres Marias Islands, Mexico	676	Gray sand	39	3	Types.
4407	3.2 miles southwest of southeast point Santa Catalina Island.	478-600	Gray sand, rocks	--------	1	Albatross, 1904.
4427	7 miles southwest Point San Pedro, Santa Cruz Island.	447-510	Black mud, rocks	--------	5	Do.

Remarks.—This very distinct species combines in a curious manner the appearance of *Pedicellaster* when viewed dorsally with that of *Myxoderma* when viewed ventrally—but a *Myxoderma* with uniform monacanthid adambulacrals.

If the unique specimen of *Ampheraster hyperoncus* (H. L. Clark) [30] is typical of the species, it is sharply separated from *marianus* by having strictly biserial tube-feet, even the ambulacral pores being biserial. I have examined this specimen which has R 68 mm., r 7 mm. There are only two series of very large dorsolateral skeletal meshes (four in all) which are clearly indicated by Clark's figure. The superomarginal plates are very unusual in form. Instead of being regularly ✚ form, the proximal plates are Y-shaped, while the rest might be described as similar to two Y's joined by fusing the handles. (See Pl. 32 fig. 4.) Interpolated among these is an occasional Y-shaped plate. The superomarginals of *hyperoncus* are well spaced from the inferomarginals, most of the intermarginal papular areas being broader than long.

AMPHERASTER CHIROPLUS, new species

Plate 31, Figures 3, 3*a*–3*d*; Plate 32, Figure 2; Plate 35, Figure 2; Plate 37, Figure 2

Diagnosis.—Rays five. R 33 mm.; r 5 mm.; R = 6.6 r; breadth of ray at base, 6 mm. Disk small; rays slender, slightly swollen, gradually tapered; skin rather thick; distally two series of large skeletal meshes on either side of the carinal plates; proximally the biserial order is broken and there may be but one broad mesh; superomarginal plates three-lobed, forming a zigzag series; spinelets very small, rather widely spaced; adambulacrals strictly monacanthid, the spines rather long and slender, subequal to the slightly stouter inferomarginal spines; straight pedicellariae, very large, spatulate, unguiculate, the shank constricted; crossed pedicellariae in profile broader distally and blunter than in *A. hyperoncus* or *A. atactus;* tube-feet quadriserial proximally.

Description.—The abactinal skeleton consists, distally, of four longiseries of meshes and proximally, irregularly of two or four. When there are only two each mesh extends from the series of fairly regular four-lobed carinal plates to the superomarginals The dorsolateral plates are generally regularly Y and ⅄ form, distally, forming on either side a zigzag series; but on the proximal half of the ray they are not regular. The superomarginal plates are usually the same shape as the distal dorso-

[30] *Pedicellaster hyperoncus* H. L. Clark, Bull. Amer. Mus. Nat. Hist., vol. 32, art. 8, 1913, p. 201, pl. 44, figs. 3 and 4; station 5645 southwest of San Cristobal Bay, west coast of Lower California, 284 fathoms, bottom temperature, 44.6° F.

laterals, and are unlike the carinals and inferomarginals. They form a zigzag series and occasionally, as shown in the figure, one of the plates is four-lobed, as if consisting of two fused plates. This type of superomarginal plate is present in *Ampheraster hyperoncus* (Clark), and *A. atactus*, especially distally, since in that species the proximal plates are sometimes normally four-lobed. (See Pl. 32, fig. 2.) If all the superomarginal plates were regularly ⅄ and Y form there would be twice as many as in the inferomarginal series, since it is only the alternate, Y-form, plates which overlap the ascending lobe of the inferomarginals.

The inferomarginals are normal, the lower lobe, which joins the adambulacral plates, being very short. As shown in the figure, there are sometimes two intermediate dorsolateral ossicles between the primary plates, and proximally there is a rather long intermarginal ossicle. There is a quartet of enlarged superomarginals in the interbrachium, the first pair lying outside the primary interradial plate; the second pair is in line with the regular series and the lower ends overlie a pair of enlarged inferomarginals.

Intermarginal papular areas have proximally two papulae and the dorsolateral, four or five in the smaller areas and about twice as many in the large.

The skin is rather thick and pulpy, pretty well hiding the skeleton until dried. The spinelets are small, solitary, widely spaced, not very slender, tapered, bluntly pointed, and terminally prickly; length, abactinal, 0.4 to 0.5 mm. long. The superomarginal are not different from the abactinal spines, but the solitary inferomarginal spines are, as usual, much longer (1.7 mm. proximally), terete, slender, bluntly pointed, a little stouter than the single, subequal, adambulacral spines. The latter are always one to a plate, very slender, terete, blunt. There are 29 adambulacrals to 10 proximal inferomarginals. The first adoral pair of adambulacrals do not meet interradially.

Oral plates narrow with a huge unguiculate pedicellaria as long as the plates on the actinostomial end. There are two slender, slightly tapered, suboral spines.

The straight pedicellariae are relatively huge, with broad spatulate jaws and four or five curved tines. The proximal part of each jaw is narrowed as a rule. They are very conspicuous and are scattered over the abactinal, marginal, and adambulacral plates, a few overhanging the furrow, and four guard the actinostome. The length is 1.1 to 1.25 mm.

Crossed pedicellariae scattered, not so numerous as in *A. atactus* or *A. hyperoncus*. Only one to three occur on the superomarginals and usually none on the inferomarginals, except sporadically at very wide intervals; none on the adambulacrals. The pedicellariae measure 0.30 to 0.36 mm. long and differ in form from those of *hyperoncus* and *atactus*, being much broader distally (as seen in profile), less tapered, with fewer teeth than in *atactus*.

Madreporic body small, near the margin, and attached to a very regular pentagon of disk plates.

Furrow fairly broad proximally, where the tube-feet are four-ranked; distally they become biserial. The series of ambulacral pores are not nearly so straight as in *hyperoncus*, but are decidedly zigzag proximally, though distally they straighten out. The pores themselves are narrow elliptical while in *hyperoncus* they are broadly elliptical.

Anatomical notes.—The gonads, which are small with large eggs, open just above the third superomarginal (in the single case observed). Each ovary is subdivided into five lobes.

Type.—Cat. No. E. 1425, U.S.N.M.

Type-locality.—Station 4427 7 miles southwest of Point San Pedro, Santa Cruz Island, Calif.; 447–510 fathoms, black mud, rocks.

Remarks.—This species may be distinguished from *hyperoncus* Clark by the form of the straight pedicellariae. In *hyperoncus* these are never broadly spatulate, but, on the contrary, are much compressed, lanceolate in profile, and the ends of the jaws are hooked. Furthermore, in *hyperoncus* the tube-feet are biserial and the ambulacral pores are broadly elliptical, less slit-like.

Chiroplus differs from *atactus* in the form of the crossed pedicellariae, in having a more lax, open, abactinal skeleton, and a broader intermarginal area, with larger skeletal meshes, and proximally intermarginal secondary ossicles. *Atactus* has a rather rigid skeleton, that of *chiroplus* is flexible; *atactus* has on the distal plates usually two adambulacral spines; *chiroplus* never more than one. The madreporite of *atactus* is relatively larger than in *chiroplus*.

The difference in the crossed pedicellariae is quite striking, and as these are generally very conservative as regards their form, I think they are of considerable value for identification. A comparison of figures will show that the crossed pedicellariae of *hyperoncus* and *atactus* are more nearly alike. The straight pedicellariae of *chiroplus* appear very large, as they are actually as big as in the very much larger specimen of *atactus*. Whether they increase further in size is not known.

AMPHERASTER ATACTUS, new species

Plate 31, Figure 4; Plate 32, Figures 3, 3*a*–3*b*; Plate 38, Figure 5

Diagnosis.—Rays five. R 60 to 65 mm.; r 9 mm.; breadth of ray at base, 10 mm.; R = 6.6 to 7.1 r. Rays stout, slightly inflated, tapered from broadest part just beyond base; superomarginals actinolateral in position; intermarginal channel narrow. Spinelets short, conical, rough, rigid, uniformly rather widely spaced; inferomarginal spines about as long as and a little stouter than adambulacral spines, which stand one to a plate except near end of ray where there are two; straight pedicellariae, large, broadly lanceolate, with three or four strong claws to each jaw. Differing from *A. marianus* in having minutely thorny spines, smaller marginal spines, narrower intermarginal channel, mostly three-lobed superomarginals, diplacanthid distal adambulacrals, and larger and differently formed straight pedicellariae.

Description.—The skeleton of this species differs from that of *marianus* in having a broader dorsolateral region, with fewer, larger, and more irregular openings, a less regular and less prominent carinal series, narrower intermarginal region, with less regular, generally three-lobed superomarginal plates. The carinals have very short lobes and proximally the arrangement is very irregular. It is rather difficult to analyze the dorsolateral skeleton precisely. Distally, on each side of the carinal plates there are two series of broad meshes separated by a longiseries of Y and ⅄ shaped plates, which becomes more and more irregular toward base of ray. On the proximal half or two-thirds of ray the region between this primary dorsolateral series and the superomarginals widens much more rapidly than the adradial band of meshes.

In this wider region a second series of dorsolateral plates extends in great disorder for half or two-thirds the length of ray. The exact number of *proximal* dorsolateral series of meshes is therefore not easy to determine; theoretically there should be three on each side. The superomarginals are mostly three-lobed (except proximally where irregular four-lobed plates occur irregularly), the descending lobe being short and imbricated directly to the upper lobe of the inferomarginals. The intermarginal papular areas are small and roundish. The quartet of interbrachial marginal plates is less conspicuous than in *marianus*.

The abactinal and superomarginal spinelets are short (0.9 mm.), rough, conical, and sharp or bluntly pointed, well-spaced, one to a plate, and interspersed with numerous uniformly distributed crossed pedicellariae and a few broadly spatulate unguiculate straight pedicellariae. Inferomarginal spines, one to a plate, terete, rough, scarcely tapered except near tip, bluntly pointed. They are shorter than in *marianus*, being only about as long as the adjacent adambulacrals, although about 1.5 to 2 times their diameter. They do not stand out in a prominent actinal fringe.

The larger abactinal areas have five to seven papulae; the smaller two or three; the intermarginal, one or two.

The adambulacral plates are monacanthid, with here and there a diplacanthid plate; the distal 20 or 30 plates, which are small, are regularly diplacanthid. The spines are slender, terete, and rough near the bluntly pointed tips, and the longest proximal ones are equal to the length of five consecutive plates. Twenty-eight or thirty adambulacral plates correspond to the first ten spiniferous inferomarginals. The first postoral plate touches the companion plate of the adjacent ray, while the second pair nearly touch in one angle.

The width of the combined oral plates is less than in *marianus*, and the ventral surface of each plate is only wide enough to carry a longiseries of two or three slender spines a little shorter than the first few adambulacrals. A single unguiculate pedicellaria stands on the truncate actinostomial end of the mouth angle.

Crossed pedicellariae numerous, uniformly scattered on abactinal plates; few intermarginally and on the inferomarginals. They are similar in form and size to those of *marianus*, but in profile are a trifle more tapered and have a few more teeth in the vertical series (upwards of 11). Length 0.31 to 0.36 mm.

The straight pedicellariae, which are fewer than in *marianus*, are found principally on the inferomarginal plates, are about 1.25 mm. long, very broadly spatulate, with three or four prominent curved claws. The pedicellaria is larger and broader, with coarser, longer, teeth than in *marianus*. They are absent from furrow face of adambulcral plates.

Madreporic body prominent, 3 mm. in diameter, situated near margin. Ambulacral furrow rather wide, but less so than in *marianus*. Tube-feet in four series proximally, reduced to two zigzag series on outer half of ray. Gonads (ovary) similar to those of *marianus*, opening on the upper edge of the second (first spiniferous) superomarginal.

Type.—Cat. No. E. 1426, U.S.N.M.

Type-locality.—Station 4341, 3 miles southwest of South Coronado Island, vicinity of San Diego, Calif.; 266 to 323 fathoms, gray sand, black specks; bottom temperature, 42° F.

Distribution.—Known only from the type-locality.

Remarks.—Although the presence of three-lobed superomarginal plates and broadly spatulate hand-shaped pedicellariae seems to ally *atactus* rather closely with *chiroplus*, I think it is perfectly distinct. It is found in shallower water than is *chiroplus*.

Subfamily LABIDIASTERINAE Verrill, emended

Labidiasterinae Verrill, Shallow-water Starfishes, 1914, p. 26.—Fisher, Starfishes of the Philippine Seas, etc., 1919, p. 492; Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 249.

Rays numerous (9–45), long, slender; inferomarginal spines prominent, single, enveloped in a sheath (carrying on the usually expanded distal surface a conspicuous wreath of crossed pedicellariae); abactinal skeleton either very open, with large squarish meshes, or else abortive with scattered independent plates; crossed pedicellariae in abactinal spinal wreaths or thick ruffs; no actinal plates; gonads two to each ray, opening upon the side a short distance from base; tube-feet numerous, biserial to quadriserial, each with a single ampulla.

Remarks.—This rather isolated subfamily contains three genera: *Coronaster* Perrier (including *Heterasterias* Verrill), *Rathbunaster* Fisher, and *Labidiaster* Lütken (including *Labidiastrella* Verrill). A short discussion of their relationships is contained in Fisher, Starfishes of the Philippine Seas, 1919 (p. 492). There the subfamily is classified in the Pedicellasteridae. A family Pedicellasteridae consisting of Pedicellasterinae and Labidiasterinae is convenient but probably not very natural.

The Pedicellasterinae comprise a series of genera which lead rather naturally to *Tarsastrocles* and to the Asteriinae proper whereas the affinities of the Labidiasterinae appear to be not with the Asteriinae at all, but with the Coscinasteriinae. The Coscinasteriinae and Asteriinae are two divergent lines, between which there is a distinct hiatus.

SYNOPSIS OF THE GENERA OF LABIDIASTERINAE

a^1. Abactinal skeleton reduced to isolated plates bearing slender acicular spines (with a thick distally expanded sheath, bearing large crossed pedicellariae with numerous shank-teeth and enlarged lateral terminal teeth); alternate superomarginal plates and spines abortive; straight pedicellariae not spatulate, unguiculate; rays 12 to 20, very flexible---*Rathbunaster* Fisher.

a^2. Abactinal skeleton with large squarish meshes; alternate superomarginals not suppressed.

b^1. Rays 9 to 11; abactinal and marginal spines acicular, prominent, solitary, rather widely spaced; skeleton of outer part of ray not reduced to transverse bands of plates carrying cushions of pedicellariae; large straight pedicellariae, when present, spatulate, unguiculate---*Coronaster* [31] Perrier.

b^2. Rays upwards of 45 (25–45); marginal and abactinal spinelets not very prominent nor widely spaced; more or less aggregated in transverse bands; skeleton of outer part of ray reduced more or less to transverse arches carrying cushions of pedicellariae; straight pedicellariae not large, unguiculate---*Labidiaster* [32] Lütken.

Genus RATHBUNASTER Fisher

Rathbunaster Fisher, Proc. Wash. Acad. Sci., vol. 8, Aug. 14, 1906, p. 136. Type, *R. californicus* Fisher; Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 493; Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 249.

Diagnosis.—In general appearance somewhat resembling *Coronaster* Perrier. Abactinal skeleton reduced to spaced circular, independent plates (without a trace of

[31] *Coronaster* Perrier, 1885, emended Fisher. Type *C. parfaiti* Perrier. See Fisher, Starfishes of the Philippine Seas, 1919, p. 494. Synonyms, *Stolasterias* Sladen part; *Heterasterias* Verrill, 1914, p. 46. This genus includes *C. parfaiti* Perrier, Cape Verde Islands; *C. antonii* Perrier, Morocco; *C. briareus* (Verrill), off Atlantic coast of southern United States; *C. octoradiatus* (Studer) South Georgia Island; *C. volsellatus* Sladen, Philippine Islands. *C. halicepus* Fisher, Philippine and Molucca Islands; *C. eclipes* Fisher, Hawaiian Islands. (Sea Stars of Tropical Central Pacific, Bishop Mus. Bull. No. 27, 1925, p. 86, fig. 9*a*).

[32] *Labidiaster* Lütken, 1871. Type *L. radiosus* Lütken. Synonym *Labidiastrella* Verrill, 1914, p. 352. This genus includes *L. radiosus* Lütken, southern end of South America, south to 64° 48″ S.; *L. annulatus* Sladen, South Pacific north to Aru Islands; *L. crassus* Koehler, Antarctic.

connecting ossicles) bearing, along with the marginals, a slender acicular spine incased in a retractile, distally expanded sheath beset with a terminal wreath of very numerous crossed pedicellariae; inferomarginal plates spaced; superomarginal plates just above inferomarginals and connected with them, but alternate superomarginals abortive except at very base of ray; ambulacral plates not so crowded as in Asteriinae, and about the same as in *Coronaster*, the ambulacral pores, in fully grown specimens, being in two slightly zigzag series, except at ends of the ray where the line is straight; tube-feet in four ranks except at base of ray (two ranked in young specimens); adambulacral plates short and crowded as in *Coronaster*, monacanthid; oral plates of *Pedicellaster* type, but more compressed; interbrachial septa small, entirely membranous; no Polian vesicles; ampullae single; tube-feet long, with sucking disks; gonads two to each ray, attached at the side about on a level with the superomarginal plates; intestinal coecum entire; crossed pedicellariae with two enlarged terminal teeth to each jaw; straight pedicellariae not unguiculate nor broadened terminally; disk circular, rays rather deciduous, 12 to 20, but undoubtedly fewer in very young specimens; body wall thin; papulae in groups of 2 or 3 to 15, rather long and vermiform, numerous, arranged on ray in poorly marked longitudinal series; two or three to five papulae spring from a single pore.

Remarks.—This well-marked genus, which was named for the late Dr. Richard Rathbun, I compared originally with *Pycnopodia* Stimpson, to which it bears a resemblance entirely superficial. *Rathbunaster* seems to be more closely related to *Coronaster* than to any other known genus; and next to *Coronaster*, *Labidiaster* Lütken appears to be its nearest relative.

Both *Coronaster* and *Labidiaster* have a wide meshed reticulate skeleton made up of slender, lobed, cruciform plates, arranged in longitudinal and transverse series, and either joined directly by their lobes, or by one or two slender, imbricating intermediate ossicles. The papular areas are very large and usually fairly regularly quadrate except dorsolaterally on the basal portion of the ray where the more or less irregular dorsolateral (or adradial) series of plates introduces some irregularity. In neither genera are there actinal plates. The dorsal and lateral walls of the ray are composed of the two series of marginals, the adradials (proximally only) and the carinals. In both genera, but particularly in *Coronaster*, we have the characteristic sheathed and wreathed acicular spines. In both genera the abactinal skeleton, and to a certain extent the marginal connecting ossicles tend to disappear on the outer part of the ray. In *Rathbunaster* the abactinal and marginal connectives, a part of the abactinal primary plates and about half of the superomarginal plates have disappeared.

RATHBUNASTER CALIFORNICUS Fisher

Plate 12, figs. 5, 6; Plates 39, 40, 41

Rathbunaster californicus Fisher, Proc. Wash. Acad. Sci., vol. 8, Aug. 14, 1906, p. 137; Bull. U. S. Nat. Mus. 100, vol. 3, 1919, p. 493.—Verrill, Shallow-water Starfishes, 1914, p. 197.

Diagnosis.—Rays usually 17 (varying from 12 to 20). R 155 mm. (variable), r 23 mm.; R = 6.7 r (variable); breadth of ray at base, 9 to 11 mm. Disk nearly flat, circular; rays long, slender, more or less constricted at base, adjacent to disk, and somewhat inflated proximally; abactinal integument thin, membranous; abactinal skeleton reduced to small circular plates widely spaced on rays but closer on disk, each bearing a slender needlelike spine heavily wreathed by pedicellariae borne on the expanded top of a retractile sheath; inferomarginal plates spaced, with a single wreathed spine; superomarginal plates and spine above alternate inferomarginals; one rather long adambulacral spine; papulae numerous, slender, vermiform, in groups of 2 or 3 to 15, arranged in an intermarginal series, and in four to six, sometimes evident, abactinal series; without arrangement and crowded on disk.

Description.—Abactinal surface of disk typically covered with very delicate needlelike spines from 2 to 2.5 mm. long, encircled by a conspicuous globose bouquet of small crossed pedicellariae borne upon a heavy sheath. This sheath consists of a circular expansion of membrane, the upper or distal convex surface of which is thickly beset with pedicellariae, while that encircling the spinelet below is naked. These wreaths are a little larger and a little more crowded inside the middle of r, although there is more or less variation. The spines spring from small roundish independent plates imbedded in the integument and spaced about 0.5 to 2 mm. apart, each plate being 0.5 to 1.25 mm. in diameter. They are a trifle convex in the center, and are closer together on the central portion of the disk than near the periphery. On the ray the plates are spaced 1 to 4 mm. apart, and about four irregular longiseries are sometimes evident, although often no serial arrangement is observable. The abactinal plates of the ray also bear each a delicate wreathed spine. These are not nearly so numerous to the square centimeter as on the disk. Scattered between the primary plates are relatively few minute grains.

Marginal spines longer and stouter than the abactinal, with larger bouquets of pedicellariae. The inferomarginal plates are much larger than the abactinal plates, rudely lozenge-form and attached to the outer face of the adambulacrals, usually one to every four or five adambulacral plates. The inferomarginals are spaced in such a manner that proximally two or three adambulacrals (distally two) can be seen between them. The spine is borne on a ventral boss of the plate, and is about 3.5 mm. long in large specimens.

Just above each *alternate* inferomarginal is a somewhat larger oblong superomarginal, the lower end of which overlaps the upper end or side of the inferomarginal, while at the dorsal end upon a boss is borne an acicular wreathed spine subequal to the inferomarginal spine, and standing directly above it. Opposite the other, alternating, inferomarginals, the superomarginals are small and rudimentary, reduced to an ossicle devoid of a spinelet, and wholly invisible until the skin is dried. This plate disappears entirely beyond the middle of R. The first five or six inferomarginals are a little more crowded and each has a spiniform superomarginal adjacent to it.

The papulae are numerous, long, and vermiform, and are clustered in groups of from 2 or 3 to 10 or 15. There are usually about three, but up to five, and occasionally more, papulae to each pore which pierces the integument. For instance, in a group of 15 papulae the coelomic surface of the body wall shows 5 pores, evenly scattered. On the disk, the long papulae are packed in tightly between the spines and their globes of pedicellariae. On the rays the papulae are really in longitudinal series but it is difficult to make them out in most specimens, except in the case of the intermarginal series. There seem to be about six abactinal series indicated. In a specimen from station 3350 two series on either of the radial series of plates is clearly shown. The outer of these two seems to split into two less well defined lines.

The adambulacral plates are very short—much broader than long, and are oriented somewhat obliquely. The intervals between the plates are longer than the plates themselves. On the furrow margin, on a slight boss, is a single spinule about 3 to 3.5 mm. long, gently tapering, and much slenderer than the inferomarginal. Farther along the ray this spinule shortens more rapidly than does the inferomarginal spine.

Mouth plates small and those of the pair sometimes unequal in length, in such wise that the succeeding adambulacrals, which are joined along the interradial line with their neighbors, alternate with them instead of exactly corresponding. (See pl. 39, fig. 3*a*.) In form the plates are somewhat like those of the Brisingidae but much compressed. Usually there are two (sometimes three) actinostomial spinelets subequal to the foregoing, although only one suboral spine may be present, as in Plate 39, Figure 3.

Pedicellariae of two kinds, crossed and straight. The crossed pedicellariae (about 0.35 mm. long) are present on the retractile sheaths of the abactinal and marginal spines, never on the plates themselves, nor on the adambulacral spines or plates. (Pl. 39, fig. 4*a*.) The straight pedicellariae (pl. 39, fig. 4) are found sparingly on the oral plates and on the base of the oral spines; on the first few adambulacral plates, especially on the furrow face; occasionally on the marginal plates; very sparsely between the abactinal plates of the base of ray and of the disk. In specimens from station 3186, 3205, 3349, and 3350, from more northern localities than the type, the straight pedicellariae are much more numerous, especially on the furrow face of the adambulacral plates. These pedicellariae have a short peduncle and sometimes occur one on each of several consecutive plates, on alternate plates, or irregularly, especially toward the end of ray. They are more numerous also on the abactinal surface.

The ambulacral furrow is wide and shallow, and the ambulacral plates are much less crowded than in the Asteriidae. The ambulacral pores between the plates are arranged, in large fully grown rays, in two slightly zigzag series. The tube-feet, however, owing to their posture due to crowding, appear to form four series, except in the narrowed proximal portion of the furrow. The actinostome is very wide, 24 mm. on a disk of 44 mm. diameter.

Madreporic body small, circular, with radial striations, and situated one to two times its own diameter from interradial angle.

Color in life: General tint of disk and rays bittersweet pink (principally the large bouquets of papulae); skin whitish mottled and crossed by fine lines of orange scarlet (grenadine red). These lines run down sides of arms and disappear between the inferomarginal spines. Actinal surface cream color, darkest near actinostome, lighter on rays.

Variations.—The smallest specimen available has 12 rays, 2 of which are decidedly shorter than the others. In the case of the longest ray, $R=65$ mm. while $r=7$ mm. This specimen does not materially differ from the large ones except that the ambulacral pores form two straight series and the tube-feet are in two series. There are fewer pedicellariae on the wreaths.

The specimen, which is labeled as from station 3350, 75 fathoms, differs from the typical form in having 20 rays, usually 2 inferomarginal spines, numerous adambulacral straight pedicellariae, rather more numerous abactinal straight pedicellariae, and less numerous abactinal disk spines. The specimen from station 3349, 239 fathoms, has two inferomarginal spines on a few of the plates, but has fewer adambulacral pedicellariae (possibly scraped off some of the rays, as they are numerous on others). Both specimens have lost through abrasion a number of thin abactinal spines. These two examples seem to represent an incipient northern race. I do not feel sure of the correctness of the label on the specimen from station 3350. It resembles so closely in color and texture, as well as in certain individual peculiarities that from the preceding station, that I believe there is a possibility of mistake. Seventy-five fathoms is abnormally shallow for this species. The same reasonable doubt attaches to the record from station 4340.

Anatomical notes.—The coelom of the disk is almost entirely occupied by the large eversible stomach the lobes of which, very much wrinkled, reach to the base of the rays. When the stomach is entirely withdrawn and in normal position, the dorsal division, into which the hepatic coeca empty, can be clearly differentiated. Its periphery is about 0.4 the distance from the center to edge of disk. There is a well-marked constriction between this dorsal division and the ventral eversible stomach. The hepatic coeca depart from the dorsal stomach as a single wide duct, attached to the wall of the ventral stomach by a net-like mesentery. After passing through the constricted entrance to the radial coelom, the duct divides in two and extends about 0.8 the length of ray. Each duct is differentiated into numerous lateral unequal lobulate saccules arranged pinnately with reference to the central tube, which is fastened to the dorsolateral wall by a thin mesentery. Dorsal to the upper stomach is an intestinal coecum, rather acutely elliptical in form, about 10 mm. long and 4 or 5 mm. in diameter. It has a delicately plicated interior, and at the inner end has a conspicuous opening into the dorsal stomach and a small aperture leading into a very insignificant intestine.

The interbrachial septum is a tough membrane of small size. The inner free edge reaches mesad nearly as far as the inner border of the actinostomial ring, while the outer interbrachial edge, which is fused with the wall of the disk at the interbrachial angle, is opposite the eighth ambulacral plate. There is no rudiment whatever of a *horizontal* shelf projecting from the inner border of the actinostome above the first ambulacral plates and then distad into the ray, as in the case of *Heliaster*. (Such a shelf forms a coelomic cul-de-sac just above the ambulacral ridge and ventral to the hepatic coeca, and is an anatomical peculiarity of *Heliaster*.)

The gonads open upon the side of the ray about 1.5 r from the interbrachial angle, and slightly above the level of the superomarginal plates. One lobulate branch extends distad 60 mm. and another toward the base of ray about 10 or 12 mm. The short lobes of the branches are subdivided into small secondary lobes or divisions.

Ampullae large, single. They form two series along each side of the ambulacral ridge, but the pores between the ambulacral plates form a single series, fairly straight in small specimens and slightly zigzag in large ones. No Polian vesicles.

Type.—Cat. No. 21934, U.S.N.M.

Type-locality.—Station 2925, off San Diego, Calif.; 339 fathoms, mud; bottom temperature, 42.9° F.

Distribution.—Off California, from vicinity of San Diego to Point Arena, and from 207 to 369 fathoms, mud; temperature range, 41.3° to 44.1° F.; two records from under 100 fathoms open to doubt.

Specimens examined.—One hundred and fifty-one.

Specimens of Rathbunaster californicus examined

Station	Locality	Depth	Nature of bottom	Bottom temperature	Number of specimen	Collection
2892	Santa Barbara Channel, Calif.	284	Yellow mud	44.1	46	U.S.N.M.
2925	Off San Diego, Calif.	339	Mud	42.9	15	Do.
2927	do	313	Green mud	43.3	2	Do.
3186	Off Point Sur, central California	328	Black sand; mud	41.3	28	Do.
3199	Santa Barbara Channel	233	Green mud	43.9	9	Do.
3205	Off Monterey Bay	240	Black sand; rocks	43.7	1	Do.
3349	Off Point Arena, Calif.	239	Black sand	44.1	1	Do.
3350	do	75	Fine sand; mud	48.4	1	Do.
4339	Off San Diego Calif.	287-369	Green mud	41.5	9	Albatross, 1904.
4340	Off Los Coronados Islands, vicinity San Diego, Calif.	46-87	Fine gray sand, black specks.		2	Do.
4341	do	266-323	Gray sand, black specks.	42.	2	Do.
4363	Off San Diego, Calif.	207-348	Green mud; fine sand.	42.8	25	Do.
	Off Santa Cruz, Calif.	about 300	Mud and shale		10	Stanford coll., E. F. Ricketts from cod fishermen.

Remarks.—Several live specimens captured in about 300 fathoms off Santa Cruz and presented to the Hopkins Marine Station by Mr. E. F. Ricketts were kept in an aquarium for a week in water about 12 degrees higher than the 42 or 43 degrees Fahrenheit to which they were accustomed at their normal depth. These specimens were kept in subdued light and were fairly active. Small crabs and shrimps allowed to fall on the abactinal surface were instantly seized and held by the numerous batteries of crossed pedicellariae of the spine sheaths. In some cases the prey was then seized by the tube-feet and carried rapidly to the mouth. In others the victims succeeded in escaping. Doubtless in normal circumstances this species reacts as quickly and vigorously as *Pycnopodia*. The absence of a connected abactinal skeleton confers a high degree of flexibility to the rays. In the case of polybrachiate species this is also correlated with great speed for the class.

Subfamily Coscinasteriinae Fisher

Coscinasteriinae Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 249.

The carinal, the conspicuous marginal, and the actinal plates arranged in regular longiseries; carinals, dorsolaterals (sometimes also in regular longiseries), and superomarginals may carry a single, stout or slender, smooth or fluted, sharp or blunt, prominent, spikelike spine (sporadically two or three), provided with a collar of crossed pedicellariae; inferomarginals regularly with two prominent spines (sporadically three); one series of actinal plates (in one case rudimentary); adambulacral spines one or two, always without attached pedicellariae, but these may occur on oral spines; gonads open dorsally; some genera fissiparous; never paedophoric.

KEY TO THE KNOWN GENERA OF COSCINASTERIINAE

a^1. Only the outer of the two inferomarginal spines carries a cluster of crossed pedicellariae.

b^1. Adambulacral plates with two spines, at least on proximal half of ray; as a rule only two, or equivalent of two, series of dorsolateral papular areas (by no means always regular) on either side of carinal plates (alternate superomarginals usually spineless).

c^1. Rays regularly only five in adults, but six in fissiparous young of some forms; odontophore with single articulation pit on outer margin. (Pl. 43, fig. 2.)

d^1. Large spatulate, denticulate, straight pedicellariae; outer inferomarginal spines without trace of a ventrolateral web; rays semicircular or heptagonal in section; dorsal skeleton very irregular, the skeletal meshes not in two regular series on either side of the carinal line of plates; dorsolateral spines developed in even tiny specimens; they are numerous, in one or two irregular series on each side; adambulacral plates, diplacanthid proximally, monacanthid distally. Type, *Asterias sertulifera* Xantus. ---------- *Astromctis* Fisher.

d^2. Straight pedicellariae slender, lanceolate; outer inferomarginal spines connected in longiseries by a continuous more or less fibrous web confined to base of spines, much retracted in some dried specimens; rays pentagonal in section; dorsolateral skeleton regular, with two series of skeletal meshes on either side of the prominent carinal ridge; dorsolateral spines usually late in developing and in only one series; adambulacral plates with two spines throughout; the very young are fissiparous, usually six-rayed, possibly reproducing regularly by fission. Type, *Sclerasterias guernei* Perrier---------- *Sclerasterias* Perrier.

c^2. Rays seven to nine; so far as known not fissiparous; odontophore with 2 pits on outer margin (pl. 43, fig. 1); in general appearance similar to *Sclerasterias* but ray less markedly pentagonal in section; a well-developed series of dorsolateral and actinal spines; inferomarginal web absent or very rudimentary; only alternate superomarginals spiniferous, the plates generally with a conspicuous beaded area (present also in *Sclerasterias* and *Astromctis*); mouth angle rather narrow, with three to five contiguous pairs of postoral adambulacral plates; straight pedicellariae medium to large, smooth or denticulate. Type, *Margaraster scaber* Hutton---- *Astrostole* Fisher.

b^2. Adambulacral plates monacanthid throughout ray.

c^1. One series of spiniferous actinal plates; large straight pedicellariae with denticulate jaws.

d^1. Fissiparous, rays 7 to 12; skin covering skeleton not unusually thick and tough; crossed pedicellariae larger, with prominent lateral tooth to terminal lip; odontophore variable. Type, *C. muricata* Verrill---------- *Coscinasterias* Verrill.

e^1. Alternate carinal plates oblong-elliptical, without lateral lobes; mouth angle very constricted, with five or six contiguous pairs of adambulacral plates, behind the mouth plates; odontophore, with one or two pits, or irregular, with several. (Pl. 43, figs. 3, 3*a*)---------- Subgenus *Coscinasterias*.

e^2. All carinal plates four-lobed; mouth angle broader, with two or three contiguous pairs of adambulacral plates behind mouth plates, odontophore with one articulation pit on outer border; first ambulacrals broader. (Pl. 43, figs. 4, 4*a*.) Type, *Asterias tenuispina* Lamarck---------- Subgenus *Stolasterias* Sladen.

d^2. Not fissiparous, rays five to seven; skeleton obscured by a thick tough skin; crossed pedicellariae very small, round tipped, without enlarged lateral terminal tooth; odontophore with two pits on outer margin. (Pl. 43, fig. 7.) One series of spiniferous actinal plates; dorsolateral skeleton irregularly reticulated, the papular areas equivalent to three or four longiseries, but only the lateralmost in a regular series; abundant, large, broadly lanceolate, straight pedicellariae, with rather compressed denticulate jaws. Type, *Asterias gelatinosa* Meyen---------- *Meyenaster* Verrill.

c^2. One series of small, spineless actinal plates hidden by skin. Not fissiparous; rays five; dorsolateral skeleton normally fairly regular, the papular areas in two longiseries on either side of the carinal series; dorsolateral and carinal spines either regular or very irregular (*africana*); straight pedicellariae lanceolate, compressed. Type, *Marthasterias foliacea* Jullien = *Asterias glacialis* Linnaeus---------- *Marthasterias* Jullien.

a^2. The inner as well as outer inferomarginal spine carries a cluster of crossed pedicellariae; adambulacral plates with two spines.

b^1. Secondary oblong ossicles between consecutive plates of both carinal and superomarginal series; crossed pedicellariae characteristically large, double-fanged. All primary plates spiniferous; one or two series of four or five-lobed dorsolateral plates in quincunx and connected by one of more slender ossicles, forming a very open-meshed skeleton with large, triangular, and lozenge-shaped papular areas; a few relatively huge, unguiculate, straight pedicellariae; actinal plates rudimentary, spineless; adambulacral spines two, mouth angle stout, with two pairs of contiguous postoral adambulacral plates; not fissiparous. Type, *Asterias forreri* de Loriol ---------------------- *Stylasterias* Verrill.

b^2. Carinals and superomarginals directly imbricated in series, without interpolated secondary oblong ossicles; three (or the equivalent of three) or more dorsolateral series (often very irregular) of papular areas on either side of the carinal plates.

c^1. Actinal spines absent, or, if present, are devoid of attached pedicellariae; adoral carina not especially long or narrow, nor actinostome sunken (two or three pairs of contiguous postoral adambulacral plates).

d^1. A definite series of spineless actinal plates, hidden under a thick integument; each carinal and superomarginal plate regularly spiniferous.

e^1. Crossed pedicellariae with two enlarged terminal teeth on each jaw, conspicuously larger than the median terminal teeth; dorsolateral plates not exceptionally numerous, in two or three regular or irregular series on each side; one species with large unguiculate straight pedicellariae; odontophore with one pit on outer margin. (Pl. 43, fig. 5.) Type, *Asterias* (*Stolasterias*) *stichantha* Sladen *Distolasterias* Perrier.

e^2. Crossed pedicellariæ without enlarged terminal teeth; predominant straight pedicellariae relatively very large, broadly spatulate, with long curved tines (resembling a pair of clasped hands); dorsolateral plates very numerous, small, crowded, irregularly arranged, but in the equivelent of four to six (or more) series on each side; spines ornately fluted; odontophore with 2 pits on outer margin. (Pl. 62, fig. 1.) Type. *Asterias nanimensis* Verrill ---------------------- *Lethasterias* Fisher.

d^2. A conspicuous series of actinal spines (without a cluster of attached crossed pedicellariae); crossed pedicellariae very small, without any of the terminal teeth enlarged; all straight pedicellariae slender, lanceolate; two pairs of contiguous postoral adambulacral plates; each carinal and superomarginal not regularly spiniferous, usually only the alternate plates; dorsolateral spines few, scattered. Type, *Coscinasterias dubia* Clark (Australia, Tasmania) ------------------------------ *Australiaster* Fisher

c^2. A definite series of well-developed actinal spines, each with a conspicuous cluster of crossed pedicellariae on its outer side; crossed pedicellariae without two terminal teeth, larger than the other teeth; straight pedicellariae large, broadly lanceolate, compressed, to spatulate denticulate or unguiculate; oral carina narrow, with upward of five contiguous pairs of postoral adambulacral plates, actinostome sunken. Type, *Asterias koehleri* de Loriol (*O. columbiana* Verrill) ---------------------- *Orthasterias* Verrill.

Remarks.—Very poor results have followed attempts to squeeze the known species of Coscinasteriinae into a few genera. In the foregoing key the analysis of the subfamily has been allowed to proceed as far as the facts seem to warrant. A number of monotypic groups has resulted but the divisions are more natural than any which have heretofore been recognized.

The form of the crossed pedicellariae and their distribution on the marginal and actinal spines have been given considerable weight. They have shown themselves to be conservative and reliable characters by the simple process of testing results by other structural features. I have introduced tentatively the odontophore and the actinostomial ring. Only more observation will determine whether the pits in the outer margin of the odontophore are constant and reliable generic characters. The double pits of *Astrostole*, *Meyenaster*, and *Lethasterias* appear to be reliable, but too much dependance should not be placed upon this criterion. In *Coscinasterias calamaria* the odontophores are often irregular. Sometimes there are two widely separated pits which are the articulation points of two plates, or there is only one pit with the faint imprint of others. In all probability species which usually have two pits will vary to one by the simple coalescence of the two.

An arrangement of the genera in columns in order to suggest relationships is given below. Those in a column are believed to be rather more nearly related than are two genera in different columns. According to this scheme *Stylasterias* and *Distolasterias* are very far from *Orthasterias*. However *Stylasterias* and *Distolasterias* are not so closely related as *Sclerasterias* and *Marthasterias*.

Stylasterias.	Sclerasterias. Marthasterias. Astrometis.	Meyenaster.	Australiaster.	Orthasterias.
Distolasterias.	Coscinasterias. Astrostole.	Lethasterias.		

Genus STYLASTERIAS Verrill, emended

Stylasterias Verrill, Shallow-water Starfishes, etc., 1914, subgenus, pp. 48, 65, 179; genus p. 50.—Type *Asterias forreri* de Loriol.—Fisher, Ann. Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 256.

Diagnosis.—Coscinasteriinae having the inner as well as the outer inferomarginal spine armed with a pad of pedicellariae; secondary oblong ossicles between consecutive carinal and superomarginal plates; rudimentary, spineless actinal plates; unusually large crossed pedicellariae, having two conspicuous terminal teeth on each jaw; diplacanthid adambulacrals. All primary plates spiniferous; one or two series of four or five lobed dorsolateral plates forming triangular and lozenge-shaped skeletal meshes by means of connecting slender ossicles; mouth-angle stout, with two pairs of contiguous postoral adambulacral plates; marginal plates without trace of a specialized area of hyaline beads; ambulacral ossicles not severely compressed; straight pedicellariae large, wedge-shaped, with several curved interlocking teeth; not fissiparous.

Remarks.—The crossed pedicellariae alone will serve to identify this genus which appears to occupy a rather isolated position. It approaches *Distolasterias* more nearly than any other group but differs in respect to the secondary carinals and superomarginals, and in having much larger crossed pedicellariae. Basically the design of these is similar in the two genera but the characteristics are greatly exaggerated in *Stylasterias*.

All species of *Stylasterias* described since 1914 belong to other genera.

STYLASTERIAS FORRERI (de Loriol)

Plate 44; Plate 45; Plate 46; Plate 47, Figures 1–3; Plates 48–50; Plate 51, Figure 1; Plate 53, Figure 5

Asterias forreri de Loriol, Notes pour servir à l'étude des Échinodermes II, Recueil zoologique Suisse, vol. 4, No. 3, 1887, p. 401, pl. 18, figs. 1, 1*a*–*q*; not Jennings, 1907.

Asterias (*Urasterias*) *forcipulata* Verrill, Amer. Journ. Sci., vol. 28, 1909, p. 67; Amer. Nat., vol. 43, 1909, p. 542.

Orthasterias forreri Verrill, Shallow-water Starfishes, etc., 1914, p. 179, pl. 65, fig. 1; pl. 66, fig. 1, 2; pl. 70, fig. 7; pl. 77, figs. 1–1*d*; pl. 80, figs. 1–1*e*.

S [*tylasterias*] *forreri* Verrill, Shallow-water Starfishes, etc., 1914, pp. 48, 50.

Orthasterias forreri forcipulata Verrill, Shallow-water Starfishes, etc., 1914, p. 180, pl. 62, figs. 2, 3; pl. 70, fig. 9; pl. 88, figs. 6, 6*a* (6*a* is an error, since the crossed pedicellariae are not those figured in the photograph of the type, nor do they belong in this genus).—Fisher, Ann. Mag. Nat. Hist. ser. 9, vol. 12, 1923, p. 257 (*forreri*).

Orthasterias leptolena Verrill, Shallow-water Starfishes, etc., 1914, p. 182, pl. 64, fig. 1, 1*a*, 2, 2*a*; pl. 77, fig. 2, *a–d*.—Fisher, Ann. Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 257 (*forreri*).

Diagnosis.—Rays five, long, slender, subterete, more or less deciduous; disk very small; dorsal spines slender, tapered, smooth; in three to five longiseries proximally, three distally; heavily wreathed by basal cushions of the large crossed pedicellariae; each primary marginal spiniferous; inferomarginals grooved and truncate distally, each with a prominent tuft of pedicellariae; inner adambulacral shorter and slenderer than outer which has often a truncate grooved tip; large wedge-shaped straight pedicellariae with two to five teeth scattered between spines, dorsally laterally and sparingly on actinal channels. R (in fully developed specimen) 185 mm.; r 15 mm., R = 13.3 r; breadth of ray at base, 19 mm. R varies to 16 r.

Description.—The long, slender, spikelike, evenly tapered, bluntly pointed abactinal spines are rather uniformly spaced about their own length apart or more, depending upon the degree of inflation of ray. They are arranged in three fairly regular longiseries but in most specimens other than young there is a lateral series on either side beginning near base of ray and extending a variable distance toward the extremity. In very large specimens (as Port Chester, R 290 mm., pl. 44, fig. 1) these series extend about half the length of ray, and one can count five rows of spines between the two series of superomarginals of the same ray. In this large specimen the longest dorsal spines are 4 mm.; space between, 5 to 7 mm. In a large specimen from La Jolla (R 190 to 200 mm.) the longest spines are 4.5 to 5.5 mm. in length. In Monterey Bay examples, which may be regarded as typical, the lateralmost series is short so that over most of the ray there are but three longiseries.

Superomarginal spines, one to each primary plate, are closer together than carinals (pl. 44, fig. 1) and a little longer and slenderer. Intermarginal channel slightly less in width than length of these spines.

Inferomarginal spines, two to a plate in an oblique series, are about equal, or the outer a trifle the larger and a little longer than adjacent superomarginal spine. The tips are slightly expanded, truncate, and typically gouge-shaped, the channel extending sometimes a third or half way to the base. Each spine carries a thick cushion of crossed pedicellariae on the outer side. Actinal interradial areas very small, often quite bare, or with one or two large straight pedicellariae. The narrow area between the inferomarginal spines and adambulacrals is crossed by fine transverse furrows (one between each pair of adambulacrals). These converge (sometimes meeting) to pass between the inferomarginal combs and on irregularly across the dorsum. This actinal area sometimes carries a few large straight pedicellariae. Beneath the skin and invisible except in cleaned specimens is a series of thin actinal plates set with edge to surface. (Pl. 53, fig. 5.) At base of ray is a second series of rudimentary plates adjacent to adambulacrals. Actinal spines never present.

Opposite first 10 spiniferous inferomarginal plates (really second to eleventh) there are 34 to 38 adambulacral plates; 34 or 35 in fairly large Monterey Bay examples; 38 in specimen from Port Chester, Alaska. Each plate carries two very slender, flattened truncate spines in an oblique series, the outer the heavier and longer. Its extremity is shallowly grooved and sometimes slightly broadened, as on the proximal part of ray. The inner spine is attached lower on the furrow face of the plate, is abruptly tapered at base, thence is very slender; not expanded nor sulcate distally. Outer spine, 6 mm.; inner, 5.5 mm.

Mouth angle broad, not at all sunken, with two postoral pairs of adambulacral plates in contact interradially. (Pl. 45, fig. 7.) In young specimens (pl. 44, fig. 4) only the inner half of the first pair is in contact. The first adambulacral carries one spine, the second, either one or two. Mouth plates with usually two, rarely three, marginal spines and one long, slender, suboral spine. (Pl. 45, figs. 6, 7.)

Skeletal meshes large dorsally, but papulae are in small, spaced groups of from 3 to 10 papulae, there being from 2 to 6 of these groups in each mesh of the abactinal skeleton. Intermarginal papulae in a single group of from 8 to 10 to a skeletal interval, while actinally there are as many as 10 papulae proximally and only 1 or 2 distally (series extends 0.7 to 0.8 length of ray in large specimens).

The thick circumspinal clusters of crossed pedicellariae in alcoholic specimens nearly touch one another and form broad cushions marking the primary skeletal plates. The pedicellariae are unusually large and are of a very characteristic form, having two relatively large terminal fangs to each jaw with a row of three or four prominent teeth below on the shank, the series ending with a group of four or five denticles where the jaws cross. In a large specimen the pedicellaria is commonly from 0.95 to 1.3 mm. long. (La Jolla; for other measurements see pl. 46.) An attentive comparison of many of these pedicellariae has not revealed variations which can be correlated with habitat. Almost the maximum variation is found in one specimen from Kell Bay, Alaska. (pl. 46. figs. 1, *1a*, *1b*.) Very young specimens have the characteristic pedicellaria, only much smaller. (Figs. 2, *2a*.)

Straight pedicellariae (pl. 45, figs. 1–4) are of the wedge-shaped, clawed type, generally large (figs. 1, 2, 3) but sometimes predominantly small (figs. *3a*, 4) the difference without apparent correlation to locality. These occur on the dorsal integument, intermarginally and sparingly on the actinal plates, especially interradially. The largest are 2.8 mm. long and are equally well developed in specimens from Alaska, Monterey Bay, and off southern California. (Fig. 3). The smaller sort (figs. *1b*, *3a*) occur on the same specimens with the larger. Sometimes an example will occur with only the smaller type. (Fig. 4, station 4552.) Small, broadly lanceolate, acute pedicellariae sometimes occur sparingly on the furrow margin but are more often entirely absent.

Madreporic body large, circular, exposed; striae fine, radiating.

Color in life from Monterey Bay examples: General tint of dorsal surface olivaceous sepia; spines whitish. Integument between the thick tufts of pedicellariae, deep brown, especially on disk, but little of this brown is visible on the rays on account of the masses of pedicellariae. Actinal surface, buffy white. Occasional specimens have the ground color dark bluish gray instead of brown.

Variations.—These are comparatively slight considering the distribution in latitude of the species. The difference in number of large and small straight pedicellariae has already been mentioned.

An example from station 4410 (pl. 48, fig. 1) is notable for the slender spines and long slender rays (R = 16 r), yet an example from station 4421 (pl. 49, fig. 2) from even deeper water (229–291 fathoms) matches Monterey Bay specimens from 56 fathoms. The first specimen (4410) has numerous very large straight pedicellariae while the second has very few.

No specimens from the southern part of the range are so large as the three from Naha Bay, Kell Bay, and Port Chester (pl. 51, fig. 1), although from station 4553, Monterey Bay, is a typical specimen with R 240 mm. The Kell Bay example has R 280 to 290 mm. The type of Verrill's *forcipulata* has a ray 325 mm. long. (Departure Bay, 18 fathoms.) This last form is simply a giant *forreri*, typical in all respects.

Anatomical notes.—The skeleton of the adult (pl. 44, fig. 1) if a little more regular would consist of a series of triangular meshes adjacent to carinals (point, outward) another adjacent to superomarginals (point, mesad) and separating these two, a series of quadrilateral or lozenge-shaped meshes. The actual approximation to this ideal can be observed in the figure, from which the rudimentary actinals and the adambulacrals have been omitted. Although the open dorsolateral skeleton suggests *Coronaster*, the resemblance is entirely superficial. *Coronaster* has very large, square intermarginal meshes with secondary ossicles connecting the superomarginals to inferomarginals.

A characteristic feature of the skeleton is the presence of secondary superomarginal and carinal plates between the lobed primary plates. These begin to develop in very small specimens (pl. 44, figs. 2, 3), and in fully grown examples there may be two or three between two carinals but generally only one between the superomarginals.

The ambulacral plates are less crowded (and hence less compressed) than is usual in the Asteriidae. Thus in a space of 10 mm. at the base of ray there are 10 ambulacral plates in the large Port Chester example, while in an equally large *Orthasterias koehleri* there are 14, and in *Evasterias troschelii*, 13. The ambulacral pores are unusually large and the outer pore series is nearer to the inner than in *Orthasterias*.

The small actinostome is surrounded by a massive ring of plates (pl. 45, fig. 5) composed chiefly of conspicuous odontophores and the enlarged proximal end of the ambulacral ridge. In Figure 5*b* is shown an unusual side view of the end of the ambulacral ridge, with a single mouth plate attached, the mouth pair having been separated at the median suture. The sutural face, as well as that of the first two adambulacrals, is exposed. The odontophore abuts against the points x and xx, acting as a keystone to that arc of the circle. (Fig. 5*a*). A dorsal process of the mouth plate (M′) also forms an essential part of the circle.

The first spiniferous inferomarginal is really the second plate (pl. 44, fig. 2, 4, II) of the series. The first plate is early shoved out of line and is *under* the second. In small specimens (fig. 4) it would be mistaken for an actinal. The latter are later developed between it and the adambulacrals. The small unpaired "actinal" plate shown in Figure 4 (*AC*, fig. 2) forms a part of the interbrahcial septum and in old specimens sinks under the integument. It is apparently not a true actinal plate.

Viscera: There is a large three-parted intestinal coecum, the thin-walled lobes of which extend into the base of three rays. Its dorsal surface is closely pressed against the dorsal wall of the disk. The dorsal stomach is fairly well differentiated from the ventral and the large hepatic coeca extend a little over two-thirds the length of the ray. The stomach proper is eversible, very spacious, and fills the small disk, its lobes extending into the rays a short distance. The gonads, undeveloped in the specimen examined, lie wholly within the ray. Each consists of a central axis and numerous lobulated branches, irregularly arranged. The opening appears to be on the side of the ray, close to the interradial angle on a level with the superomarginal plates, which here bend upward. No Polian vesicles observed. Ampullae single, large, crowded.

Young.—Numerous young specimens taken alone and with adults, the smallest having R 9 mm., differ in appearance chiefly on account of the fewer dorsolateral spines and the relatively smaller intervals of the skeleton. The numerous connecting secondary ossicles of the adult are much fewer in number. The crossed pedicellariae are absolutely diagnostic in cases of doubt. On Plate 44, Figures 2, 3, 4, various details of the skeleton of immature examples are shown. Only a few of the secondary carinal and superomarginal ossicles are developed; the interbrachial "septum" or buttress has fewer plates than in the adult; only the first pair of adambulacrals meet behind the mouth plates; there are no actinal plates, the apparent first actinals being in reality the first superomarginals displaced. In examples with R less than 20 mm. ambulacral pores are in two series.

A specimen with R 20 to 25 mm. is easily identified. It has three dorsal lines of spines, unequal furrow spines, bare actinal interradial areas, and characteristic pedicellariae. In young specimens both the first and second pair of adoral adambulacrals at first have two spines each. Later the first plate loses the subambulacral and sometimes one of the second pair also loses a spine, leaving a transverse series of three for the pair. In specimens with R 50 to 100 mm. the straight dermal pedicellariae are disproportionately big, being nearly as long as the dorsal spines and considerably thicker when their "sheath" is still covering them.

Orthasterias leptolena is the young phase of *forreri*.

Type-locality.—Off Santa Cruz, Monterey Bay, Calif. (de Loriol).

Distribution.—Southern Alaska to San Diego, Calif.; 16 to 291 fathoms, on rocky bottom; temperature range, 43° to 51.8° F.

Specimens examined.—Eighty-three.

Specimens of Stylasterias forreri examined

Station	Locality	Depth	Nature of bottom	Bottom temperature	Number of specimens	Collection
2873	Off Washington	40	Rocks	47.8	1	U. S. Nat. Mus.
2874	do	27	do	50.3	6	Do.
2875	do	40	do	47.8	10	Do.
2954	Off southern California	65	do		1	Do.
2959	do	55	Green mud, gray sand, broken shells.	51.9	1	Do.
						Do.
3051	Off Oregon	59	Broken shells, rocky		2	Do.
3095	do	42	Rocks, broken shells	47	3	Do.
3108	Vicinity Half Moon Bay, Calif.	43	do	50.8	1	Do.
3125	Off Santa Cruz, Calif.	65	Fine gray sand, shells	48.4	1	Do.
3159	Southwest Point Reyes, Calif.	27	Rocky		1	Do.
3160	do	39	do	51.8	1	Do.
3205?	Off Monterey Bay	240	Black sand, rocks	43.7	1	Do.
3666	Monterey Bay	68	Mud, sand, boulders		1	Do.
	Port Chester				1	Do.
	Kell Bay, Alaska	16			1	Albatross, 1903.
	Naha Bay, Alaska				1	Do.
232	Naha Bay, Behm Canal, Alaska	77-83	Green mud, rocky	43.3	1	Do.

Specimens of Stylasterias forreri examined—Continued

Station	Locality	Depth	Nature of bottom	Bottom temperature	Number of specimens	Collection
4410	Off Long Point, Santa Catalina Islands, Calif.	178-195	Gray sand, gravel, rocks		1	Albatross, 1904.
4421	Off East Point San Nicholas Island, Calif.	229-291	Gray mud, rocks		1	Do.
4441?	Monterey Bay, Calif. (off Point Pinos)	28-35	Black mud, sand shells		1	Albatross, 1904.
4535	do	54-71	Hard gray sand		1	Do.
4550	do	50-57	Green mud, rocks		3	Do.
4551	do	56	Coarse sand, shells rocks		8	Do.
4552	do	73-66	Green mud, rocks		9	Do.
4553	do	74-65	Rocks		4	Do.
4554	do	60-80	Green mud, rocks		7	Do.
4555	do	66-69	do		4	Do.
4556	do	56-59	Rocks		4	Do.
4557	do	53-54	do		1	Do.
4558	do	40-28	do		3	Do.
	Heceta Bank, Oreg.	82-87			1	Albatross, 1914.
	La Jolla, Calif.				1	Stanford.

Remarks.—This species is easily identified by the abundant large crossed pedicellariae of peculiar form, by the long slender rays, well spaced, slender spines, and entire absence of actinal plates. It is common on rocky bottom in Monterey Bay but is not for that reason easy to procure. It can seldom be captured except with heavy hempen tangles.

Orthasterias forreri forcipulata Verrill and *O. leptolena* Verrill represent, in my opinion, respectively a very large specimen and young examples of true *forreri*. I have examined the type of *leptolena*, which, like that of *forcipulata*, was taken in Departure Bay, British Columbia. Professor Verrill compares *O. forreri forcipulata* with *Urasterias linckii* and *O. leptolena* with *Orthasterias koehleri*. The type of *forcipulata* had been dried without being hardened so that the rays have a queer, abnormal appearance. The pedicellariae are absolutely typical of *forreri*, and the specimen is comparable to the large examples which I have from southern Alaska. It is not evident what characters Professor Verrill intended to employ in discriminating the three forms. Certain features are alluded to in his key on page 65 but these are not valid distinctions.

Under the literature referring to *forreri* is usually cited the paper by Jennings on "Behavior of the Starfish Asterias forreri de Loriol." [33] The species used by Professor Jennings is *Astrometis sertulifera* (Xantus). *Stylasterias forreri* is a deep-water species in southern California and only one specimen has ever been taken near La Jolla where Jennings's work was done. This large example (of which a ray is shown, pl. 49, fig. 1) moreover probably came from deep water at a considerable distance from La Jolla. Dr. H. L. Clark's records of *forreri* [34] from Lower California also refer to *Astrometis sertulifera*.

The fundamental differences between the two species are, of course, those which separate the two genera, *Astrometis* and *Stylasterias*. As recognition characters may

[33] Univ. of Cal. Pub. Zoöl., vol. 4, No. 2, 1907.

[34] Echinoderms from Lower California, etc., Bull. Amer. Mus. Nat. Hist., vol. 32, art. 8, 1913, p. 203; Supplementary Report, vol. 48, art. 6, p. 153.

be mentioned the following: The very large double-fanged pedicellariae of *forreri* and the presence of these on the *inner* inferomarginal spines; the rudimentary character of the actinal plates which never carry spines.

Genus DISTOLASTERIAS Perrier

Plate 60, Figures 1, 1*a*–1*d*, 3

Distolasterias PERRIER, Résult. campag. sci. du Prince de Monaco, fasc. 11, 1896, p. 34. Type, *Asterias* (*Stolasterias*) *stichantha* Sladen.—FISHER, Ann. and Mag. Nat. Hist., ser. 7, vol. 17, 1906, p. 574; Starfishes Hawaiian Islands, 1906, p. 1105 (subgenus including *Sclerasterias*); Starfishes of the Philippine Seas, 1919, p. 487 (genus, including *Sclerasterias*).—VERRILL, Shallow-water Starfishes, 1914, pp. 47, 185 (genus including *Lethasterias*).

Diagnosis.—Resembling *Sclerasterias* in having diplacanthid adambulacral plates, but differing in having on the inner as well as on the outer of the two inferomarginal spines a cluster of crossed pedicellariae; dorsolateral plates in more than a single series; crossed pedicellariae with two enlarged terminal teeth on each jaw, conspicuously larger than the median terminal teeth; normally a spine on each superomarginal (and carinal) plate; no specialized area of pebbling on superomarginals; actinal plates small, spineless, hidden under thick integument of actinal surface.

Remarks.—Perrier first used this name in a summary key to take care of those species of *Coscinasterias* with two adambulacral spines. No other peculiarities were indicated and the group apparently left no great impression, since a few pages further on he placed the diplacanthid *Stolasterias neglecta* in a genus specially characterized by monacanthid adambulacral plates; that is to say, in a group headed by *Asterias glacialis*, for which a kidnapped name, for some unexplained reason, is chosen.

The sense in which the writer employed the name in 1906 and 1919 corresponds to *Sclerasterias* of this work; while Verrill used the name in the sense of *Lethasterias*.

The known species are: *Distolasterias stichantha* (Sladen), 345 fathoms, off Japan; *D. robusta* (Ludwig), Galapagos Islands, 385 fathoms; *D. nipon* (Döderlein), Sea of Japan to Hong Kong.

In my "Preliminary Synopsis," the predominant straight pedicellariae of *Distolasterias* were said to be small, slender lanceolate. This is true of *D. nipon* and *D. robusta* but not of *D. stichantha*, the type of which I later had the privilege of examining. (See pl. 60, figs 1, 1*a*–1*d*.) Scattered over the abactinal and lateral surfaces are bivalved hand-shaped pedicellariae, an especially large one (in two interradii, two) occupying the actinal interradial area. Another slightly smaller one may stand near the first or second inferomarginal spine. The abactinal are 1.5 to 1.8 mm. long and the large interradial ones are 2.2 mm. long. In *D. stichantha* the abactinal spines are not always in such neat rows as figured,[35] although on one ray this is true. The adoral carina is composed of two pairs of postoral adambulacral plates, the plates of the outer pair not wholly in contact, since the distal ends diverge. The plates of the third pair are rather widely separated. There is a series of small spineless actinal plates hidden by the integument.

Distolasterias differs from *Lethasterias* in having prominently fanged straight pedicellariae; fewer, less crowded, dorsolateral plates; an odontophore with a single pit or depression on the outer border.

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[35] Sladen, Challenger Asteroidea, 1889, p. 586, pl. 106.

There is evidence that *D. robusta* has a fissiparous young stage similar to that of *Sclerasterias*. At station 3404, at which the type of *robusta* was taken, were dredged nine broken arms of a young sea star which Ludwig calls "Hydrasterias (?), sp. nov." [36] There is no disk and the longest arm is 24 mm. These resemble in a general way the intermediate stage between the young and adult phases, described for *Sclerasterias euplecta*. There is no special evidence of fissiparity except the apparent homology just indicated.

These probable young of *robusta* have similar pedicellariae to the adult. The straight are conspicuous, slightly spatulate, and have a few teeth. I have found one or two similar pedicellariae on the type of *robusta*. The carinal, one series of dorsolateral, and the superomarginal plates each carry a small spine, and between these the crossed pedicellariae are thickly scattered, as in the homologous stage of *Sclerasterias*. The spines have not yet developed sheaths to carry the pedicellariae, which are still absent also from the two inferomarginal spines. The tube-feet are strongly four-ranked.

DISTOLASTERIAS NIPON (Döderlein)

Plate 43, Figure 5; Plate 60, Figures 2, 2a; Plate 81, Figure 8

Asterias nipon Döderlein, Japanische Seesterne, Zoolog. Anz., vol. 25, 1902, p. 334 (Japan).
Distolasterias tricolor A. Djakonov, Zwei neue Seesterne aus dem Westlichen Nordpacific, Ann. Mus. Zool. Acad. Sci. U. R. S. S., vol 27, 1926 (1927), p. 315, pl. 22, figs. 3–8; pl. 23, figs. 9, 10 (Peter the Great Bay, near Vladivostok).

Diagnosis.—Rays 5. R 155 mm., r 21 mm., R = 7.4 r; breadth of ray at base, 23 mm. (Peter the Great Bay); R 176 mm., r 20 mm., R = 8 r; breadth of ray at base, 27 mm. (type, northeast coast Honshu, Japan). Disk small, rays slender. Abactinal spines, surrounded by thick wreaths of crossed pedicellariae, well spaced, 2 to 4 mm. long, sharp or blunt, the distal tapered half with irregular coarse grooves or channels; carinal spines in a definite series more closely set than the dorsolaterals, which are not in definite longiseries (pl. 89, fig. 8); superomarginal spines one to a plate, inferomarginals two to a plate, a little longer than abactinals, shallowly gouge-shaped and subtruncate, sometimes bifid; adambulacral spines two, very slender, nearly as long as inner inferomarginals; straight pedicellariae, lanceolate, slender; crossed pedicellariae with two prominent terminal fangs.

Description.—The general habit is indicated by Figure 8, Plate 81, a specimen from Peter the Great Bay (near Vladivostok) and now in the Museum of Comparative Zoölogy. A similar specimen was forwarded to the writer by Doctor Djakonov.

The largest example recorded by Djakonov has R 233 mm., r 35 mm. In his specimens, R varies from a little less than 7 r to 8 and 9 r. My large Hong Kong example measures R 200 mm., r 25 mm., R = 8 r, exactly the proportions of a Vladivostok example. In the type, from the northeast coast of the main island of Japan, R equals 8.8 r.

The abactinal integument of a dried or alcoholic specimen is a characteristic blackish or very dark brown color, against which the yellowish spines and their rather broad encircling cushions of pedicellariae are in sharp contrast. The abactinal spines vary somewhat in stoutness but taper from a generally cylindrical or

[36] Mem. Mus. Comp. Zoöl., vol. 32, p. 246, fig. 205.

slightly swollen base, the distal portion being more finely grooved in small than in fully grown examples. Carinals normally one to every plate; dorsolaterals much more widely spaced, and in the equivalent of two or three longiseries, but not regularly arranged, because the plates are not in definite longiseries.

The abactinal skeleton of the ray consists of a close-meshed network of four-lobed carinal and three to five, rarely six, lobed dorsolateral plates. The carinals (with broader longitudinal than transverse lobes) are sometimes irregular in outline where the series is distorted, but are directly imbricated in a definite, fairly regular, line. The marginals are also directly imbricated, but the dorsolateral skeleton consists of primary, spiniferous plates, connected by slender transverse, and very short longitudinally oriented, intermediate ossicles. (Djakonov, pl. 22, fig. 6.) In each mesh of the skeleton one, rarely two or three, groups of 7 to 15 papulae (even more in largest specimens and fewer in young examples).

Superomarginal spines one to a plate in a very regular longiseries at edge of abactinal area. Separated from them by a regular series of papular areas, but by usually less than their own length, is a double series of subequal inferomarginals. The marginal spines are characteristically gouge-shaped and the tip is usually slightly narrowed, subtruncate, or double pointed if the groove is deep. There is no trace of an inferomarginal web, but each inferomarginal spine carries a basal tuft of crossed pedicellariae.

Actinal plates small, wedged between the inferomarginals and adambulacrals, and entirely hidden by the thick integument. A regular series of actinal papular areas, containing six or seven, or more, papulæ.

Adambulacral spines two, very slender, slightly tapered, the outer nearly as long as inferomarginals, the inner usually a little shorter. Adoral carina consists of three or four pairs of plates, the inner two usually each with one spine; first plate distinctly longer than second. The specimen from Hong Kong has five pairs in the adoral carina.

Mouth plates short, each with one suboral and two actinostomial spines; that next to median suture is tapered, blunt, about as long as plate, the other quite small.

Crossed pedicellariæ (pl. 60, figs. 2, 2*a*) are often rather more tapered toward the end than shown by figure and are characterized by unusually large terminal teeth on either side of each jaw. These are stouter than in *D. stichantha* (Sladen). (Pl. 60, figs. 1*c*, 1*d*.) Average abactinal pedicellariæ measure: Ayukawa, Japan, 0.45 mm.; Peter the Great Bay, 0.40 to 0.45 mm.; Hong Kong, 0.48, to 0.55 mm.

The straight pedicellariae are characteristically slender, lanceolate and pointed. Small ones, from 0.40 mm. to 1.0 mm. long, are fairly abundant on the abactinal, lateral, and actinal surfaces, and on the adambulacral plates. Larger ones, 1.5 mm., are found in the intermarginal channels and actinal interradial regions. In the larger specimen from Peter the Great Bay a very few of these pedicellariae show one or two incipient teeth at end of jaw. (Djakonov, fig. 8.)

Madreporic plate large, exposed, convex, one-third to one-fourth r in diameter, and situated at about middle of r.

Color in life: Entire actinal surface and all spines and wreaths of pedicellariae yellowish white; skin of abactinal surface between the stoles of pedicellariae velvet black, with dark gray papulae; madreporic plate, deep orange (Djakonov.)

Type-locality.—Japan (northeast coast of Honshu).

Distribution.—Japan Sea (Peter the Great Bay); Japan; Hong Kong. Common in Peter the Great Bay on muddy bottom, to 15 fathoms; off Japan, to 81 fathoms.

Specimens examined.—Peter the Great Bay, Dr. A. Djakonov, two; Mororan, Hokkaido, two; Ayukawa, Japan, one; Hong Kong, China (U. S. Nat. Mus.), two; *Albatross* stations 3773 and 3774, off Honshu, Japan, 78–81 fathoms, three.

Remarks.—*D. nipon* differs from *D. stichantha* in having larger crossed pedicellariae provided with longer terminal fangs (pl. 60, figs. 2*a* and 1*d*); in lacking the unguiculate straight pedicellariae of *stichantha*; in having less regularly arranged dorsolateral plates. I have compared specimens of *D. tricolor* directly with Japanese material of *nipon* and am not able to differentiate the two forms. The Hong Kong specimens greatly extend the known range of this species. Their crossed pedicellariae average slightly larger and the spines a little heavier than in northern examples.

Genus SCLERASTERIAS Perrier, emended

Stolasterias, part, Sladen, Challenger Asteroidea, 1889, pp. 563, 583. Type *Asterias tenuispina* Lamarck, by designation.—Perrier, Résult. camp. sci. du Prince de Monaco, fasc. 11, 1896, p. 37.—Ludwig, Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 221.

Sclerasterias Perrier Comptes-rend., vol. 112, No. 21, May 5, 1891, p. 1227. Type, *S. guernei*, monotypic. Nominal reference on p. 1226 is "*Scleraster Guernei*." Résult. camp. sci. du Prince de Monaco, fasc. 11, 1896, p. 35.—Fisher, Bull. Inst. Océanographique, No. 444, 1924, p. 2.

Distolasterias Perrier, part, Fisher, Starfishes of the Hawaiian Islands, 1906, p. 1105; Starfishes of the Philippine Seas, etc., 1919, p. 487 (Bull. U. S. Nat. Mus., 100, vol. 3); Ann. Mag. Nat. Hist., ser. 7, vol. 17, 1906, p. 574.

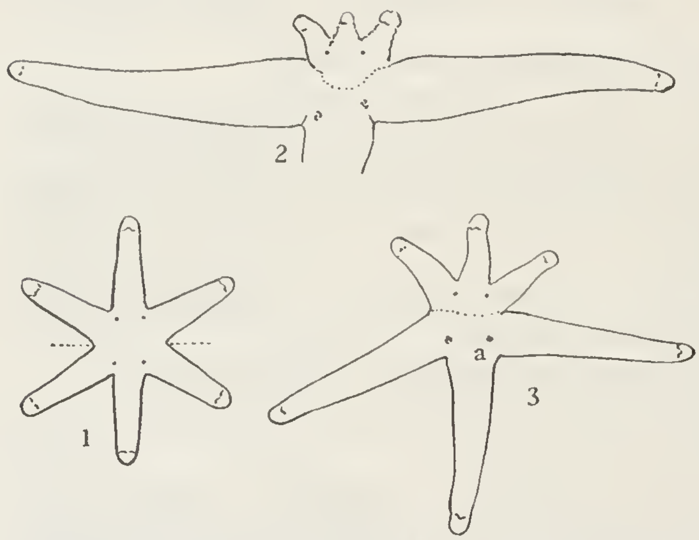
Orthasterias part, Verrill, Shallow-water Starfishes, etc., 1914, pp. 48, 168, 370.

Stylasterias part, Verrill, Shallow-water Starfishes, etc., 1914, p. 48.

Eustolasterias Fisher, Ann. and Mag. Nat. Hist. ser. 9, vol. 12, Aug. 1923, p. 255. Type, *Coscinasterias* (*Distolasterias*) *euplecta* Fisher.

Diagnosis.—Coscinasteriinae differing from *Distolasterias* in lacking crossed pedicellariae on the inner inferomarginal spine; in the presence of an inferomarginal web; in the restriction of the dorsolateral plates to at most a single adradial series; in the presence of one terminal lateral enlarged tooth on the outer face of each jaw of the crossed pedicellariae (instead of one enlarged tooth on each side of each jaw). Adambulacrals diplacanthid; rays pentagonal in section; dorsolateral skeleton regular, consisting in the adult of two regular series of transverse ossicles overlapping about midway between the carinal and superomarginal plates; superimposed on these overlapping ends, the three or four lobed dorsolateral plates form a single series (often late in developing); dorsolateral spines in a single series, usually poorly developed, sometimes absent; superomarginal plates large with a broad descending lobe; the surface of plate with a circumscribed area of tiny hyaline, beadlike protuberances (pl. 56, fig. 2); alternate superomarginals spineless; beyond base of ray, alternate carinals, usually spineless; outer series of inferomarginal spines united by a more or less evident retractile emarginate web; mouth angle relatively primitive with one or two pairs of contiguous postoral adambulacral plates; no longitudinal, intermediate ossicles in carinal or superomarginal series; spines large, mostly solitary, spikelike, the abactinal and superomarginal encircled by a wreath of crossed pedicellariae, and the outer inferomarginal spine by a half wreath; a series of small actinal plates, sometimes spiniferous proximally; straight pedicellariae ovate to lanceolate, acute, not spatulate or dentate; crossed pedicellariae with one enlarged tooth on the outside of the expanded lip of each jaw (pl. 52, figs. 3 and 5); the tooth is not greatly larger than the other terminal teeth. Young of three species known to have a six-rayed fissiparous stage, unlike adult in appearance.

Name.—I separated this genus from *Coscinasterias* and *Distolasterias* in my Preliminary Synopsis of the Asteriidae (1923). I had not then seen a specimen of *Sclerasterias guernei* Perrier, for which I gave certain differential characters, following the circumstantial account by Perrier[37] and the notes of Koehler.[38] *Sclerasterias* had been considered, in America at least, as a very unusual small asteriid, related to the Coscinasterias group. Undue emphasis was placed upon the thick integument.



FIGS. 1–3.—1, SCLERASTERIAS EUPLECTA. THE SMALLEST SYMMETRICAL SIX-RAYED SPECIMEN R 5.5 MM. THE DOTTED LINES INDICATE PLANE OF CLEAVAGE. THE FOUR MADREPORITES ARE INDICATED BY DOTS; ×3. 2, SCLERASTERIAS HETEROPAES. INDIVIDUAL REGENERATING THREE NEW RAYS AND TWO NEW MADREPORITES; ×3. 3. SAME; A MORE ADVANCED STAGE. IN ONE SPECIMEN SIMILAR TO THIS THE MADREPORITE *a* IS LACKING; ×3.

During a visit in November, 1923, to the Musée Océanographique of Monaco I had an opportunity to examine the type of *Sclerasterias guernei;* and through the kindness of Dr. Jules Richard, director of the museum, I was permitted to retain for further study a very well preserved ray, from which were taken the pedicellariae figured on Plate 52, Figure 1, 1*a*. (Fig. 1*b* on the same plate is from a specimen preserved in the British Museum.)

For some curious reason Perrier figured the most immature specimen of the four, and apparently his description is based upon this undeveloped example (or, since he ignores the other specimens, more probably upon the picture). It is equally strange that the resemblance of the larger specimens to his *Stolasterias neglecta* was not noted. For instance, Perrier says that there are no intermarginal papulae and only a single series of dorsolateral papulae. The *original type*, station 57, has two rows of dorsolateral papulae at the base of the ray, and I was able to follow this double series fully three-fourths the length of one ray. There is *a well-developed series of intermarginal papulae*, but as yet no actinal papulae, although a few actinal plates have made their appearance in a specimen from station 60 (listed by Perrier).

The skeleton is precisely similar to that of very small specimens of the genus which I had called *Eustolasterias*. The superomarginals and lateral face of the infero-

[37] 1896, p. 35, pl. 1, fig. 1, 1*a*.

[38] Faune de France, 1921, p. 26, fig. 20.

marginals are marked by the pebbling so characteristic of *Eustolasterias* and certain allies. The integument of *Sclerasterias guernei* is not thicker than that of young *S. heteropaes* in the definitive phase. The transverse dermal furrows between consecutive skeletal arcs of *Sclerasterias*, darker in color and passing from the adambulacrals of one side across the ray to the other, are equally characteristic of "*Eustolasterias*." In large specimens these fine furrows become more numerous and irregular and doubtless are lined with special nerves and cilia. The specimen of *Sclerasterias guernei*, from the Bay of Biscay, identified by Dr. R. Koehler and now in the British Museum, has a slight inferomarginal web, which is discernible also in the paratype from station 60 (Bay of Biscay, 300 meters). Finally, the crossed pedicellariae of *S. guernei* are similar to those characteristic of *Eustolasterias*. The small enlarged tooth on the outer side of the terminal dentiferous lip is very similar to that of other related species, as figured on Plate 52.

The specimens of *S. guernei* are small, R 17 mm. or less, that figured by Perrier being the smallest. Koehler states that they may reach a size with R 34 mm. The diminutive size of the specimen figured by Perrier would seem to indicate the absence of a fissiparous six-rayed stage such as is characteristic of *S. euplecta*, *S. alexandri* and *S. heteropaes*. Yet little is known of *S. guernei* beyond the fact that it lives in the Bay of Biscay region, in from 190 to 500 meters. Whatever may be its early history, I am unable to find tangible characters by which to separate it from the group later named *Eustolasterias* by me. The apparent differences mentioned in my synopsis (1923) are fictitious, and were derived from Perrier's description and figures.

Component species.—The genus *Sclerasterias* comprises the following species:

Name	Original genus	Habitat
*alexandri** Ludwig	*Stolasterias*	Bay of Panama, 52 to 210 fathoms.
*contorta** Perrier [1]	*Asterias*	Florida to Barbados, 11 to 188 fathoms.
*euplecta** Fisher	*Distolasterias*	Hawaiian Islands, 63 to 198 fathoms.
*eustyla** Sladen	*Stolasterias*	Tristan da Cunha, 100 to 150 fathoms.
*guernei** Perrier	*Sclerasterias*	Region of Bay of Biscay, 190 to 500 meters.
*heteropaes** Fisher	*Sclerasterias*	California coast, 27 to 85 fathoms.
*hypacantha** Fisher	*Distolasterias*	Philippine Islands, 83 to 165 fathoms.
mazophora Alcock and Wood-Mason	*Asterias*	Andaman Sea, 120 to 200 fathoms.
*mollis** Hutton	*Asterias*	New Zealand.
neglecta Perrier	*Stolasterias*	Bay of Biscay (type loc.); eastern Mediterranean 160 to 485 meters.
*peregrina** [2] Bell	*Asterias*	Saya da Malha Bank, western Indian Ocean, 150 fathoms.
stenactis [3] H. L. Clark	*Eustolasterias*	Natal, 194–218 fathoms.
*subangulosa** Verrill	*Stylasterias*	*Asterias angulosa* Perrier, Florida, 15 to 110 fathoms.
*tanneri** Verrill	*Asterias*	Atlantic coast of North America, between north latitude 40° 08' and 35° 10', 48 to 194 fathoms (Verrill).

[1] A specimen of *Asterias linearis* Perrier (No. 1279, Mus. Comp. Zool., Barbados) with R 26 mm. appears to be young *contorta*.

[2] *Asterias peregrina* Bell. I have seen the type so labeled in the British Museum but the description was apparently never published.

[3] *Eustolasterias stenactis* H. L. Clark, Union of South Africa. Fisheries and Marine Biological Survey, Report No. 4. Special report 7, pt. 2, May, 1926, p. 23, pl. 4. This probably includes the "*peregrina*" above.

The species which I have personally examined are marked by an asterisk.

Three forms, *euplecta*, *hypacantha*, and *stenactis*, are closely related and appear to be small species or races of a wide-ranging species. Probably *mazophora* is in the same category. After more experience with this genus I am inclined to give much less weight than formerly to the presence of actinal spines. One of the alleged differences between *euplecta* and *hypacantha* is the presence in the latter of well-developed actinal spines, but on going over some old material of *euplecta* I find actinal spines present, though less well developed, in two Hawaiian specimens. It seems probable, therefore, that the record of *euplecta* from the Philippines (Fisher, 1919, p. 487) is based upon a specimen of *hypacantha* without actinal spines. The forms will stand:

Sclerasterias euplecta (Fisher), Hawaiian Islands.

Sclerasterias euplecta hypacantha (Fisher), Philippines.

Sclerasterias euplecta stenactis (Clark), Natal.

S. euplecta hypacantha closely resembles *euplecta* but has longer, slenderer rays in fully grown specimens (type of *euplecta*, R = 8.8 r; type of *hypacantha*, R = 16 r; probably extreme of difference). The crossed pedicellariae, however, are the best criterion. Those of *hypacantha* have more numerous teeth in the vertical series, when the inner side of the jaw is compared in profile. (Pl. 52, figs. 4, 5.) I have seen the type of *S. stenactis*, but have not been able to compare it directly with *S. hypacantha* which it greatly resembles. This form, like *euplecta* and *hypacantha*, has an evident inferomarginal web. There is a series of small dorsolateral spines. Finally all three of these forms may prove to be races of *mazophora*. Alcock [39] in a rather detailed description states that "each plate of the midradial (carinal) and superomarginal rows and in large specimens each plate of the other two rows (dorsolaterals), bears at the decussation of its composite cross pieces a large spine." As regards the carinals and superomarginals, this is not typical of *Sclerasterias*. If true, *mazophora* bears no close relationship to the three forms under discussion for these, as well as most species of *Sclerasterias*, bear spines only on alternate carinal and superomarginal plates. It may prove to be a *Distolasterias*.

S. tanneri, however, frequently has most of the carinals spiniferous and is aberrant also in lacking, except in quite small specimens, the specialized areas of pebbling on the superomarginals.

S. contorta (Perrier) is a well-marked species from off Barbados to Florida. As in *tanneri*, the carinal spines are more numerous than every other plate, but unlike *tanneri* the superomarginals have a pebbled area. *Asterias angulosa* Perrier, not Müller [= *Orthasterias* (*Stylasterias*) *subangulosa* Verrill], is probably the young.

In the above enumeration of species are not included certain young forms of which the adult is not known but which probably belong in this genus.

Asterias richardi Perrier 1892 (*Hydrasterias richardi* Perrier, 1894).

Sclerasterias nitida Koehler, possibly the young of *S. mazophora*.

In the description of *Hydrasterias richardi*, Perrier [40] states that only one inferomarginal spine is present and so figures it. There are two. This species may be a form of *neglecta*.

Verrill [41] has included *S. tanneri* and *S. eustyla* in *Orthasterias*, and *S. contorta*, *S. subangulosa*, and *S. neglecta* in his subgenus (or genus) *Stylasterias*. In this also he places *Distolasterias robusta* (Ludwig).[42] In my opinion *Orthasterias* and *Stylas-*

[39] Ann. and Mag. Nat. Hist., ser. 6, vol. 11, 1893, p. 116.

[40] Expéd. Travailleur et Talisman, 1894, p. 109, pl. 9, fig. 4.

[41] 1914, Shallow-water Starfishes, pp. 48, 168, 370.

[42] Mem. Mus. Comp. Zoöl., vol. 32, 1908, pp. 350, 373.

terias, as represented by their respective types, are highly restricted and peculiar genera, only remotely related to the species under discussion.

Asexual reproduction.—The life history of three species of *Sclerasterias*, namely *euplecta, alexandri*, and *heteropaes*, affords an example of an alternation of sexual reproduction with asexual. These species have a definite immature stage, unlike the adult, in which hexamerous, not pentamerous, symmetry is predominant. The crossed pedicellariae are not in circumspinal wreaths but are scattered, as in *Pedicellaster*, between the spinelets, which are short, uniform, and two to four to each carinal and two or three to each superomarginal plate. The superomarginals usually carry two flattened spines without attached pedicellariae, and the adambulacrals are diplacanthid. The integument is not unusually thick.

In this stage the sea stars actively divide by splitting into equal halves. The number of these divisions is not known, but is not improbably several. In one instance, in *S. euplecta*, a division has taken place nearly at right angles with the plane of the prior fission. Since adult *Sclerasterias* are almost invariably pentamerous and the majority of the young are hexamerous, a ray is lost somewhere in the process, probably at the last division.

These dividing young range in size from R 8 to R 20 mm., the latter being unusually large. R 15 mm. is nearer the usual maximum size of fissiparous individuals.

Asterias richardi of the Mediterranean, two specimens of which I have examined (U. S. Nat. Mus., No 18287, lat. 33° 56′ N., long. 22° 56′ E., H. M. S. *Pola*) is probably the young phase of a *Sclerasterias*. It is at first hexamerous, then pentamerous, and its structure is closely similar to that of young *euplecta*, *alexandri*, and *heteropaes*.

Sclerasterias nitida [43] Koehler from the vicinity of the Andaman Islands likewise appears to be a typical juvenile phase of a *Sclerasterias*, possibly of *Sclerasterias mazophora* (Alcock and Wood-Mason), Andaman Sea, 120 to 250 fathoms.

All the specimens which I have examined—probably the great majority of those known—were taken by hempen tangles. Rocky situations, unsuitable for dredging, are favored by these tiny sea stars. The presence of rocks would suggest their use for shelter, especially during the time immediately after divisions. Likewise the critical period, during which the fissiparous, hexamerous young changes to the nonfissiparous pentamerous adult phase, is probably passed in a quiescent state in crevices or cavities of the rocks or under stones, which would account for the absence of this stage in collections. But during the growth of new rays the young are probably abroad and feeding, and hence are more readily snared by the tangles.

The largest series of young stages known is that of *S. euplecta*, secured during the Hawaiian cruise of the *Albatross* in 1902 and briefly commented upon by the writer in 1906.[44]

Young phase of S. euplecta.—The following is the list of specimens of the young phase of *S. euplecta* (pl. 81, fig. 7):

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[43] Echinoderma of the Indian Museum, pt. 6., Asteries littorales, 1910, p. 170, pl. 19, figs. 2, 3, 4.

[44] Hawaiian Starfishes, p. 1105, pl. 42, fig. 3.

Station	Number of specimens	5 rays	6 rays	Actively dividing	Remarks
3835	1	1	-------	---------	R 25 mm.; intermediate with adult phase.
3885	1	1	-------	---------	R 18 mm.; intermediate with adult phase.
3859	15	1	14	13	R 6 mm. to 17 mm.; 1 symmetrical 5 ray (R 12 mm.) and 1 symmetrical 6 ray (R 6 mm.) not dividing; one specimen has 4 buds and 2 rays; 1 ray lost subsequent to cleavage.
4045	5	-------	5	5	Smallest (R 6 mm.) is regenerating 4 rays; another has 1 short and 5 much longer rays.
4046	1	1	-------	---------	R=8 mm., symmetrical (pl. 81, fig. 7).
4066	2	2	-------	---------	One (R 13 mm.) has dropped 1 ray; 4 symmetrical.
4079	8	-------	8	8	One specimen divided at nearly right angle to first cleavage; 1 longer and 2 short rays, the latter regenerating from first cleavage; 3 tiny buds from second cleavage.
4100	2	2	-------	---------	One (R 7.25) with symmetrical rays; 1 (R 13 mm.) has dropped 2, the wound healed but new buds not yet started.
4128	1	1	-------	---------	

There are thus 36 specimens of which 9, or one-fourth, have five rays. Among the 26 actively dividing specimens, none has five rays. Two five-rayed specimens are definitely intermediate between the young and adult phases. Most of those actively dividing have three small rays in various stages of regeneration.

The outstanding features of this phase of *euplecta* are the scattered pedicellariae and the more numerous spinelets. Each proximal carinal has usually three short subclavate spinelets, one to each of the three exposed lobes of the plate; while at the end of the ray only a median spine usually persists. There is usually a single series of similar dorsolateral spinelets of varying number according to size of specimen. The superomarginal plates carry two or three subclavate spinelets subequal to the abactinals. Usually the dorsal and exposed median, or adoral, lobe each have a spinelet; sometimes the ventral lobe carries a spinelet, but less often than in *S. heteropaes*. The first pair of postoral adambulacral plates are in partial contact medially, and the adambulacral spines are flattened and sometimes narrowly spatulate.

The specimen from station 3885, at which the type of the species was dredged, is intermediate but gives no clue to the origin of pentamerous symmetry nor to the fate of the extra ray of the prevalent six-rayed young. This example, with R 18 mm., differs from the fissiparous phase in having only one carinal spinelet to each plate, the laterals having been absorbed. Similarly the dorsal spine of the superomarginals has disappeared and only the adoral remains on each plate. The pebbled area on these plates is more definitely circumscribed and that of the inferomarginals persists. There is a definite and regular series of dorsolateral spines, one to a plate, and corresponding to each superomarginal spine, extending two-thirds length of ray. There are two series of transverse dorsolateral connectives joining dorsolateral plates with carinals and superomarginals. Straight pedicellariae on furrow margin.

This specimen differs from the adult phase in (1) presence of spine on each carinal and superomarginal plate, instead of on alternate plates only; (2) in the presence of a well-developed series of dorsolateral spines, practically absent in adult; (3) absence of circumspinal wreaths of crossed pedicellarise, these being spaced uniformly over the surface; (4) presence of "pebbling," or tiny bosses, on inferomarginal and carinal plates (especially well marked distally). This is a feature of very young specimens also. The pebbling is evidently a juvenile character which persists in the adult only on the superomarginals. This is its history in other genera, as, *Astrometis.*

The loss of spines is apparently due to absorption, the material being transferred to new plates and to persisting spines which show a relative increase in size. Scars are sometimes left on plates to mark the place where spinelets stood at an earlier stage.

In *S. heteropaes* 14 out of 15 young are six-rayed. Twelve out of these fourteen have four madreporites symmetrically placed with two on either side of the plane of fission (the two opposite interradii through which the disk splits being without them). Thus each half, after fission, has two madreporites—one on either side of the central ray of the triad. (Text figs. 1–3.) The exceptions are a tiny symmetrical specimen, with R 7.5 mm., on which I can find only one madreporite; and a specimen with two pores on the regenerating half and only one on the original half. (Fig. 3.) At this stage they are normally very small and hard to find. The material of *S. euplecta* is not so favorable for a census since on regenerating specimens the new rays are small, but in the better preserved six-rayed specimens there are three or four madreporites placed as in *heteropaes.*

Of the nine *five-rayed* specimens of *S. euplecta,* eight have *one* madreporite and one has three madreporites (station 3859). These three madreporites are very small and are smaller than in the other specimens. The only five-rayed young of *S. heteropaes* has two madreporites in neighboring interradii.

It is clear that active fissiparity is correlated with six rays and with usually four symmetrically placed madreporites; for none of the five-rayed examples shows evidence of having split through the disk. In these only separate rays have been shed as in ordinary autotomy, the disk remaining entire with the five oral angles uninjured. In fissiparity two opposite oral angles are split neatly in twain.

The location of the madreporites with reference of the plane of splitting would provide two directly opposed "physiologically anterior" points (Cole) and would thus automatically favor an equal splitting of the disk. Crozier[45] regards the multiplication of madreporites at separated points on the disk of *Coscinasterias tenuispina* as furnishing an assurance that portions of the body separated by autotomy will each be provided with a madreporic canal. This seems reasonable. However, a large, nonfissiparous species, *Acanthaster planci,* with upward of 16 rays has 4 to 8 madreporites.

The utility of several madreporites in fissiparous species would appear to be clear. But as to origin it is not evident in *Sclerasterias* that the extra madreporites are solely post-larval developments as a preparation for fission. Furthermore, we have a transitory post-larval hexamerous symmetry to account for in a characteristically pentamerous genus. The six-rayed young with four madreporites may have descended from larvae with four hydropores. If so it is likely that we have in nature the sort of hydropore duplication reported by Newman[46] in laboratory cultures of *Patiria miniata.* This physiological twinning in the larva may be here a normal precursor to a subsequent post-larval "untwinning", by which the six-rayed, four-pored, fissiparous young becomes a five-rayed, nonfissiparous adult with one madreporite. [I have specimens showing this last stage, *before* the spines

[45] Biol. Bulletin, vol. 39, 1920, pp. 122–128.

[46] Idem, vol. 40, pp. 118–125. Journ. Exper. Zool., vol. 33, pp. 321–352.

and pedicellariae have assumed the fully adult reduction and concentration.] In other words, some of the incentive to splitting may be due to a sort of physiological duality locked up in the young with six rays. The five-rayed young with one madreporite would naturally be derived from larvae with one hydropore. Possibly the five-rayed young with two or three madreporites are descended from incompletely twinned larvae; or again they may already have accomplished the reduction division without showing outward signs.

Although the mechanics behind this curious condition are as yet material for speculation, the phenomenon itself seems to produce a fairly definite asexual generation following close on the heels of the larval stage. This asexual mode of reproduction is associated with an abnormal symmetry for the genus.

Young phase of S. alexandri (Ludwig).—This was described as *Hydrasterias diomedeae* Ludwig.[47] I have examined four specimens from the following stations: One from station 3368, near Cocos Island, 66 fathoms, rocky, R 6.5 mm. Three from station 3397 (at which adult *alexandri* were taken), Gulf of Panama, 85 fathoms, green mud, broken shells (R 20 mm.). See Plate 81, Figure 6.

Ludwig records seven specimens in all, of which six are six-armed and one seven-armed (with four large and three small rays). All are regenerating three rays. These specimens differ from the adult in the same features that have been detailed above for *euplecta.* Furthermore the young stage resembles that of *euplecta* much more closely than does the adult that of *euplecta.* The crossed pedicellariae are figured for comparison with those of the adult. (pl. 52, figs. 2, 2*a*.)

Ludwig in the same brochure, (p. 246, pl. 35, fig. 205) describes without naming a new species of *Hydrasterias* from station 3404, at which the incomplete type of *Distolasterias robusta* (Ludwig) was taken. There are nine arms but no disks. They appear to me to represent a young phase of *D. robusta.*

SCLERASTERIAS HETEROPAES Fisher

Plate 43, Figure 2; Plate 52, Figures 3, 3*a*; Plate 53, Figures 1*a*–1*d*; Plate 54; Plate 56, Figure 2; Plate 81, Figures 1–5

Sclerasterias heteropaes FISHER, The Genus *Sclerasterias* Perrier, Bull. Inst. Océanographique, Monaco, No. 444, 1924, p. 7, text-fig. 2.

Diagnosis.—Rays five, frequently unequal, constricted at base, pentagonal in section, very gradually tapering to a blunt extremity; dorsolateral surface of ray steeply sloping as a rule; intermarginal face wide, vertical. Spines in fairly regular series; carinal and superomarginal with one spine on alternate plates; dorsolateral spines usually few or absent, in one series if present; two inferomarginal spines; actinal spines few or absent; dorsal spines terete, tapering, blunt; superomarginals a little longer; inferomarginals compressed, often truncate, at tip; oral spines often narrowly to fairly broadly spatulate and gouge-shaped; crossed pedicellariae in conspicuous circumspinal wreaths; absent from actinal and inner inferomarginal spines; straight pedicellariae few, small, lanceolate, toothless. R = 90 mm.; r = 12 mm.; R = 7.5 r, breadth of ray at base, 13 mm.

Description.—In most specimens the ray is pentagonal in section, the carinal plates marking the odd angle of the pentagon. The dorsolateral areas slope more or less steeply to the superomarginal angle, the intermarginal areas being broad and nearly vertical. In the type there are three dorsal series of spines, namely, the carinal

[47] Mem. Mus. Comp. Zoöl., vol. 32, 1905, p. 242, pl. 34, fig. 204; pl. 35, fig. 206.

and a fairly regular dorsolateral on either side, though the latter is frequently either absent or represented by an incomplete series of much smaller spines than the carinals. Normally every alternate carinal plate carries a robust, terete, slightly tapering, or sometimes faintly capitate, blunt or truncate, terminally roughened spine, there being 20 to 24 such in medium and large specimens, the proximal, 2 to 2.5 mm. long (type). In the type a very few plates carry two to four such spines. Dorsolateral spines vary from a nearly complete series in the type to entire absence. The majority of specimens have only a few small spines distributed at irregular intervals along the proximal half of the ray. A pentagon of spines on the disk surrounds a prominent central spine, or group of two or three.

Superomarginal spines, 15 to 22 in medium-sized and large specimens, occur on alternate plates and are generally closely similar to the carinals but a little longer. They vary from a slight to a decided taper, are bluntly pointed, round-tipped, or truncate, and in the type are frequently compressed and gouge-shaped at the end. In small specimens the superomarginals may be slightly shorter than the carinals.

Intermarginal channel relatively broad, especially in small and medium-sized specimens, where it is as broad as the dorsolateral area (but in the type only about 0.5 or 0.6 as broad). Inferomarginal spines two to each plate, in an oblique transverse series, on the actinolateral border of the ray, along which they form a bristling fringe. The spines are a little shorter than the superomarginals, are slightly tapered, and the outer has a flattened truncate tip. The inner is a trifle slenderer, may be similar in form or nearly terete and bluntly pointed. Under especially favorable conditions the thin web connecting the bases of the outer spines may be seen. In a specimen from station 3110 it involves about half the length of the spines. The inner spine is independent of this lateral web but is more or less bound to the outer spine by a membrane at the base. The lateral web is homologous with the ordinary sheath of the dorsal spines, and like it is usually very strongly contracted in alcoholic specimens.

Actinal channel very narrow. A single series of actinal plates, which in the type extends far along the ray, is wedged between the inferomarginal and adambulacral series—one plate to each inferomarginal. In the type and a few of the medium-sized specimens the plates bear a single, terete, tapering, blunt spine for about half the length of the ray. There is a good deal of variability in respect to the numbers of actinal spines. In a specimen from station 3110, with R 50 mm., the plates are small and the spines entirely absent. In three specimens from station 4431: One, with R 37 mm., has spinelets on the first five or six plates (17 plates in the series); another, with R 46 mm., has only one or two or no spine to each series; a third, with R 58 mm., has 13 or 14 spines, the series reaching halfway to tip of the ray. Neither the inner marginal nor the actinal spines carry any pedicellariae.

Adambulacral spines two, slender, tapering, bluntly pointed and nearly equal. There are 38 adambulacral plates in the length of 10 inferomarginals at base of ray.

Oral angle, broader than in *Orthasterias*, composed of mouth plates and two pairs of contiguous adambulacral plates. In small specimens there is but one pair of contiguous adambulacrals. Each pair of mouth plates has a fan of four spines on the actinostomial margin, the median two long, flattened, narrowly lanceolate to subspatulate, the laterals only about one-third to one-half as long. There is usually but one suboral to each mouth plate (occasionally three to the pair of plates) and these as well as the first few adambulacral spines are sometimes markedly spatulate and shallowly gouge-shaped (with rounded tip) as at stations 4431, 3110, 4552; or rather slender, with a slight channel at the tip, as in the type.

Straight pedicellariae (pl. 53, fig. 1*d*) very scarce, practically absent on dorsal and lateral surfaces. Small lanceolate pointed pedicellariae (0.5 to 0.6 mm. long in type) occur in clusters on the actinal interradial area and scattered, proximally, on the actinal surface of the ray. Small pedunculate ones are attached along furrow margin and a few occur on the shortest mouth spine.

Crossed pedicellariae 0.26 to 0.34 mm. long (pl. 52, figs. 3, 3*a*) occur in conspicuous wreaths around the base of all the dorsal and superomarginal spines, and as a half wreath, or cluster, attached to the base of the outer inferomarginal spine. There are no pedicellariae on the inner inferomarginals nor on the actinals. The enlarged subterminal lateral tooth of the outer side of jaw is rather better developed than usual in this genus. A comparison with the figures of *S. alexandri* (fig. 2) shows a number of differences. These are more marked in the fissiparous stages of the two species than in the adults (figs. 2*a*, *alexandri*; 3*c*, 3*d*, *heteropaes*).

Papulae increase with age. In the type there are 8 longitudinal fairly regular rows of papular areas. On each side of the carinal series: two rows of large area with 6 or 8 papulae to an area; an intermarginal series with 5 or 6 papulae, and an actinal with 3 or 4.

Madreporic body just outside the pentagon of spines, medium-sized, flat, with radiating striae.

Color in alcohol. The type is faded yellowish, near a dull yellow ocher, with faint cross-bands of faded brown. Other specimens, faded yellow with well-marked cross-bands of brown; or sepia banded with faded yellow. The integument is marked by fine channels, either darker or lighter than the surrounding integument. Actinal surface yellowish.

Variations.—The principal variations have already been mentioned in the foregoing description. The breadth of the ray at widest part varies from one-fifth to one-sixth R. The rays are usually unequal however, and the longest is taken as a measure. The most noticeable variations are the number of dorsolateral spines (these being entirely absent, or in various numbers to a nearly complete series) and the number of actinal spines. The suboral and adjacent adambulacral spines are also variable in form, being sometimes markedly spatulate and gouge-shape, or slender lanceolate, round tipped, and faintly gouge-shape.

Straight pedicellariae are always few in number, lanceolate, never broadened, toothed, or unguiculate.

Anatomical notes (*pl. 53, figs. 1, 1a–1c*).—In the fully adult the skeleton consists on the rays of 13 series of plates, namely, the carinals, and on either side, one series of dorsolaterals, two of marginals, one actinal, one adambulacral, one ambulacral. The carinals are four-lobed and closely imbricated. The dorsolaterals are unequal, rather irregularly three or four lobed and joined to the carinal and supermarginal plates by a slender ossicle which develops before the dorsolateral plates. In young specimens the superomarginal and carinal plates are joined directly by one or two of these slender ossicles which were not counted in the tally of plates.

The superomarginals might be described as kiteshape with arcuate sides, the descending half of the plate being very much larger than the dorsal half, and overlapping the dorsal edge of the inferomarginals (the exposed surface of which is less than half as large as that of superomarginals and occupies the sharp actinolateral border of the ray. The superomarginals overlap (adoral edge outermost) and present a broad lateral surface largely occupied by a roughly circular area of hyaline acorn-shaped bosses closely placed, so that in an area with a diameter of 2 mm., 8 to 12 can be counted in a line from one side to the other. In a specimen cleaned with caustic potash this area is conspicuously white against the smooth yellowish surface of the rest of the plate. As in other members of this genus, only the alternate plates carry a spine, but the hyaline area is about the same in all the plates. The inferomarginals lack a marked ventral lobe. The principal lobe is dorsal, and underlies the descending lobe of the superomarginal. The plates are strongly imbricated and it is really the obliquely oriented lower border which carries the two spines. The actinal plates are rather thick subcircular disks with the margin to surface. The ambulacral plates are not very compressed. There are 16 to 10 mm. in the type; in *Stylasterias forreri* of the same ray-length there are 16; in *Orthasterias koehleri*, 20; in *Lethasterias n. chelifera*, 19 to 22. The pores have flaring lips and the two rows are a little more widely separated than in *Stylasterias*.

The actinostomial ring is stout and the actinostome small. The inner end of the ambulacral ridge is as long as the succeeding six ambulacral plates. The first pore is conspicuous though but little larger than the next three, which stand in a triangular group. The interbrachial septum is calcified but very narrow on account of the small disk.

Viscera.—Intestinal coecum with two rather long unequal digitiform lobes (without subdivisions). Hepatic coeca long. Gonads opening dorsally near interbrachial septum, on level with superomarginal plates. No Polian vesicles.

Young.—There are two sorts of young: (1) Those which have five rays, the spines essentially as in the adult (that is, single spines on alternate carinals and superomarginals), and the crossed pedicellariae in wreaths surrounding the spines. (2) Those which are six-rayed, fissiparous, and have more than one carinal and superomarginal spinelet; the crossed pedicellariae are scattered between the spinelets.

Of the first sort there is a specimen from station 2934 with R as small as 20 mm. It closely resembles the adult, but there is only a single dorsolateral (adradial) spinelet on one ray. The madreporic body is relatively large and conspicuous, with numerous fine striae—entirely unlike the small madreporites of the fissiparous young.

An example from station 2966 has one R 22 mm. The other four rays are regenerating and have R 10 mm. This is not a case of fissiparity, since the original disk is intact. The new rays are of the adult and not the fissiparous stage. Apparently once this immature stage is left it is not repeated in small regenerating rays of the adult. No extremely small specimens in the adult phase were taken. These are all in the fissiparous, predominantly six-rayed stage.

Fissiparous stage.—Young specimens in the fissiparous stage were taken at the following localities.

Station	Number of specimens	Actively dividing	Remarks
4328	2	1	1 specimen with 6 nearly equal rays, although 3 have regenerated; 1 with 3 small buds and 3 normal rays, R 15 mm. pl. 81, fig. 5; 1 ray of an adult.
4370	1	1	1 symmetrical 6-rayed specimen, R 10 mm.
4416	2	1	1 regenerating 5-rayed specimen (R 5 mm. to 8 mm.) pl. 81, fig. 4; 1 symmetrical 6-rayed specimen, R 7.5 mm.
4431	7	7	All asymmetrical with 3 small and 3 large rays; from this station 11 adults. (pl. 81, figs. 1-3.)
4535	2	0	1 specimen with 3 rays nearly completely regenerated; 1 with 6 symmetrical rays, R 10 mm.
4554	1	0	3 rays with R 7 mm. and 3 with R 10 mm., the former representing regenerated rays.

With the exception of one specimen from station 4416 all have six rays. Thirteen six-rayed specimens have four madreporites symmetrically placed, the opposite interradii involved in the fission being without them. Thus each of the two halves, after splitting, has two madreporites. From 4416 there is a five-rayed specimen with two madreporites, situated in neighboring interradii; and a six-rayed specimen (R 7.5 mm.) on which I can find but one madreporite.

The largest specimen, from station 4328, has R 15 mm. The crossed pedicellariae are spaced between the spines and there is as yet no aggregation into circumspinal collars, nor do the spinelets exhibit any evident sheaths. The carinal plates generally have four spinelets and most of the superomarginals three spinelets (the first two or three have two) in the positions marked by the black dots in the figure. (Pl. 53, figs. 1, 1*a*.) The inferomarginals have two flattened, subtruncate spines (occasionally three) which are much larger than any above them. The proximal are sometimes slightly expanded and very shallowly gouge-shaped. There are five or six dorsolateral spines on either side of the carinals in a fairly straight series extending about a third the length of ray.

The greater part of the surface of the superomarginals is marked by the minute protuberances characteristic of a circumscribed area on the adult and the lateral face of the inferomarginals has a small similar pebbled area (absent from the adult).

The first pair of postoral plates is in partial contact as in *Tarsaster*. It is interesting to note that when this animal divides in half, the cleavage splits equally two opposite mouth angles. Consequently there are two small regenerating mouth angles belonging to the three new rays; facing these are two normal mouth angles; and on either side of these pairs an angle consisting of a normal mouth plate and a tiny regenerating one.

The straight pedicellariae, apparently confined to the mouth plates, are broadly lanceolate with the tips of the jaws crossed. They are relatively broader than in the adult. The crossed pedicellariae are figured for comparison with those of the adult (pl. 52, fig. 3*c*–*d*).

Type.—Cat. No. E. 1427, U.S.N.M.

Type-locality.—Station 4554, northwest of Point Pinos, Monterey Bay, Calif., 60 to 80 fathoms, rocks and green mud.

Distribution.—Half Moon Bay to south of San Diego, Calif., in 27 to 85 fathoms, fine sand and rocks; bottom temperature, 51 to 58.2 F. Records of station 4416, 448 fathoms, open to doubt as to correctness of label.

Specimens examined.—Forty-two, of which 15 are in the young fissiparous, 6-rayed stage.

Specimens of Sclerasterias heteropaes examined

Station	Locality	Depth	Bottom	Bottom temperature	Number of specimens	Collection
2899	Off Santa Rosa Island., Calif.	44	Gray sand, broken shells		1	U.S.N.M.
2907	Santa Barbara Channel, Calif.	44	Fine gray sand		1	Do.
2934	Southwest of San Diego, Calif.	36	Gray sand	58.2	1	Do.
2945	East of Santa Cruz Island	30	Pebbles		1	Do.
2965	Santa Barbara Channel	27	Fine gray sand, rocks	58	1	Do.
2966	do	30	Coarse mud	58.5	1	Do.
3110	South of Half Moon Bay, Calif.	39	Rocky	51	1	Do.
3160	Southwest of Point Reyes, Calif.	39	Rocky	51.8	1	Do.
4328	Off Point La Jolla, San Diego, Calif.	71–57	Green mud, fine sand, rocks.		2	Albatross, 1904.
4361	Off Point Loma, San Diego, Calif.	91–97	Gray sand, rocks		1	Do.
4370	do	99–147	do		1	Do.
4384	do	164–85	do		1	Do.
4416 [1]	Southwest of Santa Barbara Island	448	Dark green mud		2	Do.
4420	Northeast of San Nicholas Island, Calif.	33–32	Fine gray sand		1	Do.
4431	Off Brockway Point, Santa Rosa Island, Calif.	38–40	Coarse gray sand, rocks		17	Do.
4535	Northwest of Point Pinos, Monterey Bay	71–54	Hard gray sand		2	Do.
4552	do	73–66	Rocks, green mud		2	Do.
4554	do	60–80	do		3	Do.
4558	Northeast of Point Pinos	40–28	Rocks		1	Do.
	San Pedro				1	University of California.

[1] Probably error in station number.

Remarks.—Geographically the species nearest to *heteropaes* are *S. euplecta* (Fisher), Hawaiian Islands, and *S. alexandri* (Ludwig), Gulf of Panama. *Stolasterias robusta* Ludwig from 704 meters, south of Chatham Island, Galapagos, is a *Distolasterias*, in the restricted sense. I have examined specimens of all three species. *Alexandri* has a rather more delicate skeleton than *heteropaes*, with all the spines (including inferomarginal) slenderer, terete, regularly tapered and sharp. The inner, or lower, inferomarginal is conspicuously shorter and slenderer than the outer and may be faintly compressed. The dorsolateral spines are lacking. The wreaths of pedicellariae are less voluminous, the integument thinner, and the crossed pedicellariae both in the adult and fissiparous young stages differ in detail. (Pl. 52, figs. 2 and 3.) The carinal and marginal plates do not overlap so strongly as in *heteropaes* so that the spines are more distantly spaced. There is an incomplete series of small actinal plates but no spines. The adambulacral spines are a little more delicate, and on the first two or three plates, as well as here and there along the ray there may be only one spine. On the outer third of the ray the plates may alternate with one and two spines; and finally near the tip there is usually only one spine. The mouth angle is a little broader than in *heteropaes*, with one pair of contiguous adambulacral plates (R = 45 mm.). The mouth spines are slender, tapered, blunt, and not gouge-shaped.

A very important feature of *alexandri* is the presence of a delicate web, connecting (with deep emarginations between) the outer inferomarginal spines. This web meets the spine about two-thirds the distance from base to summit and bears on the lower side a few delicate, slender straight pedicellariae, others being present on the plates themselves. The inner, shorter, spine is not involved in this web, which is more prominent than in *heteropaes*, where it is with difficulty seen.

The outstanding feature of the Hawaiian species, *euplecta*, is the presence of a still wider actinolateral web, which involves also the basal half of the inner spine. It is so tough that it has persisted in a specimen cleaned in potash. This web sometimes reaches nearly to the tip of the chisel-shaped spines, and sometimes is retracted, leaving a third or even more of the spine free. When the spines are bent downward the web is very conspicuous. The mouth angle is broad with one pair of contiguous adambulacral plates behind the mouth plates, and the second pair well separated.

Genus ASTROMETIS Fisher

Astrometis Fisher, A Preliminary Synopsis of the Asteriidae, etc., Ann. Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 254. Type, *Asterias sertulifera* Xantus.
Marthasterias Verrill, Shallow-water Starfishes, 1914, p. 100.
Orthasterias Verrill, part, Shallow-water Starfishes, 1914, pp. 48, 175, 184.

Diagnosis.—Coscinasteriinae resembling *Sclerasterias* but differing in having large, spatulate, denticulate straight pedicellariae; outer inferomarginals without trace of ventrolateral web; rays semicircular or heptagonal in section; dorsolateral skeleton very irregular; the skeletal meshes not in two regular series on either side of the carinal line of plates; dorsolateral spines developed in even tiny specimens; they are numerous, in one or two irregular series on each side; adambulacral plates diplacanthid proximally, monacanthid distally. Only the outer of the two inferomarginal spines with cluster of crossed pedicellariae; superomarginal plates with specialized pebbled area, the alternate plates spiniferous; actinal series of plates incomplete, proximally spiniferous as a rule; first pair of postoral plates larger than the second, in close contact; second pair in partial contact; crossed pedicellariae with a conspicuously enlarged lateral tooth on outer side of terminal lip; not fissiparous.

Remarks.—So far as observed, this genus has no immature fissiparous stage such as is known for three species of *Sclerasterias*, nor is it fissiparous in the adult phase as in the case of true *Coscinasterias*.

The dorsolateral spines develop earlier than in the postfissiparous stage of *Sclerasterias*. Even in specimens as small as R 13 mm., the dorsolateral series of spines extends to the end of the ray (six dorsolateral spines to seven or eight carinals).

In *Sclerasterias* the dorsolateral skeleton is somewhat like a set of rafters to a roof. The carinal ridge is joined to the superomarginal "eaves" by fairly regular transverse bars consisting of two elongate often terminally spatulate ossicles which overlap about midway; over this joint the primary dorsolateral plates arise. Usually before these develop, short longitudinal connectives appear along the line of the dorsolateral plates, dividing the "roof" into two regular longiseries of skeletal meshes or intervals. (Pl. 53, fig. 1*b*.)

In *Astrometis*, however, these transverse connectives are irregular in arrangement and are made up of several pieces. The intervals are very unequal in size and unsymmetrical in contour and arrangement. There is frequently only one large mesh extending from the carinals to the superomarginals, followed by two; or two adradial meshes may correspond to three adjacent spaces next to the marginal plates. (Pl. 56, fig. 1.)

In *Sclerasterias* the ray is pentagonal in specimens that have not been distorted by drying or the amenities of preservation, while in *Astrometis* the ray is arched dorsally, subplane actinally, hence more semicircular in section, or if angles appear there are generally seven.

In *Sclerasterias* the ambulacral ossicles are less compressed. In *Astrometis*, in a space of 10 mm. near but not exactly at base of furrow, there are 19 or 20 plates and 16 in a comparable example of *Sclerasterias*.

In true *Orthasterias*, which is far removed from *Astrometis*, the inner as well as outer inferomarginal spine bears a cluster of crossed pedicellariae, as also do the prominent actinal spines; the adoral carina is narrow and is composed of upwards of five pairs of contiguous adambulacral plates; the actinostome is sunken; the crossed pedicellariae are larger, without an enlarged terminal tooth.

ASTROMETIS SERTULIFERA Xantus

Plate 55, Figures 1, 1*a*, 1*b*, 2, 2*a*, 4, 4*a*–4*c*, 5, 5*a*; Plate 56, Figures 1, 1*a*–1*f*, 3; Plate 57, Figures 2, 2*a*, 3, 4; Plate 58; Plate 59, Figures 2, 3

Asterias sertulifera Xantus, Proc. Acad. Nat. Sci. Philadelphia, 1860, p. 568.—Ives, List Cab. Stearns 1890, p. 2 (according to Verrill).

Asterias forreri Jennings, Univ. Calif. Publ. Zool., vol. 4, 1907, pp. 53–185, 19 text fig.—H. L. Clark, Echinoderms from Lower California, etc., Bull. Amer. Mus. Nat. Hist., vol. 32, 1913, p. 203; Echinoderms from Lower California: Supplementary Report, Bull. Amer. Mus. Nat. Hist., vol. 48, 1923, p. 153.

Coscinasterias sertulifera Baker [Fisher], Some Echinoderms collected at Laguna, First Annual Report of Laguna Marine Laboratory, 1912, p. 89.

Marthasterias (?) *sertulifera* Verrill, Shallow-water Starfishes, etc., 1914, p. 100.

Orthasterias dawsoni Verrill, Shallow-water Starfishes, etc., 1914, p 175, pl. 23, figs. 1, 2; pl. 75, figs. 2–2*b*; pl. 80, figs. 2, *a*–*g*; pl. 81, figs. 3–3*b*.

Orthasterias [*Stylasterias*] *gonolena* Verrill, Shallow-water Starfishes, etc., 1914, p. 184, pl. 67; pl. 68, fig. 1; pl. 69, fig. 2; pl. 82, figs. 3–3*b*, 4–4*a*.

Astrometis sertulifera Fisher, A Preliminary Synopsis of the Asteriidae, etc., Ann. Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 254.

Diagnosis.—Rays five, occasionally six, more evenly rounded dorsally than angular, often swollen, constricted basally, slightly tapered, bluntly pointed; dorsal spines in three to five series proximally, three distally, prominent often bristling; superomarginal spines longer than dorsals; carinals frequently on several consecutive plates proximally; two prominent chisel-form or slightly gouge-shaped inferomarginal spines; a variable number of actinal spines in mature examples; distal adambulacrals frequently monacanthid; first pair of post-oral adambulacral plates conspicuously larger than second, which are in partial or full contact. In life, flexible and quite slimy. R 81 mm.; r 13.5 mm.; R = 6 r; breadth of ray at base, 11 mm.; at widest part, 13 mm.

Description.—The rays of carefully killed alcoholic specimens are evenly arched and slightly to decidedly swollen, depending upon the condition of the gonads. In one specimen with very much enlarged gonads the height of the rays is greater than the width. The actinal surface is subplane, and the width is increased by the ventrolateral fringe of spines. The dorsal spines stand in three regular rows or sometimes (as in Verrill's cotype of *gonolena* from San Diego) there may be a second short dorsolateral series near the base of the ray, with upwards of five spines in the series;

or, proximally, the dorsolateral series, and less often, also, the carinal series, may be quite irregular. In distorted dried examples the irregularity is unnaturally accentuated. The carinal spines stand on every other plate, or sometimes on as many as 18 consecutive plates in large examples; but in a few equally large specimens (as with R 80 mm.) the alternation of spiniferous and spinless plates is scarcely broken. These spines are rather short, stout, tapering, and blunt-acute to subtruncate, sometimes in old specimens slightly swollen terminally and are upward of 3 mm. long. The dorsolateral spines are still longer and the superomarginals subequal to the dorsolaterals, or even a little longer (upwards of 4 mm.). The dorsal spines are not regularly fluted, but are minutely roughened at the tip. In large specimens from La Jolla and San Diego the carinal, dorsolateral, and some of the superomarginal spines may be strongly compressed at the tip only, or may have one to three grooves at the slightly expanded blunt extremity. Rarely a dorsolateral plate carries two or three spines. On the disk there is a circle or pentagon of close-set spines enclosing 1 to 12, irregularly placed.

The superomarginal spines regularly stand on alternate plates, quite often opposite the nearly equally numerous dorsolaterals to which they are subequal, or a trifle longer. The spines are stout, tapering, bluntly pointed, sometimes in old and spiny specimens compressed, or even expanded, truncate and slightly gouge-shaped. (San Diego, No. 7473; La Jolla; Santa Catalina; Laguna Beach; in varying degrees.) The terminal plate is large subcircular with a terminal armature of numerous short spinelets.

The intermarginal channel is fairly wide, but not quite so wide as the length of the superomarginal spines. The inferomarginal spines, two to a plate in an oblique series, are slightly tapered, flattened, truncate, with sometimes a poorly defined groove on the outer, or upper, side near tip. The spines are subequal or the inner slightly the shorter.

Actinal plates small, corresponding to the inferomarginals, the series incomplete and of variable length, perhaps in relation to the age of the specimen. Small examples usually lack actinal spines whereas in grown examples, from R 50 mm. on, the spines are generally present, although an example with R 70 mm. has none, while another with R 55 mm. has nine, extending nearly a third the length of ray (La Jolla). The spines when best developed reach about to the middle of the ray with upwards of 18 to the series (La Jolla). The condition of a specimen with unequal rays is interesting. On a ray having R 67 mm., there are 13 and 14 spines reaching about 0.4 the length of ray, while on a ray with R 42 mm., there are no actinal spines. A specimen with R 53 mm. from San Francisquito Bay, Lower California, has 15 actinal spines the series ending in the middle of the ray. (See Variations.) The spines are similar to the inferomarginals though considerably smaller, and stand in the same oblique series. Actinal channel very narrow.

Verrill writes (1914, p. 184) that the actinal plates are "sporadic, spineless" and that the "species differs from *Orthasterias californica*, and *O. columbiana*, both of which it resembles, in lacking peractinal spines." But his cotype of *gonolena* (No. 1825, M. C. Z.) from San Diego has a short series of from five to nine actinal spines, while in a specimen (No. 1214, M. C. Z.) from the Gulf of California, with R 45 mm., and listed on page 185, there are three to five small spines in the actinal series. In the fragment of a ray that serves as a type of this species (40 mm. long and 11 mm. broad at base) there is a series of well-developed actinal spines for half the length of the ray.

Adambulacral spines regularly two on the proximal two-thirds (more or less) of the ray, and frequently irregularly one and two, or one only, on the terminal third. The outer spine is the larger, chisel-shaped, slightly expanded, and faintly grooved toward the truncate or rounded tip. The inner is slenderer, a trifle tapered, and less often grooved, and becomes relatively smaller toward the end of the series, which usually dies out, as stated above, in the terminal third of the ray, or even sooner. In the type, contrary to what Xantus says, many of the adambulacral plates are diplacanthid. Scattered irregularly among these, especially distally, are monacanthid plates.

Mouth angle not narrowed into a carina; two pairs of contiguous adambulacral plates behind the mouth plates, the first pair larger than the second, firmly joined, while sometimes the second simply touch. The third pair is well separated. The mouth plates are broader than the first pair of adambulacrals, and are broadest on the actinostomial margin, which bears a pair of spines for each plate, or a fan of four. The laterals are short and stubby, with a cluster of small lanceolate straight pedicellariae. The other is about as long as the mouth plates, slightly tapered, and blunt, or truncate. The suboral spine (one to a plate) is still longer, terete tapered and blunt. The first adambulacral is still longer, as a rule, either tapered or not, terete or flattened, blunt or subtruncate. The actinostome is never greatly sunken as in *Orthasterias*, owing to the short adoral carina of only one pair of adambulacrals.

Straight pedicellariae of two general sorts: (1) small, ovate-lanceolate, with jaws less than 1 mm. long, and (2) heavy spatulate wedge-shaped toothed ones measuring from 1.5 to 2 mm. long. The latter are very variable in numbers, being fairly numerous or nearly absent. They are broadly wedge-shaped with spatulate, terminally rounded denticulate jaws, and are often as stout as the carinal spines. They are scattered over the abactinal surface, in the intermarginal area, in the actinal channel, and also sometimes (especially when numerous dorsally), on the furrow face of the adambulacral plates. Rarely one occurs on the actinal face of the adambulacrals. The first sort are present sparsely on the dorsal and lateral surfaces, in the actinal channel (especially interradially) and along the furrow face of the adambulacrals. The latter have short peduncles, the jaws being about 0.5 mm. long or less.

The crossed pedicellariae are numerous and occupy conspicuous cushionlike wreaths surrounding the base of the dorsal and superomarginal spines, and a conspicuous pad on the outer side of the outer inferomarginal (absent from inner inferomarginal and actinal spine). The diameter of the wreaths is usually a trifle less than the height of spine. On the outer part of ray they nearly touch. The pedicellariae range from 0.32 to 0.44 mm. in length, their salient characteristics having been noted in the generic diagnosis.

Papular areas small, numerous, irregularly arranged on the dorsum, but in regular intermarginal and actinal series. Papulae dorsally 1 to 10 to an area in close tufts; intermarginally about five to eight, in grown specimens; and actinally usually two to five proximally, and one or two distally.

Madreporic body about 2 mm. in diameter, plane, set on a slant near edge of disk, and with interrupted meandering striae.

Color: Some specimens received from Scripps Institution and preserved in formalin retained some of the life colors. Integument dark rich green, the pedicellariae gray or greenish gray, and straight pedicellariae whitish or yellowish white; abactinal and marginal spines bright vermilion on distal half or at tip, shading rather quickly into dark blue or purple at the base; adambulacral and actinal spines lighter, with only a little blue at base; tube-feet rich cadmium yellow, the disk pale straw yellow.

Variations.—The principal variations have been pointed out in the foregoing description. In order to eliminate the question of geographic variations, 10 specimens have been selected at random from the ample La Jolla collection. These range in size from R 49 to R 81 mm., being mostly over R 65 mm.

Four have the dorsal spines frankly in three series and six have extra spines laterally to the dorsolateral series (a second incipient dorsolateral series). There is no age (size) correlation with the abundance of larger straight pedicellariae, nor with the presence of actinal spines (for all 10 have them in some degree), nor with the number of distal adambulacral plates having only one spine (the extremes are present in both groups).

If this sample selection of 10 specimens is divided into two groups on the basis of the number of actinal spines: (*a*) six specimens have 10 or more spines, and (*b*) four have less than 10. There is no correlation with size, group *a* ranging from R 55 to R 85 mm., and group *b*, from R 49 to R 76 mm. It is true, however, that *most* specimens of *small* size have only a very few actinal spines, or else lack them; large specimens likewise may have only a few spines. In group *a*, a specimen with a radius of 64 mm. has 14 actinal spines while another with radius of 51 mm. lacks them entirely, and a third of 54 mm. has 11. This will indicate the haphazard occurrence of this character. In group *a*, three specimens have three rows of dorsal spines and three have extra laterals; in group *b*, one (the smallest) has three series of dorsals, and three have extra dorsolateral spines. In group *a*, five have the large straight pedicellariae abundant enough to be easily seen at a glance, and in one they are scarce; in group *b*, three have abundant pedicellariae, and one (the smallest specimen, R 49 mm.) has only two or three incompletely developed large pedicellariae. Thus if two groups were made on the abundance of pedicellariae eight would have the pedicellariae well-developed and two poorly developed. Small examples generally have very few, or even none, of the large pedicellariae; yet one of the above two specimens has R 70 mm., which is well beyond the medium size for this species.

Three of the sample 10 have mostly only one spine on each adambulacral plate of the terminal third of the ray, while on the other seven the terminal area is more restricted.

There is some variation in respect to the stoutness of the ray, but the size of the gonads will affect this feature.

A specimen from San Francisquito Bay, Lower California, (*Albatross*, 1911) has R 53 mm. and 15 actinal spines, extending half the length of ray. The dorsal spines are a shade slenderer than in the average northern specimens, rather sharp, and largely covered by the pedicellaria sheaths which are not retracted. The large straight pedicellariae are very few and less heavy than in La Jolla examples, except along the furrow margin where they are numerous (but not in Gulf of California specimens, No. 1214, M. C. Z.). The adambulacral spines are a trifle slenderer and longer than in most northern specimens, especially proximally, but the Gulf of California specimens are not tangibly different from small La Jolla examples. This

San Francisquito Bay specimen does not have a shallow groove near the end of the outer spine but the groove is present in the Gulf of California examples (except very small ones). The suboral spines are slender, tapered, terete, pointed.

During the summer of 1919, Mr. G. F. Ferris collected at La Paz, the type-locality, one specimen which he found at low tide under loose coral. This specimen, which has R 46 mm., r 6.5 mm., breadth of ray at widest part, 8.5 mm., differs less from the La Jolla examples than does the San Francisquito Bay example noted above. The spines are normally stout—more robust, in fact, than in some of the southern California examples of the same stature. On the proximal half or two-thirds of the ray most of the carinal plates bear spines, and on the distal portion the alternation of spineless and spiny plates is by no means invariable. The dorsolateral spines do not form a very regular series, and on each of the dorsolateral areas there are from four to eight spines out of line (but not always in the same position), constituting an incipient accessory series, as in certain of the Californian examples.

In this specimen the adambulacral spines are unequal, the inner being conspicuously slenderer and shorter than the outer, beyond the proximal fifth of the furrow-length. The outer are flattened, very slightly tapered, chisel-shape. The inner decrease in length relatively faster than the outer spines, so that the disparity in length increases as they proceed along the ray. At about the middle of the ray the plates cease to have two spines regularly; beyond that point the inner spine, which is here one-half to two-thirds the length of the outer, may be absent from one or from several consecutive plates (as many as 15), but in no regular manner. The majority of plates of the distal half of ray have but one spine.

There are usually four to seven actinal spines, but one ray has only one on one side and none on the other. There are two contiguous pairs of adambulacral plates external to the mouth plates. Small lanceolate-ovate pointed straight pedicellariae, scarcely longer than the crossed pedicellariae are scattered on disk and base of rays, but I find only two of the larger denticulate sort—one in an interradial sulcus, the other above it near the primary radial plate. These are about 1 mm. long, wedge-shape as viewed from the side, and narrowly spatulate viewed frontwise. They are much smaller than those commonly found in Californian examples. These smaller pedicellariae are about the only tangible difference I can find as compared to Californian specimens. The San Francisquito Bay example has major pedicellariae about intermediate in size.

The La Paz specimen was kept for several months in formalin in a sealed tin. When taken out it showed what were probably nearly its life colors. General tint of dorsal surface and sides pale pinkish brown, broadly cross-banded with brown madder; abactinal and lateral spines flesh color, the distal half nearly vermilion; wreaths of pedicellariae raw or sometimes burnt sienna, the minor pedicellariae pale grayish; actinal surface, raw sienna, the spines salmon pink; furrow spines pale straw color; tube-feet a milky sepia.

Anatomical notes.—(See pl. 56, figs. 1, 1*a*–1*e*, 3, 3*a*.) Plates of the ray are in 13 longitudinal series, namely, the carinals, and on either side one series of dorsolaterals, often irregular; two series of marginals, one incomplete series of actinals, and the usual ambulacral systems. The carinals have four short rounded lobes, are longer than broad, overlap strongly, and the series is sometimes rather irregular. Commonly alternate plates are spineless, but specimens occur in which several consecutive plates bear spines. There are about 30 plates in the series when R is 55 mm. The dorsolaterals, irregularly three or four lobed, are in a zigzag series as a rule and are connected together (and with the carinals and superomarginals) by one or two slender elliptical ossicles of different lengths. The superomarginals are the largest plates, somewhat arcuately kite-shape in form, 32 in number when R is 55 mm., and overlapping rather strongly. There is a conspicuous area of hyaline protuberances on the lateral surface, larger on the alternate, regularly spineless plates. The inferomarginals are a little smaller than the superomarginals, but the ascending lobe is shorter than (and is covered by) the descending lobe of the superomarginal. The lower border of the inferomarginals is rather rounded and thickened, the two spines being on a very slight lobe. The actinal plates are small, flattened, a little higher than long, and placed with the edge outward. The marginals are relatively smaller than in *Sclerasterias heteropaes.* The actinostomial ring (pl. 56, fig. 3) is fairly stout, but not quite so strong as in *Stylasterias forreri.* The enlarged inner end of the ambulacral ridge is as long as the six following plates. The first ampulla pore is larger than the three following pores which form an unequal triangle. The interbrachial septum is very short on account of the relatively small size of the disk. The ambulacral plates are more compressed than in *Sclerasterias heteropaes*, there being in the space of 10 mm. at base of ray 19 or 20 plates while in the comparable equal-sized type of *heteropaes* there are 16. The plates are about as much compressed as in *Orthasterias koehleri.* The pores are smaller than in *Sclerasterias*, have very flaring lips, and the two series are more widely separated—but there is variability in this feature.

Viscera.—Intestinal coecum with three branches, two about 10 mm. long, without subdivisions, and the third with six short branches. Dorsal stomach small; hepatic coeca slender, reaching nearly to end of ray, ventral stomach spacious, with strong retractors. Gonads large, reaching nearly to end of the ray. Each consists of a fairly stout axis with numerous small lobules on the side toward marginal plates, and numerous rather long tapering irregularly lobulated branches on the mesial side. Each gonad opens on a level with the superomarginal plates near interradius. Ampullae single, but broad and incipiently two-lobed when partly contracted; no Polian vesicles; tube-feet rather large, crowded.

Young.—The smallest specimen from La Jolla has R 22 mm., breadth of ray at base and r, 3.5 mm. The rays are slender and scarcely tapered until near the tip. The spines are relatively long and crossed pedicellariae few. On the base of each ray, dorsally, are two to four very slender, lanceolate acute straight pedicellariae which appear relatively large though only 0.6 to 0.7 mm. long, and there are several other quite tiny ones scattered over the disk and rays; others a little larger occur in the interradial angles laterally and below. Four or five similar to the larger dorsal ones, but a little less slender, occur in the intermarginal channel. These seem to be the large spatulate denticulate pedicellariae of the adult, in the process of development, and this is the only very young specimen in which I have observed them. No visible actinal plates. Only a few distal adambulacrals with one spine. Furrow spines relatively long and slender. One pair of contiguous adambulacral plates behind the mouth plates. The carinal, dorsolateral, and marginal spines are in quite regular series. The first two or three carinals are spiniferous; beyond these only the alternate plates. Color in formalin when received, pale yellowish pink (Scripps Institution). Another young specimen (R 31 mm.) recently placed in formalin was colored as follows: Skin of actinal surface raw sienna, the sides richer, and back and sides marbled with brown madder, the wreaths of pedicellariae lighter, yellowish raw sienna, the pedicellariae whitish; spines pinkish or reddish with pale yellow tips; tip of ray rich reddish cadmium yellow (cadmium plus burnt sienna); tube-feet pale ocher with transparent disks.

The youngest specimen examined is from Patos Island, Gulf of California; R 9 and 10 mm. There is a series of dorsolateral spines, well spaced, on the distal half of ray, nearly as long as the superomarginals. On the distal 0.4 of ray the adambulacrals are monacanthid. The crossed pedicellariae, rather few in number, form wreaths around the dorsal and superomarginal spines, and a few are found on the outer side of the base of the outer inferomarginal spine.

Orthasterias dawsoni Verrill (pl. 55, figs. 2, 2*d*, 5, 5*a*; pl. 57, figs. 2, 2*a*, 4).—The type was very kindly forwarded by the Ottawa Museum. It bears two labels, both indicating that the specimen was taken at Vancouver Island, 1875, by Richardson, Canadian Geological Survey. Verrill (1914, p. 176) gives Queen Charlotte Islands as the type-locality, evidently an error.

The specimen is in poor condition, having been dried without previous preservation and is about ready to fall to pieces. It is very evidently not congeneric with the type of *Orthasterias*, and I can find no satisfactory characters by which to separate it from *Astrometis sertulifera*. About 12 actinal spines are present, reaching a third the length of ray, while the plates themselves continue to seven or eight tenths the length of the ray. The dorsolateral spines continue practically to the end of the ray, but owing to the condition of the specimen it is impossible to be certain if they are proximally in more than one series. The superomarginals are alternately spiniferous and have large beaded or pebbled areas. The ventral lobes of the distal plates—say from the twentieth on—are very broad and rounded (pl. 57, fig. 2*a*). I thought this might be used as a character by which to separate *dawsoni* from *sertulifera*. However, the variation in *dawsoni* is not known. There is considerable variation in typical *sertulifera;* and while specimens tend to have narrower ventral lobes, some have broad lobes on the distal plates. (Pl. 57, fig. 3*a*.) The proportions of the ventral lobe of the proximal plates is also variable. The longer of the two apical mouth spines is rather flatter in *dawsoni* than is usual in the southern specimens, but here again there is variation.

No specimen of "*dawsoni*" other than the type has been taken. It would indeed be strange to find in deep northern waters a representative of a species from intertidal and shallow waters of southern California and Lower California. If "*dawsoni*" is hiding in deep water off Vancouver Island, it certainly constitutes an anomaly of distribution. I think it is not entirely unlikely that Californian specimens of *Astrometis sertulifera* may have survived on the bottom of lumber schooners and have found their way northward. Only more specimens from the region can settle the status of *dawsoni*, which seems to have few claims to recognition as a distinct race.

The pedicellariae (pl. 55, figs. 2, 2*a*, 5, 5*a*) have been carefully examined and show no peculiar features. Incidentally, the crossed pedicellariae figured by Verrill [48] are not all accurately drawn.

Type.—Cat. No. 1252, U.S.N.M. (one ray).

Type-locality.—Cape San Lucas, Lower California.

Distribution.—Gulf of California to Santa Barbara, Calif.; Vancouver Island; very low tide and shallow water.

Specimens examined.—One hundred and eight.

Specimens of Astrometis sertulifera examined.

Locality	Depth	Collection	Number	Collector
Catalina Harbor, Calif.		U. S. Nat. Mus.	1	W. H. Dall.
San Clemente Island, Calif.		do	1	Albatross, 1887–88.
San Diego, Calif.		do	1	Rosa Smith.
Point Loma, Calif.		do	2	
San Francisquito Bay, L. C.		do	6	Albatross, 1911; Nos. 32345 and 32449.
Gulf of California		do	2	R. E. C. Stearns; No. 8964.
Santa Margharita Island, Lower California		do	1	Albatross, 1888; No. 38533. (Pl. 58, figs. 1–3.)
Station 2828, Gulf of California (24° 11′ 30″ N., 109° 55′ W.)	10 fathoms, shells	do	1	Albatross.
Station 3001, Gulf of California (24° 55′ 15″ N., 110° 39′ W.).	33 fathoms, fine gray sand.	do	1	Albatross. (Pl. 58, fig. 4.)
Cape San Lucas		do	1	No. 1252, type, part of a ray.
Ensenada, Lower California	Low tide	Stanford University	3	E. F. Ricketts.
Santa Catalina Island		do	3	
Isthmus Harbor, Santa Catalina Island	Very low tide	do	17	Univ. Southern California.
San Pedro, Calif.	Roots of nereocystis	do	1	Do.
Venice, Calif.		do	1	Do.
San Diego, Calif.	Low tide	do	2	E. C. Starks.
La Jolla, Calif.	do	do	48	Scripps Institution.
Half Moon Bay, Calif.[1]		do	1	
Monterey Bay, Calif.[1]		do	1	
Salsipuertas, Lower California		Calif. Acad. Sci.	1	Expedition of 1921 (V. Owen).
Isla Partida, Gulf of California	Midtide	do	2	Expedition of 1921 (Fred Baker).
Tepoca Bay, Gulf of California		do	1	Do.
Patos Island, Gulf of California	4½ fathoms	do	1	Do.
La Paz, Lower California	Low tide	do	1	G. F. Ferris, 1919.
Do		Mus. Comp. Zool.	1	(No. 1215.)
Gulf of California		do	3	(No. 1214.)
San Diego, Calif.		do	1	(No. 1825.)
La Jolla, Calif.		do	1	(No. 1211.)
Santa Barbara, Calif.		do	1	(No. 1213, Fewkes.)
Laguna Beach, Calif.		do	1	(No. 2432.)

[1] Correctness of label open to doubt. No other specimens have ever been found in these localities.

ASTROMETIS CALIFORNICA (Verrill)

Plate 55, Figures 3, 3*a*; 6, 6*a*; Plate 57, Figures 1, 1*a*, 5; Plate 59, Figure 1.

Orthasterias californica Verrill, Shallow-water Starfishes, 1914, p. 174, pl. 68, fig. 2; pl. 70 fig. 5; pl. 80, fig. 3, 3*a*; pl. 81, figs. 2, 2*b*; text fig. 3, p. 37.

[48] Shallow-water Starfishes, 1914, pl. 80, fig. 2.

Diagnosis.—Differing from *sertulifera* in having the first adambulacral plate subequal to the second and in the sharp decrease in the height of the superomarginal plates from the fifth or sixth toward the first; ventral lobe of proximal superomarginal plates broader.

Discussion.—Only the type is known. It is something of a problem and I feel that in all probability it is only an extreme variant or perhaps the representative of a distinct forma of *sertulifera*. The specimen, which I have examined, measures R 82 mm.; r 9 mm.; r = 9 r. The difference in the proximal marginal plates and in the first pair of adambulacral plates exists, however. The status of the form can not be definitely estimated until sufficient material is at hand to determine the range of variation.

I am even in doubt concerning the type-locality. Verrill states that the type is from "off San Francisco." He gives the type-locality of *gonolena* as "off southern California."[49] Yet in part 2 (p. 136, pl. 67) the type is said to be from "off San Francisco." Both types were presented by Prof. W. E. Ritter and not improbably came from the vicinity of San Diego or of San Pedro, where Professor Ritter is known to have explored extensively.

The straight and crossed pedicellariae are like those of *sertulifera* in size and detail. The intermarginal straight pedicellariae are numerous. The superomarginal spines are pretty regularly on alternate plates. The dorsolateral spines are in two fairly complete series for two-thirds the length of ray, after which there is a single series practically to the tip. They frequently form an arcuate transverse series with the carinals and superomarginals. The actinal spines reach nearly to the middle of the ray, and the plates a short distance further. The first three or four adambulacral plates are monacanthid, and near the end of the ray for a very short distance they are alternately monacanthid and diplacanthid, then monacanthid. In the ventral interradial channel are 14 to 20 small lanceolate, compressed, straight pedicellariae and a cluster of smaller ones on the outer apical oral spine, as in *sertulifera*. The apical oral spines stressed by Verrill in Key (p. 64) are about as long as the median suture of the plate and are not longer than in *sertulifera*, although rather flatter than usual. They are about the same as in a large six-rayed specimen of *sertulifera* in the Stanford University collection labeled, probably erroneously, Half Moon Bay, Calif. (Pl. 56, figs. 1*e*, 1*f*.)

Professor Verrill placed *californica* in his subgenus *Orthasterias* as contrasted with the subgenus *Stylasterias*, under which *gonolena* (= *sertulifera*) was described. This classification was based primarily upon the presence of actinal spines in *californica* and their supposed absence in *gonolena*. But, as I have shown, they are present in *sertulifera*, even in the cotype of *gonolena*.

The specimen of *sertulifera* alleged to be from Half Moon Bay (a short distance south of the entrance to San Francisco Bay) is entirely unlike the type of *californica* in respect to the first adambulacral plate and the proximal superomarginals. The latter have especially long and rather narrow ventral lobes, as in the typical Lower California examples. Large spatulate pedicellariae, with unusually broad jaws and 10 to 12 teeth are numerous in the intermarginal channels. (Pl. 55, figs. 1*a*.) If this locality is really authentic, which I doubt, then *sertulifera* in a typical form ranges at least to central California.

[49] Shallow-water Starfishes, 1914, p. 185.

I am indebted to Prof. Wesley R. Coe for the photograph of the type.

Type.—In the Yale Museum.

Type-locality.—"Off San Francisco, probably in rather shallow water (Prof. W. E. Ritter)."

Genus COSCINASTERIAS Verrill

Plate 42, Figures 1–3; Plate 43, Figures 3, 4

Coscinasterias Verrill, Trans. Connecticut Acad., vol. 1, pt. 2, 1867, p. 248. Type *C. muricata* Verrill (rel. *Asterias calamaria* Gray).—Perrier, Expéd. Trav. et Talism., 1894, p. 108.—Fisher, Ann. Mag. Nat. Hist., ser. 7, vol. 17, 1906, p. 574; ser. 9, vol. 12, 1923, p. 256.

Stolasterias Sladen, *Challenger* Asteroidea, 1880, p. 583. Type *Asterias tenuispina* Lamarck.—Fisher, Ann. Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 256 (subgenus).

Lytaster Perrier, Expéd. Trav. et Talism., 1894, p. 98. *L. inaequalis* Perrier=*A. tenuispina* Lamarck, juv. See Fisher, Ann. Mag. Nat. Hist., ser. 9, vol. 18, 1926, p. 197.

Polyasterias Perrier, Expéd. Trav. et Talism., 1894, p. 108. Type, *A. tenuispina* Lamarck.

Diagnosis.—Fissiparous Coscinasteriinae, with 7 to 12 rays, having monacanthid adambulacral plates, pedicellariae on only the outer of the two inferomarginal spines, one series of spiniferous actinal plates (sometimes abortive). Skin covering skeleton not extraordinarily thick and tough as in *Meyenaster*; crossed pedicellariae with an enlarged tooth on outer side of terminal lip; large straight pedicellariae with denticulate jaws usually present.

Subgenus Coscinasterias ss.

Plate 42, Figure 1; Plate 43, Figure 3

Diagnosis.—Alternate carinal plates oblong-elliptical, without lateral lobes; mouth-angle very constricted, with five or six contiguous pairs of adambulacral plates behind the mouth plates.

Southern Hemisphere: Indian Ocean and Pacific (Madagascar to Chile).

The species of this group require a complete revision based upon specimens and not upon scattered notes and inferences. It is customary to unite Verrill's *muricata* of New Zealand with Gray's *calamaria* of Mauritius and neighboring Indian Ocean, whereas they may be distinct. A Chilean species, *C. gemmifera* (Perrier, 1869), probably the same as *Asterias echinata* Gray, 1840, is distinct from *C. muricata*, of which the type still exists in the Yale Museum.

I am indebted to Dr. H. L. Clark for the loan of numerous specimens from New Zealand, New South Wales, and Victoria. Doctor Clark and I have long been aware of the existence of two species of *Coscinasterias*, ss, among the sea stars of the Museum of Comparative Zoölogy.

Clark [50] reports *C. gemmifera* from Tasmania and *calamaria* from South Australia. It may well be that the ranges of two species overlap in Australian waters, but their correct names must remain at present uncertain. True *gemmifera* is distinct from *calamaria*, however.

I have seen the type of *gemmifera* (in alcohol) at the Museum d'Histoire Naturelle (Eydoux et Souleyet, 1832). Rays 11. Along inside of furrow are small slender straight pedicellariae, but no large ones elsewhere as in *calamaria*. In the middle third of ray there are a few spiniferous actinal plates occurring sporadically but not

[50] Report on Sea-Lilies, etc., of the "Endeavour," 1916, pp. 72, 74.

as a regular series, and they appear to be entirely absent at base of ray where the inferomarginals abut against the adambulacrals. There are two stout inferomarginals more or less webbed together basally, the outer with a thick tuft of pedicellariae which occasionally involves the inner. The superomarginal, dorsolateral, and carinal plates form five regular longiseries, their acicular, nearly equal, spines with thick stoles of pedicellariae, which toward the end of ray nearly touch. The spine sheaths and the integument covering the plates is thick and tough. The alternate carinal plates are without lateral lobes. Adoral carina narrow with six pairs of contiguous postoral plates, the plates of the first four pairs longer than the succeeding.

The form of the straight pedicellariae and the behavior of the actinal plates (if not confined to this specimen) appear to be peculiar.

C. muricata Verrill is perfectly distinct from *gemmifera*. It has large straight pedicellariae scattered over the body and a well-developed series of spiniferous actinals. I have examined the type.

Specimens of true *calamaria* from the western Indian Ocean should be compared with Australian and New Zealand examples.

Subgenus STOLASTERIAS Sladen. (LYTASTER Perrier, POLYASTERIAS Perrier.)

Plate 42, Figures 2, 2*a*–2*c*, Figure 3; Plate 43, Figure 4

Diagnosis.—Differing from *Coscinasterias*, ss, in having all carinal plates four-lobed; mouth plates broader, with two or three contiguous pairs of adambulacral plates behind the mouth plates. Type, *Asterias tenuispina* Lamarck.

Northern Hemisphere: Japan, Hawaiian Islands, Mediterranean, eastern Atlantic, Brazil, West Indies.

There are two known species: *C. acutispina* from Japan and the western part of the Hawaiian Group [51] and the well known *C. tenuispina*.

I examined the seven small types of *Lytaster inaequalis* Perrier at the Museum d'Histoire Naturelle and found them to be very young specimens of *Coscinasterias tenuispina*. Among other features the crossed pedicellariae agree with those of the adult.

Fissiparity or voluntary splitting of the whole animal into two is characteristic of *Stolasterias* even into adult life. In *Coscinasterias* it appears to be confined to young individuals and is not practiced in adult life.

Genus MARTHASTERIAS Jullien

Plate 42, Figure 4; Plate 43, Figure 6

Marthasterias JULLIEN, Bull. Soc. Zool. France, 1878, p. 141. Type *M. foliacea*=*Asterias glacialis* O. F. Müller.—FISHER, Ann. Mag. Nat. Hist., ser. 7, vol. 17, 1906, p. 575; ser. 9, vol. 12, 1923, p. 256.—VERRILL, Shallow-water Starfishes 1914, p. 47.

Stolasterias PERRIER (not Sladen), Expéd. Trav. et Talism., 1894, pp. 108, 109. Type, *A. glacialis*.

Diagnosis.—Nonfissiparous, normally five rayed, Coscinasteriinae with monacanthid adambulacral plates, pedicellariae on only the outer of the two inferomarginal spines, and one series of small spineless actinal plates hidden by skin. Dorsolateral skeleton normally simple and fairly regular, the dorsolateral papular areas in two

[51] Fisher, Sea Stars of Tropical Central Pacific, Bull. Bishop Mus. No. 27, 1925, p. 82; Ocean (Cure) Id., Pearl and Hermes Reef

longiseries on either side of the carinal series; dorsolateral and carinal spines either in three regular longiseries or irregularly scattered (*africana*). Crossed pedicellariae with slightly enlarged lateral tooth on each side of terminal lip; straight pedicellariae slender lanceolate to ovate, not unguiculate.

North Atlantic (west to Iceland); Mediterranean; south Africa.

Three species are at present recognized: *M. glacialis* (Müller), having an extraordinary range from the North Atlantic (Iceland and Finmark) along the coast of Europe into the Mediterranean, the Canary and Cape Verde Islands, thence to Cape of Good Hope (Clark); *M. africana* (Müller Troschel) Cape of Good Hope to Natal; *M. rarispina* (Perrier), Cape of Good Hope.

M. glacialis grows to considerable size. Ludwig mentions 400 mm. as a common diameter in the Mediterranean [52] which is about the same as the 15 inches given by Forbes for British specimens.[53] Forbes records an example of 33 inches (840 mm.) in diameter, the largest of the rays being 14 inches (360 mm.). This record is the largest for any of the Coscinasteriinae and compares favorably with the giant Pisasters and Pycnopodias, which are the Goliaths among sea stars, both as to diameter and weight.

Genus ASTROSTOLE Fisher

Plate 42, Figures 6–8; Plate 43, Figure 1

Astrostole Fisher, Ann. Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 255. Type *Margaraster scaber* Hutton, 1872.

Diagnosis.—Nonfissiparous, seven to nine rayed Coscinasteriinae, with diplacanthid adambulacral plates, pedicellariae on only the outer of the two inferomarginal spines, one well developed series of spiniferous actinal plates, inferomarginal web absent or very rudimentary. Resembling *Sclerasterias* but ray less markedly pentagonal in section; dorsolateral spines well developed, in one or two longiseries on either side; only alternate superomarginals spiniferous, the plates generally with a conspicuous beaded area; mouth angle rather narrow; three to five contiguous pairs of postoral adambulacral plates; crossed pedicellariae much larger than in *Meyenaster*, without or with only a slight enlargement of the terminal lateral teeth; straight pedicellariae medium to large, smooth or denticulate; odontophore with 2 pits on outer margin as in *Meyenaster* and *Lethasterias*.

Pacific south of Tropic of Capricorn (New Zealand, Kermadecs, Easter Island, Juan Fernandez).

Includes *A. scabra* (Hutton), New Zealand; *A rodolphi* (Perrier), Kermadec Islands; *A. platei* (Meissner),[54] Juan Fernandez; *A. paschae* (Clark),[55] Easter Island.

Genus MEYENASTER Verrill

Plate 42, Figures 9, 9*a*; Plate 43, Figure 7

Meyenaster Verrill, Amer. Journ. Sci., vol. 35, 1913, p. 348; Shallow-water Starfishes, 1914, p. 54. Type *Asterias gelatinosa* Meyen.—Fisher, Ann. Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 256.

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[52] Seesterne des Mittelmeeres, p. 365.

[53] British Starfishes, p. 80.

[54] Meissner, Archv. f. Naturges., 1896, pp. 103, 104, pl. 6, figs. 1 and 2. *Polyasterias fernandensis* Meissner (Archiv. f. Naturges., 1896) is probably young *platei*, which not improbably includes also the Easter Island form.

[55] Clark, H. L., Mem. Mus. Comp. Zoöl., vol. 39, No. 3, 1920, p. 105, pl. 4. fig. 3 (as *Stylasterias*).

Diagnosis.—Nonfissiparous, five to seven rayed Coscinasteriinae with monacanthid adambulacral plates, pedicellariae on only the outer of the two inferomarginal spines, one series of spiniferous actinal plates, and a thick tough skin covering the skeleton, of which the dorsolateral portion is irregularly reticulated; the papular areas equivalent to three or four longiseries, but only the lateralmost regular. Crossed pedicellariae small, round tipped, without any enlarged terminal teeth; straight, pedicellariae abundant, large, broadly lanceolate, with rather compressed denticulate jaws; odontophore with two distinct pits on the outer (septal) margin.

West coast of Chile.

Only one species is known, *M. gelatinosus*, five to seven rayed, which reaches a diameter of 500 [56] mm.

Verrill (1914, p. 357) records another unnamed species with five rays "supposed to be from the Society Islands (No. 1427, Mus. Comp. Zoöl.)." I have examined this specimen which is *Marthasterias glacialis*, of which there is a large series in the Museum of Comparative Zoölogy. It is not from the Society Islands.

Although this genus bears a considerable resemblance to *Marthasterias*, it has very different crossed pedicellariae and an unusual sort of odontophore. It is probably much closer to *Astrostole*.

Genus AUSTRALIASTER Fisher

Plate 42, Figures 5, 5*a*

Australiaster Fisher, Ann. Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 253. Type *Coscinasterias dubia* Clark (Tasmania).

Diagnosis.—Nonfissiparous, five-rayed, Coscinasteriinae with diplacanthid adambulacral plates, pedicellariae on both inferomarginal spines, a well-developed series of spiniferous actinal plates (without spine pedicellariae) and very small crossed pedicellariae without enlarged lateral terminal teeth. Dorsolateral region relatively broad, with irregular skeleton and, in type, few irregularly scattered prominent spines; each carinal and superomarginal not regularly spiniferous—usually only the alternate plates (which are sporadically diplacanthid); two pairs of contiguous postoral adambulacral plates; straight pedicellariae slender, lanceolate.

Australia, Tasmania.

The only known species is the type.[57]

Genus LETHASTERIAS Fisher

Lethasterias Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 258. Type *Asterias nanimensis* Verrill.

Diagnosis.—Asteriidae differing from *Distolasterias* in having very numerous and irregularly arranged dorsolateral plates, and crossed pedicellariae without a conspicuously enlarged tooth on each side of the end of the jaw; odontophore with two pits. Carinal and superomarginal plates small, four-lobed, strongly imbricated, all spiniferous; superomarginal plates smooth, without trace of a specialized area of hyaline beads; dorsolateral plates unusually numerous, without well-defined order in arrangement, and with small intervening papular areas; two inferomarginal

[56] Clark, Echinoderms of Peru, Bull. Mus. Comp. Zoöl., vol. 52, 1910, p. 337.

[57] Clark, H. L. Mem. Austr. Mus., vol. 4, pt. 11, 1909, p. 532, pl. 49, figs. 3, 4; pl. 50. Report on Sea-Lilies, etc., of the "Endeavour," 1916, p. 73, pl. 30, figs. 1, 2.

spines, each with a heavy half-wreath of crossed pedicellariae; the numerous abactinal and superomarginal spines with thick wreaths of the same; one series of small actinal plates wholly spineless and hidden under integument; mouth angle primitive; two pairs of adambulacral plates in contact behind the rather large mouth plates; adambulacrals diplacanthid; large unguiculate straight pedicellariae may be present.

Remarks.—The genus to which *Lethasterias* shows greatest superficial resemblance is *Distolasterias* Perrier, of which I have examined three species: *D. stichantha* (Sladen, genotype), *D. robusta* (Ludwig, as *Stolasterias*), and *D. nipon* (Döderlein, as *Asterias*).

The points of resemblance common to all species of *Distolasterias* and to *Lethasterias* are the small, spineless, immersed actinal plates in a single series; the diplacanthid adambulacrals; the rather short adoral carina; the similarity of the superomarginal and inferomarginal plates.

But other, totally unrelated genera have a single series of actinals, and a short adoral carina. On the other hand, the three species of *Distolasterias* have a common form of crossed pedicellaria different from that of *Lethasterias*. This is a conservative, reliable character. *Lethasterias* also has very numerous plates and spines. In two nearly equal-sized specimens, *D. nipon* has 70 inferomarginal plates and *L. nanimensis chelifera* has 100; while as an index to the number of dorsolateral plates, *nipon* has the equivalent of two or three dorsolateral series at base of ray while *chelifera* has five. *Lethasterias* has a characteristic odontophore with two pits on the outer border, as in the very different *Meyenaster* and *Astrostole*.

LETHASTERIAS NANIMENSIS (Verrill)

Plate 60, Figures 5, 5*a*; Plate 61, Figures 2, 2*a*–2*e*; Plate 62, Figure 3; Plate 64, Figure 1

Asterias nanimensis Verrill, Shallow-water Starfishes, 1914, p. 105, pl. 61, figs. 1, 1*a*, 1*b* (*Asterias manimensis*, err. typ.).

Distolasterias nanimensis, Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 258.

Lethasterias nanimensis, Fisher, Ann. and Mag. Nat. Hist., ser 9, vol. 12, 1923, p. 258.

The type of this species, as figured by Verrill on Plate 61 of his well-known work, was kindly forwarded to me by the authorities of the Ottawa Museum. The label is as follows: "Geological Survey Dept. Canada, 1905, no. 19. *Distolasterias chelifera* Ver., cotype." This specimen, as just noted, is figured as the type of *nanimensis*, and it undoubtedly also forms the basis of the description. On page 187 Verrill lists the same specimen as the cotype of *chelifera*, indicating certain artificial peculiarities such as the stained and varnished surface. The measurements of this specimen, as the type of *nanimensis*, are practically the same as those given on page 185, for the cotype of *chelifera*.

This specimen appears not to have been hardened before drying so that the skin became somewhat macerated. The papular areas are slightly sunken and the skeleton is rather plainly visible. Altogether it looks very unnatural. If any large unguiculate pedicellariae were present, as is likely, at least in the actinal interradial channels, these have sloughed off. Practically all the straight pedicellariae of the adambulacral plates have disappeared. There are no oral pedicellariae. The viscera have been removed through openings at the base of the rays.

A well-preserved alcoholic specimen from station 3464, Straits of Fuca, due south of Victoria, Vancouver Island, about on the international boundary line, 40 fathoms, gray sand and pebbles, has precisely the same appearance as typical *chelifera*, but lacks the abundant, *abactinal*, long-clawed, unguiculate straight pedicellariae which can be readily seen, without the aid of a glass, on all specimens of *chelifera*. In *nanimensis* the abactinal straight pedicellariae are few or absent, and when present have short claws.

Diagnosis.—Rays five, long, flexible, swollen at base, rather slender, gradually tapering to an attenuate, bluntly pointed extremity. Abactinal surface with numerous, uniform, rather small, capitate, terminally fluted, black-tipped, "stone drill" spines, heavily wreathed with crossed pedicellariae; abactinal spines without regular serial arrangement; the carinal series more or less differentiated by greater regularity, though not larger size; wreaths of pedicellariae frequently touching; papulae fairly conspicuous; one superomarginal (sometimes two proximally), two inferomarginal spines, the latter usually gouge-shaped and also sometimes striated or fluted; a very few actinal and intermarginal unguiculate, straight pedicellariae, with the tines shorter than in *chelifera*; abactinal straight pedicellariae few or absent; crossed pedicellariae slenderer and with smaller terminal tip than in *chelifera*. R 205 mm.; r 25 mm.; R = 8r; breadth of ray at base, 26 mm. (station 3464). Type, R 180 mm., r 18 mm.

Type.—No. 19, Geological Survey of Canada, Ottawa Museum.

Type-locality.—"Departure Bay, Nanaimo, British Columbia, 25 fathoms mud." Verrill.

Distribution.—Known only from the two specimens here listed.

Specimens examined.—The type and one from station 3464, Straits of Fuca, Washington, due south of Victoria, B. C.; 48° 14′ N., 123° 20′ 40″ W.; 40 fathoms, gray sand, pebbles; bottom temperature, 47.8° F.

Remarks.—It is unfortunate that *Asterias nanimensis*, by reason of its page priority, must be given precedence over *chelifera* to designate the composite species, of which two geographical races are here recognized. What I have called the subspecies *chelifera* is in fact the more important, boreal, form ranging from Saghalien to the Gulf of Alaska. The subspecies *nanimensis*, on the other hand, is a southern offshoot, or differentiation, from *chelifera* and probably has a comparatively restricted range. It would be much better biology to call the British Columbia race *Lethasterias chelifera nanimensis*.

Since *chelifera* is really the representative, wide ranging race of the species, a detailed description will be given of that rather than of *nanimensis* of which I have only one good specimen. The two races are alike in external appearance and in the gross anatomy. They differ in the details mentioned in the diagnosis. The differences in the form of the pedicellariae can be best appreciated from the figures.

In order to justify the use of the name *chelifera* for the northern subspecies it must be explained that the type, No. 1346, Museum of Comparative Zoölogy, is not from Vancouver Island as Verrill states [58] but is labeled "Alaska." It is in fact of the northern race and as it is known to have been dredged by the *Albatross*, it is most likely from one of the localities listed below, under *chelifera*.

As to the type of *nanimensis*: Verrill states that it is from Departure Bay, 25 fathoms. The labels now borne by the type do not indicate locality. The dredging operations conducted by the Canadian Biological Laboratory, under the direction of Dr. C. McLean Fraser, have not produced a duplicate specimen from Departure

[58] Shallow-water Starfishes, p. 186.

Bay, nor from that general region. In fact the *Albatross* specimen is the only other known.

In his description of *Asterias nanimensis* Verrill has the plates erroneously classified.[59] His upper marginal plates are the outermost row of abactinals. His inferomarginal plates, which he describes as bearing a single spine, are really the superomarginals. His diplacanthid peractinal plates are the true inferomarginals. On page 187, under *Distolasterias chelifera*, the plates of this specimen are correctly given. Here it is stated that no peractinal (that is actinal) plates are visible.

In the type the fluted, stone-drill abactinal spines are arranged in quincunx, dorsolaterally, although the regularity is disturbed. The fluting of the spines is rather deep, five or six grooves to a spine. Many of the inferomarginal spines are shallowly gouge-shaped at the tip in addition to being grooved. The prominence of the carinal plates is unnatural and is due to the shrinking away of the integument.

The example from the Straits of Fuca, the measurements of which are given in the diagnosis, is well preserved and the mats of crossed pedicellariae surrounding the spines are so dense that they are in close contact. The unguiculate straight pedicellariae are few and are actinal in position. A large interradial pedicellaria is figured. (Pl. 60, figs. 2, 2*b*, 2*c*.) The superomarginal plates of the proximal half of the ray usually have a second smaller spine on the descending lobe of the plate. A similar variation is present in a specimen of *chelifera* from Bering Island.

The lanceolate pedunculate straight pedicellariae, which are abundant on the adambulacral and oral plates of *chelifera*, are very few in this specimen. This may constitute an additional difference between the two races. (Compare pl. 62, figs. 2*a* and 3.)

LETHASTERIAS NANIMENSIS CHELIFERA (Verrill)

Plate 60, Figures 4, 4*a*–4*e*; Plate 61, Figures 1, 1*a*–1*g*; Plate 62, Figures 1, 1*a*, 2, 2*a*; Plate 63; Plate 64, Figure 2

Distolasterias chelifera VERRILL, Shallow-water Starfishes, 1914, p. 185, pl. 81, figs. 1, 1*a*–1*b*; pl. 110, figs. 1, 2.

Diagnosis.—General appearance the same as that of *L. nanimensis;* differing in having abundant abactinal, intermarginal, and actinal unguiculate, straight pedicellariae with two or three longer curved claws or tines; crossed pedicellariae with a heavier terminal lip. Largest specimen, R 297 mm.; r 26 mm.; R = 11.4 r; breadth of ray at interbrachium, 30–32 mm.; at widest part, 40–45 mm.; width of furrow, 9–10 mm.

Description.—The type of this subspecies, which I have examined, is a comparatively small specimen (R = 100 mm.). The following description is based upon large examples, especially one with R 280 mm., from station 4787, and another with R 297 mm., from station 3282. (Pl. 63, figs. 1 and 2.) In such large specimens the spines are not arranged in definite series, nor in regular quincunx, nor is the carinal series distinguishable by regularity or size of spines, except sometimes on the outer part of the ray. At the base of the ray one can count across the ray between the two series of superomarginals, and exclusive of them, 15 to 20 spines, or in medium-sized examples, 10 to 18. The spines are therefore rather close set and are conspicuous because of their dark gray or blackened color, which is accentuated by a zone of blackened integument between the spine tip and the thick wreaths of crossed pedicellariae. The spines are borne on a raised boss of the plate, are 1.7 to 2.2 mm. long in large

[59] Shallow-water Starfishes, p. 105.

specimens, and the capitate end is marked by four to eight unequal channels. It resembles a miniature drill.

The superomarginals are situated low on the side of the ray and separated from the inferomarginals by only a narrow channel often completely covered by the wreaths of pedicellariae. The spines are similar to the dorsals, one to each plate, and the series is sometimes a bit irregular, near the base of the ray, in large specimens. The inferomarginal spines are a little heavier and longer than the superomarginal, yellowish in color, and form a transverse oblique series of two, or sometimes three, on the outer part of the ray. The spines are flattened and broadened at the tip, are irregularly channeled, and sometimes shallowly gouge-shaped (especially well marked in the Saghalien and Bering Island specimens). On the outer part of the ray the inferomarginal and superomarginal spines are so close that they appear as one transverse series of three (or four), but the superomarginal spine is usually blackish.

The actinal channel is very narrow as the actinal plates are small, spineless, and not visible without special preparation (see *Skeleton*). The adambulacral spines, two to a plate, are, therefore, close to the inferomarginals, the outer spine being of about the same length as the adjacent inferomarginal, while the inner is shorter and slenderer, and set slightly lower on the edge of the furrow margin. The spines are slender, terete, slightly tapered, and blunt. There are about 33 adambulacral plates opposite 10 inferomarginals starting with the second or third.

The mouth angle is not deeply sunken but is fairly broad, and composed of the mouth plates and two pairs of contiguous adoral adambulacral plates. The mouth plates are fair-sized, being as long as the first 2 adambulacral plates in medium-sized specimens and as long as the first 3.5 or 4 in the large examples. The armature consists of a very short and a much longer, terminally flattened, tapering or untapered, narrow to fairly broad, blunt, actinostomial spine (four to each angle) and either one or two tapering, slender, suboral spines, which with the first half-dozen adambulacral spines are longer than the rest of the adambulacrals. First one or two adambulacral plates with only one spine. The mouth plates are plentifully provided with rather large, mostly unguiculate, straight pedicellariae, and forms intermediate between these and the ordinary lanceolate furrow pedicellariae. (See pl. 62, figs. 2, 2*a*.) One or two large pedunculate pedicellariae spring from the middle of the combined oral plates, and often the following one or two pairs of adambulacrals carry a similar one. Less strongly unguiculate, smaller pedicellariae (1. to 1.5 mm.) on long peduncles are found on the actinostomial border, singly or in clusters of two or three, these being homologous with the lanceolate furrow pedicellariae, which are often very numerous—two to four on the proximal adambulacrals and two on the distal. These oral and proximal adambulacral pedicellariae are rare in *nanimensis*.

Owing to the very numerous abactinal plates, the papular areas are small, the abactinal containing, in large specimens, upward of 5 to 10 papulae, or in some cases several more, especially on the disk, where the areas are poorly defined; the intermarginal areas have five to eight, or as few as only two or three in small specimens; the actinal areas have one in small specimens and two or three in the largest.

Crossed pedicellariae, measuring in large specimens about 0.38 to 0.43 mm. in length, are very numerous, and form massive wreaths around the abactinal and superomarginal spines, and half-wreaths on the outer side of the inferomarginals. These wreaths frequently touch one another in alcoholic specimens. The pedicellariae differ slightly but constantly from those of *nanimensis* in having a heavier terminal lip, which as seen from the side, extends further down the jaw. The pedicellariae of the smallest specimen (station 2856, R 33 mm.) are about two-thirds the length of the largest. (Pl. 60, figs. 4*b*, 4*c*, 4*d*.)

Straight pedicellariae very numerous. (Pl. 61, figs. 1*a*–1*d*; pl. 62, figs. 2, 2*a*.) The common sort is somewhat spatulate in form with usually two or three curved claws which interlock with those of the opposite valve. Sometimes only one tooth meets two, or two interlock with three. Such pedicellariae are scattered liberally over the dorsal surface; in the intermarginal and actinal channels; between the inferomarginal plates; in the actinal interradial area, and on the mouth plates. They have longer claws than the very much less numerous corresponding pedicellariae of *nanimensis*, and in length measure from 1.2 to 2.25 mm., the largest being in the actinal interradial channel. Besides these, there are a few smaller wedge-shaped or subconical, toothless abactinal pedicellariae. Along the furrow at the base of the inner spines are numerous lanceolate, long-peduncled pedicellariae, as many as four or five to a plate in some examples from Bering Sea and the Kamchatkan region. A representative example measures 1.17 mm. long by 0.40 broad at the base of valves. The tips of the jaws are sometimes slightly crossed and near and on the mouth plates are forms intermediate with the unguiculate variety. In *nanimensis* the furrow pedicellariae are very few.

Madreporic body variable in size, medium to large, with fine radiating striae.

Color in alcohol, yellowish brown to dark gray; tips of abactinal spines blackish.

Variations.—Since the race ranges from the Gulf of Alaska to Saghalien and from low tide, in some localities, to 93 fathoms (off Unalaska), it is not surprising that there should be considerable variation. What might be called the average or mean for the species however is found in all parts of the range, with only trifling differences, and the most striking variations are local—at least so far as known.

Perhaps the most conspicuous variation is in the stoutness of the rays. A specimen with R 115 mm. from station 4795 has relatively thick, short rays, their breadth at the widest part being about one-fifth length of ray measured on the side. This specimen has very large gonads. In sharp contrast are three specimens from station 2856, Gulf of Alaska, 68 fathoms, which have slender rays. In one of these (with R 130 mm.) the greatest width of the ray is only one-eighth of the length (there being only a rudimentary gonad). In average specimens the rays are six to seven times as long as the greatest breadth.

There is some variation in the form and number of unguiculate straight pedicellariae, and they are relatively larger upon small than upon big specimens. On the former they often exceed the spines in length, but the reverse is true for large examples. The lanceolate pointed pedunculate pedicellariae of the ambulacral margin are usually numerous, but not always so. The depth and number of vertical furrows at the tip of the dorsal and marginal spines is quite variable, but the channels are usually relatively few and deep. As noted in the description, the inferomarginal spines are often gouge-shaped in full-grown examples.

The most striking departure from the normal for the race is exhibited by a large example (R 220 mm.) taken by the Vega Expedition, August 14, 1879, at station 1075, Bering Island, 65 fathoms, clayey sand. The proximal superomarginal plates carry a vertical row of two or three spines, rather slenderer than usual, while beyond the middle of ray there is practically never but one spine. The specimen was probably quite old as the abactinal spines are very numerous—20 or more between the two series of superomarginals. The inferomarginal spines are unusually deeply gouge-shaped and variously eroded or sculptured by irregular channels. (Pl. 61, figs. 1*e*.) A similar, though less striking, variation toward multiple superomarginal spines is shown by the specimen of *nanimensis* from station 3464.

Anatomical notes.—In the cleaned skeleton the carinal plates are clearly distinguishable from the others as they imbricate strongly, whilst the dorsolaterals are generally connected by slender secondary ossicles. The carinals have four short lobes while the dorsolaterals are usually irregularly three or four lobed, or elliptical. (Pl. 61, fig. 1.) The smaller, secondary ossicles often carry spines. The dorsolateral plates are very irregularly arranged, there being no semblance of series at the base of the ray, but on the outer attenuate part, three or four series can be distinguished on either side of the carinals. The superomarginal plates are the largest of all, are strongly four-lobed, the transverse lobes being the more prominent, while the strong descending lobe is the longest. The plates are not, however, very large when compared to those of *Marthasterias* or *Sclerasterias* in which the intermarginal area is broad, especially in species of the latter genus. On the outer half of the ray the plates of the two marginal series are more nearly of a size. The ventral lobe of the inferomarginals is shorter than the dorsal and longitudinal lobes. Between the inferomarginal and adambulacral plates is a single series of small oblong-elliptical actinal plates placed one opposite each inferomarginal, with the end toward the surface and superficially hidden by tissue. The series extends nearly to the end of the ray, but the distal plates are very tiny. The ambulacral ossicles are somewhat larger than those of *Orthasterias koehleri* and more crowded than in *Stylasterias forreri*. It is not easy to give comparative measurements of these plates because there is no constant for comparison. In the large Port Chester specimen of *Stylasterias forreri* there are 10 ambulacral plates in a space of 10 mm. at the base of the ray, while in a comparable example of *chelifera* from station 4787 there are 13, and in *Orthasterias koehleri* of the same size, 15 or 16. The pore scars are oval or pyriform, as in *Stylasterias*, but narrower.

The actinostomial ring is stout (pl. 62, figs. 1, 1*a*) and the actinostome broader than is *Stylasterias*. The proximal end of the ambulacral ridge is as long as the seven succeeding plates. The first ampulla pore is scarcely larger than the following three (which form a triangular group) while in *Stylasterias* the following three or four are much smaller. The interbrachial septa are strongly calcified but are small on account of the small size of disk. The odontophore has two pits where it abuts against the interbrachial septum.

A comparison of the skeleton with that of *Orthasterias koehleri* shows a very striking similarity in form, spinulation, and mode of connection of the abactinal and marginal plates, and in the relative size of the ambulacral ossicles. There are two points of difference: The actinal plates of *Orthasterias koehleri* are larger, bear a spine at the lower end, and the proximal plates, at least are incipiently four lobed. These lobes are entirely covered by the inferomarginal plates, only the ventral end of the actinal plate being visible externally. The second important difference is the narrow oral angle of *Orthasterias*, composed of small mouth plates plus five pairs of contiguous adoral adambulacral plates, as against two in *chelifera*. The mouth plates of *chelifera* are about twice as broad as those of *Orthasterias*.

Viscera.—The intestinal coecum has three long divisions which are irregularly subdivided and lobed, the longest subdivision being about as long as the diameter of disk. The hepatic coeca are very long and voluminous, reaching nearly to tip of ray. The gonads consist of a thick central axis and many lobulated divisions, short on the side toward the body wall and long toward the mesial line. The opening is close to the interbrachial angle and near the superomarginal plates, the series of which bends upward to the dorsal surface at the base of the ray. The spacious ventral stomach has very strong retractors. No Polian vesicles.

Young.—Small specimens are generally easy to recognize on account of the dark-tipped spines and unguiculate pedicellariae which may exceed the dorsal spines in length by as much as 100 per cent. (Station 3310, R 38 mm.) The smallest example from station 2856 has R 33 mm., r 5 mm. The spines are relatively slenderer than in the adult and though capitate are less conspicuously so than in larger specimens. The characteristic fluting is already started but the grooves are fewer and occupy less of the total length of the spine. The wreaths of crossed pedicellariae are well developed, and while the unguiculate pedicellariae are as yet few they are very conspicuous by their size. There is an irregular zig-zag series of three or four lobed dorsolateral plates, with occasionally one out of place to spoil the regular order. Generally a secondary ossicle intervenes between the spiniferous dorsolateral plates (but not between consecutive carinals nor marginals). The skeleton is very open and the actinal system is present only in a few rudimentary plates at the base of the ray. In the mouth angle the second pair of adambulacral plates barely touch.

Type.—No. 1346, Museum of Comparative Zoölogy.

Type-locality.—Alaska. Verrill [60] erroneously states that the type-locality is Vancouver Island. The precise Alaskan locality is unknown, but the specimen was taken by the *Albatross*.

Distribution.—From Saghalien to Bering Strait thence to Gulf of Alaska off Kadiak Island (Kamchatka, Commander Islands, Aleutian Islands, Bering Sea, Alaska Peninsula). Bathymetrical range, low tide to 93 fathoms, on sand, gravel, or sand and mud, or clayey sand. Known temperature range, 38.4° to 45.6° F.

Specimens examined.—Fifty-four.

Specimens of Lethasterias nanimensis chelifera examined

Station	Locality	Depth	Nature of bottom	Bottom temperature	Number of specimens	Remarks
2842	Off Unalaska	72	Pebbles	41	1	U.S.N.M.
2844	do	54	Gray sand	42	3	Do.
2856	Gulf of Alaska, 58° 07′ N., 151° 36′ W	68	Gray shells	44	3	Do.
3264	Bering Sea north of Unimak 54° 57′ N., 164° 48′ W.	40	Coarse sand, gravel	40.5	1	Do.
3272	Bering Sea, 55° 31′ 40″ N., 163° 07′ W	31	Stones	42	1	Do.
3273	55° 44′ 30″ N., 162° 56′ W	39	Gray sand, mud	38.5	2	Do.
3278	56° 12′ 30″ N., 162° 13′ W	47	Fine gray sand	38.8	1	Do.
3282	56° 30′ 45″ N., 161° 50′ 15″ W	53	Fine gray sand, green mud	38.2	1	Do.
3310	North coast Unalaska	58	Fine sand, mud	41.5	3	Do.
3311	do	85	Green mud	41	2	Do.
3335	do	93	Mud	40.8	1	Do.
3546	Northeast of Unalaska	36	Gravel, black sand	45.6	4	Do.
3611	Bering Sea, 56° 45′ N., 167° 25′ W.	50	Green mud, sand	34.6	1	Do.
4283	Chignik Bay, Alaska Peninsula	30–41	Broken shells, brown specks.	--------	1	Albatross 1903.

[60] Shallow-water Starfishes, 1914, p. 186.

Specimens of Lethasterias nanimensis chelifera examined—Continued

Station	Locality	Depth	Nature of bottom	Bottom temperature	Number of specimens	Remarks
4784	Off Attu Island, 52° 55′ 40″ N., 173° 26′ E.	135	Coarse pebbles		2	Albatross 1906.
4786	Off Copper Island, Commander Islands	54	Green sand		4	Do.
4787	do	54	do		1	Do.
4794	Off Petropavlovsk, Kamchatka	58–69	Sand, pebbles		1	Do.
4795	do	69–48	Green sand, pebbles		3	Do.
4796	do	48	Sand, pebbles, shells		2	Do.
5003	Off southwest coast of Saghalien Island 47° 32′ 30″ N., 141° 45′ E.	35	Fine gray sand	42.4	1	Do.
5007	Aniwa Bay, Saghalien	42	Green mud, fine gray sand	34.8	1	Do.
1075	Bering Island	65	Clayey sand		1	Riksmus. Stockholm, Vega Exp.
	Medni Island	Shore.			1	Albatross 1906.
	Bering Island				1	U.S.N.M.
	Old Harbor, Kadiak Island				1	Do.
	Adakh Island				4	Do.
	Iliuliuk Harbor, Unalaska	10	Shingle		3	W. H. Dall, 1871 No 129 (777). U.S.N.M.
	Port Clarence				3	Stanford University.

Genus ORTHASTERIAS Verrill

Orthasterias Verrill (part), Shallow-water Starfishes, 1914, p. 168 (48).—Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 257 (emended).

Diagnosis.—Coscinasteriinae differing from all others in having a well-developed series of actinal spines bearing a small tuft of crossed pedicellariae; inner as well as outer inferomarginal spine with cluster of pedicellariae; crossed pedicellariae without any of the terminal teeth enlarged; straight pedicellariae large, broadly lanceolate, compressed to spatulate, denticulate or unguiculate; oral carina narrow composed of from three to five pairs of contiguous postoral adambulacral plates; actinostome sunken; carinals and superomarginals directly imbricated in series, without interpolated secondary oblong ossicles; two to three (or equivalent) series of dorsolated plates, joined by secondary ossicles into a close-knit, irregular skeleton; adambulacrals diplacanthid.

Rather large, slender to stout rayed, small-disked sea stars, of a bright red color mottled with tawny or yellowish, having numerous prominent abactinal spines, rather heavily sheathed and provided with a conspicuous ruff of pedicellariae; three definite series of ventrolateral spines, adjacent to adambulacrals, each with a tuft of pedicellariae.

ORTHASTERIAS KOEHLERI (de Loriol)

Plate 47, Figure 4; Plate 51, Figure 2; Plate 62, Figure 4; Plate 64, Figure 3; Plates 65–72

Asterias koehleri P. de Loriol, Notes pour servir à l'étude des Échinodermes V., Mem. Soc. Phys. et d'Hist. Nat. Genève, vol. 32, No. 9, 1897, p. 21, pl. 3 (18), figs. 3, 3*a*–3*d*.

Orthasterias columbiana Verrill, Shallow-water Starfishes, 1914, p. 168, pl. 24, figs. 1, 2, 4; pl. 35, fig. 1; pl. 65, fig. 2; pl. 78, figs. 1, 1*e*; pl. 79, figs. 3–3*c*; pl. 109, figs. 2–2*b*.

Orthasterias biordinata Verrill, Shallow-water Starfishes, 1914, p. 173, pl. 63, figs. 1, 2; pl. 82, figs. 2–2*b*.

Orthasterias koehleri Verrill, Shallow-water Starfishes, 1914, p. 175, pl. 75, figs. 3, 3*c*.

Diagnosis.—Same as that of genus.

Description.—The extremes of variation in this species include forms with slender, tapering, sharp spines (varying in number and spacing) contrasted with others having robust, subcylindrical, blunt, or even slightly claviform, subcapitate ones (forma *biordinata*). In between these are gradations. In addition, the form of the ray differs greatly in response to the degree of inflation at time of death, but there is also considerable difference in the actual stoutness of the ray, which is normally rather slender in life and contracts greatly in alcohol or formalin. In the region of Vancouver Island most all the known variations are found and the greatest extremes are exhibited by two specimens, one from low tide at Port Renfrew, on the Straits of Fuca; the other (forma *leptostyla*) from 100 fathoms in the same straits. (Pl. 67, figs. 2 and 5; pl. 69, figs. 1, 3; see also pl. 70, fig. 2, 125 fathoms.)

The type of *Asterias koehleri* is undoubtedly a slender spined form as shown by de Loriol's figure. His specimen was dried without first being hardened. I have almost its double from Departure Bay, Vancouver Island. The type was taken at Saanich Inlet, on the east, or sheltered, side of Vancouver Island between Victoria and Departure Bay (Nanaimo). In my specimen the abactinal integument softened before drying so that it collapsed, the plates becoming unnaturally jammed, together with their spines variously misplaced. In such a mummy the ray is very narrow and shrunken and entirely unlike a well-preserved specimen. Verrill gives a copy of de Loriol's figure. (1914, pl. 75, figs. 3, 3*a–c*.)

I have selected as a good representative of the type forma a specimen from station 4202, Queen Charlotte Sound, off Fort Rupert, Vancouver Island, British Columbia, 36 to 25 fathoms. I have collected practically identical specimens at lowest spring tides, Departure Bay, British Columbia. This is sufficiently near Saanich Inlet to answer the practical purposes of a type-locality.

In the specimen from station 4202 (pl. 68, fig. 2; pl. 71, figs. 1–3) R = 210 mm.; r 21mm.; R = 10 r. Rays slightly inflated above base, well rounded and not pentagonal; disk convex. Abactinal spines relatively slender (pl. 67, fig. 4) but strong, slightly tapered, the end swollen a trifle and blunt. Some of the spines have a few terminal shallow furrows (drill type). The carinal spines are proximally 4 or 5 mm. long and each carinal plate normally carries a spine. On either side are two or three very irregular dorsolateral series of spines well-spaced proximally but becoming more crowded and a little more regular distally where the wreaths of pedicellariae touch. Here three dorsolateral series can be counted. The dorsolateral spines are obviously more widely spaced than the carinals or marginals. Thick wreaths of crossed pedicellariae attached to a tough sheath surround the abactinal spines.

Superomarginal spines form a very regular series which curves upward proximally to meet the corresponding series of adjacent ray at abactinal entrance to interbrachial, or axillary, channel. At base of ray each plate usually carries a spine; then only alternate plates on median third of ray; and finally, on outer part, each plate is generally armed. There are 80 to 85 spines in a series (varying with age; in a specimen with R 65 mm., 45 marginals) and each bears a thick wreath of pedicellariae.

Separated from superomarginals by an intermarginal channel about as broad as the length of a superomarginal spine are two series of inferomarginal spines on the actinolateral border of the ray, these paralleled by an equally regular series of actinal spines, which extends in grown specimens five-sixths the length of ray, all three with half-wreaths of pedicellariae on the outer side. These spines, which form regular transverse combs of three, increase in size toward the outer, and their form is rather variable proximally where they may be clavate with compressed channeled tips, or in large specimens gouge-shaped, or swollen with two or three broad channels, the broad end terminating in two or three unequal, almost malformed tips. (Pl. 67, fig. 7*a*, 7*b*, station 3466.) Beyond the basal third or half of ray (and throughout in medium-sized and small specimens) the spines are slenderer, tapered and blunt, the outer being frequently variably compressed, and all three, or only the outer one or two, rather faintly channeled.

Adambulacral spines two, slender, blunt, or truncate, sometimes tapered slightly, sometimes untapered, only slightly shorter but very much slenderer than the actinal spine. The spines are usually compressed and form two very regular, not very divergent series; and the spines on the adoral carina and succeeding plates are longer than the rest. The largest specimen (pl. 64, fig. 3; pl. 68, fig. 1), from station 3466, 56 fathoms off Washington (R 300 mm.) has the proximal spines with a sulcus at the tip. This is the same example in which the inferomarginals are modified. There are 30 to 36 adambulacral plates to 10 inferomarginals at basal third of ray.

Adoral carina somewhat narrowed behind the mouth plates and composed of three to five pairs of contiguous adambulacral plates, each bearing a spine which is slightly longer than those a dozen plates farther along the ray. The actinostome is sunken and the oral plates are not superficially visible. The latter are bent downward somewhat as viewed from below, and bear a small spine on the actinostomial margin directed over the mouth of the furrow close to the nerve cord, and another (less often two) adjacent to inner end of median suture. The latter spine is usually flattened, blunt, or truncate, a trifle curved and rarely spatulate. There is generally one, sometimes two, suboral spines similar to the succeeding adambulacral spines. These all form a very bristling armature over the mouth and are noticeably longer than the spines a little farther along the ray. (Pl. 65, fig. 9.)

The skeleton is unusually stout and close-knit so that the papular areas are small. (Pl. 67, figs. 1, 1*a*.) The primary plates are four-lobed and convex and the carinals and marginals are very strongly imbricated. The carinal series is not straight in grown specimens. The dorsolateral plates are very irregularly arranged and are connected with one another and with the carinals and superomarginals by irregular elliptical or oval secondary ossicles. The ventral apophysis of the superomarginal plates is comparatively short, and the face of the plate lacks a specialized area of hyaline beads (except in very young specimens). The actinal plates are pretty regularly opposite each inferomarginal and are separated from one another by a space equal to their own size, or somewhat less.

Papulae three to five to an area, or as high as nine in the largest specimen. There is a definite series of actinal papulae alternating with the actinal plates and two or three to an area. In living specimens the papulae are conspicuous.

Madreporic body large, flat, with fine radiating striae.

Straight pedicellariae, greatly variable in numbers, are scattered over the abactinal surface among the spines, along the intermarginal channel, among the actinal spines, and on the margin of the ambulacral groove. The larger ones of the superomarginal and abactinal plates are usually rather acute-ovate as viewed from the side and narrowly or broadly spatulate (with two to four curved short teeth which interlock) seen frontwise. There are also smaller ones which are lanceolate, acute, and without teeth. The largest unguiculate pedicellariae may equal 2 mm. in length. Those of the adambulacral plates vary greatly in size. They are usually borne on rather long peduncles, sometimes as frequently as one to each plate and the largest are usually little wider than the adambulacral spines, while the smallest may be only one-third as broad. They are ovate-lanceolate or lanceolate, acute, and ordinarily the tips meet without crossing. Two specimens (forma *leptostyla*) from station 3445, 100 fathoms off Washington, are notable for having the furrow pedicellariae very large—two or three times as broad as the inner furrow spine, although much smaller ones are present—and some of them end in one or two curved claws. (Pl. 66, fig. 9.) A series of figures uniformly enlarged twenty-five times shown on Plate 66 will demonstrate the range of variation much more effectively than a description. The measurements are indicated in the explanation of plates.

Crossed pedicellariae rather large, very numerous, on tough sheaths surrounding the abactinal and superomarginal spines, and in conspicuous tufts on the outer face of the inferomarginal and actinal spines. In live animals the wreaths nearly touch. In preserved specimens the space between the clusters depends upon the degree of inflation of ray as well as upon the number of spines. The length of the pedicellariae varies suprisingly little, ranging from 0.4 to 0.5 mm. (abactinal), in specimens which are widely diverse in size. Dorsal pedicellariae from a huge specimen from station 3466 are 0.45 mm. long, the same size as those of the type of Verrill's *columbiana* and several other much smaller specimens. A series of drawings uniformly magnified one-hundred times shows the variations in specimens from different parts of the range. (Pl. 65.)

A characteristic of the crossed pedicellariae is the absence of the enlarged lateral terminal tooth or teeth so well developed in *Coscinasterias*, *Distolasterias*, *Sclerasterias*, *Astrometis*, and especially in *Stylasterias*. The latter has pedicellariae resembling those of *Coronaster*, and of the Coscinasteriinae is probably the genus most nearly related to *Coronaster* and is certainly far removed from *Orthasterias*.

Color in life.—A singularly beautiful species and very conspicuous in grottos or rock pools, among algae. In the vicinity of Monterey Bay, specimens give the general impression of being bright dark red banded or mottled with yellow ocher and with whitish or lilac spines. Analyzed, the color is: Abactinal spines pale phlox pink often brighter at ends of ray and whitish on the yellow areas; spine sheaths Nopal red or Brazil red; papulae and spaces between wreaths of pedicellariae darker, oxblood red. Arms either mottled on side or crossed by bars of cinnamon or sayal brown. Lower surface, pinkish buff. The Departure Bay form has the same general coloring. There is some difference in the lighter bands, these varying toward pinkish vinaceous or vinaceous cinnamon. The colors are rather vivid.

Anatomical notes.—The gonads consist of 10 long branched masses extending from the point of attachment which is interradial on the dorsal wall of disk, just above the superomarginal plates (which turn upward at base of ray). The aperture is apparently between two dorsal lobes of the superomarginals, hence technically abactinal in position. The gonads extend to about 0.6 the length of R. Each gonad is covered with many globose small divisions and along the mesial border about 25 rather long slender, basally lobulated branches extend over the ambulacral ridge and are in contact with those of the other side. The ventral eversible portion of the stomach is spacious and is anchored to either side of the ambulacral ridge by strong muscles. The intestinal coecum consists of six branches about 15 mm. long, the two middle extending into the left trivial ray, the other two pairs into the anterior and left bivial ray, respectively. The actinostomial ring viewed from above is massive and strongly united to the five heavy calcified interbrachial septa. On either side of the adoral end of the adambulacral ridge (composed of the first two united ambulacral ossicles) is a large pore corresponding to the first tube-foot. The succeeding three pores form a triangle just back of this adoral knob, the length of which equals that of the next six plates. Ampullae single, in a close double series on either side.

Young.—Two very small specimens were taken at station 4431 along with a big specimen, and with the adults and peculiar young of *Sclerasterias heteropaes*. One specimen measures R 3.5 mm.; the other R 8 mm. The latter greatly resembles a *Sclerasterias* as it lacks actinal plates and has "beaded" areas on the superomarginal plates. However, unlike *Sclerasterias* of this small size, the crossed pedicellariae are in wreaths surrounding the base of the carinal and superomarginal spines (no dorsolateral spines) and form a tuft on the outer side of the outer inferomarginal spine. Here and there the forerunner of another tuft has appeared on the inner spine—which is never the case in *Sclerasterias*. The form of the crossed pedicellariae is also characteristic. There are about 12 superomarginal plates with relatively coarse spines on the alternates. This arrangement, the beaded areas, and the absence of dorsolateral spines on the pentagonal ray gives the appearance of *Sclerasterias*.

An example from station 3159 with R 22 mm. is figured. (Pl. 47, fig. 4.) There are five to eight actinal spines, varying on the 10 areas, while the dorsolateral spines are confined to the distal part of ray. The straight pedicellariae are few and compressed lanceolate. The relatively stout spines are slightly grooved at the end.

Variations.—The most conspicuous variations are in the numbers of major pedicellariae, the form and stoutness of the abactinal spines, the occurrence of superomarginal spines, whether on alternate or consecutive plates, and the degree of regularity or rather irregularity of the carinal and dorsolateral plates.

The carinal spines form a slightly wavy line in typical specimens, but in extreme cases, as at station 4233, 39 to 45 fathoms, Yes Bay (forma *leptostyla*), it is impossible to follow the carinal series with certainty, and even the superomarginal series is irregular.

The spines seem to thicken and to become terminally scored with increasing age; but at the same time, irrespective of age, the spines become slenderer in depths of 30 fathoms or more, and tend to lose the terminal furrows.

In the specimen from station 4202, used in the description, the spines are about a mean between the stoutest and slenderest. The longest are about 5 mm., by 1 mm. at base, and the tip is slightly swollen, obtuse, and furrowed anywhere from four to ten times, the grooves being shallow.

The irregularity in occurrence of the superomarginal spines, whether on all plates or only on alternates, is apparently not correlated with geography or depth. On the outer part of the ray the spines are almost always on every plate, but proximally, there is great variation, differences occurring on different rays of the same specimen.

The spines are on most of the proximal, as well as distal plates in specimens from stations 4431 (southern California), 4555 (Monterey Bay), 3443 and 3445 (Straits of Fuca), 4233 (Yes Bay, Alaska); and Monterey Bay, lowest tide (some specimens). They pretty generally are on alternate plates proximally in examples from Monterey Bay, lowest tide (some specimens); from stations 3461 and 3464 (Straits of Fuca); 3053 (off Oregon); Naha Bay, Alaska (small specimens). In the largest example (from station 3466, Straits of Fuca, pl. 68, fig. 1), corresponding to the first easily counted 25 inferomarginals, there are on the five rays the following numbers of superomarginal spines: 19, 15; 15, 12; 19, 16; 19, 18; 15, 18. On the distal half of the ray superomarginal spines occur on nearly every plate, and near the tip are crowded into a zigzag line. Other specimens, for instance two from lowest tide, Monterey Bay, tend to skip alternate plates proximally, but not with any regularity. In the beautifully preserved specimen from station 4202, the condition on two rays selected at random will show the variation. Corresponding to the first easily counted 25 inferomarginal plates there are the following number of superomarginal spines: 20, 22; 20, 18. In the small specimens from Naha Bay (pl. 70, fig. 3) there is more nearly a true alternation with 13 or 14 superomarginal spines to 25 inferomarginal plates. In contrast to this is a slender rayed form from Monterey Bay with 22 superomarginal spines to 25 inferomarginal plates (forma *montereyensis*); and one from station 3445, 100 fathoms, Straits of Fuca, with 25 superomarginal spines to the same number of inferomarginal plates (forma *leptostyla*).

The form which is sometimes found at the lowest tide in rocky situations in the vicinity of Point Pinos, Monterey Bay, and along the rugged coast at the mouth of Carmel Bay, to the south, is sensibly different from the British Columbian forms. The rays of the Monterey form are long and average slenderer, while the spines are usually much heavier (except as compared with forma *biordinata*) with somewhat heavier sheaths. There are usually more numerous superomarginal spines, and the dorsolateral spines are less widely spaced on the proximal third of the ray. But all these items have their exceptions.

So far as the spines are concerned, three specimens from Monterey Bay (forma *montereyensis*) exhibit the extreme of robustness, with the single exception of a specimen from Port Renfrew, Vancouver Island (forma *biordinata*). In example one (R 107 mm.) the longest spines are 3 mm., by 1.2 at base, and the tip is capitate, well rounded, and scored by upward of 25 well-marked grooves. The spines resemble those of *Pisaster giganteus* somewhat. (Pl. 67, fig. 3, 3*a*, right-hand figures.) The second specimen has the spines slightly longer, scarcely swollen, and with fewer shallower furrows at the tips. In a third example (with R 150 mm.) the longest spines are 4.5 mm., by 1 mm. at base. (Pl. 67, figs. 3, 3*a*, left.) Some of them taper slightly, then at about mid-height swell slightly, to taper a trifle again to an obtuse tip, this distal portion having upward of 15 shallow grooves. These spines are distinctly stouter than those of the Yes Bay specimen, although the latter, is larger. But in a fourth specimen collected at lowest tide, Point Pinos, the abactinal spines are as slender as in the type forma, 4 to 4.5 mm., by 0.75 mm. at base, and taper gradually to a blunt tip, which is not furrowed.

There appears to be a very definite physiological difference between these Monterey specimens and those from Vancouver Island (both the typical form and forma *biordinata*). The northern specimens shed their rays very easily and are rather difficult to preserve well. The Monterey form is not at all difficult to preserve and does not detach its rays readily. I have handled both sorts, alive, and have kept the Monterey form in aquaria where it is fairly active and eats a variety of food including dead squid, crabs, and fish.

Type-locality.—Saanich Inlet, Vancouver Island, B. C. (de Loriol).

Distribution.—From Yakutat Bay, Alaska, to Santa Rosa Island, California. Bathymetrical range, lowest tide and subtidal zone to 125 fathoms. Temperature range, 44° to 50.3° F. at off shore stations, and to 52° or 53° F. in Monterey region at lowest tide.

Specimens examined.—Fifty-seven. (See p. 147.)

Forma KOEHLERI de Loriol

Plate 65, Figures 1–5, 7; 9; Plate 66, Figures 1–6, 10; Plate 67, Figures 4, 6, 7; Plate 68; Plate 69, Figures 1, 2; Plate 70; Plate 71.

This is the typical forma and includes the type of *Orthasterias columbiana* Verrill. It has slender tapered spines, bluntly pointed as a rule and with inconspicuous shallow terminal grooves. Straight pedicellariae narrow to broad, unguiculate. Sometimes with lanceolate, only slightly toothed, or even toothless, pedicellariae predominating over the heavier sort. Rays slender to fairly stout; considerable variation in form of marginal mouth spines; variation in spacing of proximal abactinal and superomarginal spines. (See above.) This intergrades bathymetrically with several deep-water subformae which have only one common character—tapered slender spines. Well marked examples of these have the abactinal spines especially slender toward the tip which may have a few very inconspicuous grooves, or none. Usually the dorsolateral spines are few on the proximal third of the ray, forming only a single fairly straight or irregular series. This is well shown in specimens from station 3452, Straits of Fuca, 125 fathoms (pl. 70, fig. 2), station 3464, same locality, 40 fathoms; 4551, off Point Pinos, Monterey Bay, 56 fathoms (pl. 70, fig. 1); and 4431, off Santa Cruz Island, 41 fathoms, the southern limit of the known range (pl. 67, fig. 6).

This last specimen has R 210 mm.; r 24 mm. The abactinal spines are strong, tapering, and fairly acute, the longest measuring 6 mm. by 1.5 mm. at base. They are grooveless, except for slight indications on some of the thicker and obtuse superomarginal spines. (Pl. 70, fig. 6.) Five contiguous pairs of adoral adambulacral plates continue the oral carina. Some of the pedunculate, lanceolate furrowed pedicellariae have two or three small teeth.

Forma LEPTOSTYLA, new forma

Plate 65, Figure 6; Plate 66, Figure 9; Plate 67, Figure 2; Plate 72

This is the deep-water forma characterized by very slender acute spines some of which are faintly grooved; superomarginal spines, especially on proximal half of ray on nearly every plate and hence have the appearance of being crowded and close together; skeleton unusually close-knit and dorsolateral region of proximal third of ray well studded with spines which if in regular order would form two or three series; carinal spinules crowded, often very irregular; furrow pedicellariae sometimes, but not always, unusually large. Dorsal straight pedicellariae not especially numerous in typical examples, a large proportion of the lanceolate compressed type without or with only a few teeth.

Station 3443, Straits of Fuca, 97 fathoms; station 3445, same locality, 100 fathoms; station 3461, same locality, 114 fathoms; station 4233, Behm Canal, Alaska, 39–45 fathoms.

The type is from station 3443 and measures R 195 mm., r 27 mm., breadth of ray at base, 29 mm. Two smaller specimens from station 3445 have the peculiarities even better marked.

A specimen from the vicinity of Departure Bay (Canadian Biological Station), depth unknown, is referable to this forma, but it has abundant abactinal straight pedicellariae, mostly lanceolate with compressed usually toothless jaws (of the sort shown on plate 66 figure 1*b*, figures 8, 8*a*).

This has the appearance of a distinct species but I think it will prove to be but a form of *koehleri*. A specimen of the type forma from 125 fathoms near the type locality (station 3452) is in marked contrast, having few proximal dorsolateral spines and most of the alternate carinal and superomarginal plates spineless. (Pl. 67, fig. 2 (3452)).

Type.—No. E. 1239, U.S.N.M.

Forma BIORDINATA Verrill

Plate 67, Figure 5; Plate 69, Figures 3, 3*a*

Orthasterias biordinata VERRILL 1914.

This forma is characterized by heavy subclavate spines, often with thickened tips marked by numerous fine longitudinal striae. The type which I have examined has large broadly lanceolate abactinal straight pedicellariae without teeth, or they may be formed as shown in Verrill's plate 82 (fig. 2*b*, *b*); or still broader subspatulate ones are found in the intermarginal channel. These are much fewer than the lanceolate sort.

A fine specimen collected by Dr. John C. Brown at Port Renfrew on the Straits of Juan de Fuca, low tide (pl. 69, figs. 3, 3*a*; pl. 67, fig. 5) has thicker rays and heavier spines than the type. The spines are scored longitudinally by fine, not very regular striae, and the end of a spine resembles a madreporite. The abactinal straight pedicellariae are mostly of the lanceolate type, but some with broader toothed jaws are present and predominate in the intermarginal channel. Curiously, the mouth spines are not heavy but on the whole rather slender.

Doctor Brown writes that this form is rather rare, but can usually be found at Port Renfrew at low tide well up between tide lines, in pools, on algae and kelp. It is an extremely fragile species and generally falls to pieces if carried by the arms without support. They suffer if left above the tide for very long and large bubbles of gas collect in various parts of the arms, forming projections. This species shows a decided tendency to rapid regeneration of its lost arms, as many individuals have imperfectly developed rays, shorter than the rest. The tube-feet are exceptionally long in life and the eye-spots quite prominent. The movements are very slow. The color of a healthy specimen is almost rose-madder with yellowish white breaks here and there which make a variable pattern.

Verrill (1914, p. 174) states that his type came from Departure Bay, British Columbia, but the label attached to the type specimens is inscribed "No locality, Geol. S. Can. 1909." No other specimen similar to the type is among numerous specimens which I have examined from the vicinity of Departure Bay. I think it more likely that the type was collected on the south or west coast of Vancouver Island. It was probably an intertidal specimen living where there was some surf.

Forma MONTEREYENSIS, new forma

Plate 51, Figure 2; Plate 65, Figure 8; Plate 66, Figures 7, 7*a*, 7*b*; Plate 67, Figures 1, 1*a*, 3, 3*a*

This forma is distinguished from *biordinata* (which it resembles in having heavier spines than forma *koehleri*) in having uniformly slender, long rays, unusually thick sleeves of tissure and wreaths of pedicellariae surrounding the abactinal spines, abactinal straight pedicellariae predominantly the large spatulate unguiculate sort (the lanceolate being also present, but fewer than in *biordinata*); the rays are not nearly so deciduous as in the northern formae.

This is probably a subtidal (littoral) form only, for in deep water in Monterey Bay is a slender spined variant of forma *koehleri* (pl. 70, fig. 1) with which it undoubtedly intergrades over rocky bottom.

As mentioned under "Variations," the Monterey form has a large proportion of the superomarginals spine bearing, and as the dorsolateral area is narrow the abactinal spines appear close set. The wreaths of pedicellariae frequently touch.

In this form the inner marginal mouth spine is rather long, slender, blunt, or truncate. I have never observed it to be short and broad as is sometimes the case in forma *koehleri*.

This is not a regular "low-tide" species but is found only at the lowest tides of the year and apparently wanders inshore from subtidal regions, in very rocky situations.

Type (forma *montereyensis*).—No. E. 1428, U.S.N.M.

Specimens of Orthasterias koehleri examined

Station	Locality	Depth	Nature of bottom	Bottom temperature	Number of specimens	Collection
2874	Off Washington	27	Rocks and shells	50.3	2	U.S.N.M.
2875	do	40	do	47.8	1	Do.
3052	Off Oregon	48	Rocky broken shells	49	1	Do.
3053	do	64	do	47.3	1	Do.
3054	do	53	Rocks	48	2	Do.
3159	Off Golden Gate, Calif.	27	Rocky		2	Do.
[1] 3443	Straits of Fuca, Wash.	97	Green mud, pebbles	46	1	Do.
[1] 3445	do	100	Rocky	44	1	Do.
3452	do	125	Rocky	44.5	1	Do.
3461	do	114	Gray sand, gravel, rocks	48.5	1	Do.
3464	do	40	Gray sand, pebbles	47.8	1	Do.
3466	do	56	Gray sand, shells, rocky	48.5	1	Do.
4202	Queen Charlotte Sound, off Fort Rupert, Vancouver Island, British Columbia.	36–25	Gray sand	48.2	1	Albatross, 1903.
[1] 4233	Yes Bay, Behm Canal, Alaska	39–45	Gray mud, rocks	41.7	2	Do.
4431	Off Brockway Point, Santa Rosa Island, Calif.	41–38	Green mud, rocks		3	Albatross, 1904.
4532	Off Point Pinos, Monterey Bay, Calif.	30	Gray sand, rocks		1	Do.
4551	do	56–46	Coarse sand, shells, rocks		1	Do.
4555	do	66–69	Green mud, rocks		1	Do.
3079	Off Empire City, Oreg.	55	Rocky	40.7	1	Bishop Museum.
	Naba Bay, Alaska				3	Albatross, 1905.
	Monterey Bay [2]	Lowest tide.	Very rocky situations	52	10	Stanford.
	Off Hope Island, North end of Vancouver Island.	20–23			1	Do.
	Off North end of Vancouver Island				2	Do.
	Departure Bay, Vancouver Island, British Columbia.	Lowest tide.	Among rocks, grottoes		4	Canadian Biol. Sta.
	Do	do	do		3	Cal. Acad. Sci.
	Do				1	U.S.N.M.
	Port Renfrew,[3] Vancouver Island	Low tide	Rocks and kelp.		1	Stanford.
	Forrester Island, Alaska	do			6	Do.
	Santa Cruz, California				1	M. C. Z. No. 1212.[4]

[1] Forma *leptostyla*. [2] Forma *montereyensis*. [3] Forma *biordinata*.
[4] Recorded by Verrill, 1914, p. 185, as *Orthasterias gonolena* (= *Astroractis sertulifera*) from Santa Cruz *Island*, which is an error.

Remarks.—I have examined the types of *O. columbiana* and *O. biordinata* and believe that both are to be included in one species which de Loriol described earlier from a specimen taken at Saanich Inlet.

The genus does not seem to me to be closely related to *Coscinasterias*. The crossed pedicellariae are entirely different and lack the enlarged terminal canine-like lateral tooth which is also characteristic of *Sclerasterias*, *Astrometis*, *Astrostole*, and *Marthasterias*, while *Distolasterias* and *Stylasterias* have an enlarged tooth on each side of the jaw. The latter, however, is isolated and is as far from *Coscinasterias* as is *Orthasterias*. *Orthasterias* has well-developed actinal spines which have the peculiarity of carrying a tuft of pedicellariae (as do the actinal spines of Asteriinae). Although the relationship is not close, all things considered, I think *Australiaster* of Tasmana is structurally nearest to *Orthasterias*.

Subfamily PYCNOPODIINAE Verrill, 1914

Pycnopodidae (part) STIMPSON, Proc. Boston Soc. Nat. Hist., vol. 8, 1861, p. 261.
Pycnopodiidae FISHER, Proc. Wash. Acad. Sci., vol. 8, 1906, p. 136.
Pycnopodiinae VERRILL, Shallow-water Starfishes, 1914, p. 197.— FISHER, Ann. and Mag. Nat. Hist., ser. 9, vol. 12, 1923, p. 250.

Differing from Coscinasteriinae in having almost no abactinal skeleton, there being only weak isolated plates, and irregular tongues of ossicles; sporadically there is a very feeble, interrupted reticulum near periphery of disk. Rays 5 to 24, actinal plates absent. Crossed pedicellariae with enlarged, external, terminal tooth on each jaw.

Pycnopodia Stimpson, *Lysastrosoma* Fisher.

Genus LYSASTROSOMA Fisher

Lysastrosoma FISHER, Ann. and Mag. Nat. Hist., ser. 9, vol. 10, Dec. 1922, p. 590; A Remarkable New Sea Star from Japan, Proc. U. S. Nat. Mus., vol. 64, art. 3, 1924, p. 1. Type, *Lysastrosoma anthosticta*.

Diagnosis.—Rays five, soft and weak; abactinal skeleton reduced to isolated small spiniferous plates sometimes interspersed with vestigial perforated spineless platelets; marginal skeleton weak; superomarginals, well separated, connected by a chain or festoon of small secondary ossicles; alternate superomarginals reduced in size and spineless; inferomarginals diplacanthid, spaced, sometimes connected by one or two secondary small ossicles; abactinal and marginal spines surrounded by a conspicuous, tough, retractile sheath expanded distally (and bearing numerous small crossed pedicellariae), that of the inferomarginals common to the two spines; adambulacral plates monacanthid, the spinelets without pedicellariae; mouth plates broad, with one pair of enlarged postoral adambulacral plates in contact; crossed pedicellariae with a conspicuously enlarged tooth on one side of the end of jaw, two or three smaller teeth on the opposite side, and very numerous small teeth on the shank.

Most nearly related to *Pycnopodia* Stimpson but differing in having marginal plates disconnected or joined only by secondary intermediate marginal ossicles; broad mouth plates and enlarged post-oral adambulacral plates; more conspicuous marginal circumspinal sheaths, the inferomarginal being common to two spines; adambulacral plates not sunken below level of inferomarginals; rays 5, not upward of 24.

First pair of postoral adambulacral plates with the median or interradial suture much shorter than that of the mouth plates; intermediate superomarginal ossicles very weak; lacking on outer part of ray; submicroscopic perforated plates numerous in abactinal integument. *anthosticta* Fisher.

First pair of postoral adambulacral plates with the median or interradial suture longer than that of the mouth plates; intermediate superomarginal ossicles stout proximally, persisting to the end of ray; submicroscopic perforated plates absent except at end of ray, where there are a few laterally--*desmiora* Clark.

LYSASTROSOMA ANTHOSTICTA Fisher

Plate 73, Figures 1, 1*a*–1*j*; Plate 75

Lysastrosoma anthosticta Fisher, Ann. and Mag. Nat. Hist., ser. 9, vol. 10, 1922, p. 591, figs. 1 and 2; Proc. U. S. Nat. Mus., vol. 64, art. 3, 1924, p. 2, text figs. 1, 2, 3, 5, pls. 1, 2.

Diagnosis.—Rays five. R 63 mm., r 9 mm., R = 7 r; breadth of ray at base, 8 to 10 mm. Disk small; rays marked off from disk by a slight constriction at base; abactinal surface more or less swollen; entire body very soft and flexible; axils rounded; abactinal skeleton reduced to widely separated, isolated plates, interspersed with minute spineless vestigial "holothurioid" platelets; abactinal surface with numerous widely spaced, small, acicular spinelets mostly hidden by obconical tough sheaths bearing numerous crossed pedicellariae on the distal expanded end; each alternate superomarginal plate with a similar but much larger spine (3 mm.); each inferomarginal with two subequal spines in a single sheath bearing terminal pedicellariae; adambulacral plates monacanthid; one pair of enlarged adambulacrals meeting behind the large oral plates, their median suture shorter than that of oral plates; straight pedicellariae very small, lanceolate; tube-feet large, crowded, in four rows, furrows broad.

Description.—The whole body is very weak and flabby much as if it had been decalcified. This is due to the absence of a connected abactinal skeleton and also to the very loose connection between the marginal plates. Even the ambulacral and adambulacral plates are rather loosely articulated and the plates themselves are not hard and firm but rather spongy.

The abactinal skeleton consists of widely separated, entirely disconnected, small irregular or faintly lobed plates, ordinarily from 0.4 to 0.6 mm. in diameter, each bearing a slender acicular spine surrounded by a thick tough sheath broadly expanded at the summit, which is very thickly beset with crossed pedicellariae. These spinelets (1 to 1.5 mm. long) are conspicuously smaller than the superomarginals and are not at all in regular series. There appears to be the equivalent of about five longiseries, although at the base of some rays the arrangement is far too irregular to admit of exact determination. Scattered all over the abactinal surface among the spiniferous plates and completely immersed in the integument, are numerous perforated "vestigial" plates of a generally subcircular or elliptic contour, which resemble holothurian plates and are 0.08 to 0.18 mm. in diameter. (Pl. 73, fig. 1*e*.) The skin is rather thickly beset with small lanceolate straight pedicellariae of several sizes, the number varying in different examples.

Alternate superomarginal plates are spineless and smaller than the spiniferous. While at the very base of the series they touch one another, over most of the ray they are spaced, and are connected by a curious festoon of small intermediate ossicles as indicated in figure 1. (Pl. 73.) The alternate and larger subquadrate superomarginals carry a conspicuous acicular spine about 3 mm. long with a tough sheath expanded and convex at the summit, which usually hides the tip of the spine and is thickly covered with crossed pedicellariae. On the outer part of the ray the vestigial intermediate ossicles disappear entirely, while the marginals become very small.

The inferomarginal plates which are also disconnected, except at the base of the ray, each carry two equal somewhat flattened, blunt or truncate, stout spines (subequal to the superomarginal) involved in a single sheath, which generally exceeds the spines in length, and has an expanded convex summit closely beset with crossed pedicellariae. Vestigial intermediate ossicles subtend the ends of many of the proximal inferomarginal plates but disappear entirely on the outer half of the ray. (Pl. 73, fig. 1*a*.)

Adambulacral plates small, thin, the surface sunken somewhat below that of the inferomarginal plates which overlap them. The single spine is slender, a trifle tapered, blunt, or else untapered and subtruncate, and devoid of pendant pedicellariae. Small pedunculate lanceolate straight pedicellariae occur on the furrow face of the plates.

Papulae large, numerous, in ill-defined longitudinal bands abactinally, and several to each intermarginal mesh. None actinal.

Actinostome not at all sunken. Mouth plates prominent with usually two chisel-shaped actinostomial spines shorter than length of plate and one similar, or more tapered, suboral spine near the outer end of plate. The lateral or outer actinostomial spine bears a flap of tissue covered with numerous very small lanceolate straight pedicellariae. The first pair of postoral adambulacral plates is enlarged and in contact interradially; the second pair is widely separated. The median suture of the first pair of plates is shorter than that of the oral plates.

Ambulacral furrows wide, with large, very crowded, quadriserial tube-feet. The ampullae are single and very large. The furrow widens at the base, in a very characteristic way, for the length of the first 8 to 12 ambulacral plates. The first two combined ambulacral ossicles are conspicuously enlarged; the others are very thin, and the pores are in four distinct series. The actinostome is large and apparently very flexible. The nerve cord of each ray widens abruptly as it approaches the actinostome and the circumoral cord, or fold, is conspicuous.

The madreporic body, sometimes invisible, is situated near the edge of the disk and surrounded by several spinelets.

Small crossed pedicellariae (0.2 to 0.22 mm. long) are situated, as detailed above, on the distal surface of the abactinal and marginal spine sheaths. Their form is best appreciated by the figure. The enlarged tooth on one side of the jaw and the numerous shank teeth are characteristic.

Straight pedicellariae are small, slender to broadly lanceolate but delicate and compressed; jaws apparently never spatulate. They are scattered over the surface of the body and occur on the furrow margin and outer actinostomial oral spine. Length, 0.15 to 0.65 mm.

One of the characteristic features of this species is the fact that the rays are slightly spaced on the circumference of the disk so that there is no sharp interbrachial angle. Back of the mouth plates there is a vertical, broad, axillary channel having several fine furrows leading from the abactinal to the actinal surface. This axillary region is bounded by a distinct constriction, or furrow, which encircles each ray at its base; and beneath the skin, a series of small (invisible) plates extends upwards from the interradial marginal plates to the abactinal end of the channel, the last plate being probably the primary interradial. (Pl. 73, fig. 1*b*, *i*.) This column acts as a buttress from which a slight but tough membranous interbrachial septum projects into the lumen of the disk. The gonads are attached to the dorsolateral body wall, well above the superomarginal plates, at a distance from the base of ray about equal to minor radius. They have the usual branched structure.

Type.—Cat. No. E. 1429, U.S.N.M. Cotypes in zoological collection, Stanford University, and in the British Museum (Natural History).

Type-locality.—Mororan, Hokkaido, Japan. Collected by D. S. Jordan and J. O. Snyder.

Remarks.—*Lysastrosoma* is sufficiently close to *Pycnopodia* to be included in the Pycnopodiinae.

The structure of the crossed pedicellariae is strikingly similar[61] in the two genera. In *Lysastrosoma* the large inferomarginal spinal sheath envelops both spines, but in *Pycnopodia* each spine has its sheath and a distinct mass of pedicellariae. The difference in the size of the mouth plates is of course due in part to the crowding of the rays in *Pycnopodia* but not entirely, since some polybrachiate forms—*Coronaster* for example—avoid extreme compression of the oral plates. The line drawings show the essential difference in the arrangement of marginal plates in specimens of approximately equal size. (Pl. 73, fig. 1, and pl. 79, fig. 1.)

LYSASTROSOMA DESMIORA Clark

Plate 73, Figure 2; Plate 74; Plate 76

Lysastrosoma desmiora Clark, Some Sea-Stars from the Riksmuseum, Stockholm. Arkiv för Zoologi, vol. 18 A, No. 8, p. 5, figs. 1 and 2.

Diagnosis.—Rays five. R 92 mm.; r 11 mm., R = 8.3 + r; breadth of ray at base, 13 mm. Rays slender, gradually tapering, pointed; disk small; interbrachial angles obtuse; integument thin, revealing the abactinal and marginal plates in the dried specimen. Differing from *L. anthosticta* in having more numerous abactinal plates; more strongly built marginal skeleton with *intermediate secondary* superomarginal and inferomarginal ossicles throughout the ray; with much stronger secondary marginal ossicles, especially on proximal half of ray; with broader mouth plates and much larger specialized first adambulacral plates; submicroscopic abactinal platelets lacking, except a relatively few distally.

Description.—The abactinal spines are rather uniformly spaced 2 or 3 mm. apart without serial order; eight or nine can be counted in a zigzag line across the base of ray. They are tapered, stoutly acicular, with usually a slightly swollen, minutely thorny tip. The longest are on the proximal half of ray (2 to 2.5 mm.) whence they decrease in length and caliber on the disk (1.5 mm.) and toward the end of ray, on the outer half of which they are less numerous. Each spine is invested in a membrane which is expanded distally and bears a terminal convex circular mass of pedicellariae, for the latter form a subterminal thick wreath. This membrane is probably thick and rather tough, as in alcoholic specimens of *anthosticta*.

The abactinal plates from which the spines arise are easily seen in the dried membrane, and have an irregular circular or lobed contour and average about 1.5 mm. broad. They are quite independent of one another, but each plate usually has under one or more of its lobes a small platelet or sometimes two or three in series,

[61] The figures given by Verrill, Shallow-water Starfishes of the North Pacific Coast, etc., 1914, text fig. 2, pl. 74, fig. 6; pl. 88, fig. 7c for *Pycnopodia* are unlike any pedicellariae I have met with in that species. Some of the figures suggest *Stylasterias*.

apparently the rudiments of a degenerated reticulate skeleton. Rather seldom two or three plates are close enough to be connected by one or two of these secondary platelets. Scattered, isolated, tiny, subcircular, spineless platelets are immersed in the membrane, but the numerous smaller deposits of the abactinal membrane of *anthosticta* are not present.

There is a prominent acicular sheathed superomarginal spine, about 4 mm. long, on each alternate superomarginal plate, and two (rarely one) slenderer, tapered, bluntly pointed or flat-tipped inferomarginal spines, invested by a single, common, membrane on *each* inferomarginal plate. The superomarginal spine is stouter and conspicuously longer than the abactinals, and carries a heavier terminal wreath or subglobular bouquet of pedicellariae. The two inferomarginal spines stand in a longitudinal (sometimes slightly oblique) series on the plate and one is usually a shade slenderer than the other (proximally the adoral, distally the aboral of the two is the slenderer, if any difference is observable). The shrunken sheath bears a thick terminal cluster of pedicellariae. Normally this would extend well beyond the tips of the spines and still does in many cases.

The marginal skeleton consists of a series of superomarginals somewhat pear-shaped in contour, not directly imbricated as in *Pycnopodia*, but connected by short arches of two or three overlapping elliptical or ovate-oblong rather stout ossicles, while the inferomarginals usually are connected by two secondary ossicles smaller than the above. Furthermore, alternate superomarginal plates are degenerated and spineless and only a little over half as broad as the spiniferous plates. Both sorts slightly overlap the upper edge of the corresponding narrower but longer, faintly-lobed inferomarginals. There is no difference in the size of alternate inferomarginals. Near the end of the ray the intermediate superomarginal ossicles shrink considerably in size (along with the primary plates) and more nearly represent the condition characteristic of the *proximal* part of the ray of *anthosticta*. But on the outer half of the ray of *anthosticta* the secondary superomarginal ossicles are not present, the primary plates existing as spaced, independent elements except for their connection with the corresponding inferomarginal. As the end of the ray is approached the spineless superomarginal degenerates rapidly and becomes very tiny. In the present species the smaller intermediate plates persist to the tip of ray. The secondary inferomarginal plates, which are usually in couples on the proximal part of the ray, on the distal are reduced to one between a pair of primary plates, and are, relative to these plates, larger than on the proximal part of the ray. In *anthosticta* these plates are only rudimentary on the proximal part of the ray and are entirely lacking distally.

The terminal plate is rather prominent, armed with numerous short spinelets, the slightly concave adoral abactinal border being flanked by a row of 8 to 10 tiny platelets (absent in *anthosticta*).

The adambulacral plates, though fairly broad (average 1.25 mm.), are very short, the exposed surface being only about one-third the dimensions of the intervening muscular area. The very slender, tapered, subtruncate, often flat-tipped, spines, one to a plate, form a very even row along the margin of the broad, shallow furrow. The spines are two-thirds to three-fourths as long as the corresponding inferomarginals, but scarcely half as thick, and are entirely devoid of pedicellariae. The much-enlarged first pair of postoral adambulacrals are in contact, the sutural margin being decidedly longer than the length of the mouth plates measured on the furrow margin.

In *anthosticta* the plates are smaller and the sutural margin is much shorter than the mouth plates. There are 34 or 35 adambulacrals in the length of the first 10 spiniferous inferomarginals.

The combined mouth plates are broader than long. Each plate has a curved actinostomial margin carrying two chisel-shaped spines invested with membrane bearing lanceolate straight pedicellariae. A somewhat similar though usually longer suboral spine stands on the outer part of the plate.

Papulae numerous and prominent abactinally, on proximal half of ray and marginal portion of disk; few on outer part of ray and center of disk; several in each intermarginal area throughout ray, but more numerous proximally.

Crossed pedicellariae of generically characteristic form (pl. 73, fig. 2) are very numerous on the abactinal and marginal spines. Each jaw has on one side of the tip an enlarged terminal tooth and on the other two or three enlarged teeth, but smaller. There are numerous shank teeth. The pedicellariae which measure about 0.27 mm. long are not different in essentials from those of *anthosticta.*

Very small lanceolate straight pedicellariae 0.2 to 0.3 mm. long are scattered over the abactinal and lateral surfaces and along the furrow margin. The latter are pedunculate and at the base of ray several may occur in a cluster, recalling a characteristic of *Pycnopodia.* They occur also on the actinostomial oral spines, in the actinal interradial region (reaching 0.5 mm.), and on the inferomarginal plates where they are largest (0.6 to 0.7 mm.).

The madreporic plate is large (3.5 mm. in diameter), slightly convex, with fine radiating branched striae, and is situated near the margin.

The ambulacral furrows are broad and shallow and show at the base only a faint indication of the broadening that characterizes alcoholic specimens of *anthosticta.* At the second adambulacral the furrow is as wide as the length of the first 3.5 spiniferous inferomarginals (7 mm.). Ambulacral pores in four distinct series; tube-feet long, probably very crowded. Actinostome not at all sunken, 8 mm. in diameter. Radial nerves broad, as in *anthosticta.*

Type.—In Riksmuseum, Stockholm (Orig. No. 556).

Type-locality.—De Castries Bay, Amur Province (opposite Saghalien), eastern Asia. Museum Godeffroy.

Distribution.—Known only from the type.

Remarks.—I am indebted to Dr. H. L. Clark for the loan of the type which has enabled me to make satisfactory comparisons directly with specimens of *anthosticta.*

Genus PYCNOPODIA Stimpson

Pycnopodia Stimpson, Proc. Boston. Soc. Nat. Hist., vol. 8, 1861, p. 261. Type *Asterias helianthoides* Brandt.—Viguier, Squelette des Stellerides, 1879, p. 109.—A. Agassiz, North American Starfishes, 1877, p. 100.—Verrill, Shallow-water Starfishes, 1914, p. 197.

Diagnosis.—Size large, rays numerous (upward of 24); abactinal skeleton abortive, consisting of isolated plates and lateral oblique tongues of small plates widely spaced on proximal part of ray, imbedded in the very flexible, tough integument; abactinal spines solitary, subacicular, surrounded by a thick sheath bearing a pompon of crossed pedicellariae; papulae large, compound, aggregated in clusters springing from a common coelomic passage; superomarginal plates lateral, lobed, alternately monacanthid and spineless, directly imbricated and united to the ventrolateral, diplacanthid inferomarginals by a broad descending lobe, with intervening papular areas; each inferomarginal spine with its own sheath capped by several clusters of crossed pedicellariae; no actinal plates nor actinal papulae; adambulacral plates small and crowded, monacanthid, with pedunculate furrow bouquets of small straight pedicellariae; large ovoid pedunculate straight pedicellariae; crossed pedicellariae with a very conspicuous enlarged lateral tooth on outer side of terminal lip and numerous shank teeth; madreporic body single, tube-feet very numerous, large, crowded, forming six or eight longiseries in large specimens; ambulacral plates, thin, crowded; pores quadriserial (except near actinostome); adoral carina long, narrow; mouth plates compressed, small; actinostome large; stomach eversible; gonads opening abactinally.

Remarks.—This genus is peculiar to the west coast of North America and contains one species which ranges from Unalaska to San Diego, Calif. Its only close relative is *Lysastrosoma*, of Hokkaido and the Gulf of Tartary, from which it differs in having numerous rays and directly imbricated marginal plates.

In *Lysastrosoma* there are five rays and broad mouth plates. In *Pycnopodia* the very young at first have six rays (exceptionally five). Usually but not invariably new rays are interpolated in pairs on either side of an axis of symmetry passing along a definite radius, which is the second, clockwise, from the madreporic interradius of normal six-rayed young.

PYCNOPODIA HELIANTHOIDES (Brandt)

Plates 77–80

Asterias helianthoides Brandt, Prodromus, 1835, p. 271. (Sitka).—Stimpson, Boston Journ. Nat. Hist., vol. 4., 1857, p. 529.

Pycnopodia helianthoides Stimpson, Proc. Boston Soc. Nat. Hist., vol. 8, 1861, p. 261.—A. Agassiz, North American Starfishes, Mem. Mus. Comp. Zoöl., vol. 5, no. 1, 1877, p. 100, pl. 13 (structure).—Whiteaves, Trans. Royal Soc. Canada, vol. 4, 1886, p. 116.—Ritter and Crocker, Proc. Wash. Acad. Sci., vol. 2, 1900, pp. 247–274, pls. 13, 14.—Clark, Proc. Boston Soc. Nat. Hist., vol. 29, 1901, p. 329 (Port Townsend).—Verrill, Shallow-water Starfishes, 1914, p. 198, pl. 29, fig. 1; pl. 30; pl. 31, figs. 1, 2; pl. 73, fig. 1; pl. 74, figs. 1–3*a*; pl. 88, figs. 7–7*d* (7*e* very inaccurate); text-fig. 2, p. 35 (very inaccurate; misleading).—Hamilton, W. F., Journ. Comp. Psychology, vol. 1, 1921, p. 475 (behavior).

Diagnosis.—Disk large; rays upward of 24, usually 15 to 23 in adult specimens, capable of inflation, gently tapered, very soft and flexible in live specimens owing to absence of a connected dorsal skeleton; whole surface of body crowded with large clumps of prominent papulae among which are scattered thick pompons of crossed pedicellariae, surrounding usually a slender, sharp, or blunt spine; marginals heavily stoled, and somewhat larger than the scattered dorsals, the superomarginals lateral, the inferomarginals (two to a plate) actinolateral or actinal in position; adambulacrals sunken below level of inferomarginals, slender, in single longiseries; furrow broad, tube-feet large; usually numerous large ovoid peduncled dermal pedicellariae; skin tough, soft, highly glandular, completely obscuring skeleton. R upward of 400 mm.; commonly 200 to 300 mm. R = 2.5 to 3 r. (Specimens shrink considerably in preservation due to the highly muscular integument.)

Description.—Abactinal surface very soft and yielding, having very numerous, irregularly and closely placed clumps of large, slender, numerous crowded papulae. In large specimens there are upward of 75 papulae to the larger groups and 30 to 50 in the medium-sized. Spaced among the clusters are convex, circular, bouquets of very numerous crowded crossed pedicellariae, borne on sheaths having on the outer half of ray usually no supporting spine. At the end of ray these expanded sheaths are close enough to touch, but become rapidly more and more spaced proximally until they are widely separated over the basal half of ray and on disk. On the latter region the sheaths surround well developed acicular, cylindrical or even clavate spinules, which may be developed also on the basal parts of the ray especially laterally. Here, however, they are smaller than on the disk. The form of the spines follows the rule for the body generally.

Abactinal plates small, widely scattered on the ray, and in old specimens becoming absorbed. In small and medium-sized specimens a few tongues of overlapping plates extend inward from the superomarginal plates (pl. 79, fig. 1), while on the peripheral parts of disk a disappearing reticulum may be indicated (pl. 79, fig. 1*a*). On the central area of disk the subcircular plates are separated, with sometimes very small discrete platelets scattered in irregular lines and ranks between. These small platelets are similar to, though sometimes more numerous than, the smallest indicated in the above figure.

Scattered among the papulae, attached often to the hernialike base from which the papulae spring, are numerous very small, long-pedunculate lanceolate straight pedicellariae; or they may form small pedunculate, dermal clusters (pl. 77, figs. 2, 3). There is also a variable number of heavy, ovoid pedunculate pedicellariae, sometimes abundant, reaching a length of 1.75 mm. (Pl. 77, fig. 1; pl. 78, figs. 4, 5.)

The marginal plates, in sharp contrast to the obsolescent abactinal skeleton, are well developed, robust, and form the side wall of the ray. (Pl. 79, fig. 1.) They are similar to those of such genera as *Orthasterias*, and are well hidden by the thick glandular skin. Alternate superomarginals have a stout, rather rigid, heavily sheathed spine, upwards of 7 or 8 mm. long in large specimens; and each inferomarginal plate carries two similar, subequal spines sometimes slightly smaller than the superomarginals. In small specimens each sheath terminates in one to four clusters of crossed pedicellariae, increasing in size with age. (Pl. 77, figs. 2, 3.) When these are fully developed a complete wreath is formed when the sheath retracts. The form of the spines varies greatly. They may be slender, tapered, with bluntly pointed, or expanded truncate, often compressed, grooved extremities (deep water and some intertidal examples). Numerous intergradations exist between these slender spined examples and those with robust spines. Along one side of a ray the form of a spine may vary greatly. In old specimens the tips become gouge-shaped, or longitudinally grooved or irregularly eroded, sometimes terminating in several points. The first superomarginal spine is spaced distad from the interbrachial angle about one br, while the inferomarginal spines continue toward the actinostome slightly more than one br from the angle; that is, they begin about midway between mouth plates and the interbrachial angle.

Adambulacral plates monacanthid, sunken below the actinal face of the inferomarginals which form the actinolateral border of ray. (Pl. 77, fig. 3.) The spines are slender, subterete, slightly tapered and blunt. The tip is sometimes compressed. In living or alcoholic specimens the basal part of the spine appears to be rather robust by reason of the integument. On the furrow face of each plate there is usually a pedunculate cluster of small straight pedicellariae of unequal size, or sometimes two clusters. (Pl. 77, figs. 1, 3; pl. 78, fig. 5*a*.) In dried specimens these become occasionally plastered to the spinelets which never bear attached pedicellariae. The adoral carina is very long in old specimens and on account of the crowding of the rays it is not always possible to determine the number of pairs of adambulacrals involved—usually 10 to 15. (Pl. 79, fig. 3.) The spines increase in length and robustness as the oral plates are approached. (Pl. 79, fig. 2.)

Mouth plates small, with one or two actinostomial and one longer suboral spine. (Pl. 79, figs. 2 and 3.) In live and fresh alcoholic specimens the plates are obscured by pompons of tiny pedicellariae (pl. 77, fig. 1) similar to those occurring on the adambulacrals.

The crossed pedicellariae vary greatly in size according to age of the specimen. In large specimens (R 200 to 300 mm.) the abactinal are commonly 0.35 to 0.45 mm. in length (Unalaska, Vancouver Island, Monterey; pl. 78, figs. 1–3).

The large, characteristic, ovoid straight pedicellariae are found on the abactinal surface, marginal plates, and proximal adambulacral, and mouth plates. They reach a length of 1.75 mm., or occasionally slightly more in giant specimens. Such as are shown in Plate 78, Figures 4 and 5, may be found on the same specimen. The small straight pedicellariae, commonly 0.15 to 0.2 mm. long, have been noted in the foregoing description.

Madreporic body single, large (upwards of 12 mm. in diameter), situated a little adcentrally to the middle of r; striae very numerous, fine, radiating.

Color in life ranging from yellow and reddish through yellowish brown to violet brown, purplish, and slaty violet. The color of a specimen varies according to the inflation of the papulae and expansion of the pompons of pedicellariae which may almost entirely obscure the underlying skin color.

At Nanaimo large specimens may be flame scarlet, the clusters of pedicellariae yellow; or mottled rufous and dragon's blood red, the pedicellariae hazel; actinal surface pale yellow. Three rather prevalent color phases are furry gray, salmon color, and purplish or slaty purple.

In the Monterey region the yellow-red phase is uncommon, brown and violet predominating. A rather common mode: Papulae and pompons of pedicellariae mottled slaty violet and dark brown (chocolate, Vandyke brown, seal brown), the disk clear dark brown and the large pedicellariae whitish. The actual skin underneath, showing only in spots when the animal is at rest, orange red to brownish red (dragon's blood, Nopal red, Brazil red). Variations are decidedly purplish especially on outer part of rays and actinally (inferomarginals). Furrow pale yellow; tube-feet orange near end, the sucker pale straw.

At Port Renfrew, Vancouver Island, where the species is large and common, Dr. J. C. Brown found the color varying from rich orange, or even light lemon yellow, to dark lilac or brown above, with orange yellow on the actinal surface. A specimen with 10 rays had a yellowish brown background, the middle of disk and 10 radiating lines to end of rays blue-black; ambulacral areas slate blue. The yellow color of the background was sometimes almost a buff color, while again it was almost pure coral red but the blue-black banding was not variable in specimens so marked. An 18-rayed specimen was claret color where the papulae were distended, but showed deep orange as they contracted.

Anatomical notes.—The abactinal skeleton, as already indicated, is obsolescent, the spines and pedicellariae outweighing the plates themselves. The absorbed plates of old specimens may go to form the skeleton of newly added rays. In the very tough dorsal integument of old specimens (often fairly leathery where well preserved) small disconnected plates would appear to be of little practical value; whereas in age, if calcium metabolism is faulty, stored supplies might well be more readily available than that obtained in food.

In contrast, the marginal, adambulacral, and ambulacral systems are strong and very flexibly articulated. The alternation of ambulacrals mentioned by Verrill (1914, p. 201) is probably due to faulty preservation since I found no indication of it in large well preserved specimens.

The ambulacral ossicles distad to the adoral carina rapidly become very compressed. In a large dry specimen having R 275 to 300 mm. there are about 330 ambulacral ossicles on either side, or 660 to the ray. Although there are two longiseries of ambulacral pores on either side, the plates are so compressed that the large tube-feet are crowded into six longiseries. When the furrow is fully open it is wide and shallow. In living specimens the great number and size of the tube-feet form an impressive spectacle.

The actinostome is large and the membranous peristome broad, as the animal is capable of swallowing goodsized sea urchins and molluscs. A section of the peristomial ring is shown in Plate 79, Figure 4. The first ambulacral ossicles are relatively smaller than in the Coscinasteriinae.

The interbrachial septum is membranous, extensive, and fortified by irregular, oblique dorsoventral columns of plates and irregular scattered plates of various small sizes. These are apparently better developed in small than in large specimens, in some of which there are very few septal plates present.

Young.—The majority of young begin life with six symmetrical rays, as determined by Ritter and Crocker (1900) who examined many specimens from Yakutat Bay, Alaska. "The reef near the anchorage off the Indian village of Yakutat, a large area of which is exposed at extreme low tide, was everywhere strewn with large specimens, and on the *Laminaria*, which grows here in great luxuriance, were thousands of young of all sizes, from a few millimeters in diameter to practically the full-grown state." The smallest of these had only six or eight rays. The number six, however, is not invariable, since a specimen from Bayne Sound, British Columbia, having a maximum R 13 mm. started with five rays. (Text fig. 2.)

Ritter and Crocker find that new rays are budded off symmetrically in pairs with reference to a constant ray A. This ray is between rays I and II, according to the usual system, which starts with the arm adjacent to the madreporite and enumerates the five clockwise. This ray A occupies the position of the larval organ in *Asterina gibbosa* and *Asterias vulgaris* and determines a plane of symmetry which includes more or less perfectly the intestinal coeca, apical radial muscle bands, and the racemose glands.[62] The plane passes through rays A IV.

It is evident, however, that there must be exceptions to this rule, otherwise the number of rays would always be even, which is not the case.

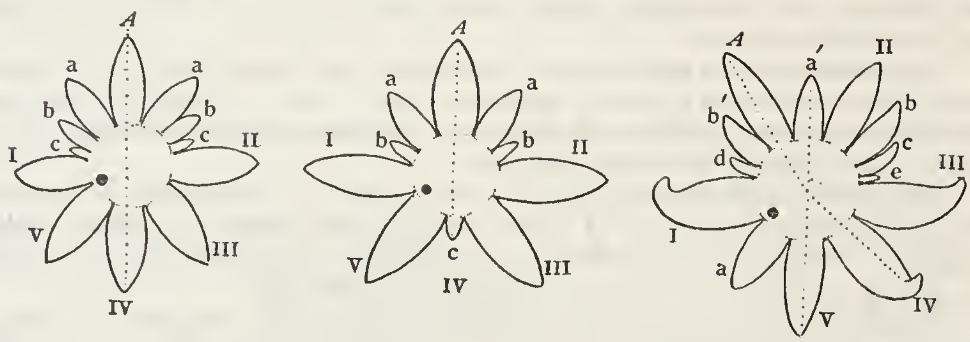
It is a curious fact that Ritter and Crocker encountered great uniformity among their many specimens, while of the three very small examples available to me for study, two exhibit marked exceptions to their rule. These three are from Bayne Sound, British Columbia and are shown diagrammatically in text Figures 1 to 3.

[62] Proc. Wash. Acad. Sci., vol. 2, 1900, pl. 13, figs 6 and 7.

In Figure 1 which is symmetrical and according to Ritter and Crocker's rule three pairs of new rays have arisen successively on either side of A, the youngest pair, adjacent to I and II, being *c c*. Ray one is slightly smaller than the other primary rays.

In specimen two (fig. 2) there are only five primary rays. Two pairs of new rays have budded symmetrically with reference to A (or II, whichever it is). An unpaired ray *c* restores the six symmetry, and may represent ray IV abnormally suppressed during metamorphosis. Ray II is usually nearly opposite I, whence the interpretation of the ray marked II in this specimen.

Specimen three is asymmetrical. The interpretation of the rays is difficult and it is not clear whether the ray marked A is homologous with that of A in Figures 1 and 2. Secondary ray a^1 is more nearly in the line of symmetry but if this is the



1 2 3

FIGS. 1–3.—1, PYCNOPODIA HELIANTHOIDES×2. YOUNG SPECIMEN WITH SIX PRIMARY RAYS SHOWING SYMMETRICAL BUDDING OF NEW RAYS ON EITHER SIDE OF RAY A. MADREPORITE SHOWN IN SOLID BLACK; I–V, PRIMARY RAYS; *aa*, *bb*, *cc*, EQUIVALENT RAYS OF PAIRS. 2, ×2. A YOUNG SPECIMEN WITH ONLY FIVE PRIMARY RAYS, THE SIX SYMMETRY BEING RESTORED BY RAY C, POSSIBLY EQUIVALENT TO IV OF FIG. 1. TWO SYMMETRICAL PAIRS OF NEW RAYS, *aa*, *bb*. 3. SAME, ×2. A PRIMITIVELY SIX, OR POSSIBLY SEVEN, RAYED SPECIMEN IN WHICH NEW RAYS APPEAR ASYMMETRICALLY AND NOT ALWAYS IN PAIRS. A—IV, THE USUAL AXIS OF SYMMETRY; $\acute{a}^1$—V ACTUAL AXIS. RAYS HAVE APPARENTLY ARISEN IN ORDER *a*, a^1, *b*, b^1, *c*, *d*, *e*; THE LAST THREE CERTAINLY NOT PAIRED. POSSIBLY III IS EQUIVALENT TO II, WHICH IS USUALLY OPPOSITE I; V WOULD EQUAL IV, AND *a* WOULD EQUAL A "SUPPRESSED" V. THEN A AND II, WHICH ARE LARGE PRIMARY RAYS, MAY BE INTERPRETED AS DOUBLE A. IF THE ANIMAL HAD LIVED NEW RAYS MIGHT HAVE APPEARED ON EITHER SIDE OF BOTH A AND II; $\acute{a}^1$ MAY REPRESENT SUCH A BEGINNING

homologue of A, what is the primary ray marked A? Likewise ray III is in the position proper to II. If it is II, what is the primary ray marked II, and why should *a* (=V in this case) be distinctly secondary in size? The smaller rays appear not to have arisen in pairs but in the sequence *a*, a^1, *b*, b^1, *c*, *d*, *e*; *d* is obviously not contemporaneous with either *c* or *e*.

In young specimens there are a few prominent abactinal spinelets, surrounded by crossed pedicellariae, springing from subcircular, mostly isolated plates, between which are tiny scattered spineless platelets imbedded in the skin. Papulae are prominent, single or two to five in a group.

Type-locality.—Sitka.

Distribution.—Unalaska, Aleutian Islands, to San Diego, California; intertidal in rocky situations, to 238 fathoms, sand.

Specimens examined.—Thirty-two, in addition to numerous living and preserved examples from Monterey Bay, Calif.

Specimens of Pycnopodia helianthoides examined

Station	Locality	Depth	Bottom	Number	Number of rays	Collection
2862	Queen Charlotte Sound, British Columbia.	238	Gray sand, pebbles	1	20	U.S.N.M.
2863	Puget Sound, Wash	67	Fine sand	1	18	Do.
3047	Southern Washington	50	Fine gray sand	1	20	Do.
3612	Bellingham, Wash	11	Green mud	2	18, 20	Do.
4222	Vicinity Port Townsend, Wash	39	Gray sand, broken shells	1	15	Albatross, 1904.
4431	Off Santa Rosa Island, Calif	38–41	Sand, mud, rocks	1	21	Do.
4457	Off Point Pinos, Calif	46–40	Dark green mud	1	20	Do.
	Dutch Harbor, Unalaska	Low tide		1	18	Stanford.
	Vicinity Cape Trinity, Kadiak	Low tide		2	18, 19	U.S.N.M.
	Karluk, Kadiak	Low tide		1	19	Stanford.
	Cordova, Prince William Sound, Alaska	Low tide		1	16, Juv.	Do.
	Union Bay, Bayne Sound, British Columbia	Low tide		3	Juv.	Albatross, 1906.
	Boundary Bay, British Columbia	Low tide		2	17, 19	Stanford.
	Point Simpson, British Columbia	Low tide		1	17	U.S.N.M.
	Nanaimo, British Columbia	Low tide		3	16 17 18	Do.
	Barclay Sound, British Columbia	Low tide		4	15, 16 18, 20	Do.
	Straits of Fuca. Port Renfrew, British Columbia.	Low tide		3	17, 19 19	Stanford.
	Puget Sound, Wash	Low tide		1	17	U.S.N.M.
	San Francisco Bay entrance	Low tide		1		Stanford.
	Monterey Bay, Calif	Low tide	Intertidal and shallow water.	Many.		Do.
	San Diego, Calif					Do.

Remarks.—This heavy, very active, and voracious sea star is a characteristic member of the intertidal fauna of rocky situations from Yakutat Bay, Alaska, to Monterey Bay, Calif. Its range, however, is much more extreme, the known limits being San Diego on the south and Unalaska Island at the north. South of Monterey region it is not common. Intertidally it frequents rocky situations rich in kelp, where it feeds greedily upon sea urchins, hermit crabs, or any other creature not too large and active to escape. In aquaria it will attack a great variety of animals, including crabs and large holothurians. Its diet undoubtedly includes dead fish and such inactive living ones as it is able to trap with its numerous, almost octopus-like rays.

When excited by food it moves very rapidly and can execute counter movements more actively than any starfish which I have observed. When under "full sail," with its thousands of tube-feet lashing back and forth, it is an impressive animal, and its numerous cushions of tenacious pedicellariae and the wide expanse of its flexible body make it a formidable engine of destruction. The fact that a large *Pycnopodia* can bring over 15,000 sucker feet into action against a struggling fish or crab suggests a reason for its success in competition for place and food.

In an aquarium both *Strongylocentrotus purpuratus* and *franciscanus* (the latter with formidable long spines) were swallowed whole and retained in the body from 24 to about 36 hours, when the cleaned test and disarticulated spines were rejected. After a battle with a sea urchin the feet of *Pycnopodia* are usually liberally beset with the pedicellariae of the urchin, which by their purple color are conspicuous against the pale yellow of the tube-feet. (See pl. 80, *ped.*)

A small *Pycnopodia* manoeuvred for hours to swallow a *Stichopus californicus* heavier than itself but was unsuccessful owing to the inability of the tube-feet to secure a firm hold on the slippery skin of the holothurian.

Pycnopodia is sometimes caught on fishing lines baited with fish or mollusk meat. One specimen examined contained hunks of beef or similar meat!

Pycnopodia when fully grown is probably the heaviest known sea star. It reaches its best development in the region of Puget Sound, the Admiralty Inlet, and in the fjords and bays of Alaska. In the Monterey region specimens seldom exceed a diameter of 18 inches or 450 mm., but in the region of Puget Sound they grow much larger. Dr. C. McLean Fraser has reported measuring a specimen 800 mm. in diameter (32 inches).[63] Dr. John C. Brown, who made color notes at Port Renfrew, Vancouver Island, reported several as weighing 10 pounds when taken from the water. Here they frequently live in the crevices of the slate ledges which tilt at an angle of about 45°.

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PLATES

EXPLANATION OF PLATES

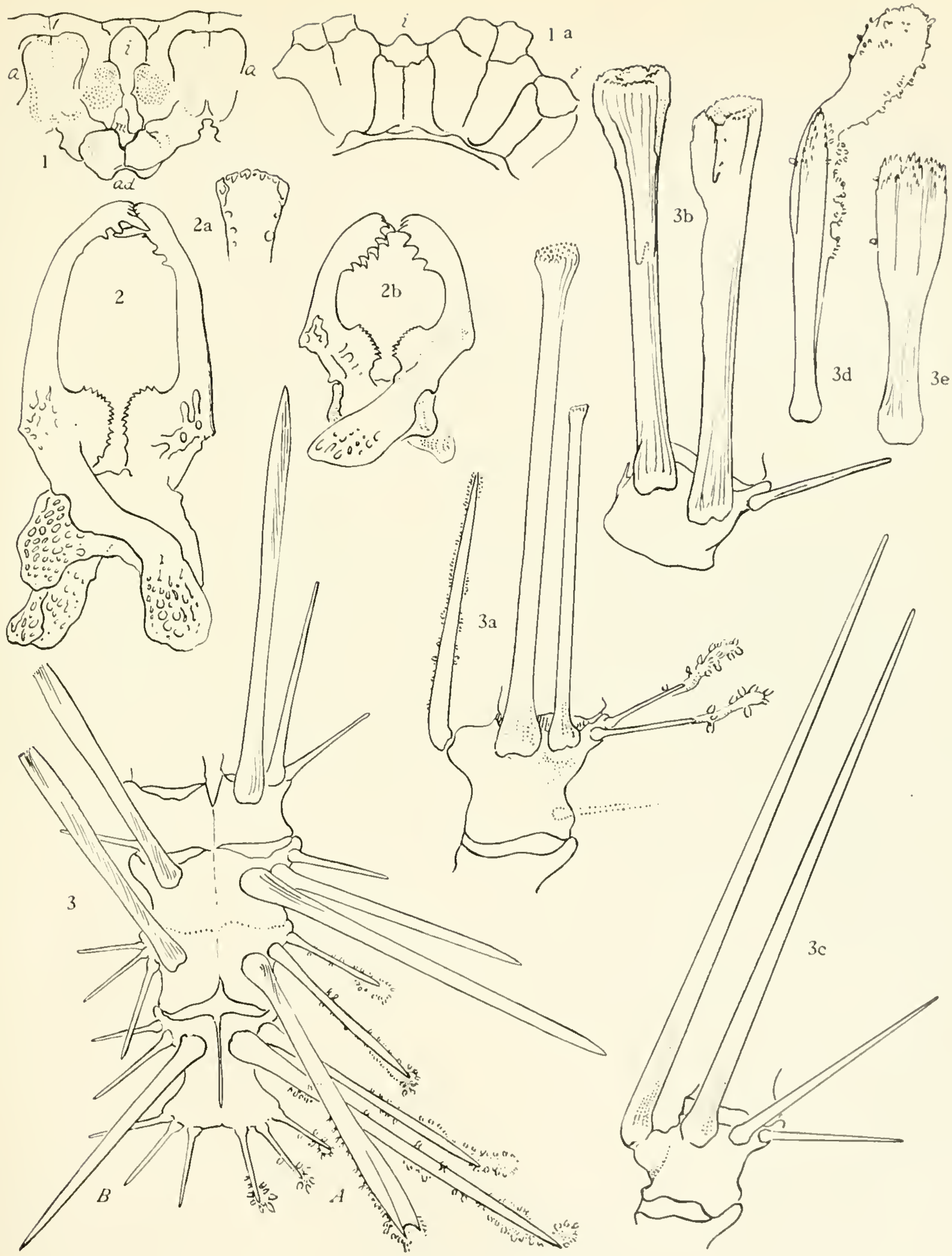
PLATE 1

Craterobrisinga synaptoma

FIG. 1. Cotype B, ×5. Actiuostomial ring showing distal facets of two pairs of ambulacral plates (*a*) where two rays have been removed; *i*, interradial plate; *m*, marginals; *ad*, adambulacrals. 1*a*. Actinostomial ring, viewed from above.

2. Large variety of pedicellaria from furrow spinelet; length 0.39 mm., ×200. 2*a*. Inside view of end of blade. 2*b*. Pedicellaria from subambulacral spine sheath, length 0.156 mm., ×200.

3. Mouth plates and first three pairs of adambulacrals; right side, plates of cotype *A*; left side, cotype *B*, ×10. 3*a*. Type, ×10. Armature of tenth adambulacral plate; sheaths removed from the two subambulacrals; marginal spine on left with pedicellariae; 3*b*. Cotype *a*, ×10. Tenth adambulacral showing two large subambulacral spines. 3*c*. Cotype *a*, ×10. Twenty-seventh adambulacral with accompanying marginal spine on left. 3*d*. Cotype *c*, ×10. A suboral spine (compare with 3). 3*e*. Cotype *c*, ×10. First subambulacral.



CRATEROBRISINGA SYNAPTOMA

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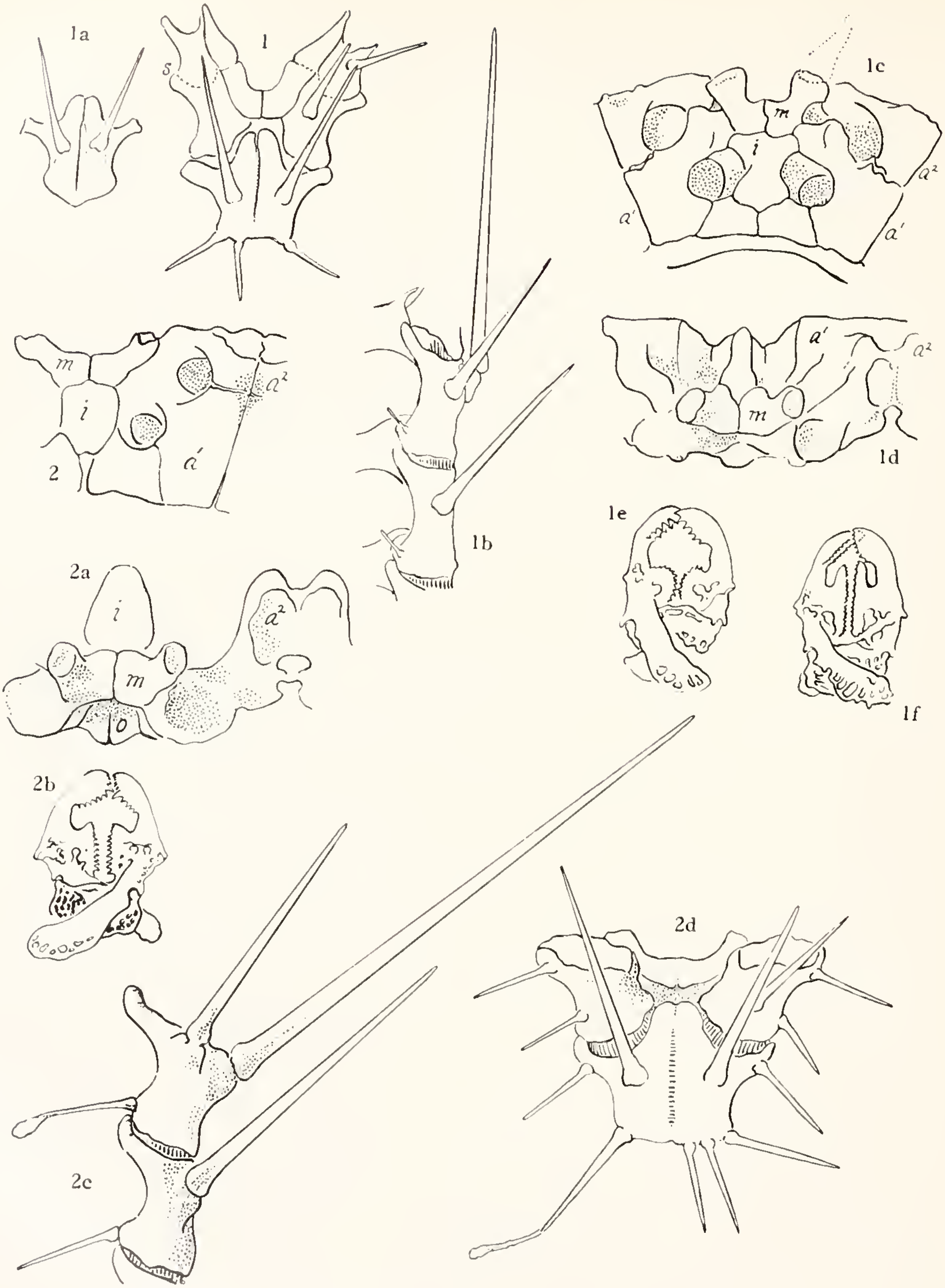


1. Brisingella pusilla. 2. B. exilis

For explanation of plate see page facing

Plate 2

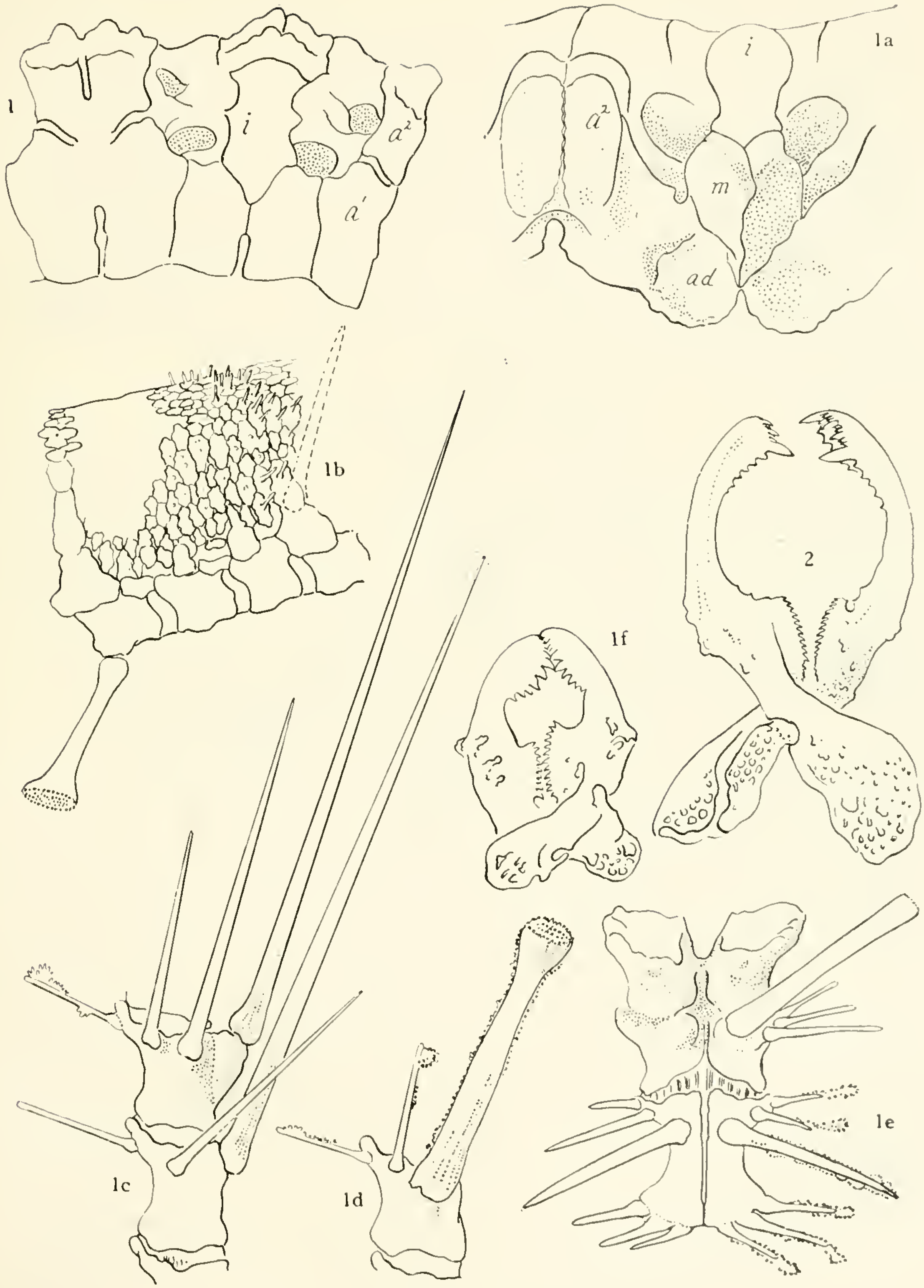
Fig. 1. *Brisingella pusilla*, type ×10. Mouth plates and first two adambulacrals; above these first two marginals; *s*, syzygial joint. 1*a*. Same, station 4127. Mouth plates. 1*b*. Same, ×10. Eighth and ninth adambulacral plates; latter with marginal plate and "lateral" spine. 1*c*. Same, station 4333, ×10. Dorsal view of section of actinostome at an interradial angle. a^1, a^2, first and second ambulacrals; *i*, interradial; *m*, first marginal; 1*d*, Same as 1*c*, but a peripheral or lateral view of angle, showing facets of the syzygial joints; lettering same. 1*e*. Same, ×300. Pedicellaria from enlarged subambulacral spine. 1*f*. Same, ×300. Pedicellaria from furrow spinelet.

2. *Brisingella exilis*, station 4387, ×8. Dorsal view of section of actinostome at interradial angle; lettering as in 1*c*. 2*a*. Same as 2 but a peripheral view; *o*, mouth plates; other letters as in 1*c*. 2*b*. Same. Pedicellaria from furrow spinelet, ×300; length 0.1 mm. 2*c*. Same, type, ×10. Two adambulacral plates, base of ray, the upper with a marginal or lateral spine at right. 2*d*. Same. Mouth plates and first adambulacral and marginal plates.

PLATE 3

FIG. 1. *Freyellaster fecundus*, ×10. Segment of actinostomial ring at interradial angle; *i*, interradial plate; a^1, a^2, first and second ambulacral ossicles. 1*a*. Same as 1 but a peripheral or external view, ×10; a^2, external facet of second ambulacral plate, at the syzygial joint; *ad*, same for the adambulacral; *m*, marginal plates. 1*b*. Side view of ray showing plating, base of ray to right; subambulacral of eleventh plate shown. 1*c*. Same, type, ×10. Twenty-fourth and twenty-fifth adambulacral plates, the upper with attached marginal plate and spine. 1*d*. Same, ×10. Sixth adambulacral plate. 1*e*. Same, type, ×10. Mouth plates and first two adambulacrals. 1*f*. Same, ×300. Pedicellaria from actinostomial spinelet, length 0.13 mm.

2. *Freyella insignis*, ×200. Type of pedicellaria from furrow and subambulacral spinelets; length 0.39 mm.



1. Freyellaster fecundus. 2. Freyella insignis

For explanation of plate see page facing

1. FREYELLA MICROPLAX. 2. F. INSIGNIS. 3. ASTROCLES ACTINODETUS

For explanation of plate see page facing

Plate 4

Fig. 1. *Freyella microplax*, $\times 10$. Mouth plates and first adambulacral, the distal joint of which is not a syzygy. 1*a*, Same, $\times 10$. Segment of actinostomial ring, peripheral view. On right the second ambulacral and first adambulacral have been removed to show mouth plates *o*; a^1, a^2, first and second ambulacral plates; *ad*, first adambulacral; *i*, interradial plate. 1*b*. Same as 1*a*, but a dorsal view, $\times 10$; lettering same as 1*a*; *o* shows the extensions of the mouth plate which normally lie behind the first adambulacrals, as in 1*a*. 1*c*. Same, $\times 300$. Pedicellaria from furrow spinelet. 1*d*. Same, $\times 10$. Ninth adambulacral plate, specimen *a*. 1*e*. Same, $\times 10$. Eleventh adambulacral plate, specimen *b*. 1*f*. Same, $\times 10$. Twenty-seventh adambulacral plate, near outer end of genital region.

2. *Freyella insignis*, $\times 10$. Ninth and tenth adambulacral plates. 2*a*. Same, $\times 20$. Fifth subambulacral spine, $\times 20$.

3. *Astrocles actinodetus*, $\times 200$. Large variety of pedicellariae of furrow spinelets, length 0.33 mm. 3*a*. Same, specimen *a*, $\times 10$. Mouth plates and first adambulacral plates. The curiously expanded valve-like, furrow spines are shown meeting across furrow, on right. 3*b*. Same, specimen *b*, $\times 10$. Note the different actinostomial oral spines.

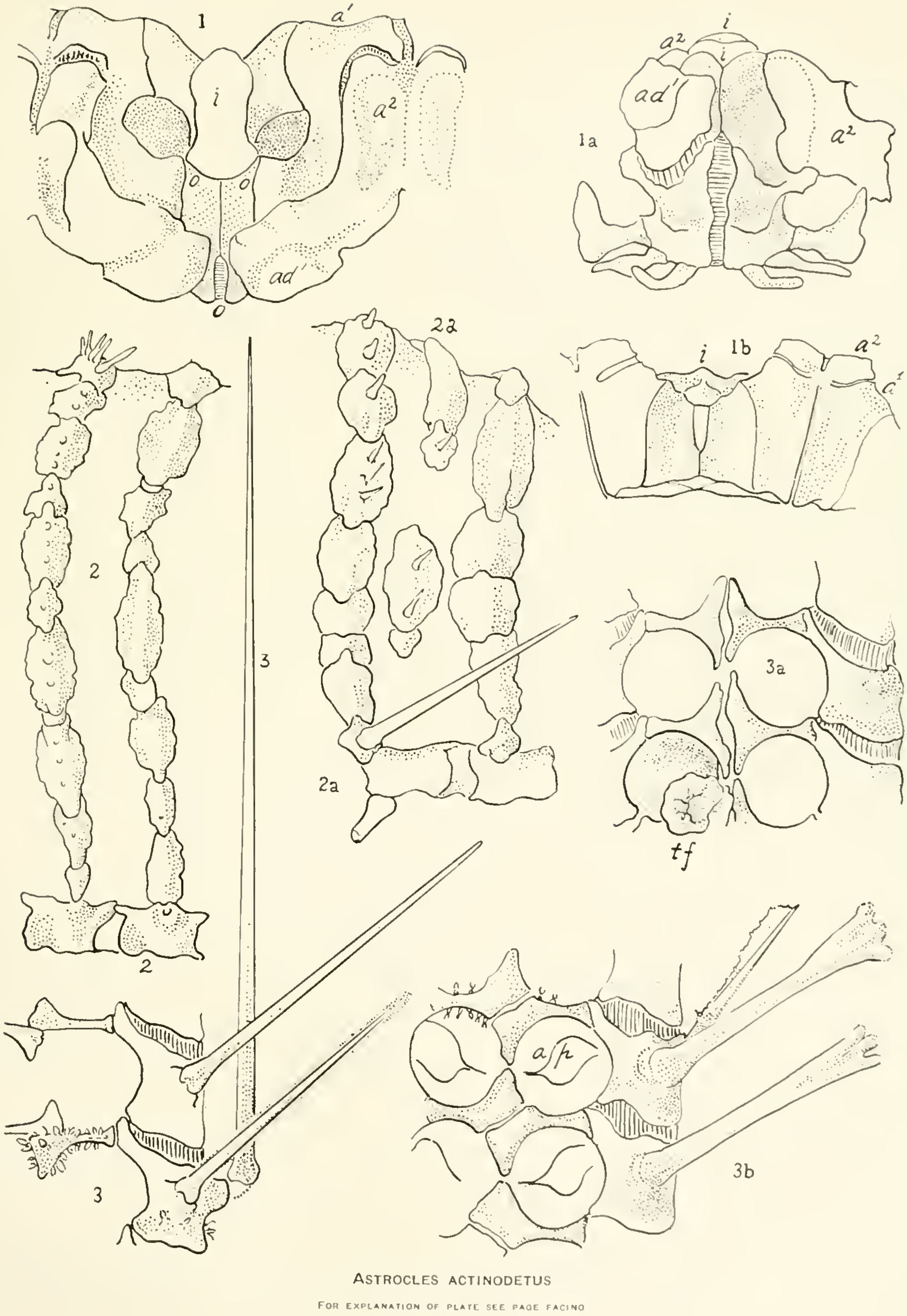
PLATE 5

Astrocles actinodetus

FIG. 1. Segment of actinostomial ring at interradius, *o, o, o*, the mouth plates $\times 10$; a^1, a^2, first and second ambulacral plates; ad^1, first adambulacral plate; *i*, interradial plate. 1*a*, Same, specimen *c*, $\times 10$. Mouth plates. On right the first adambulacral (ad^1) has been removed to show the process of the oral plate which passes upward to join the interradial (*i*); a^2, second ambulacrals. The view is ventro-peripheral. 1*b*. Same, $\times 5$. Dorsal view of segment of actinostome; lettering as in 1.

2. Side view of two skeletal arches of ray, meeting fifteenth and sixteenth adambulacral plates; disk to left, specimen *a*, $\times 10$. 2*a*. Side view of ray at ninth and tenth adambulacral plates, disk to right, $\times 10$.

3. Forty-third and forty-fourth adambulacral plates, the former with characteristically long marginal spine, $\times 10$. 3*a*. Armature of fourth and fifth adambulacrals showing position of tube-foot, *tf*, on left; subambulacral spines omitted. 3*b*. Specimen *a*, seventh and eighth adambulacrals and furrow spines of opposite side of furrow, $\times 10$. *a*, ambulacral plate; *p*, ambulacral pore.



ASTROCLES ACTINODETUS

FOR EXPLANATION OF PLATE SEE PAGE FACING

CRATEROBRISINGA SYNAPTOMA

FOR EXPLANATION OF PLATE SEE PAGE FACING

PLATE 6

Craterobrisinga synaptoma, $\times 1$

FIG. 1. Type.
2. Cotype.

PLATE 7

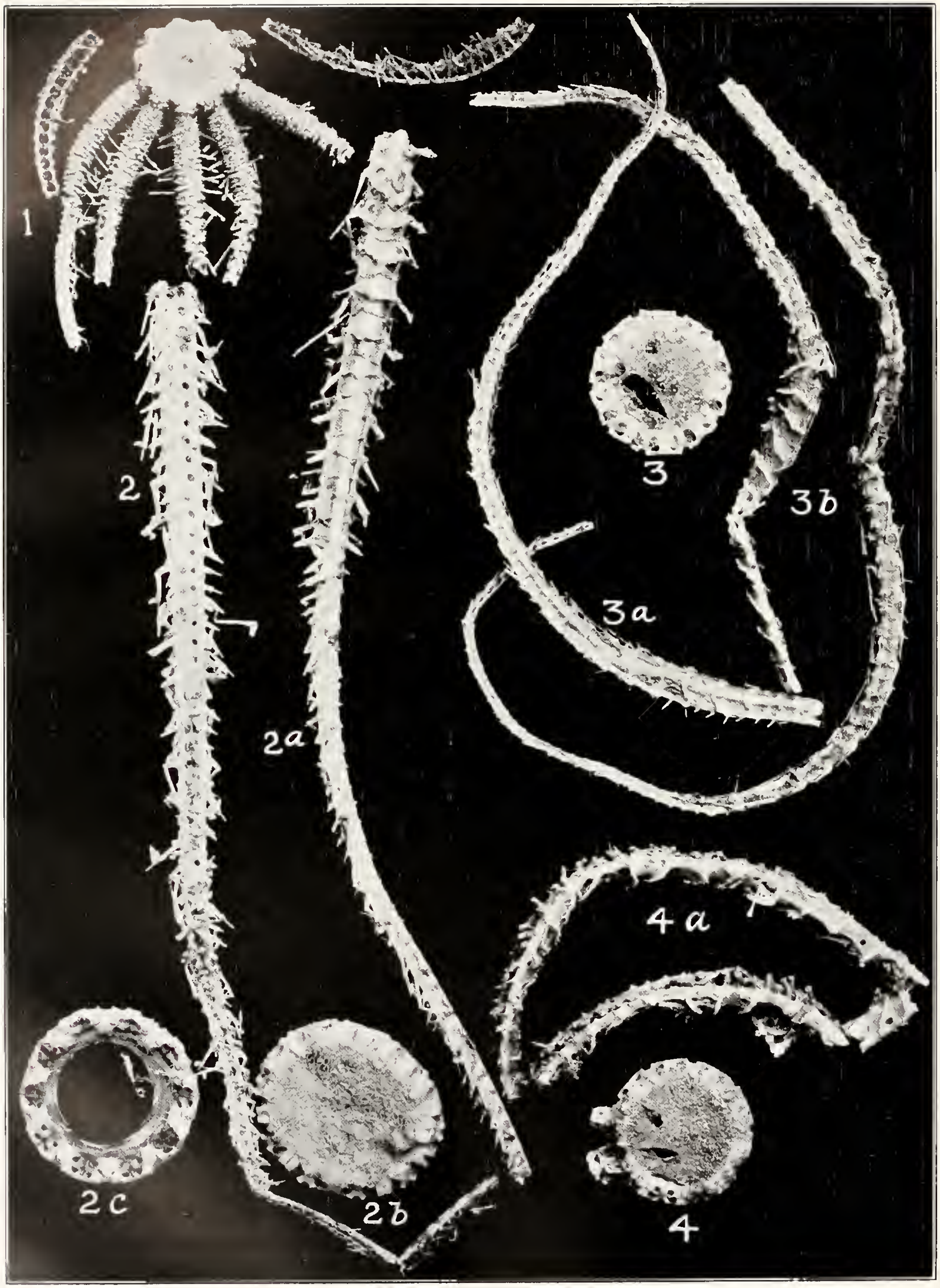
FIG. 1. *Freyella microplax*, $\times 2\frac{1}{4}$.

2. *Freyellaster fecundus*, type, $\times 2\frac{1}{4}$.

3. *Craterobrisinga synaptoma*, type, $\times 2\frac{1}{4}$.

1. Freyella microplax. 2. Freyellaster fecundus. 3. Craterobrisinga synaptoma

For explanation of plate see page facing



1. FREYELLA INSIGNIS. 2. BRISINGELLA EXILIS. 3. B. PUSILLA. 4. B. PANNYCHIA

FOR EXPLANATION OF PLATE SEE PAGE FACING

PLATE 8

All figures $\times 1\frac{1}{2}$

FIG. 1. *Freyella insignis*, station 4347 or 4397, with fragments of two arms.
2, 2*a*, 2*b*. *Brisingella exilis*, type. 2*c*. Same, actinal view of disk.
3, 3*a*, 3*b*. *Brisingella pusilla*, type, station 4427.
4, 4*a*. *Brisingella pannychia*, type.

Plate 9

Freyellaster fecundus, slightly larger than natural size.

FREYELLASTER FECUNDUS

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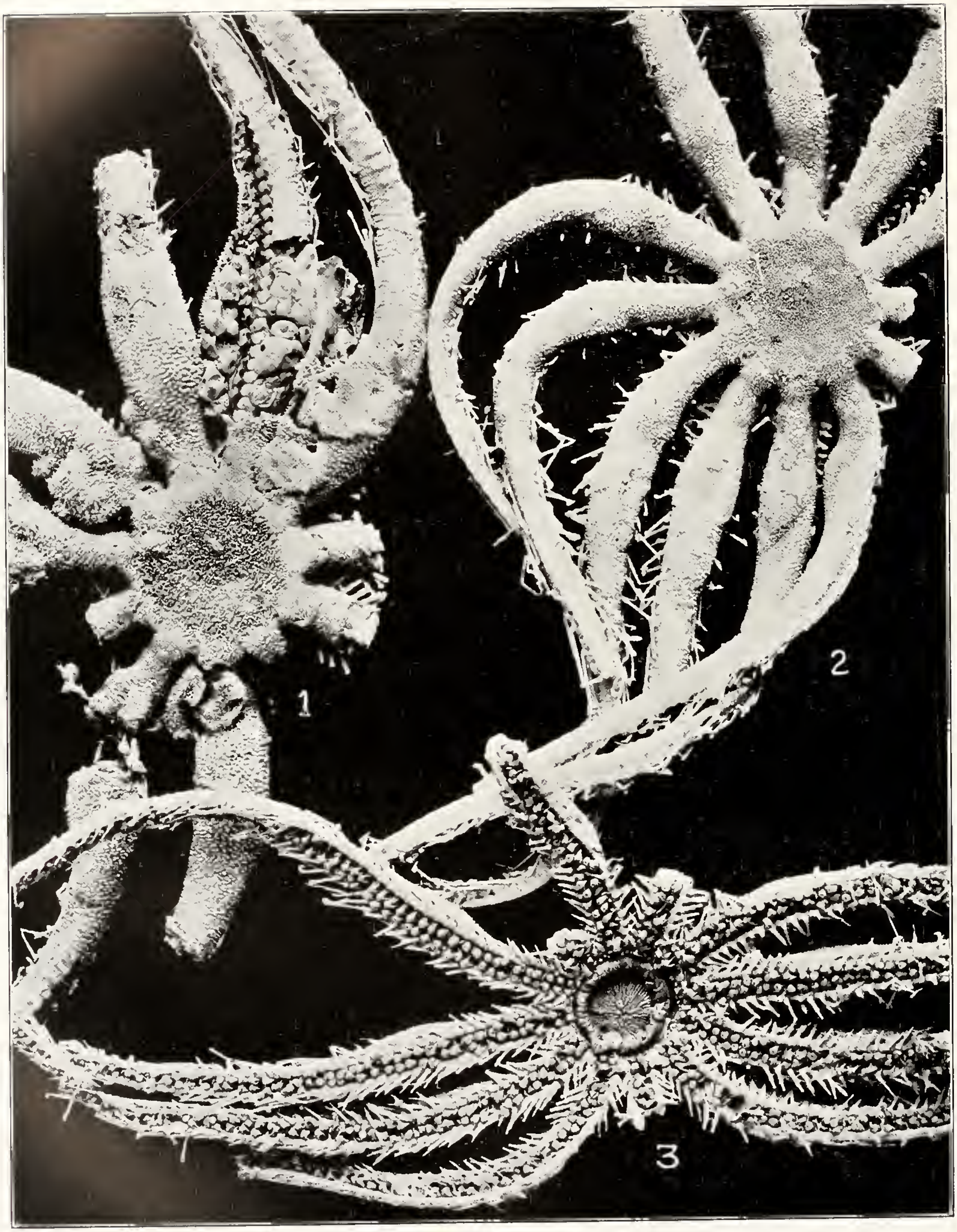


FREYELLA MICROPLAX

For explanation of plate see page facing

PLATE 10

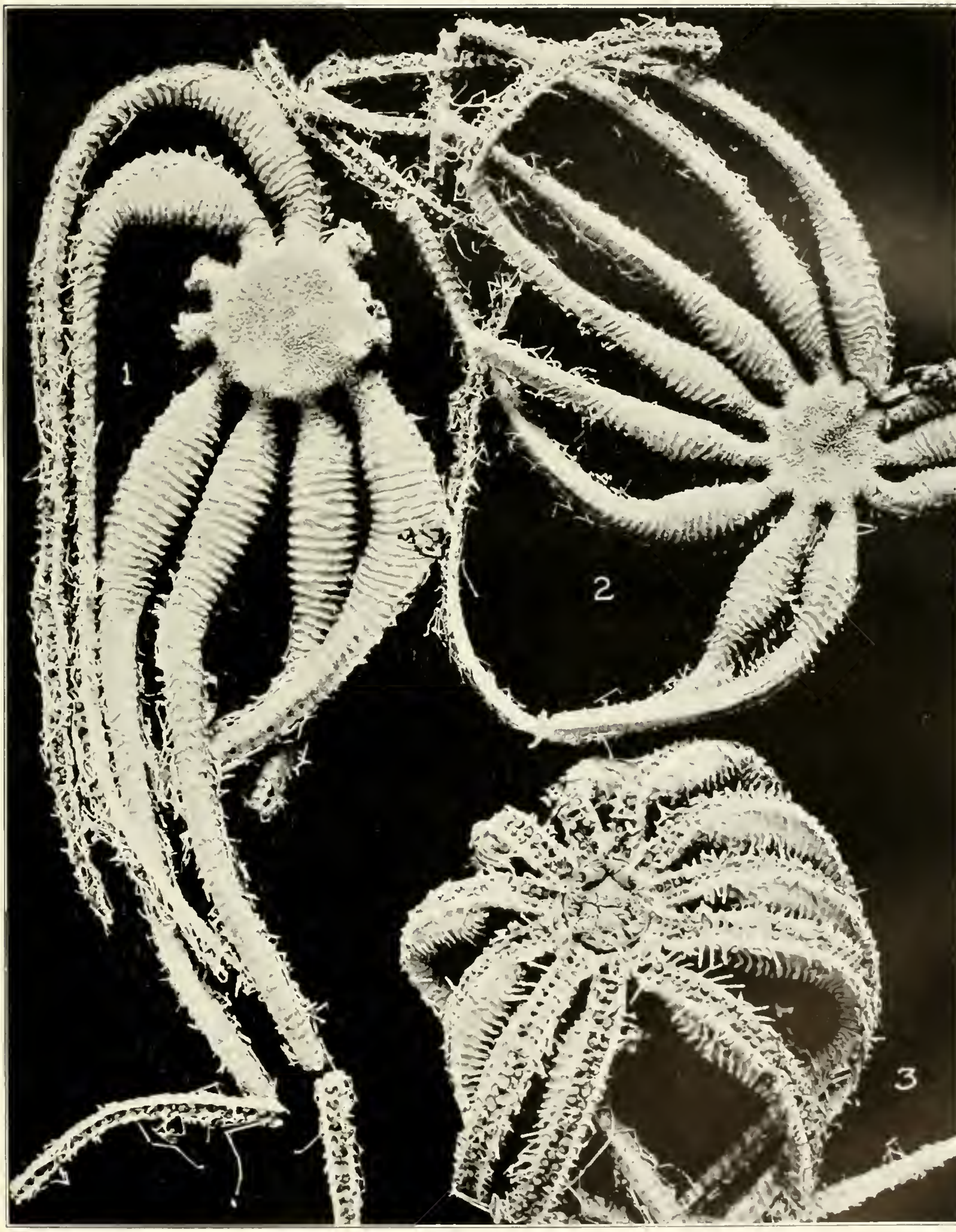
Freyella microplax, $\times 1\frac{1}{2}$

FIG. 1. Specimen with arm opened to show gonads.
2. Type, station 3342.
3. Actinal view.

PLATE 11

Astrocles actinodetus, slightly larger than natural size

FIG. 1. Cotype.
2. Type.
3. Actinal view of a cotype.



ASTROCLES ACTINODETUS

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1. Freyellaster fecundus. 2. Astrocles actinodetus. 3. Craterobrisinga synaptoma. 4. Freyella microplax. 5, 6. Rathbunaster californicus

For explanation of plate see page facing

PLATE 12

All figures ×2

FIG. 1. *Freyellaster fecundus*, type.
2. *Astrocles actinodetus.*
3. *Craterobrisinga synaptoma.*
4. *Freyella microplax.*
5, 6. *Rathbunaster californicus.*

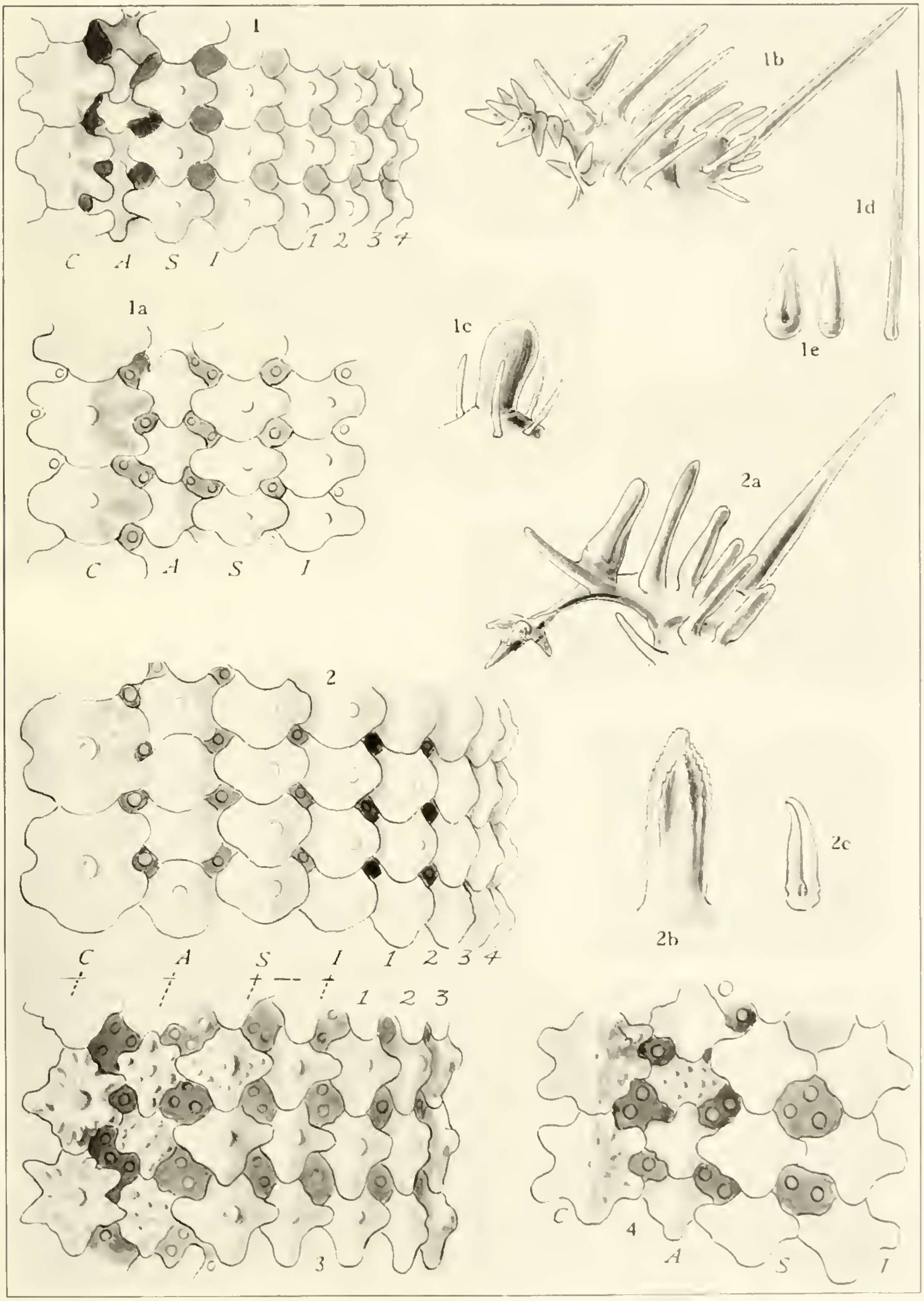
PLATE 13

FIG. 1. *Zoroaster ophiurus*, type. Plates of ray; *C*, carinal; *A*, adradial; *S*, superomarginal; *I* inferomarginal; 1, 2, 3, 4, actinolaterals, ×5. 1*a*. Same, specimen from Bering Sea, Carinal plates on left, actinolaterals omitted, ×5. 1*b*. Same, type. Two adambulacrals plates, near base of ray and 1 actinolateral spine, ×10. 1*c*. Same, station 4765. Carinal spine. 1*d*. Superomarginal spine. 1*e*. Abactinal pedicellariae, ×15.

2. *Z. actinocles*, type. Plates of ray, same lettering as Figure 1; ×5. 2*a*. Same, adambulacral plate near base of ray, ×10. 2*b*. Carinal spine, ×15. 2*c*. Abactinal pedicellaria, ×15.

3. *Z. evermanni*, station 4423. Plates of ray, same lettering as Figure 1.

4. *Z. evermanni mordax*, station 3072. Plates of ray, carinals (*C*) on left, actinolaterals omitted.



1. ZOROASTER OPHIURUS. 2. Z. ACTINOCLES. 3. Z. EVERMANNI. 4. Z. EVERMANNI MORDAX

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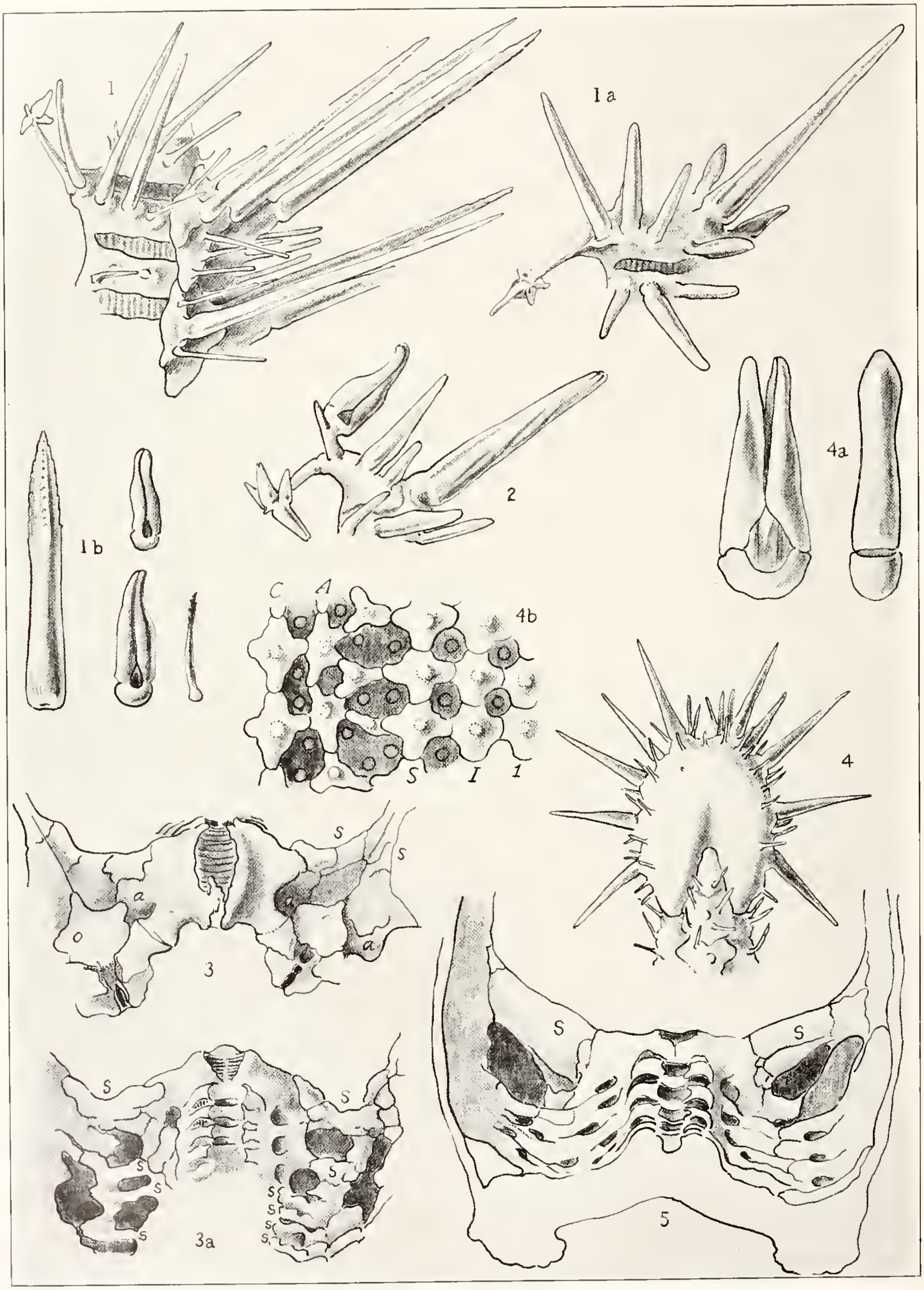

1. ZOROASTER EVERMANNI. 2. Z. EVERMANNI MORDAX. 3. MYXODERMA PLATYACANTHUM RHOMALEUM. 4. M. SACCULATUM ECTENES. 5. M. SACCULATUM

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PLATE 14

FIG. 1. *Zoroaster evermanni*, station 4423. Adambulacral plates and two plates in each of three actinolateral series; dry, ×10. *1a*. Same, station 4400. Armature of two adambulacral plates and one adjacent actinolateral plate, alcohol specimen, ×10. *1b*. Same, station 4423. A carinal spine, two abactinal pedicellariae and spinelet, ×15.

2. *Z. evermanni mordax*, station 3073, for comparison with 1*a*; base of ray; alcoholic specimen, ×10.

3. *Myxoderma platyacanthum rhomaleum*, station 2890. Dorsal view of one-fifth of actinostome showing first superambulacral stays from above (*s*, *s*). These inclose the odontophore (*o*) and two ampulla pores (*a*), ×5. *3a*. Same. Dorsal view of proximal end of ambulacral ridge looking toward disk; *s*, superambulacral ossicles, ×5.

4. *Myxoderma sacculatum ectenes*. Terminal plate of a young specimen, with R 17 mm., ×10. *4a*. Same, type. Abactinal pedicellariae, base of ray, ×16. *4b*. Same, station 4425, R 78 mm. Abactinal skeleton of ray, ×5; *C*, carinal; *A*, adradial; *S*, superomarginal; *I*, inferomarginal; *1* first actinolateral.

5. *Myxoderma sacculatum*. A section of ventral side of ray looking toward disk, the ambulacral ridge in center to show the enlarged first superambulacral buttresses (*S*); ×4.

Plate 15

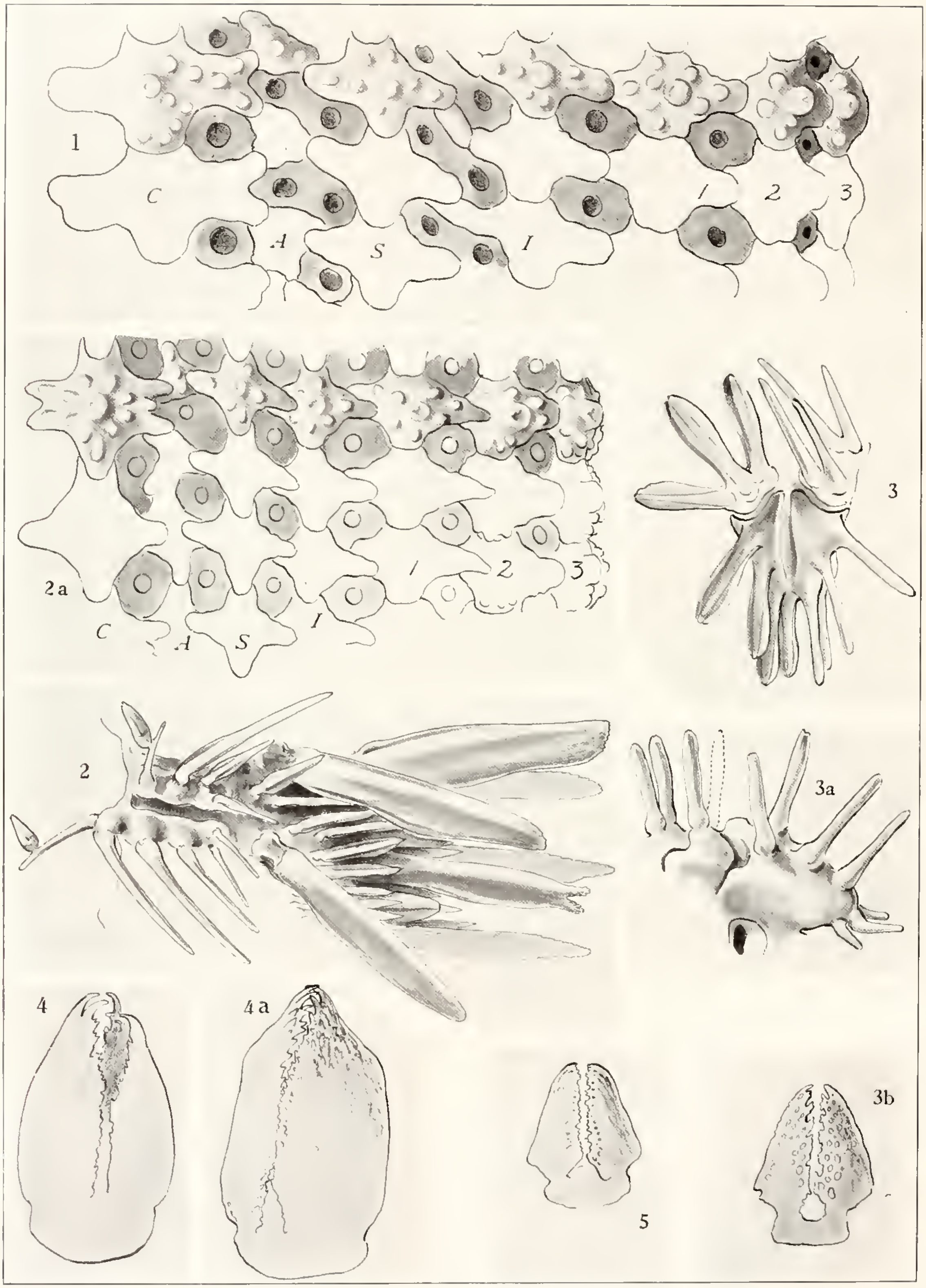
Fig. 1. *Myxoderma sacculatum.* A small portion of abactinal surface, base of ray ×8, to illustrate specimen with very fleshy spines and interspersed papulae (*P*) and pedicellariae; *C*, carinal spines; *A*, adradials; *S*, superomarginals; *I*, inferomarginals; *X*, smaller spinelets. 1*a*. Skeleton at base of ray; carinals at top (*C*), adradials (*A*), marginals (*S*, *I*), actinolaterals (1–4); station 4510, ×5. 1*b*. Three adambulacral plates of a topotype from proximal third of ray; alcoholic specimen to show sacculate spines. The subambulacral spines of nonprominent plate are not shaded; ×10. 1*c*. Station 4540; a dried adambulacral plate near base of ray, ×10.

2. *Myxoderma platyacanthum rhomaleum.* Two carinal spines, ×15. 2*a*. Abactinal pedicellariae and spinelet, ×15.

3. *Myxoderma platyacanthum*, station 4321. Carinal spine, two views of an abactinal pedicellaria and spinelet, ×15.

1. Myxoderma sacculatum. 2. M. platyacanthum rhomaleum. 3. M. platyacanthum

For explanation of plate see page facing



1. Myxoderma platyacanthum rhomaleum. 2. M. platyacanthum. 3. Pedicellaster magister. 4. P. magister megalabis. 5. P. magister orientalis

For explanation of plate see page facing

Plate 16

Fig. 1. *Myxoderma platyacanthum rhomaleum.* Projection of skeleton of one side of ray, ×10 *C*, carinal plates; *A*, adradials; *S*, superomarginals; *I*, inferomarginals; 1–3, three series of actinolaterals.

2. *Myxoderma platyacanthum.* Two adambulacral plates and armature of three actinolateral series at base of ray, ×10. *2a.* Same, station 4321. Projection of skeleton of one side of ray, ×10; lettering as Figure 1.

3. *Pedicellaster magister*, station 3223, ×10. Mouth plates and first adambulacral plates. Two plates on right allowed to dry. *3a.* Same, station 3488, ×10. Side view of one dried mouth plate and two adjacent adambulacrals. *3b.* Same, station 4792. Straight pedicellaria from furrow margin, 0.26 mm., ×100.

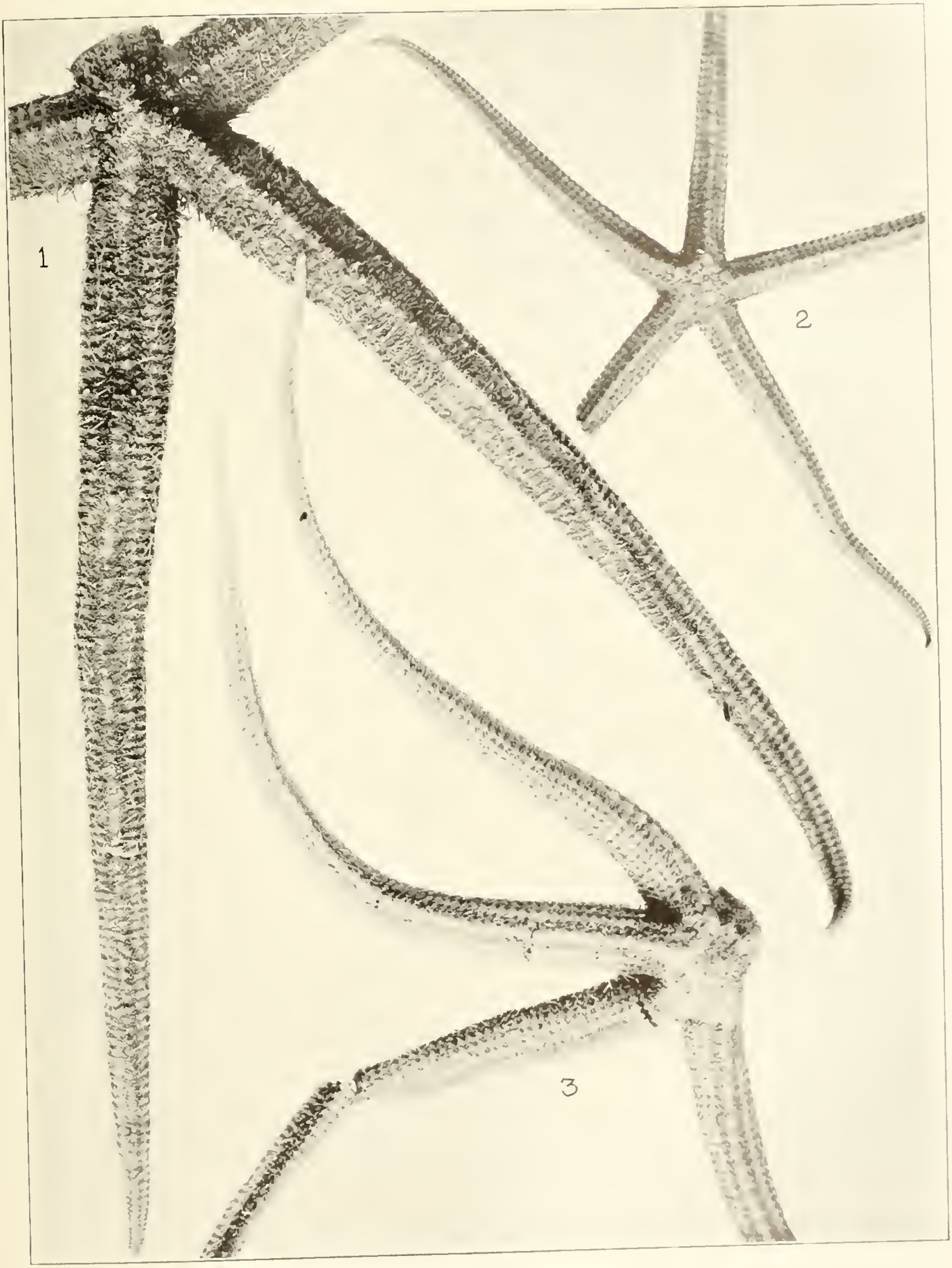
4. *Pedicellaster magister megalabis*, station 3347. Straight pedicellariae from mouth plates, 0.48 mm., ×100. *4a.* Same, station 4335, 0.18 mm.

5. *Pedicellaster magister orientalis.* Straight pedicellaria from mouth plates, ×100.

Plate 17

Zoroaster ophiurus, abactinal, $\times 1\frac{1}{6}$

Fig. 1. Station 4765.
2. Station 2919.
3. Type.



ZOROASTER OPHIURUS

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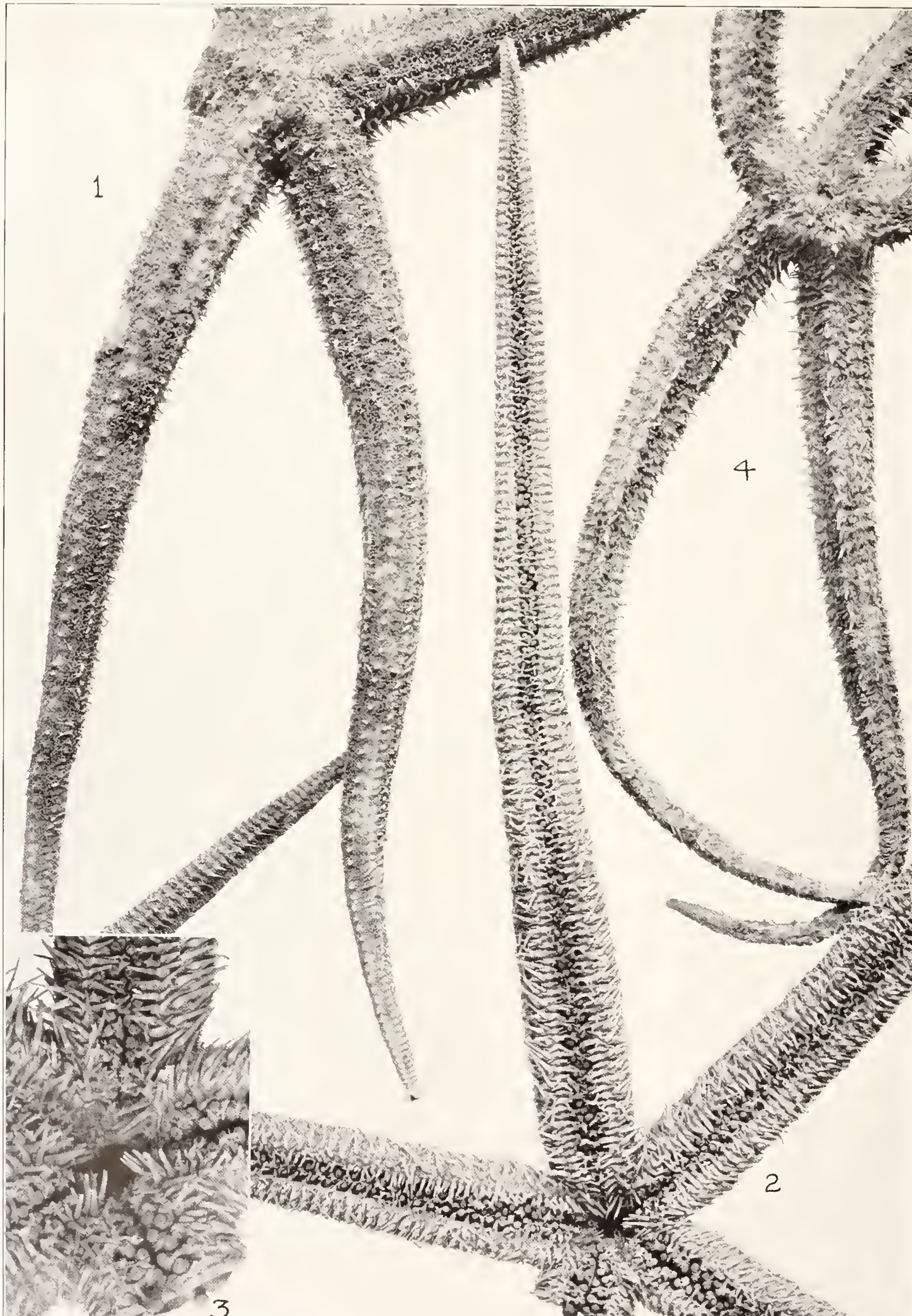


1. Zoroaster actinocles. 2, 3. Z. ophiurus. 4. Z. evermanni

For explanation of plate see page facing

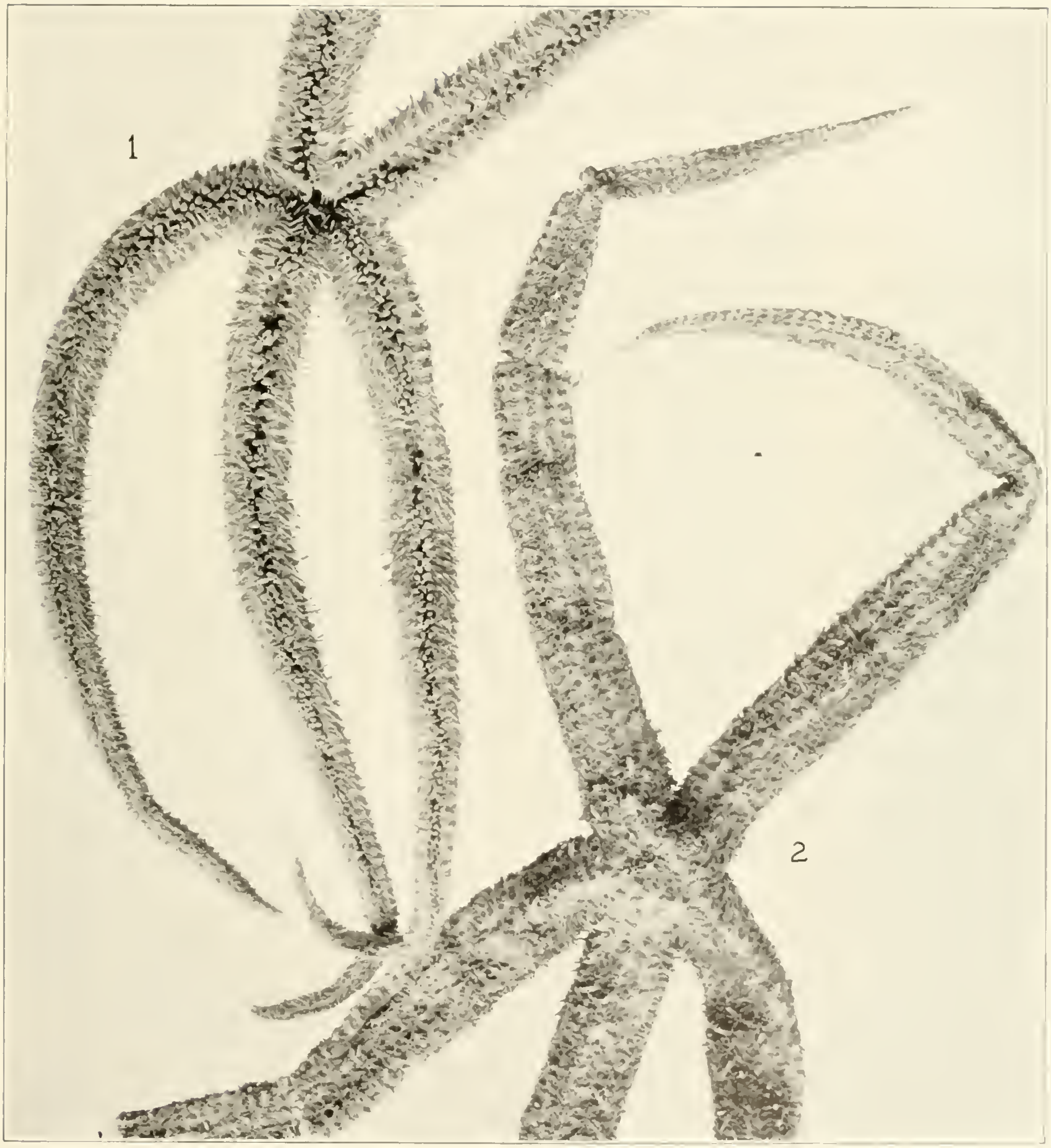
PLATE 18

All figures except 3 ×1⅙

Fig. 1. *Zoroaster actinocles*, type, station 4765.
2. *Zoroaster ophiurus*, actinal view, station 4765.
3. Same. Actinostomial region, ×2.
4. *Zoroaster evermanni*, type, station 4400.

PLATE 19

FIG. 1 *Zoroaster evermanni*, type, actinal, station 4400.
2. *Z. evermanni mordax*, abactinal.



1. ZOROASTER EVERMANNI. 2. Z. EVERMANNI MOROAX

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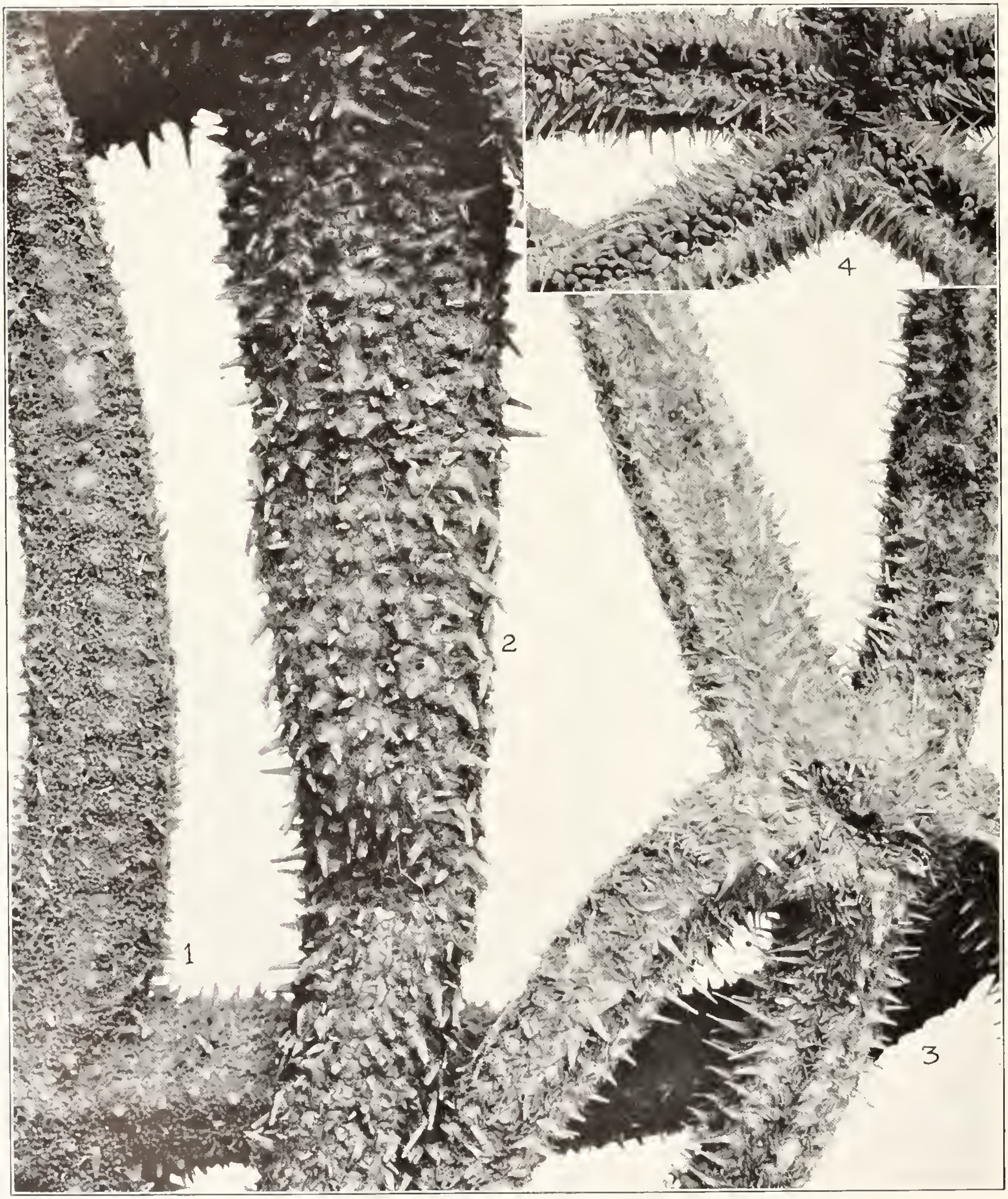


1. Zoroaster actinocles. 2. Myxoderma sacculatum. 3, 4. Zoroaster evermanni

For explanation of plate see page facing

Plate 20

Fig. 1. *Zoroaster actinocles*, type, $\times 2\frac{1}{8}$.

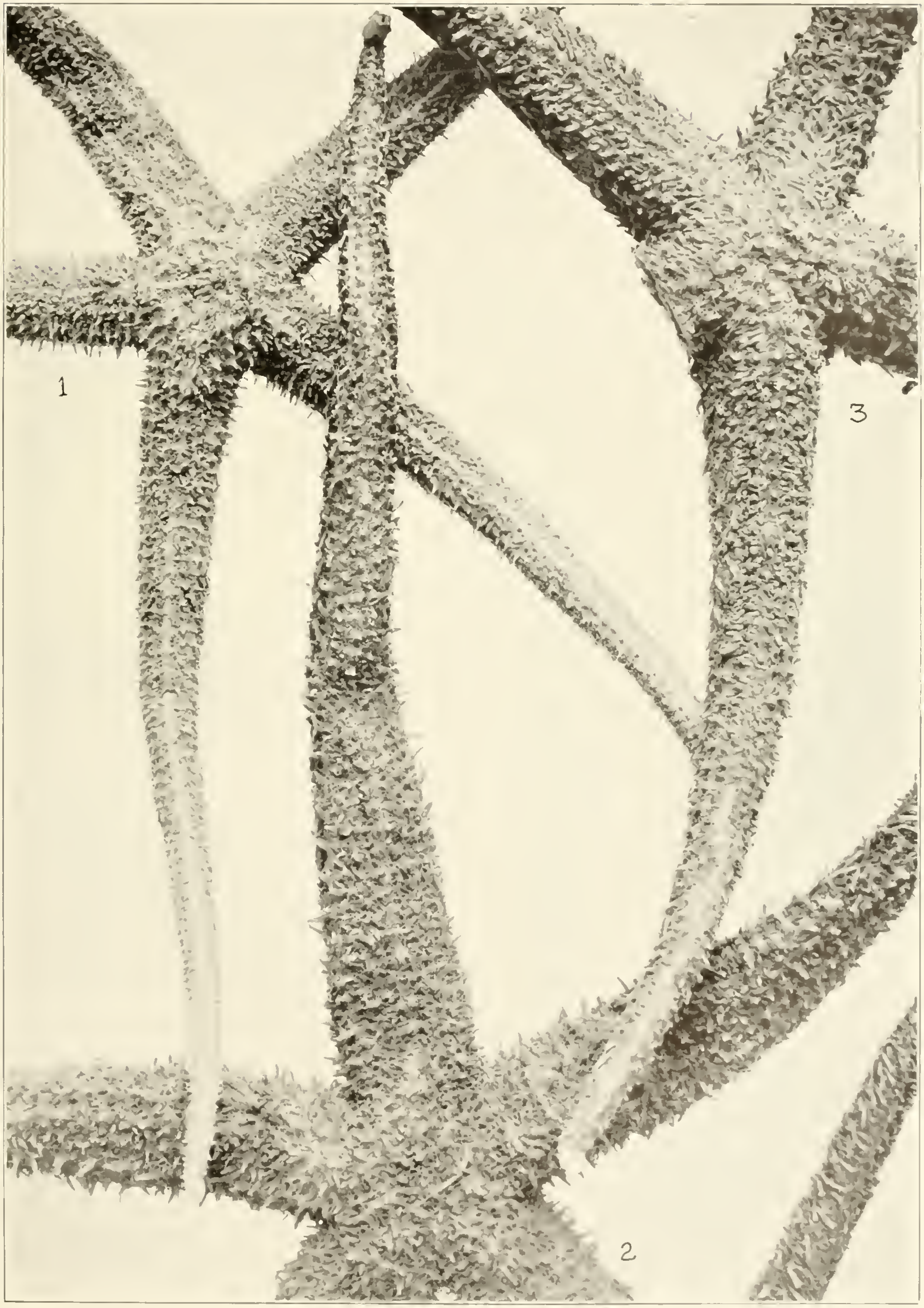
2. *Myxoderma sacculatum*, $\times 2\frac{1}{8}$.

3. *Zoroaster evermanni*, $\times 2\frac{1}{8}$.

4. Same, actinal view, $\times 2$.

PLATE 21

FIG. 1. *Myxoderma sacculum ectenes*, station 4380, $\times 1^1/_9$.
2. *Myxoderma sacculatum*, type, $\times 1^1/_9$.
3. Same, station 4775.



1. MYXODERMA SACCULATUM ECTENES. 2, 3. M. SACCULATUM

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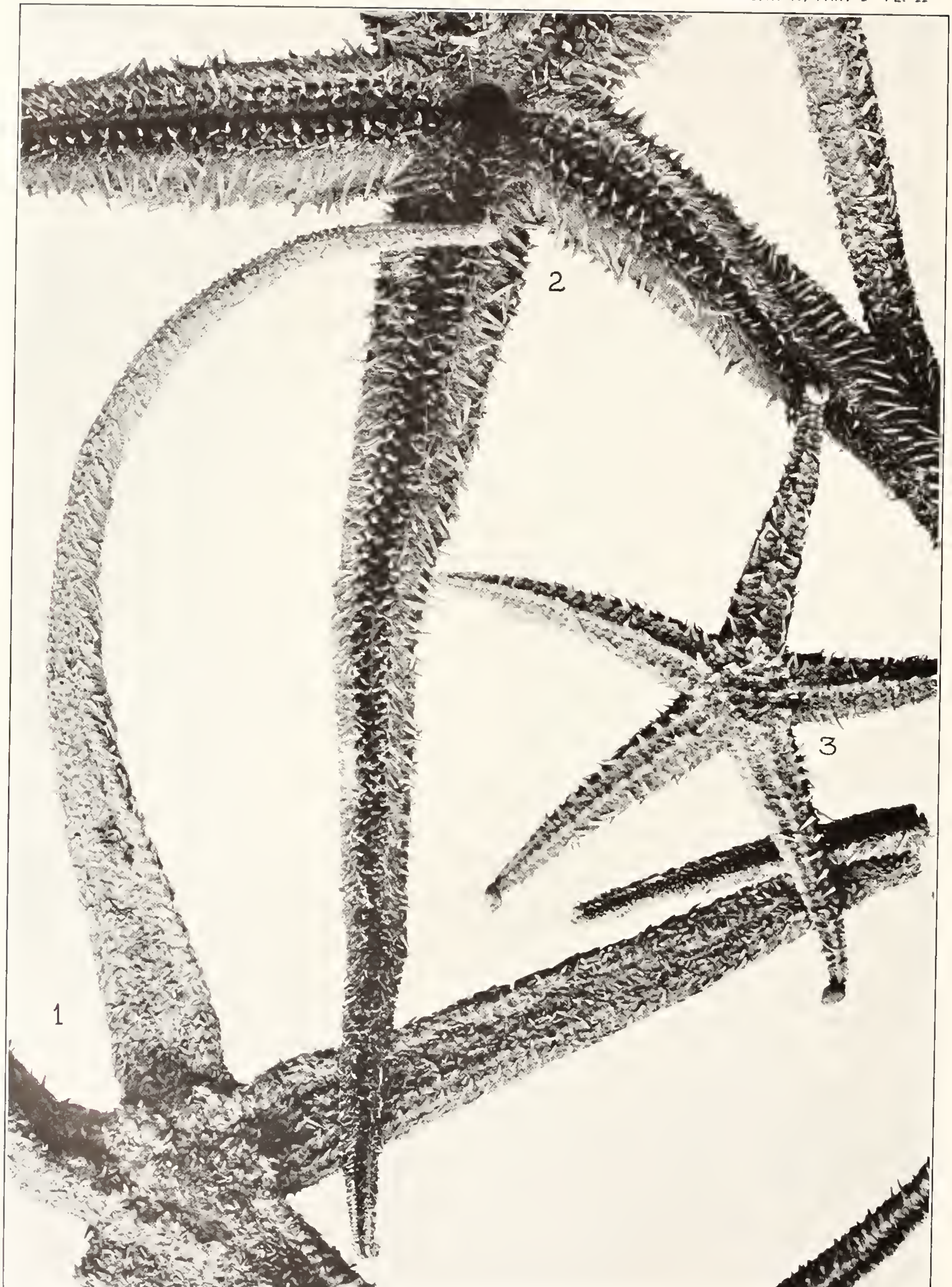

1. MYXODERMA SACCULATUM ECTENES. 2, 3. M. SACCULATUM

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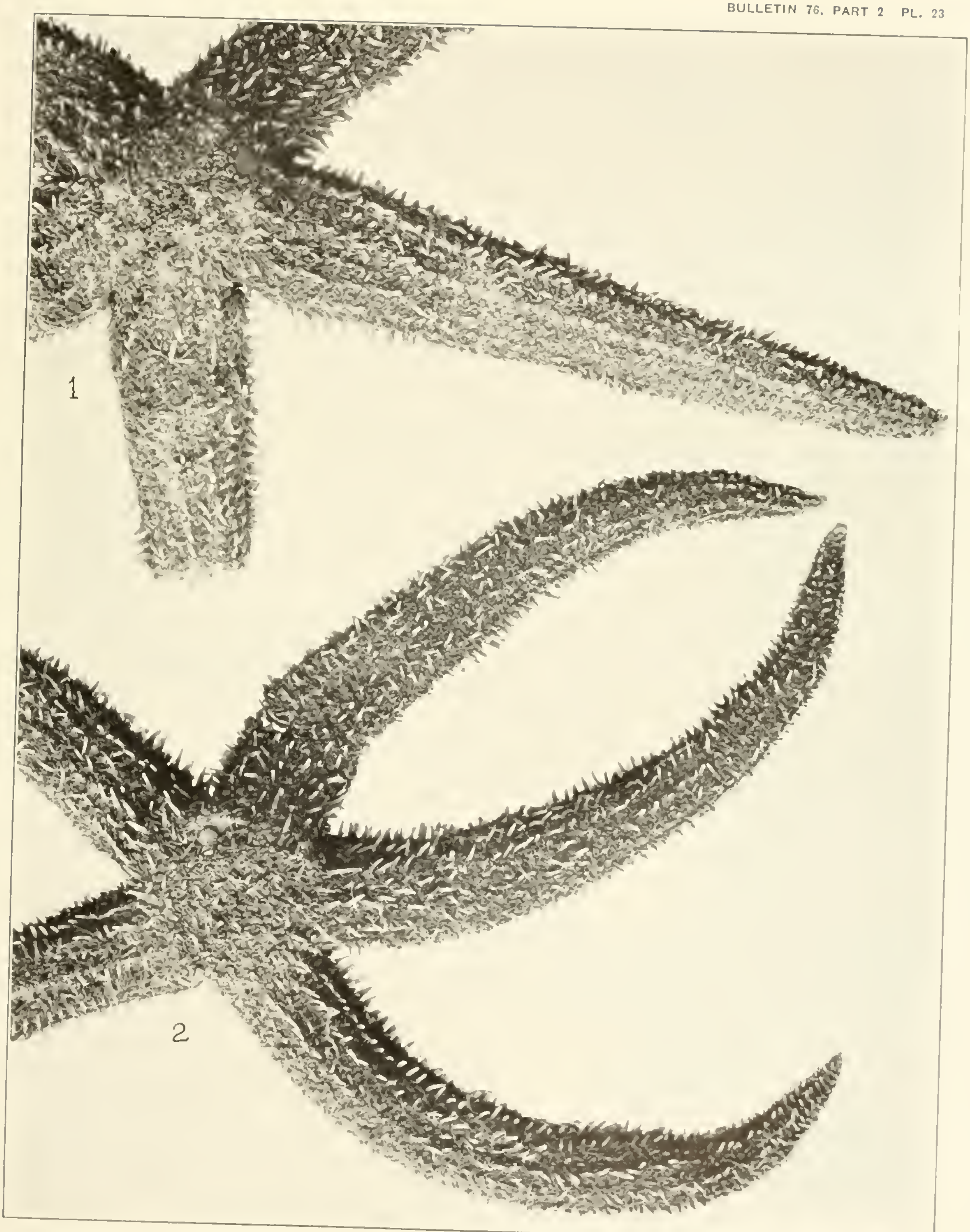
PLATE 22

FIG. 1. *Myxoderma sacculatum ectenes*, type, station 5691, slightly more than natural size.
2. *Myxoderma sacculatum*, type.
3. Same, young specimen, slightly larger than natural size.

PLATE 23

FIG. 1. *Myxoderma platyacanthum rhomaleum*, $\times 1.4$.
2. *Myxoderma platyacanthum*, station 4321, $\times 1.4$.



MYXODERMA PLATYACANTHUM RHOMALEUM. 2. M. PLATYACANTHUM

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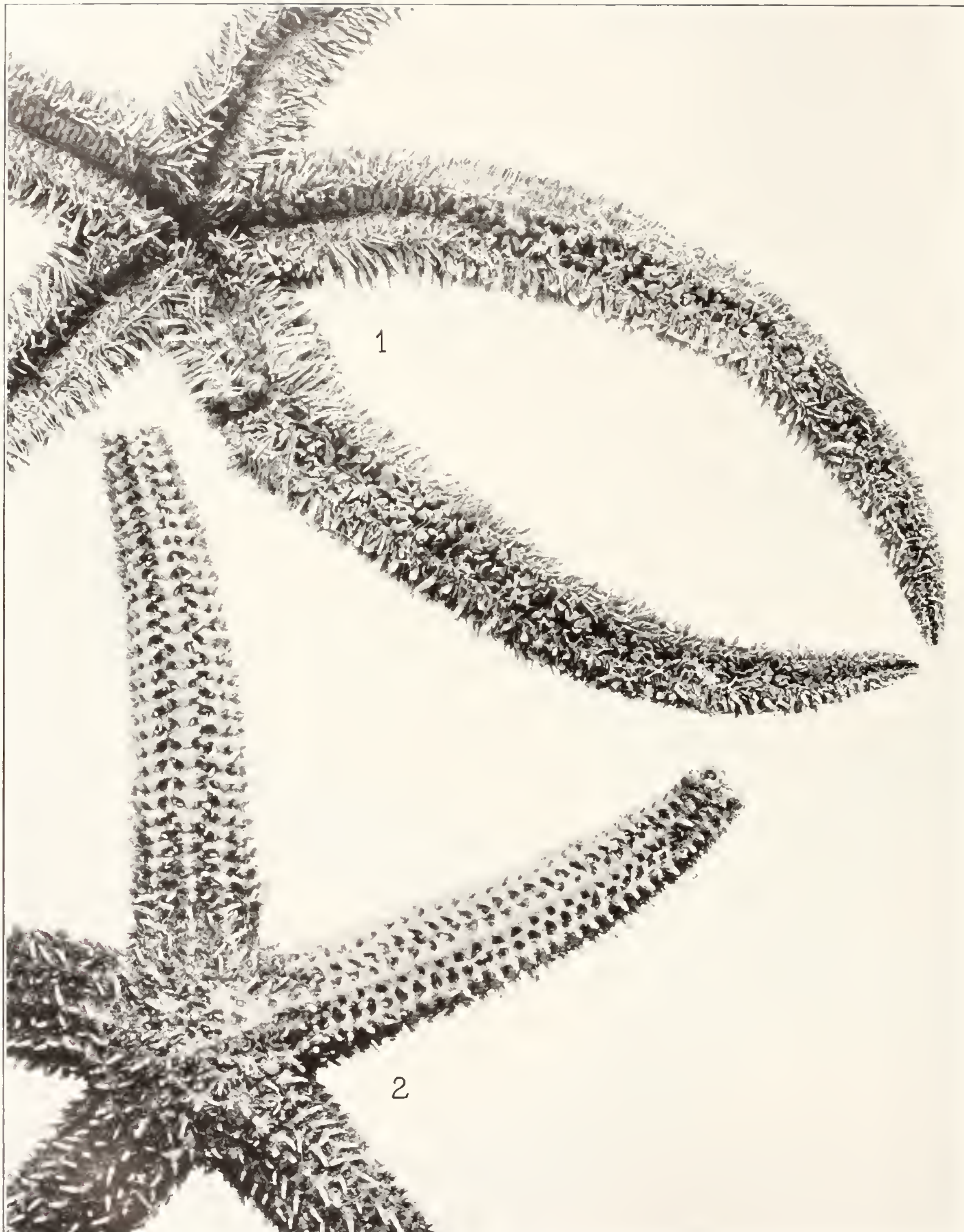


1. Myxoderma platyacanthum. 2. M. platyacanthum rhomaleum

For explanation of plate see page facing

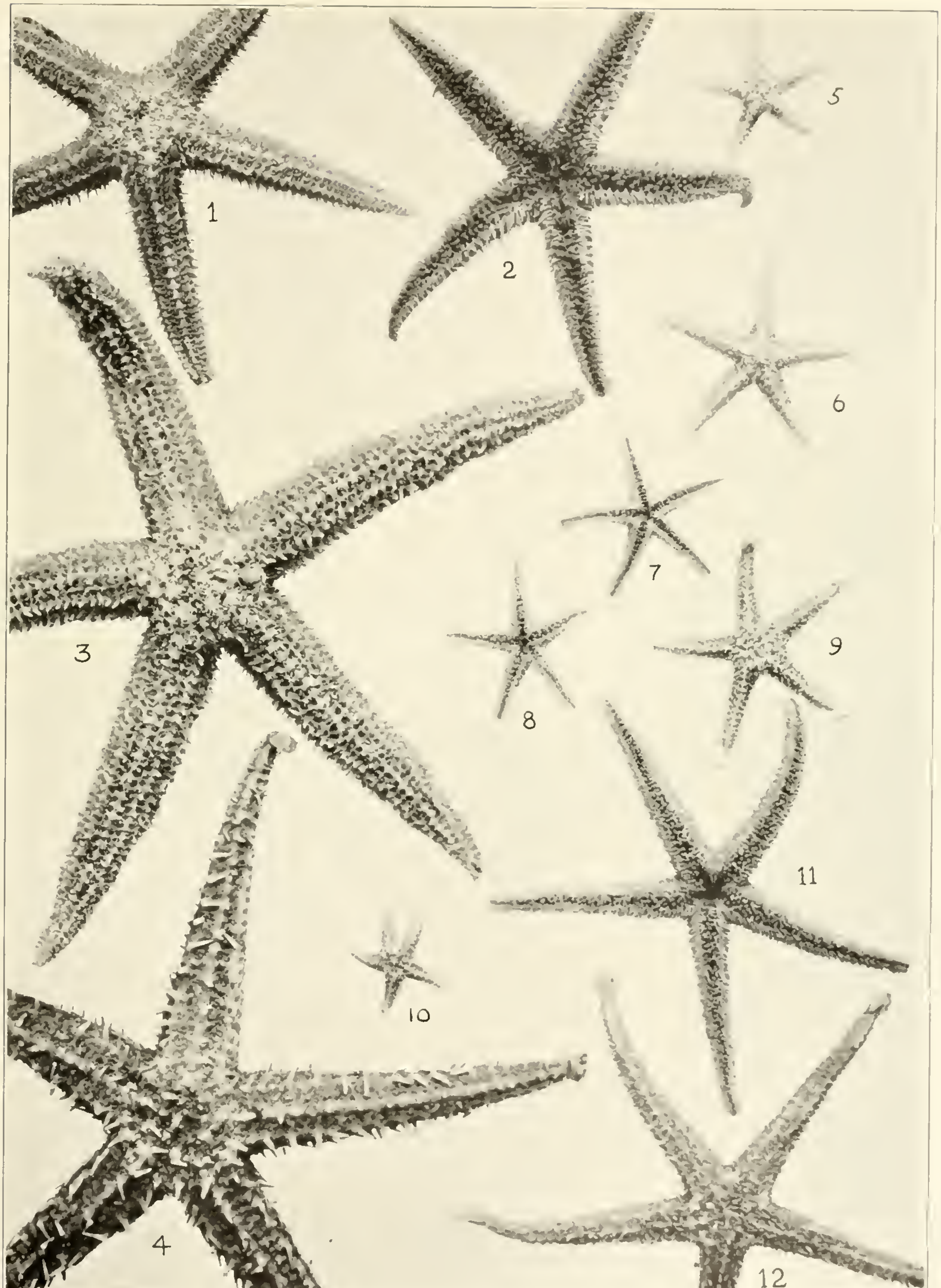
Plate 24

Fig. 1. *Myxoderma platyacanthum*, station 4321, actinal view, $\times 1.6$.
2. *Myxoderma platyacanthum rhomaleum*, station 2890, $\times 1.6$.

PLATE 25

All figures × $1\frac{1}{3}$

FIG. 1, 2. *Myxoderma platyacanthum*, young, station 4423.
3. *Myxoderma platyacanthum rhomaleum*, station 3112, medium-sized specimen.
4. *Myxoderma sacculatum*, station 4565.
5–12. *Myxoderma sacculatum ectenes*, station 4425, growth stages.



1, 2. MYXODERMA PLATYACANTHUM. 3. M. PLATYACANTHUM RHOMALEUM. 4. M. SACCULATUM. 5-12. M. SACCULATUM ECTENES

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1. PEDICELLASTER TYPICUS. 2. P. MAGISTER. 3. P. MAGISTER MEGALABIS

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PLATE 26

FIG. 1, 1*a*, 1*b*. *Pedicellaster typicus*, Norway, ×200. Actinal crossed pedicellariae 0.22 to 0.25 mm. 1*c*. Same. Abactinal, ×200.

2, 2*a*–2*e*. *Pedicellaster magister*. Characteristic actinal, crossed pedicellariae, ×100; 2, large specimen, station 4792; 2*a*, station 3500 (0.44 mm.); 2*b*, station 3258; 2*c*, station 4792 (0.56 mm.); 2*d*, station 3675 (0.36 mm.); 2*e*, station 3675 (0.45 mm.). 2*f*, station 3488, abactinal 0.27 mm., × 100.

3, 3*a*–3*e*. *Pedicellaster magister megalabis*. Crossed pedicellariae ×100 (except 3*d*, ×200); 3, actinal, station 4335 and 4333, 0.56 mm.; 3*a*, station 4333, intermediate between actinal and dorsal varieties, 0.40 mm. 3*b*–3*d*, station 4333, abactinal; 3*c*, 0.32 mm.; 3*d*, enlargement of vertical row of teeth, ×200. 3*e*, actinal station 3347, off Washington.

Plate 27

Fig. 1, 1a–1c. *Pedicellaster magister orientalis*, station 4867, Sea of Japan, ×100. 1, 1a–1b, actinal; 1c, abactinal.

2, 2a–2c. *Pedicellaster magister*, station 4792, small specimen with R 12 mm. 2, actinal and 2a, abactinal, ×100; 2b, Three valves of actinal pedicellaria, ×200. 2c. Same specimen; 2 abactinal spinelets, ×100; 2d, a subambulacral; 2f, a furrow spinelet, ×100.

3, 3a. *Pedicellaster typicus;* ×100; 3, adambulacral; 3a, abactinal spine.

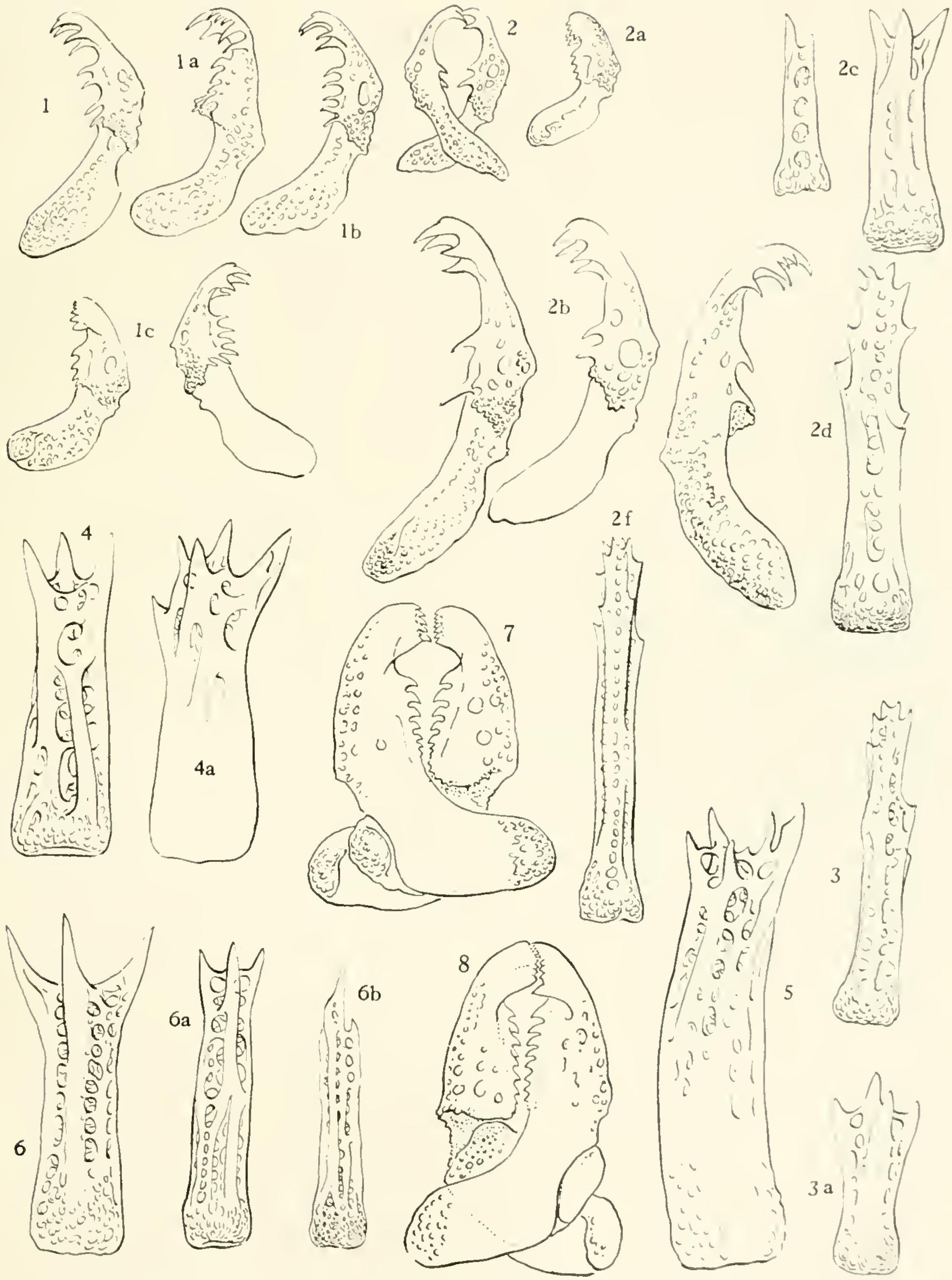
4, 4a. *Pedicellaster magister megalabis*, station 4333, ×100. Abactinal spinelets, median radial area; 4 = 0.5 mm.

5. *Pedicellaster magister orientalis*, ×100. Abactinal spinelet, 0.7 mm. long.

6, 6a, 6b. *Pedicellaster magister*, station 4792, ×100. Abactinal spinelets from radial region; 6 = 0.55 mm.

7. *Hydrasterias improvisa* (Ludwig), station 3400. Crossed pedicellaria, ×200.

8. *Hydrasterias ophidion* Sladen, type. Crossed pedicellaria, 0.27 mm. ×200.



1, 5. PEDICELLASTER MAGISTER ORIENTALIS. 2, 6. P. MAGISTER. 3. P. TYPICUS. 4. P. MAGISTER MEGALABIS
7. HYDRASTERIAS IMPROVISA. 8. H. OPHIDION

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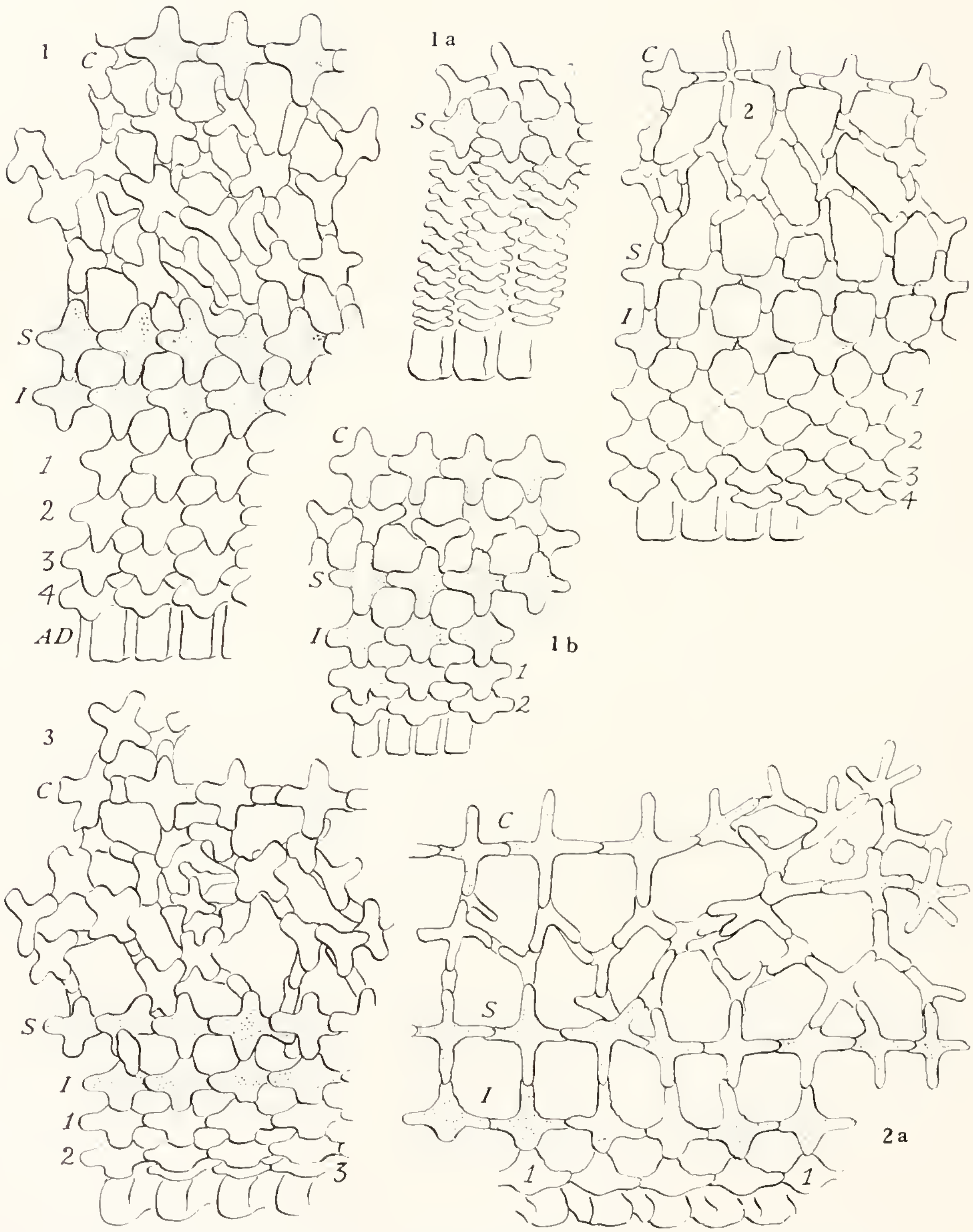

1. Pedicellaster magister. 2. P. magister megalabis. 3. P. magister orientalis

For explanation of plate see page facing

PLATE 28

FIG. 1. *Pedicellaster magister*, station 3488, × 8. Projection of skeleton of portion of base of ray; *C*, carinal plates; *S*, superomarginal; *I*, inferomarginal. *AA*, actinal; *AD*, adambulacrals; disk to left. 1*a*. Same, × 8. Middle portion of ray to show the increase in number of actinal plates in the transverse series; *S*, superomarginals. 1*b*. Same, station 4792, × 16. Small specimen, R 16 mm., to show single dorsolateral and two actinal series; lettering as in Figure 1; disk to left.

2. *Pedicellaster magister megalabis*, station 4333, R 45 mm.; × 8. Projection of skeleton for comparison with Figure 1; disk to left. 2*a*. Same, station 4333, × 16. Small example, R 19 mm. base of ray (disk to right), for comparison with 1*b*.

3. *Pedicellaster magister orientalis*, station 4867, off Matsushima, × 8. Projection of skeleton of base of ray, lettering as in 1; disk to left.

PLATE 29

FIG. 1. *Anteliaster coscinactis*, station 4427, ×10. Projection of skeleton of proximal part of ray, disk to left; *C*, carinal; *S*, superomarginal; *I*, inferomarginal; 1, 2, actinal; *AD*, adambulacral plates; the small circles indicate papulae. 1*a*. Same, ×25. Straight pedicellariae, 1 mm. long, side of ray. 1*b*. Same, ×10. Mouth angle. 1*c*. Same, actinal pedicellaria 0.4 mm., ×100. 1*d*. Abactinal pedicellaria 0.27 mm., ×100, and vertical series of shank teeth, ×200. 1*e*. Same. Abactinal spinelets, ×100.

2. *Anteliaster coscinactis megatretus*, station 5675, ×100. Abactinal pedicellaria. 2*a*. Actinal pedicellaria 0.45 mm. 2*b*. Two abactinal spinelets.

3, 3*a*. *Anteliaster microgenys nannodes*, station 4770, ×50. Straight pedicellariae from oral plates; 3 shows inside view of cleaned valve. 3*b*. Three abactinal spinelets, ×100. 3*c*, 3*d*. Abactinal crossed pedicellariae, 0.2 mm., ×100; 3*e*, ×200.

1. ANTELIASTER COSCINACTIS. 2. A. COSCINACTIS MEGATRETUS. 3. A. MICROGENYS NANNOOES

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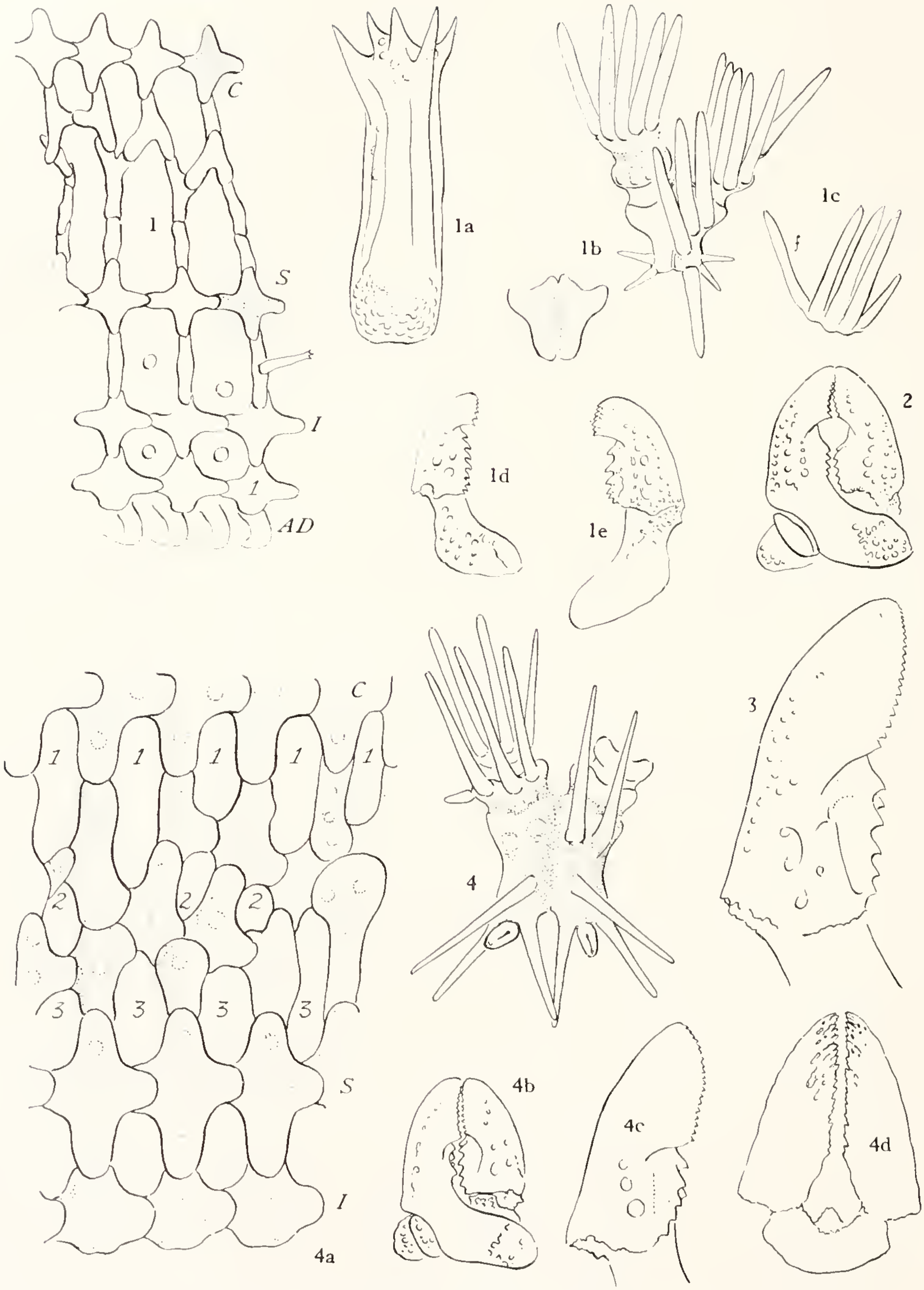

1. Anteliaster microgenys. 2. Tarsaster stoichodes. 3. T. cocosanus. 4. T. alaskanus

For explanation of plate see page facing

PLATE 30

FIG. 1. *Anteliaster microgenys*, station 2951, ×10. Projection of abactinal skeleton of a portion of base of ray; *C*, carinal series; *S*, superomarginal; *I*, inferomarginal; 1, actinal; *AD*, adambulacral. 1*a*. Abactinal spinelet, ×100. 1*b*. Oral angle of type, ×10. On left, armature of first adambulacral has been removed. Denuded mouth plates are shown. 1*c*. Armature of eighth adambulacral plate, ×10; *f*, furrow spinelet. 1*d*, 1*e*. Crossed pedicellariae.

2. *Tarsaster stoichodes* Sladen, type, ×100. A crossed pedicellariae, 0.32 mm.

3. *Tarsaster cocosanus*, ×200, abactinal pedicellaria.

4. *Tarasater alaskanus*, station 4230, ×10. Oral angle, including first 2 pairs of adambulacrals. 4*a*. Projection of skeleton of basal portion of ray, ×10. 1 adradial longiseries of meshes; 2, intermediate dorsolateral series; 3, supramarginal series; letters as in fig. 1. 4*b*. Crossed pedicellaria, 0.31 mm., ×100. 4*c*. A jaw, ×200. 4*d*. Straight pedicellaria from adambulacral plate, 0.12 mm., ×100.

PLATE 31

FIG. 1. *Tarsaster galapagensis*, ×200. Two jaws of crossed pedicellariae. 1*a*. An intermarginal straight pedicellaria, 0.36 mm., ×100. 1*b*. Internal view of a jaw.

2. *Ampheraster marianus*, station 4427, ×10. Oral angle. 2*a*. Oral angle of largest specimen showing narrower mouth plates, ×10. 2*b*. Same. Abactinal crossed pedicellariae, 0.32 to 0.36 mm., ×100. 2*c*. A jaw, ×200. 2*d*. Abactinal straight pedicellariae, 0.50 mm., ×50. 2*e*. A furrow pedicellaria (1.26 mm.) from largest specimen, ×50. 2*f*. Straight pedicellaria, station 4427, 0.9 mm., ×50.

3, 3*a*. *Ampheraster chiroplus*, station 4427, ×100. Two crossed pedicellariae, 0.36 and 0.3 mm. 3*b*, 3*c*. Same. Two straight pedicellariae (1.1 and 1.2 mm.) from side of ray, ×25. 3*d*. Same, ×10. Oral angle and skeleton of same on right.

4. *Ampheraster atactus*. Oral angle of type, ×10.

1. TARSASTER GALAPAGENSIS. 2. AMPHERASTER MARIANUS. 3. A. CHIROPLUS. 4. A. ATACTUS

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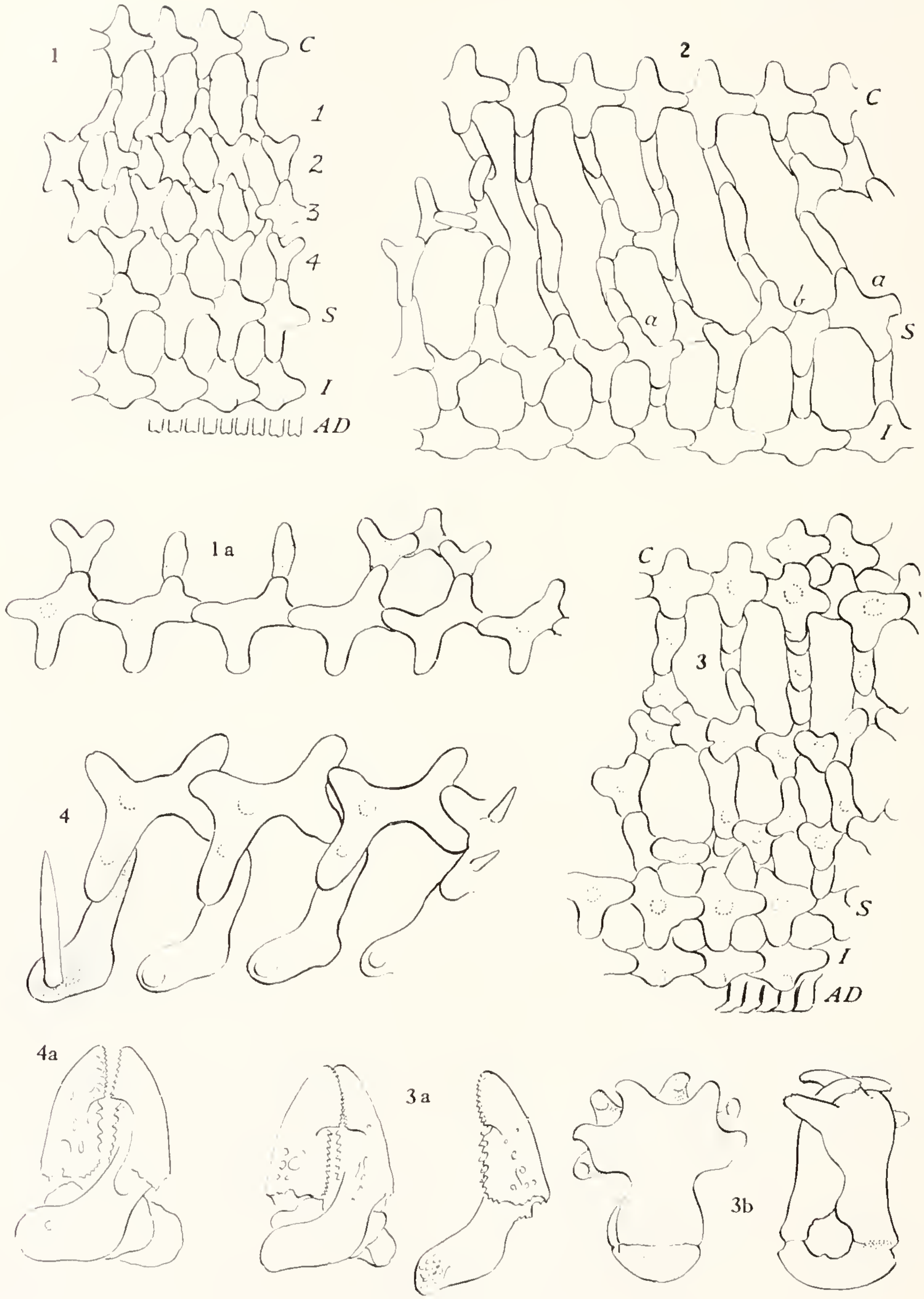

1. AMPHERASTER MARIANUS. 2. A. CHIROPLUS. 3. A. ATACTUS. 4. A. HYPERONCUS

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Plate 32

Fig. 1. *Ampheraster marianus*, station 4427, ×5. Projection of skeleton of portion of base of ray, disk to right; *C*, carinals; 1–4, dorsolateral longiseries; *S*, *I*, marginals; *AD*, adambulacrals. 1*a*. Same, station 4407, R 48 mm., ×10. Six superomarginal plates from middle of ray to show distortion; adjacent dorsolaterals, dotted; disk to left.

2. *Ampheraster chiroplus*, station 4427, ×10. Projection of skeleton of portion of base of ray; *C*, carinals; *S*, superomarginals; *I*, inferomarginals; *a*, *b*, *a*, formation of four-lobed plates from ⅄ and Y plates; disk to right.

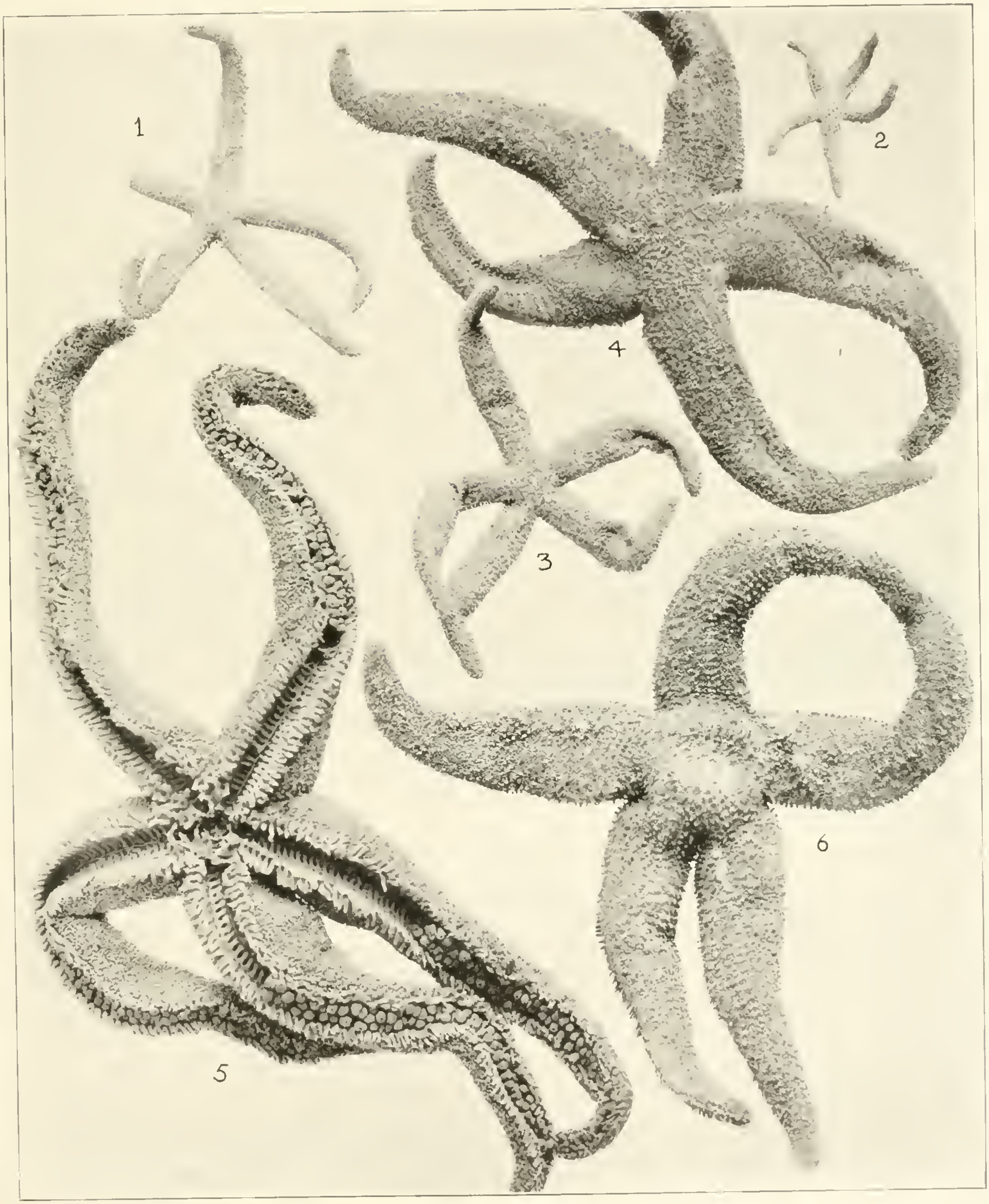
3. *Ampheraster atactus*, type, ×5. Skeleton of portion of ray near middle, disk to right; lettering as in fig. 1. 3*a*. Two crossed ped. 0.32 mm., ×100. 3*b*. Same. Two straight pedicellariae, 1.26 mm., ×25.

4. *Ampheraster hyperoncus*, ×10. Marginal plates, just beyond middle of ray, to show characteristic form; disk to left. 4*a*. Crossed pedicellaria, 0.34 mm., ×100.

PLATE 33

Pedicellaster magister, $\times 1\frac{3}{4}$

FIGS. 1 and 2. Young stages, station 4792.
3. Station 4791.
4. Station 3224.
5. Type, station 4792.
6. Station 3258.



PEDICELLASTER MAGISTER

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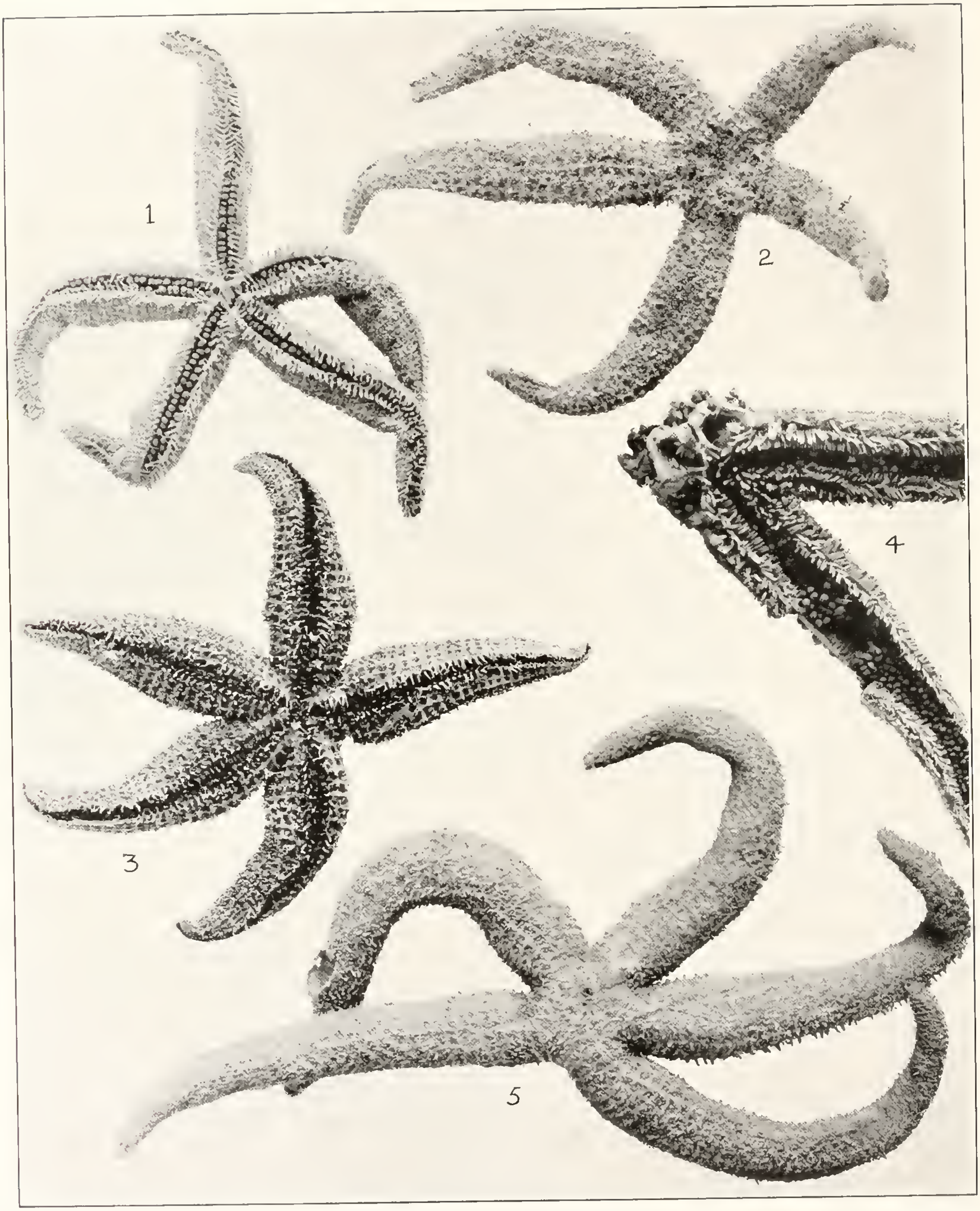

1. PEDICELLASTER MAGISTER. 2, 3. P. MAGISTER MEGALABIS. 4. APHANASTERIAS PYCNOPODIA. 5. P. MAGISTER ORIENTALIS

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PLATE 34

All figures slightly less than × 2

FIG. 1. *Pedicellaster magister*, actinal view, station 4791.

2. *Pedicellaster magister megalabis*, type.

3. Same, station 2892.

4. *Aphanasterias pycnopodia*, type. (This figure will be repeated in part 3, where species will be described.)

5. *Pedicellaster magister orientalis*, type.

PLATE 35

All figures except 1, $\times 1\frac{4}{5}$

FIG. 1. *Ampheraster marianus*, station 4407. Actinostome, enlarged.
2. *Ampheraster chiroplus*, type.
3. *Anteliaster microgenys*, type, station 2951.
4. *Anteliaster microgenys nannodes*, cotype, station 4770.
5. *Anteliaster coscinactis megatretus*, type. *5a*. Same specimen; actinal view of a detached arm.
6. *Anteliaster coscinactis*, type, station 4427.

1. Ampheraster marianus. 2. A. chiroplus. 3. Anteliaster microgenys. 4. A. microgenys nannodes. 5. A. coscinactis megatretus. 6. A. coscinactis

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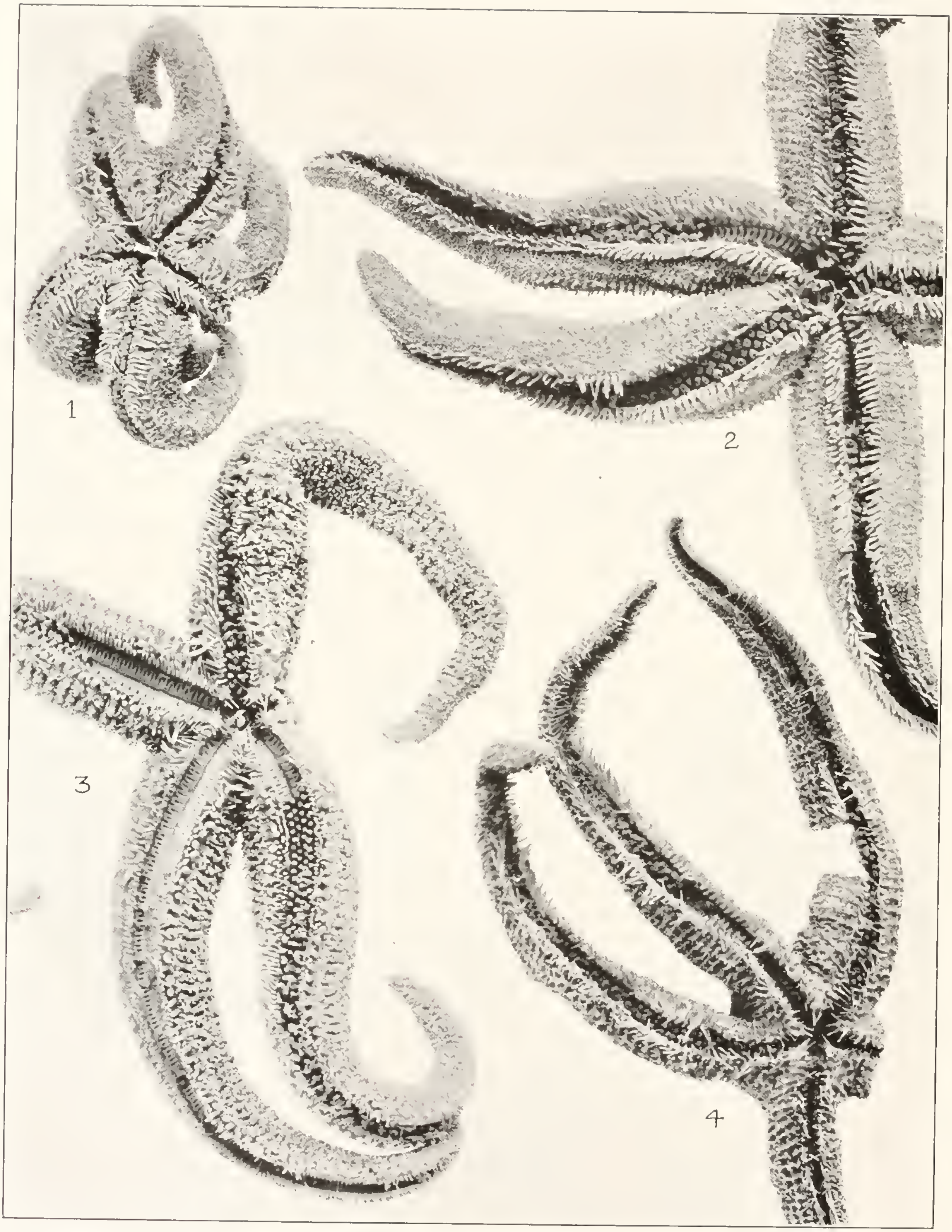

1. ANTELIASTER MICROGENYS. 2. PEDICELLASTER MAGISTER. 3. TARSASTER ALASKANUS. 4. ANTELIASTER COSCINACTIS

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PLATE 36

All figures $\times 1\frac{4}{5}$

FIG. 1. *Anteliaster microgenys*, type, actinal.
2. *Pedicellaster magister*, station 3258
3. *Tarsaster alaskanus*, type, actinal.
4. *Anteliaster coscinactis*, type, actinal.

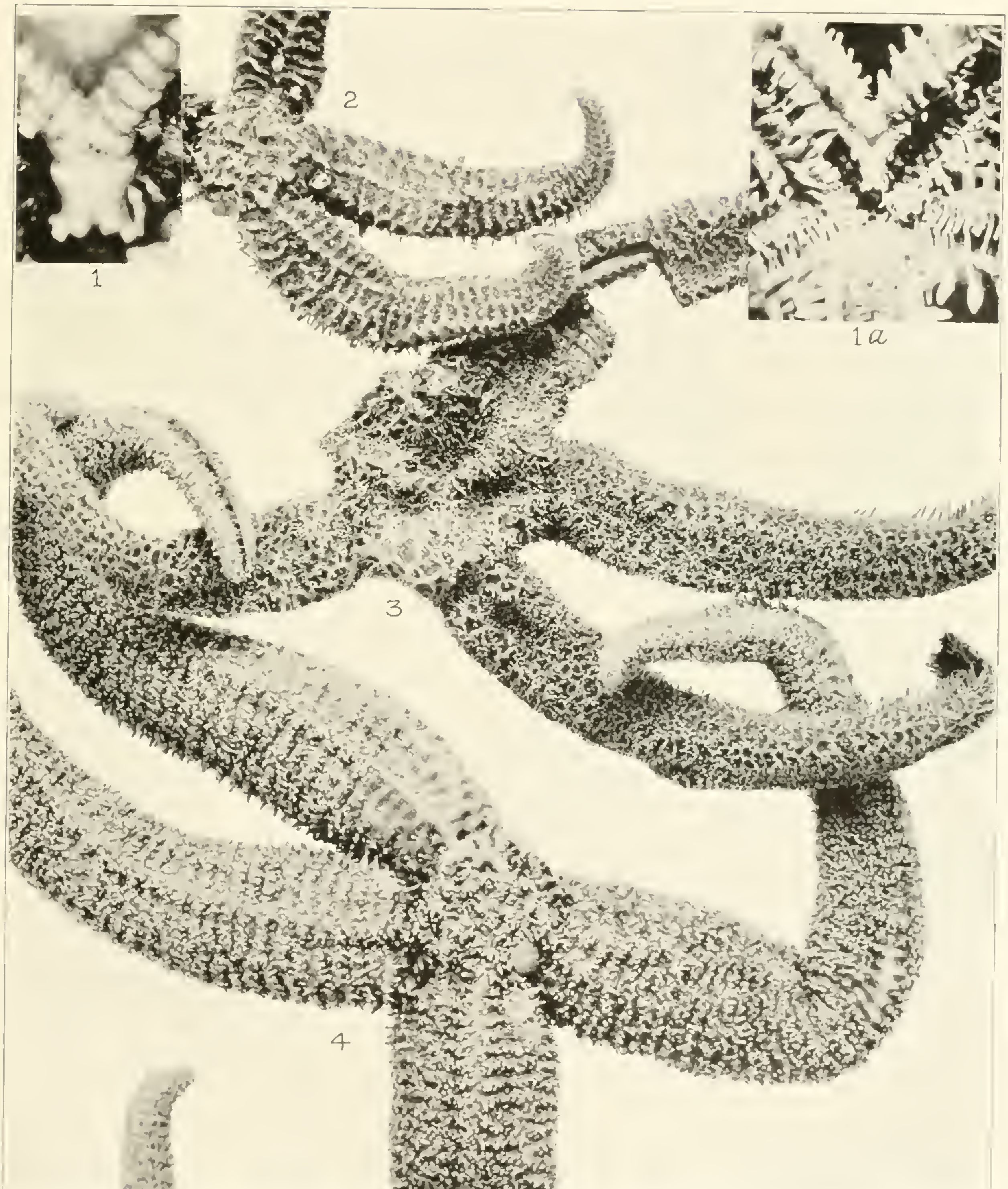
PLATE 37

FIG. 1. *Tarsaster stoichodes* Sladen, type. One oral angle, much enlarged. 1*a*. Same specimen, actinal surface.

2. *Ampheraster chiroplus*, type, $\times 2\frac{2}{3}$.

3. *Anteliaster coscinactis*, type, $\times 2\frac{2}{3}$.

4. *Tarsaster alaskanus*, type, $\times 2\frac{2}{3}$.



1. Tarsaster stoichooes. 2. Ampheraster chiroplus. 3. Anteliaster coscinactis. 4. Tarsaster alaskanus

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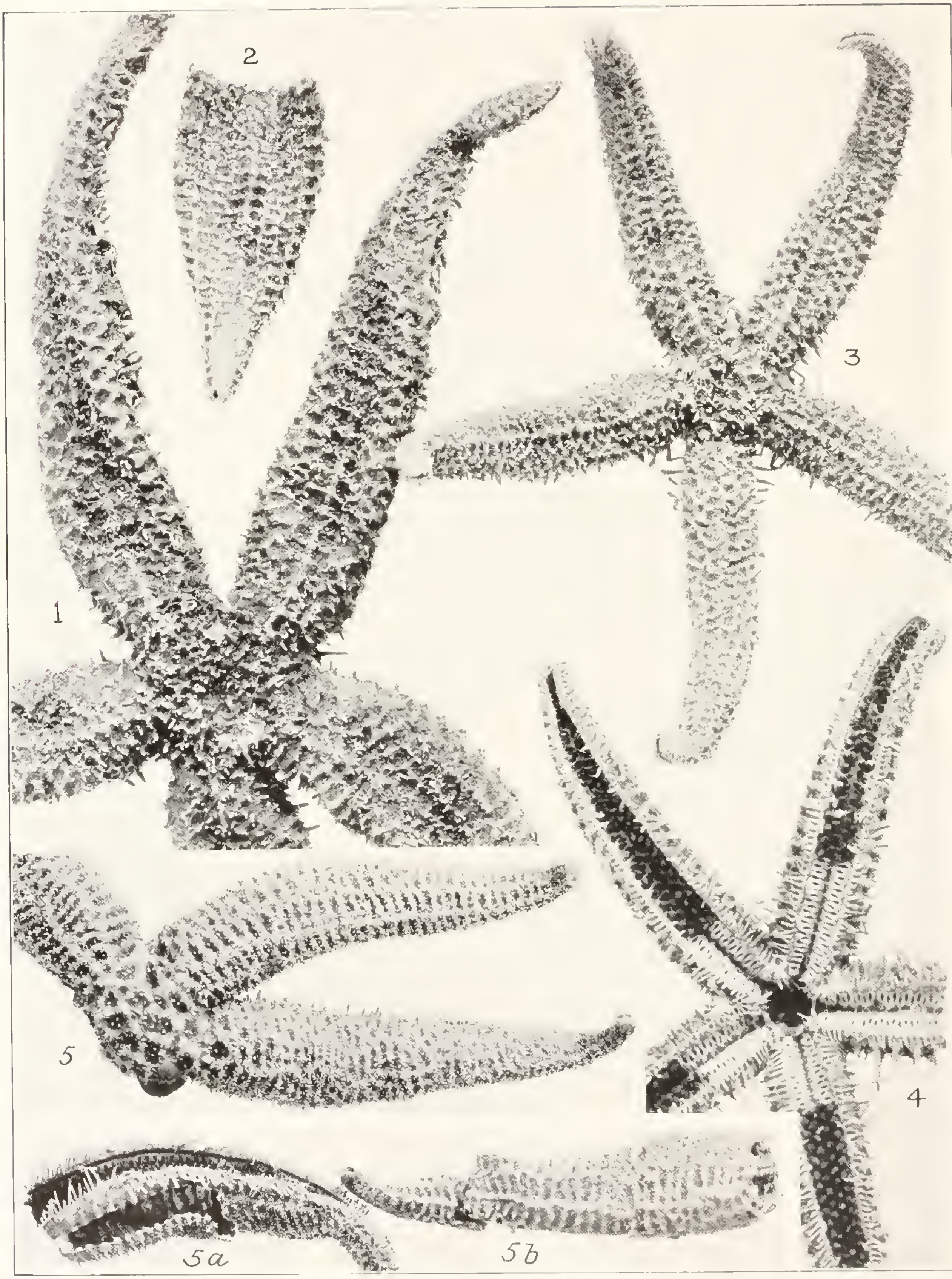

1-4. AMPHERASTER MARIANUS. 5. A. ATACTUS

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Plate 38

Fig. 1. *Ampheraster marianus*, station 2896, enlarged slightly less than two times.

2. Abactinal wall of a ray flattened to show plates.

3. *Ampheraster marianus*, station 4427, × slightly less than 2.

4. *Ampheraster marianus*, station 4407, actinal surface, × slightly less than 2.

5. *Ampheraster atactus*, type, station 4241, × $1\frac{3}{5}$. *5a*, *5b*. Same specimen, detached rays × $1\frac{3}{5}$.

PLATE 39

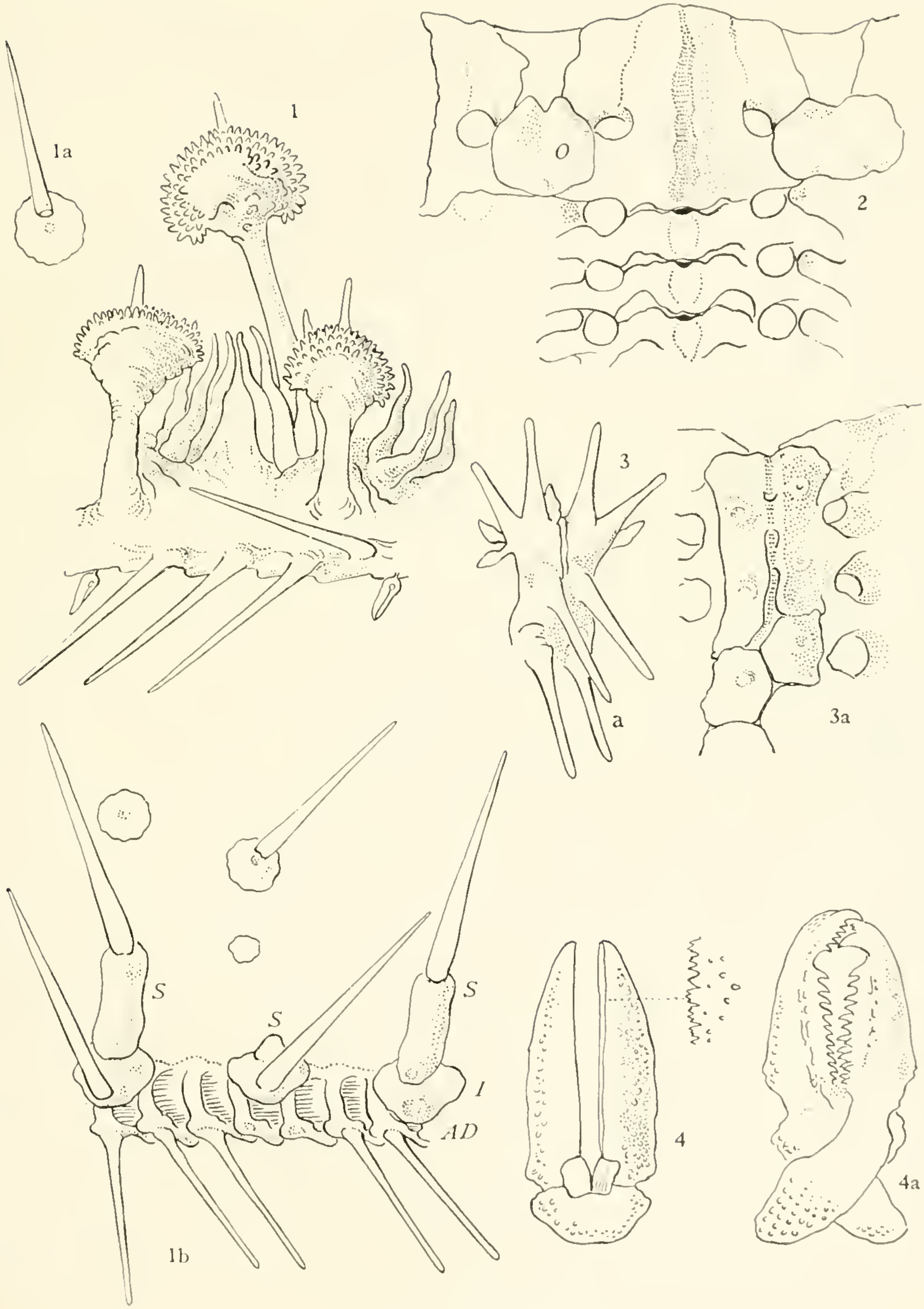
All figures *Rathbunaster californicus*

FIG. 1. Marginal and adambulacral spines at middle of ray, viewed from side, ×10. The upper spine is a superomarginal; below are two inferomarginals; three groups of papulae. 1*a*. An isolated abactinal plate and spine, ×10. 1*b*. Arrangement of skeleton of side of ray at the end of proximal third, station 4339, ×10. Above are three isolated abactinal plates; *AD*, adambulacral plates; *I*, inferomarginals; *S*, superomarginals, the median rudimentary and without spine.

2. Section of actinostomial ring from above, ×10; *O*, odontophore

3. Mouth plates, and first adambulacrals (*AD*), ×5, station 2925. Some specimens have two suboral spines; less often there are three marginal spines per plate. 3*a*. Mouth plates and first adambulacrals, cleaned, ×10.

4. Straight pedicellaria, rather larger than usual, base of ray, station 3186, ×50. 4*a*. A crossed pedicellaria from superomarginal spine, 0.35 mm. long, ×150.



RATHBUNASTER CALIFORNICUS

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RATHBUNASTER CALIFORNICUS

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PLATE 40

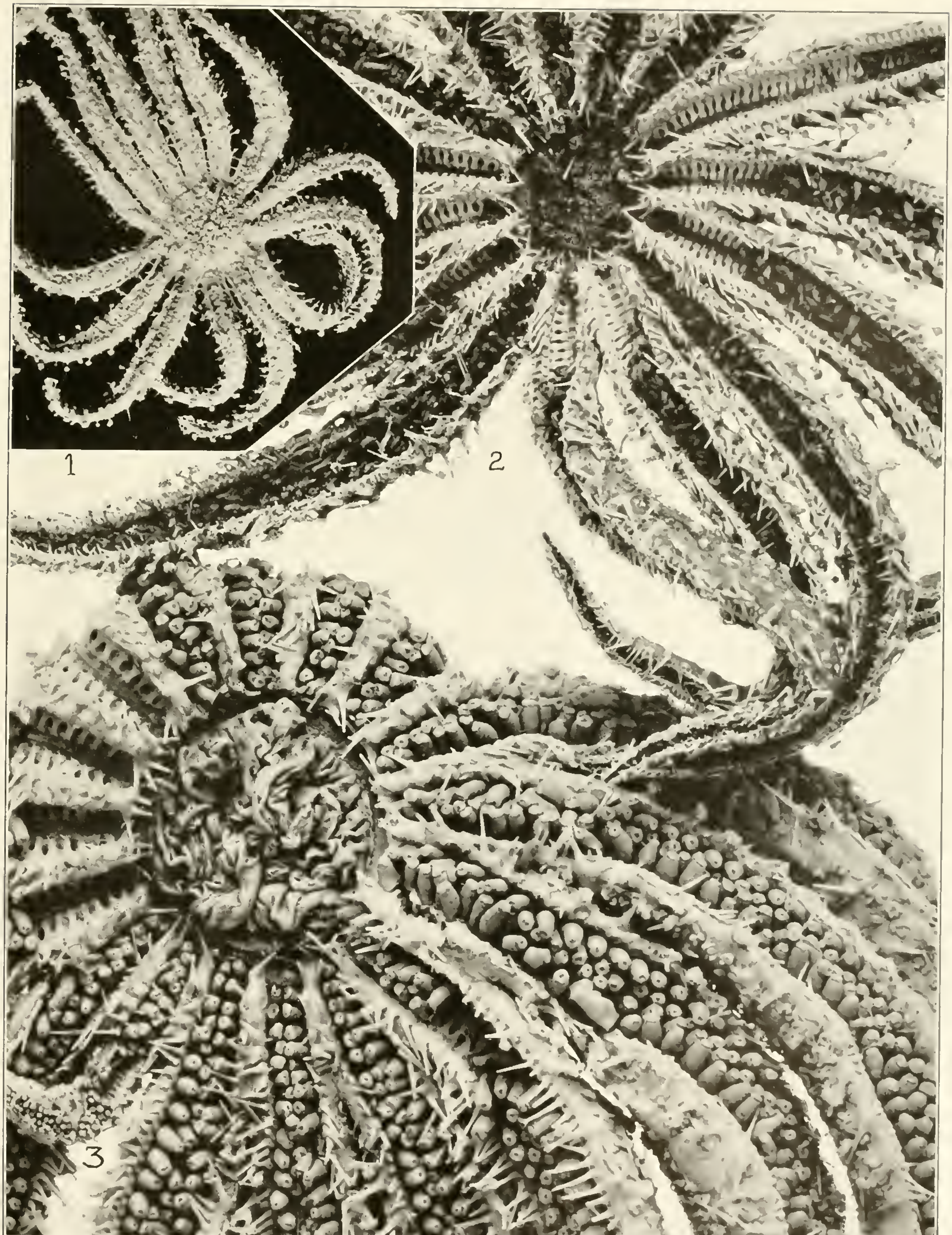
Rathbunaster californicus. $\times 1\frac{1}{4}$

FIG. 1. Dried specimen, station 3186.
2. Type, station 2925.

PLATE 41

Rathbunaster californicus

FIG. 1. Young example, station 4363, nat. size.
2. Dried specimen, actinal view, ×2.
3. Type, actinal view, ×2.



RATHBUNASTER CALIFORNICUS

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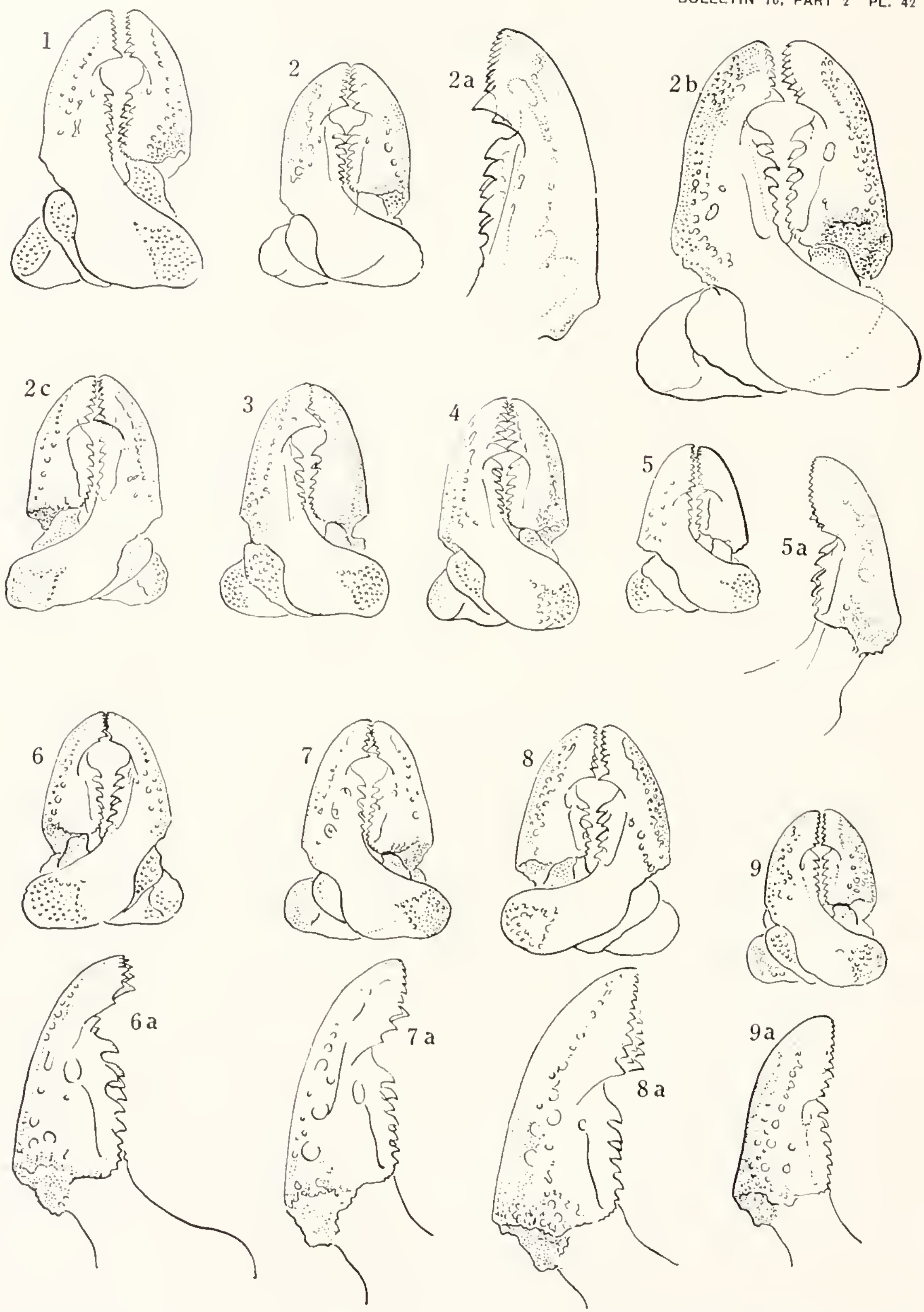


1. COSCINASTERIAS CALAMARIA. 2. C. ACUTISPINA. 3. C. TENUISPINA. 4. MARTHASTERIAS GLACIALIS. 5. AUSTRALIASTER DUBIUS. 6. ASTROSTOLE RODOLPHI. 7. A. PASCHAE. 8. A. SCABRA. 9. MEYENASTER GELATINOSUS

FOR EXPLANATION OF PLATE SEE PAGE FACING

Plate 42

Crossed pedicellariae of various Coscinasteriinae

Fig. 1. *Coscinasterias calamaria*, M. C. Z., No. 1872, 0.45 mm., ×100.

2. *Coscinasterias acutispina*, Wakanoura, Japan, 0.36 mm., ×100. *2a*. Jaw, ×200. *2b* Same, Ocean (Cure) Island, Bishop Museum, ×200. *2c*. Same, Yeddo Bay, Japan M. C. Z., No. 1182, ×100.

3. *Coscinasterias tenuispina*, Bermuda, ×100.

4. *Marthasterias glacialis*, Naples, 0.36 mm., ×100.

5. *Australiaster dubius* (Clark), Oyster Bay, Tasmania, ×100. *5a*. Jaw, ×200.

6. *Astrostole rodolphi* (Perrier), 0.35 mm., ×100. *6a*. A jaw, ×200.

7. *Astrostole paschae* (Clark), Easter Island, 0.34 mm., ×100. *7a*. A jaw, ×200.

8. *Astrostole scabra* (Hutton), Wellington, New Zealand, No. 1970, M. C. Z., ×100. *8a*. A jaw, ×200.

9. *Meyenaster gelatinosus* (Meyen), Chile, No. 1356, M. C. Z., 0.27 mm., ×100. *9a*. A jaw, ×200.

Plate 43

Details of the actinostomial ring of various Coscinasteriinae with especial reference to the odontophore (*O*) and the first ambulacral (*A*). The segment of the ring is viewed directly from above and the mouth plates are dotted to show their extent.

Fig. 1. *Astrostole scrabra* × 5.

2. *Sclerasterias heteropaes* × 10 (station 3110).

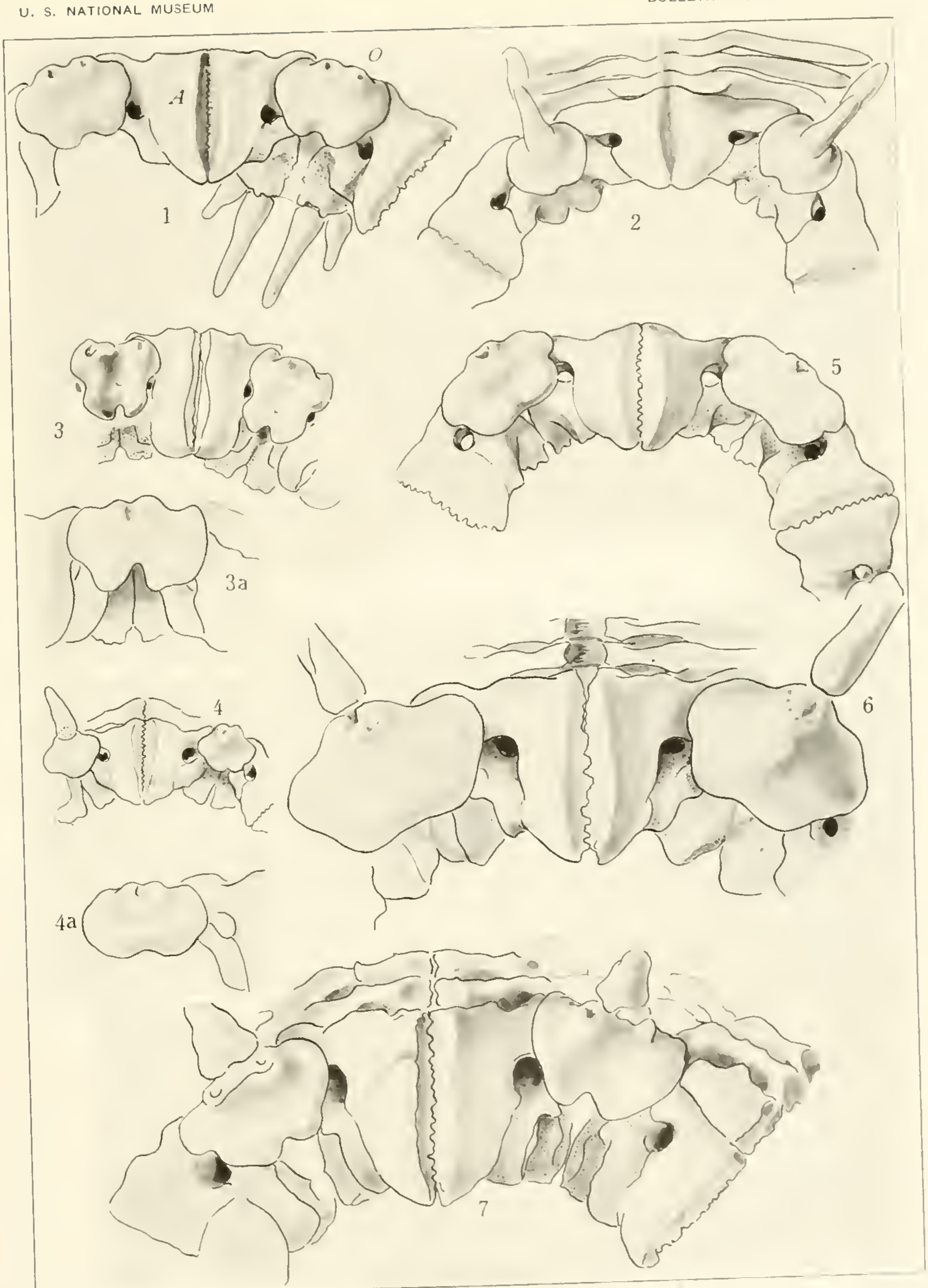
3. *Coscinasterias calamaria*, No. 1872, M. C. Z., Port Jackson, New South Wales, × 5. 3*a* Same, No. 1881, M. C. Z., Dunedin, New Zealand, × 10. These two figures show the wide variation in the odontophores which are frequently very irregular, sometimes with one, two, or several articulation points for the crowded interbrachial plates.

4. *Coscinasterias acutispina*, No. 1182, M. C. Z., Japan, × 5. 4*a*. *Coscinasterias tenuispina*, No. 2133, M. C. Z., Bermuda, × 10. These two figures are intended to show the broader first ambulacral plates of subgenus *Stolasterias* and the less variable odontophore with one articulation point for the interbrachial septum.

5. *Distolasterias nipon*, Hokkaido. × 10.

6. *Marthasterias glacialis*, No. 1261, M. C. Z., Fayal, × 10.

7. *Meyenaster gelatinosus*, No. 1256, M. C. Z., Talcahuano, Chile.



1. ASTROSTOLE SCABRA. 2. SCLERASTERIAS HETEROPAES. 3. COSCINASTERIAS CALAMARIA. 4. C. ACUTISPINA. 5. DISTOLASTERIAS NIPON. 6. MARTHASTERIAS GLACIALIS. 7. MEYENASTER GELATINOSUS

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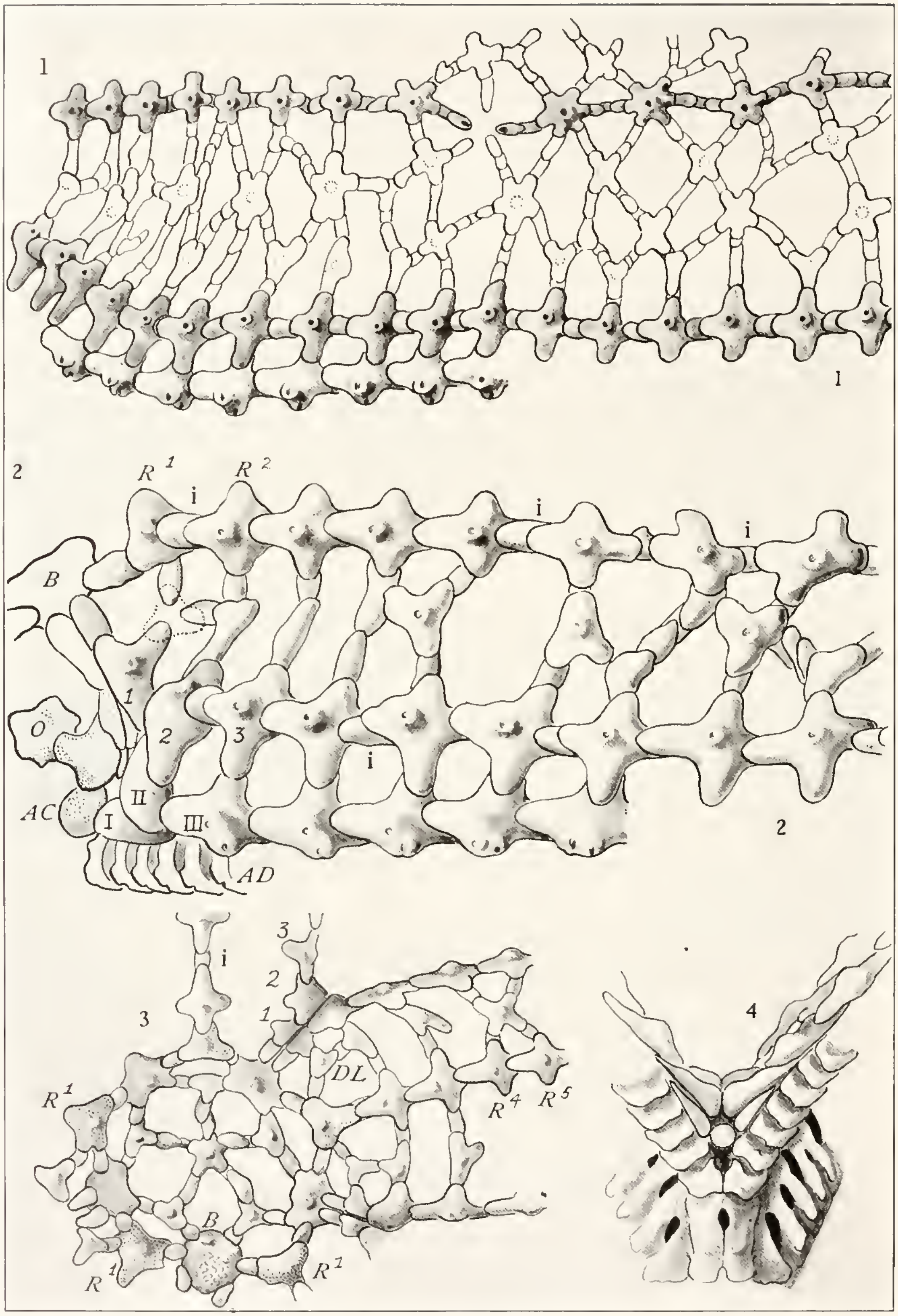

STYLASTERIAS FORRERI

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Plate 44

Stylasterias forreri

Fig. 1. Skeleton of base of ray of large specimen from Port Chester, southern Alaska. Above, the carinal, and below, the two marginal series are shaded. The intermediate secondary carinal and superomarginal ossicles are fully developed. The dorsolateral skeleton of lobed primary plates, joined by secondary ossicles, is shown without shading. The dots indicate spine attachments. In the carinal series one plate has been removed. ×2.

2. Skeleton of one side of base of ray of a young specimen from station 1555; R 32 mm., ×10. The intermediate carinal and superomarginal ossicles are beginning to appear (*i*). At the left the stippled plates are part of the interbrachial septum; one dorsolateral plate (dotted) removed to show connections. The homologous plate in fig. 3 is *DL*. *R 1*, *R 2*, first two carinal plates; 1, 2, 3, first three superomarginals; 1 is joined to *B*, the primary interradial plate of disk, by an intermediate ossicle (one of a pair as shown in fig. 3); I–III, first three inferomarginals; *AD*, adambulacrals; *AC* actinal intermediate (circular plate in figure 4); *O*, odontophore.

3. Dorsal skeleton of disk and base of ray of very young specimen, Monterey Bay; R 16 mm., ×10. The carinal intermediate plates are already beginning (*i*); first carinal (*R 1*) plates stippled; *R 4*, *R 5*, fourth and fifth plates of same series; *B*, madreporite on primary interradial plate; *DL*, first dorsolateral plate; 1–3, first three superomarginals.

4. Oral angle of same specimen as 3. ×10. The first pair of adambulacral plates only partly in contact on the interradial line; the round plate between second adambulacrals is *AC* of Figure 2. The apparent actinal on either side of this is the first inferomarginal.

Plate 45

Stylasterias forreri

Fig. 1, 1*a*. Large abactinal straight pedicellariae from large specimen, Kell Bay, Alaska; length 2.5 mm.; ×25. 1*b*. Same specimen as 1; smaller abactinal pedicellaria from skin of outer part of ray; length, 1.75 mm.; ×25.

2. Abactinal dermal pedicellaria, station 4556, Monterey Bay; length 2.3 mm.; ×25.

3, 3*a*. Same, from specimen from station 4110, off Santa Catalina Island; length of 3, 2.8 mm.; of 3*a*, 1.3 mm.; ×25.

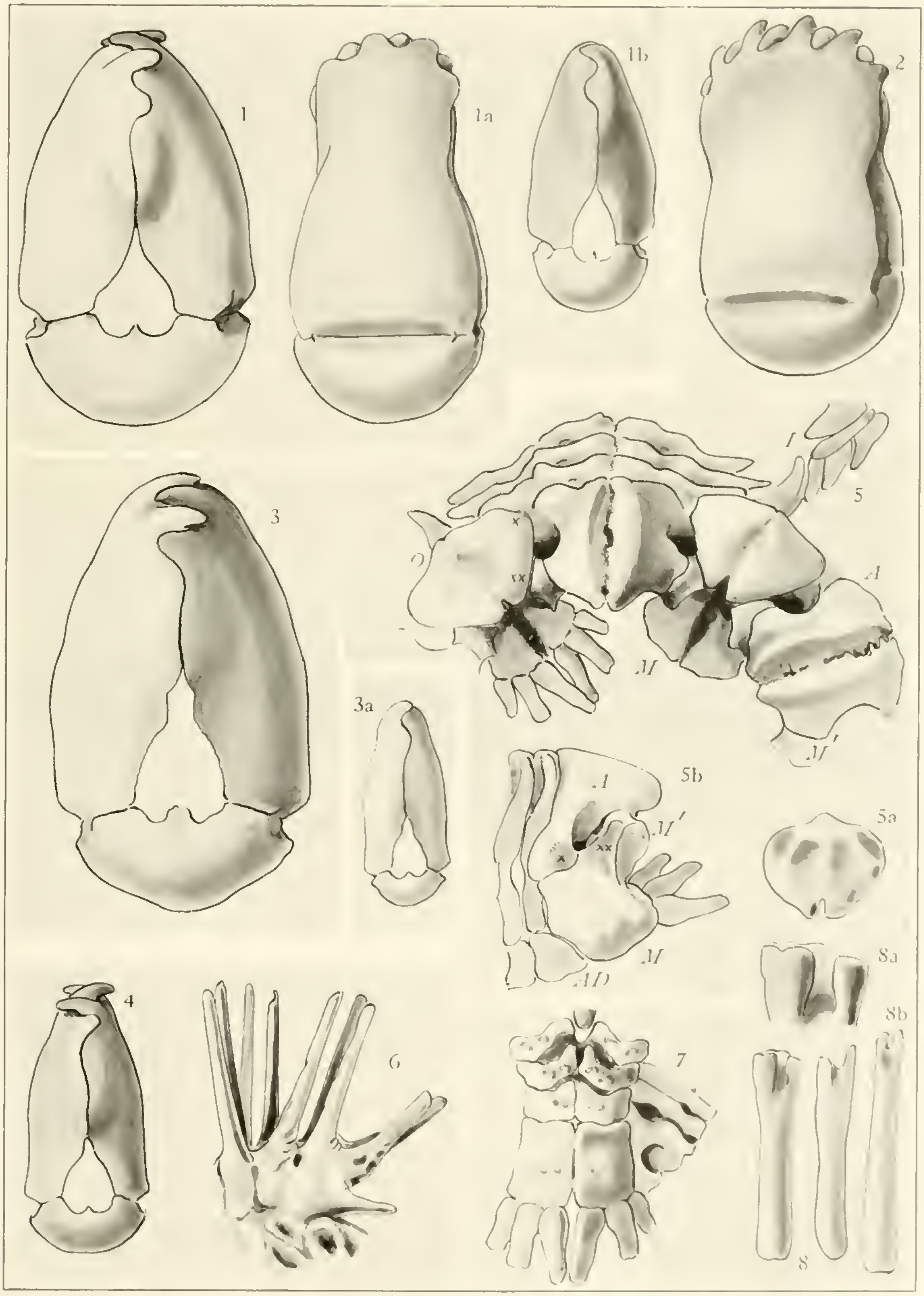
4. Specimen, from station 4552, having smaller dermal pedicellariae; length, 1.7 mm.; ×25.

5. Portion of a cleaned actinostomial ring, seen from inside, and looking out through actinostome into which two oral angles project, station 4552. ×5. *A*, enlarged first ambulacral ossicles; *I*, interbrachial pillar or septum; *O*, odontophore; *M*, oral plates; *M'*, dorsal apophysis of oral plate (see 5*b*). 5*a*. Ventral surface of an odontophore, ×5. 5*b*. Side view of first ambulacral ossicles with a single mouth plate (*M*); the median sutural face is exposed while *x* and *xx* are the junction points with the lateral facets of the odontophore (see fig. 5). The free edge, with three spines is turned away; *AD*, first adambulacral ossicle.

6. Mouth plates of an alcoholic specimen, station 4554, seen from furrow face; ×5.

7. Same specimen as fig. 5; cleaned mouth plates and first three pairs of adambulacrals; station 4552; R about 180 mm.; ×5.

8. Two inner inferomarginal spines from large specimen from Kell Bay, southern Alaska, ×5. 8*a*. End of left spine, ×10. 8*b*. An outer inferomarginal spine, ×5; all from proximal third of ray.



STYLASTERIAS FORRERI

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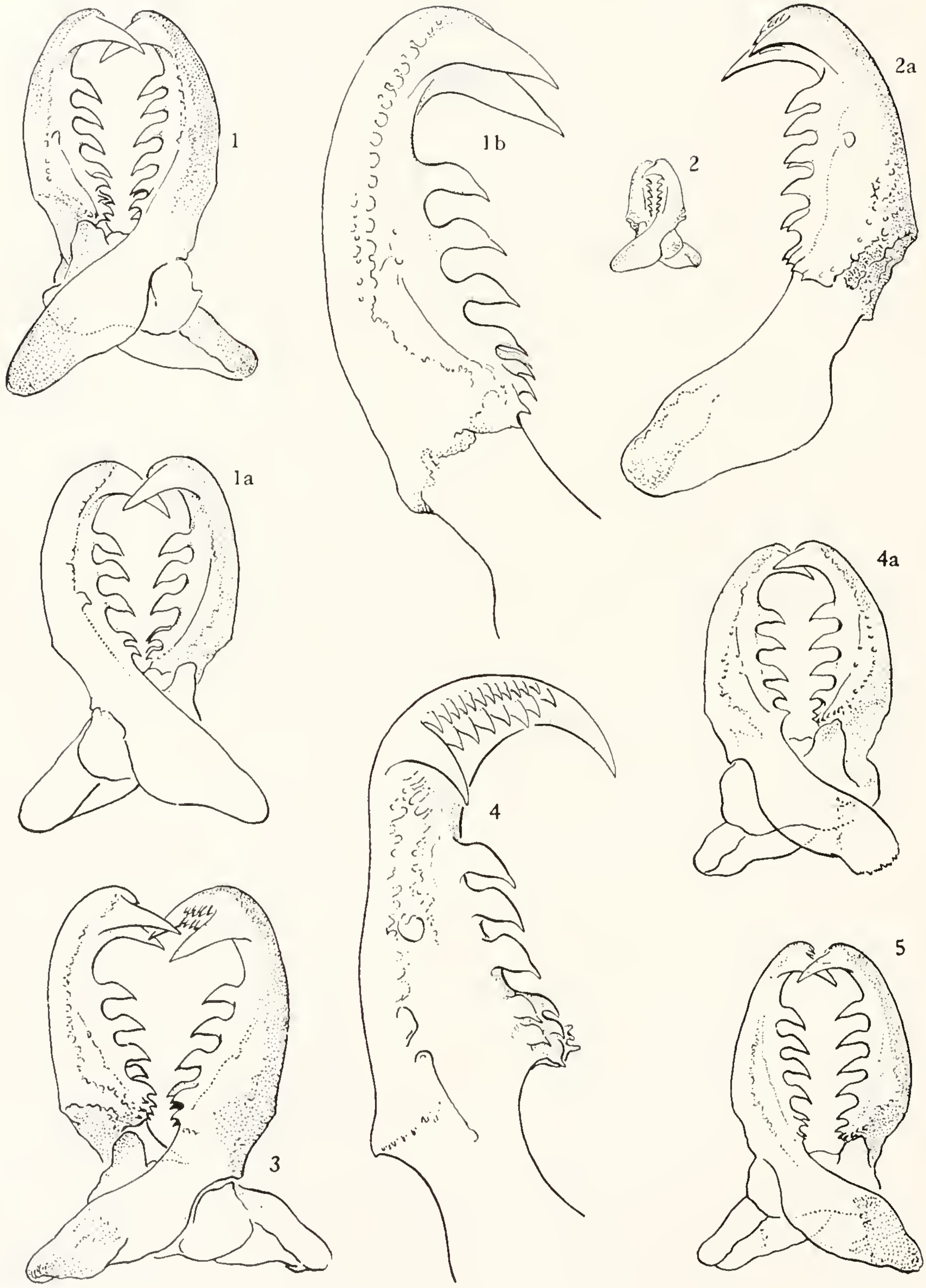


STYLASTERIAS FORRERI

FOR EXPLANATION OF PLATE SEE PAGE FACING

PLATE 16

Stylasterias forreri; all figures crossed pedicellariae from proximal dorsolateral region of ray

FIG. 1. Specimen from Kell Bay, Alaska; length 1.2 mm. ×50. 1*a*. Another distinct form from same specimen, length 1.12 mm. ×50. 1*b*. A jaw enlarged ×100 to show detail.

2. Pedicellaria from very young specimen (R 21 mm.), station 4551, drawn to same scale as fig. 1, 1*a*. 2*a*. A single jaw, same specimen, ×200. These pedicellariae varied from 0.315 to 0.35 mm. long.

3. Specimen from La Jolla, Calif., length 1.26 mm. (variations 0.95 to 1.3 mm.) ×50.

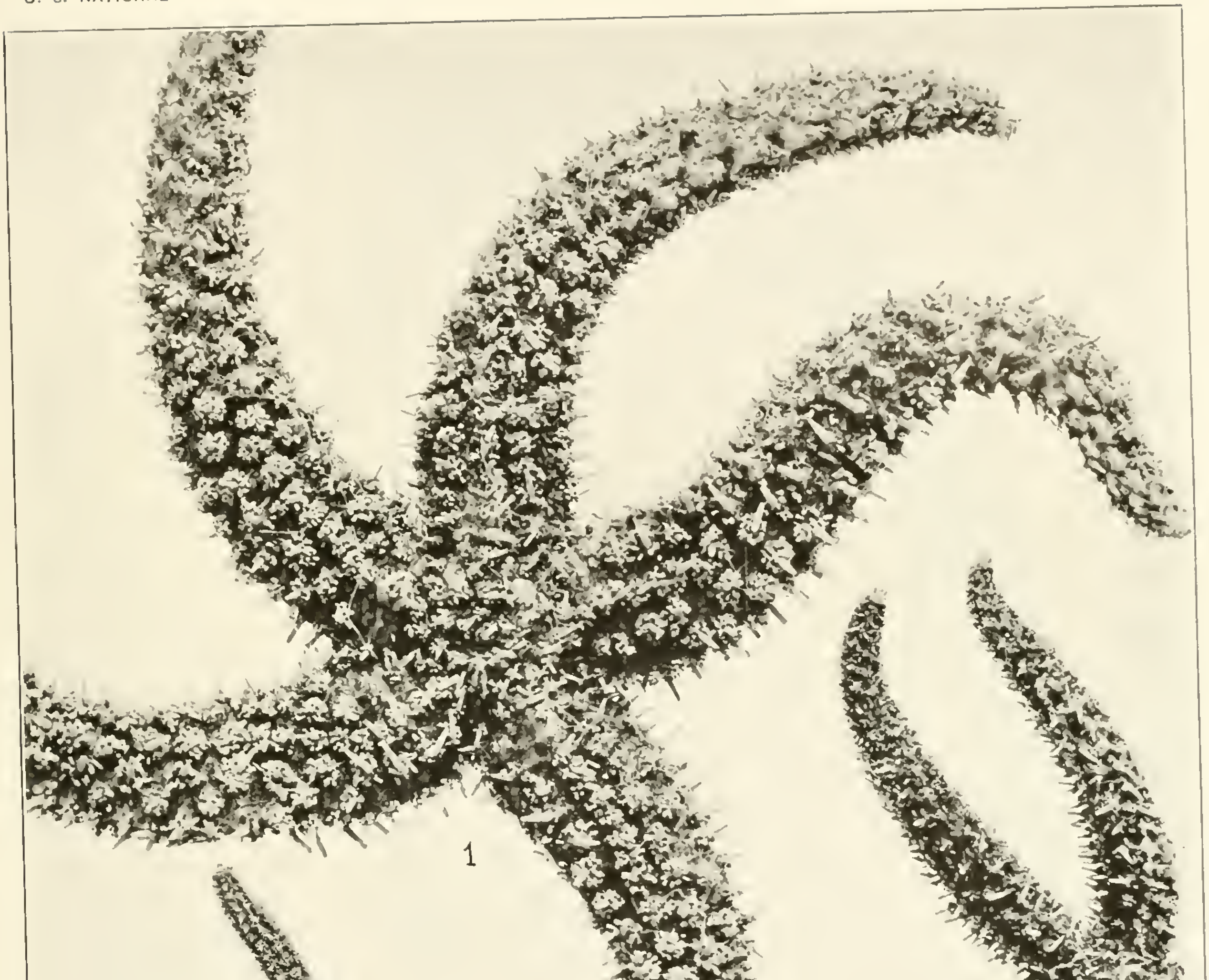
4. Specimen from station 4552, ×100. 4*a*. Same specimen, length 1.03 mm. ×50.

5. Specimen from station 4421, length 1.03 to 1.1 mm.

PLATE 47

Figures 1–3 *Stylasterias forreri* × 1.4

FIG. 1. Rather short-rayed medium-sized example from station 4535, Monterey Bay, Calif.
2. Young specimen from station 4552, Monterey Bay, Calif.
3. Young specimen from station 3108, vicinity of Half Moon Bay, San Mateo County, Calif.
4. *Orthasterias koehleri*, young specimen from station 3159; × 1.4.



1-3. Stylasterias forreri. 4. Orthasterias koehleri

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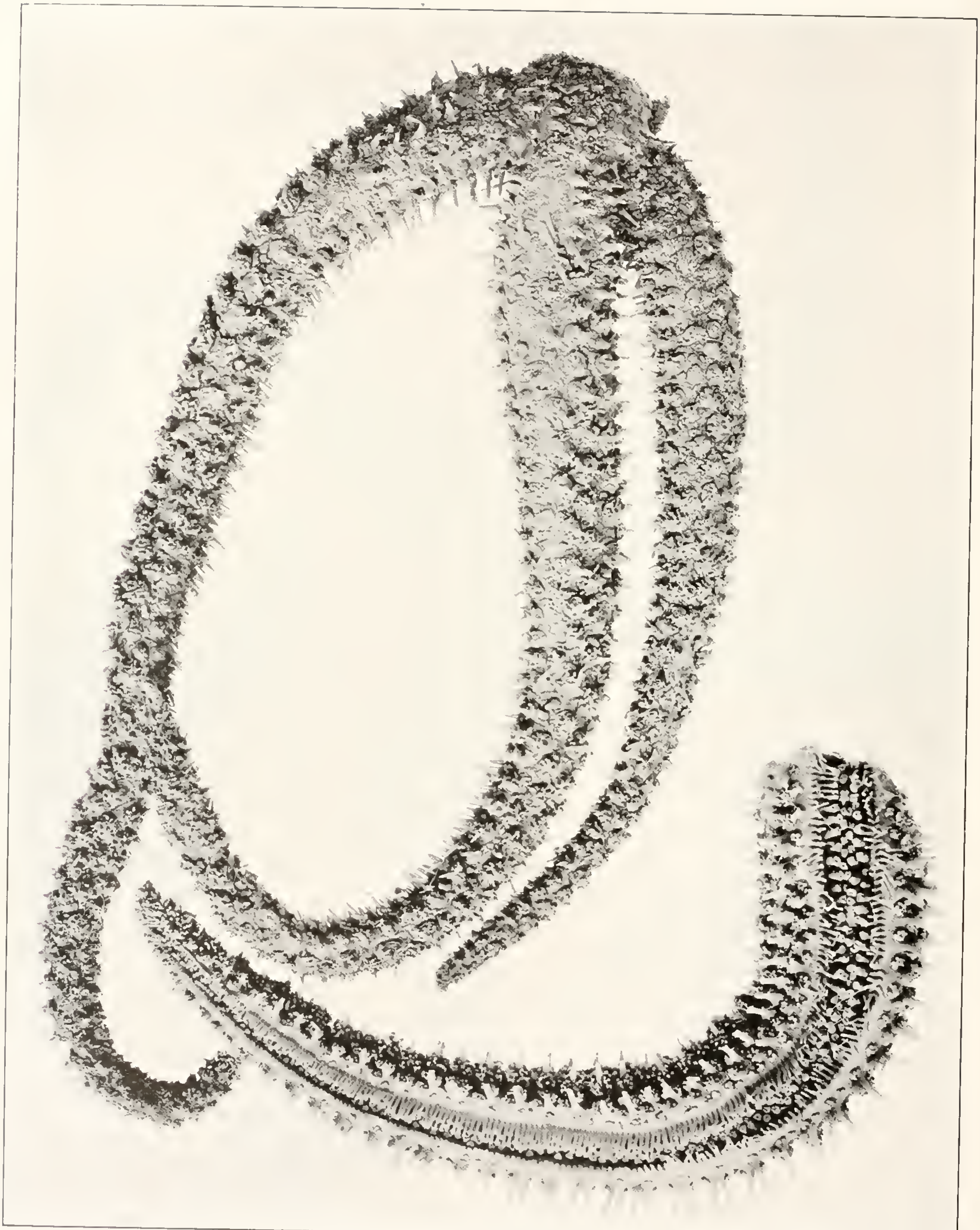


STYLASTERIAS FORRERI

For explanation of plate see page facing

PLATE 48

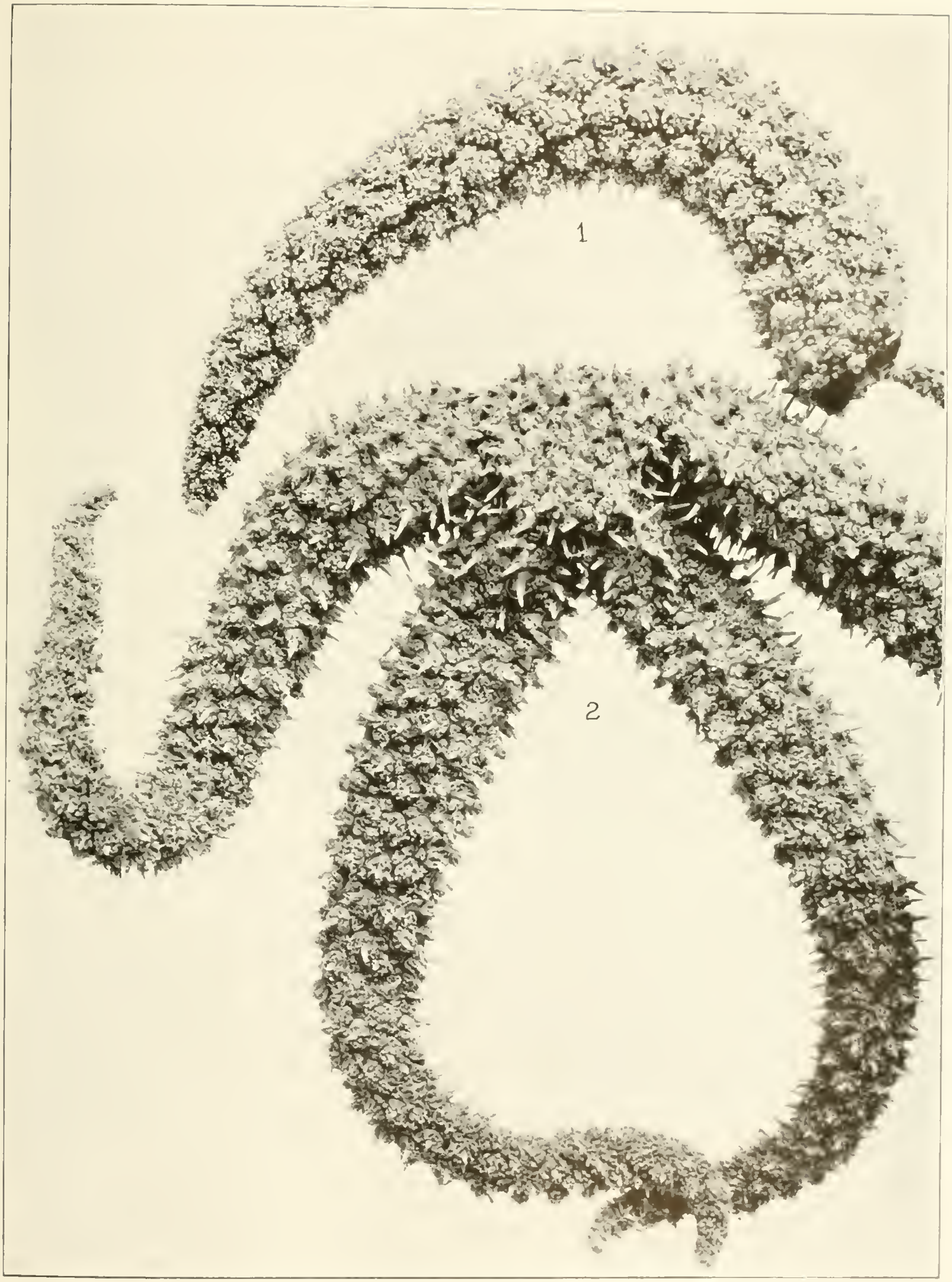
Stylasterias forreri, natural size

FIG. 1. Very slender rayed example from station 4410, mentioned in text.
2. Actinal surface of a single ray, off La Jolla, Calif.

PLATE 49

Stylasterias forreri, natural size

FIG. 1. Specimen from off La Jolla, Calif.
2. Specimen from station 4421.



STYLASTERIAS FORRERI

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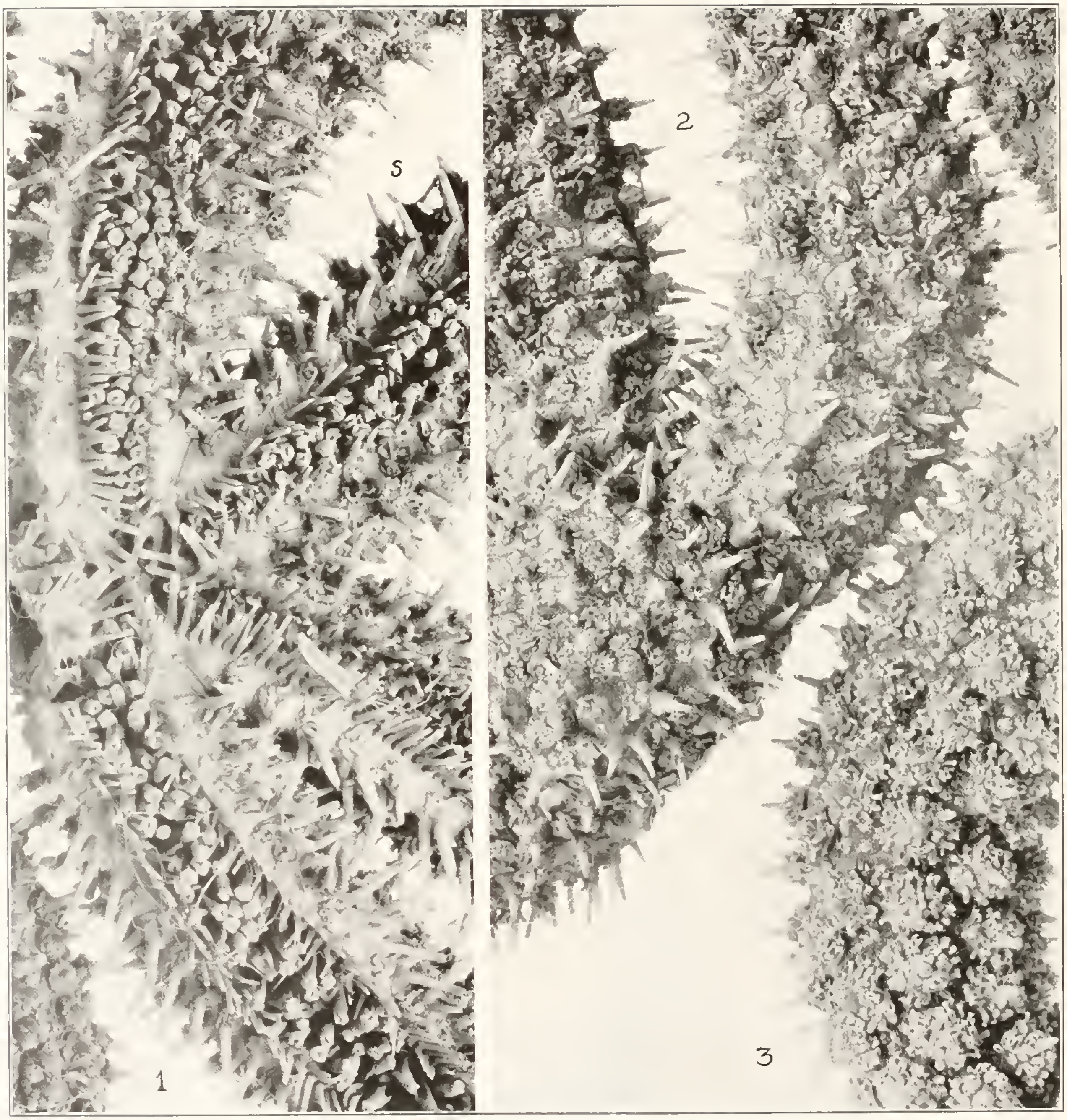


STYLASTERIAS FORRERI

FOR EXPLANATION OF PLATE SEE PAGE FACING

PLATE 50

Stylasterias forreri, ×2

FIG. 1. Actinal view of the specimen from station 4121, to show oral, adambulacral, and inferomarginal spines; *s*, pointed superomarginal spines, above double row of grooved inferomarginals.

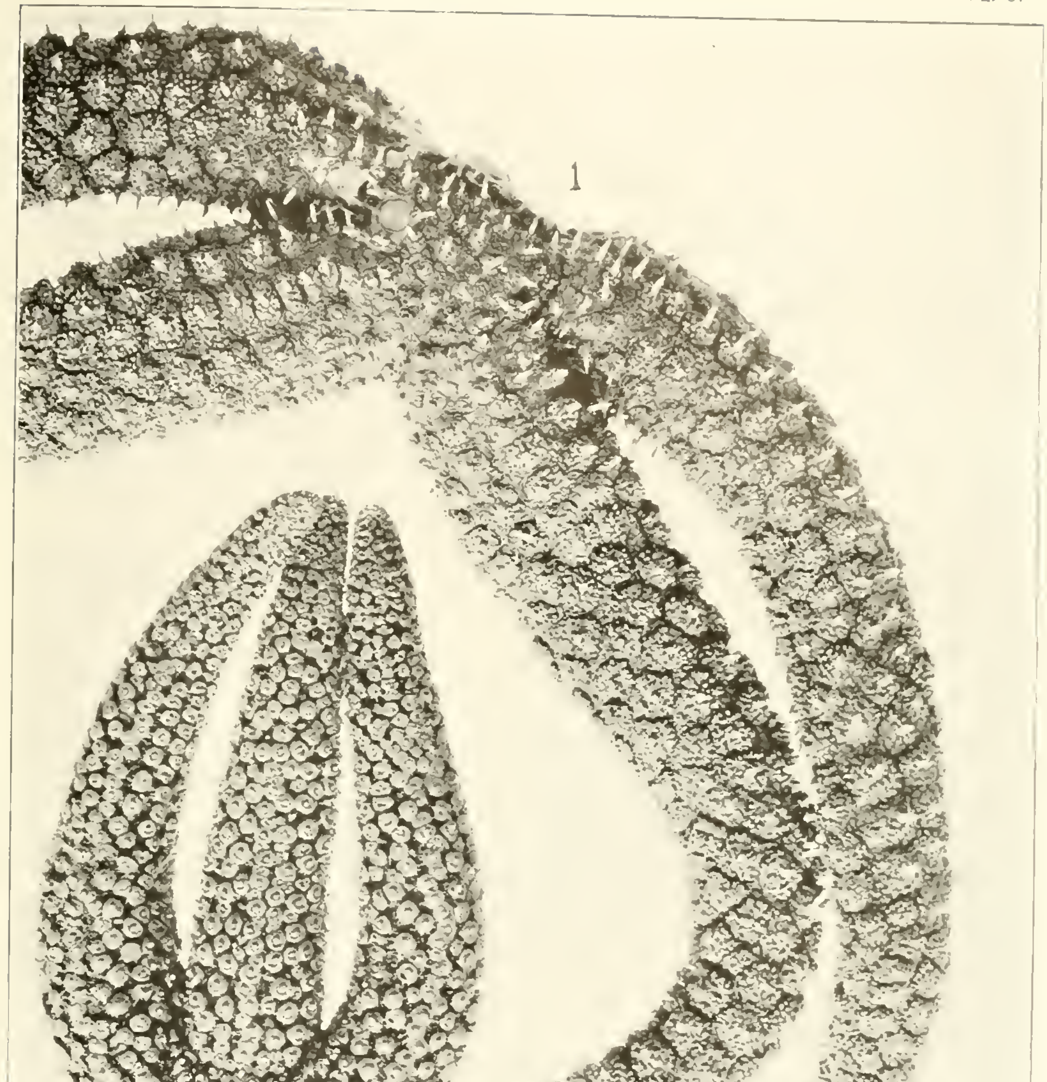
2. Abactinal view of portion of disk and two rays of same specimen. This example has fewer crossed pedicellariae than usual, and very few straight pedicellariae.

3. Abactinal surface of a portion of ray of La Jolla example, showing the abundant crossed pedicellariae.

PLATE 51

FIG. 1. *Stylasterias forreri*, large specimen from Port Chester ×4/5.

2. *Orthasterias koehleri* forma *montereyensis*, Pescadero Point, Carmel Bay, Calif., ×4/5.



1. Stylasterias forreri. 2. Orthasterias koehleri, forma montereyensis

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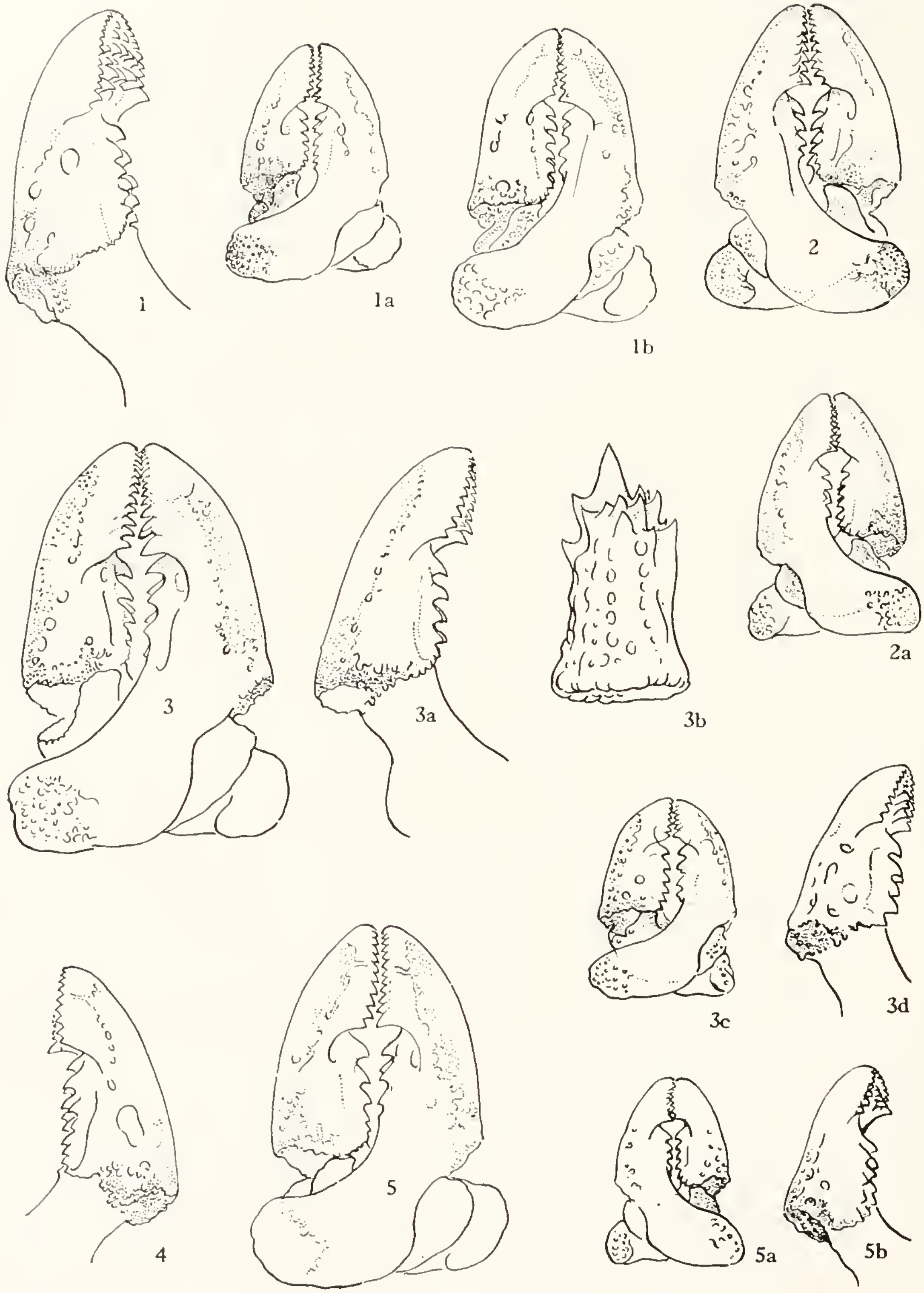


1. SCLERASTERIAS GUERNEI. 2. S. ALEXANDRI. 3. S. HETEROPAES. 4. S. HYPACANTHA. 5. S. EUPLECTA

FOR EXPLANATION OF PLATE SEE PAGE FACING

PLATE 52

FIG. 1. *Sclerasterias guernei* Perrier, paratype. A single jaw of an abactinal pedicellaria, ×300. *1a.* Same. Abactinal pedicellaria, 0.18 mm. long, ×200. The inferomarginal pedicellaria average 0.2 mm. long. Paratype. *1b.* Same. A specimen in the British Museum from Bay of Biscay; pedicellaria from inferomarginal spine, 0.22 mm. long, ×200.

2. *Sclerasterias alexandri* (Ludwig) paratype, station 3389. Abactinal pedicellariae, 0.25 mm. long, ×200. *2a.* Same, station 3397. Abactinal pedicellaria, 0.19 mm. long, from very young fissiparous specimen (= *Hydrasterias diomedeae* Ludwig), ×200.

3. *Sclerasterias heteropaes*, type, station 4554. An abactinal pedicellaria, 0.32 mm. long, ×200. *3a.* Same, station 4431. A single jaw; pedicellariae range from 0.26 to 0.34 mm. long, usually 0.31 mm., ×200. *3b.* Same. Abactinal spine from young fissiparous, six-rayed specimen, station 3341; R about 10 mm., ×200. *3c.* Same, station 4431. Pedicellaria from fissiparous, six-rayed young, with R 9.5. mm.; length 0.16 mm.; the pedicellariae vary from 0.12 to 0.16 mm. in length; ×200. *3d.* Same. A single jaw of such a pedicellaria, ×300.

4. *Sclerasterias hypacantha* (Fisher), station 5415. A single jaw, ×200.

5. *Sclerasterias euplecta* (Fisher), station 4062. Abactinal pedicellaria, 0.27 mm. long, ×200. *5a.* Same, station 3859. Abactinal pedicellaria from a very young fissiparous specimen with R 12 mm.; length 0.14 mm., ×200. *5b.* Same specimen; a single jaw, ×300.

Plate 53

FIG. 1. *Sclerasterias heteropaes*, young fissiparous phase, station 4431. Map of skeleton, base of ray, carinals above, inferomarginals below, the spots showing position of spinelets; base of ray to right; *C*, carinal plates; *tcp*, dorsolateral transverse connecting ossicles; S, superomarginals; *I*, inferomarginals. In this specimen R = 9.5 mm., the dorsolateral (adradial) plates have not yet developed; the superomarginal on extreme right is second of series; × 12.

1*a*. Same, a slightly larger fissiparous specimen with R = 11 mm., showing beginning of dorsolateral series (*DL*); superomarginal on extreme right is the second of series; × 12.

1*b*. Same, type, × 5. Diagram of the plates from inferomarginals to carinals, lettering as in 1 and 1*a*. Base of ray is on right, the first superomarginal shown being the twelfth. The pebbled areas are shown enclosed by dots. 1*c*. Same. Three inferomarginal and actinal plates seen from below; A, actinal plates; *AD*, adambulacrals.

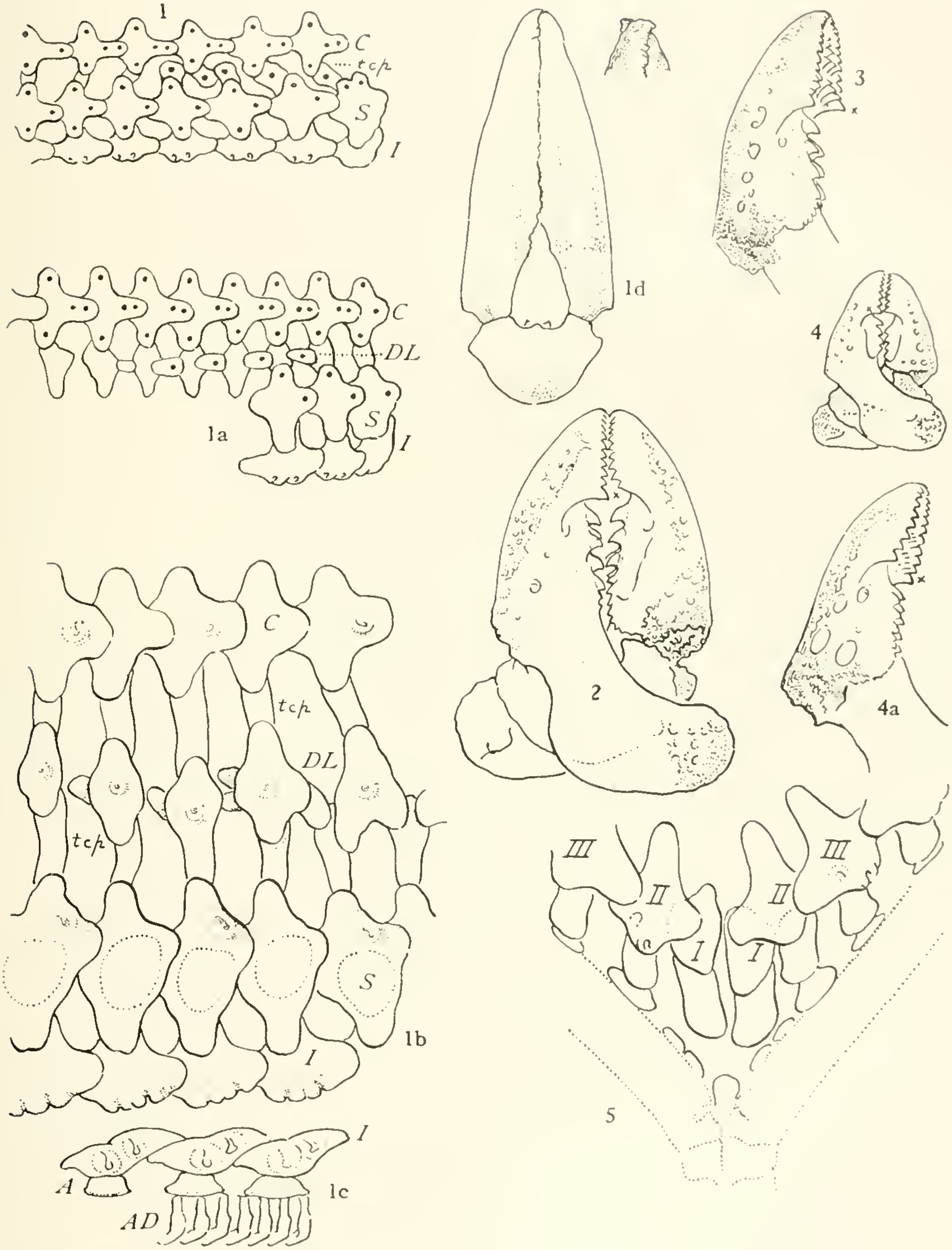
1*d*. Same. Actinal interradial straight pedicellaria from type, 0.6 mm. long, × 100, and tip of another.

2. *Sclerasterias tanneri*, crossed pedicellaria, station 2021, from abactinal spine, × 200 (0.28 mm. long).

3. *Sclerasterias contorta*, No. 1204, M. C. Z., off Barbados, inside of a single jaw to show enlarged lateral tooth, × 200.

4. *Sclerasterias mollis*, No. 1883, M. C. Z., Otago, New Zealand; abactinal pedicellaria, 0.27 mm. long, × 100. 4*a*. Same, single jaw, × 200.

5. *Stylasterias forreri*, station 4550. Plates of actinal interradial area, × 5; I., II., III., first to third inferomarginal plates; the others, actinals.



1. Sclerasterias heteropaes. 2. S. tanneri. 3. S. contorta. 4. S. mollis. 5. Stylasterias forreri

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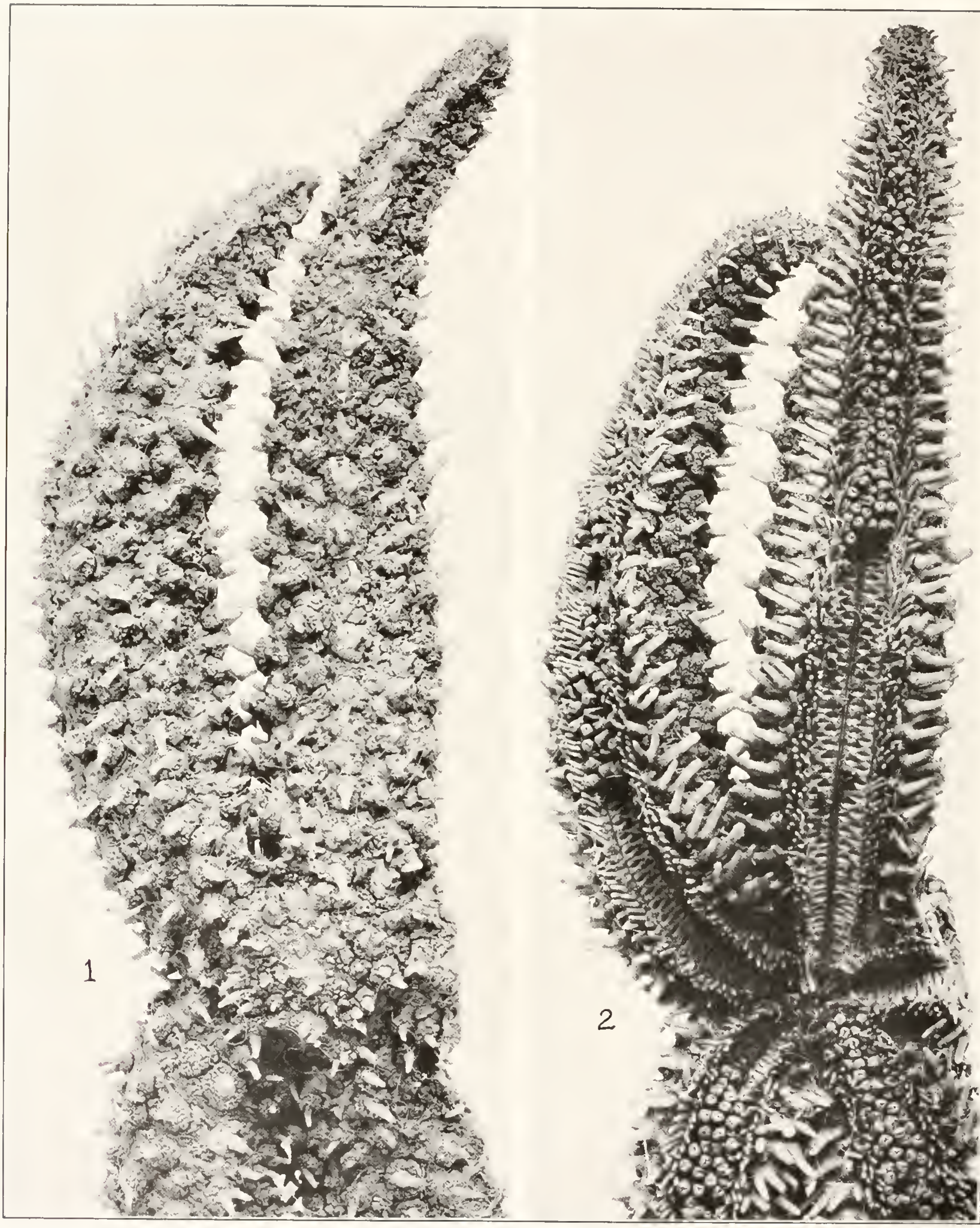

SCLERASTERIAS HETEROPAES

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PLATE 54

FIG. 1. *Sclerasterias heteropaes.* Abactinal view of type ×2.
2. Same, actinal view.

Plate 55

Fig. 1. *Astrometis sertulifera.* An abactinal straight pedicellaria 1.65 mm. long, from a La Jolla specimen, ×25. 1*a*. Same; an intermarginal pedicellaria from a specimen labeled Half Moon Bay, California; length 1.8 mm. The side view of this pedicellaria is almost exactly like 1*b*. 1*b*. Same; side view of an intermarginal pedicellaria, length, 1.9 mm. ×25.

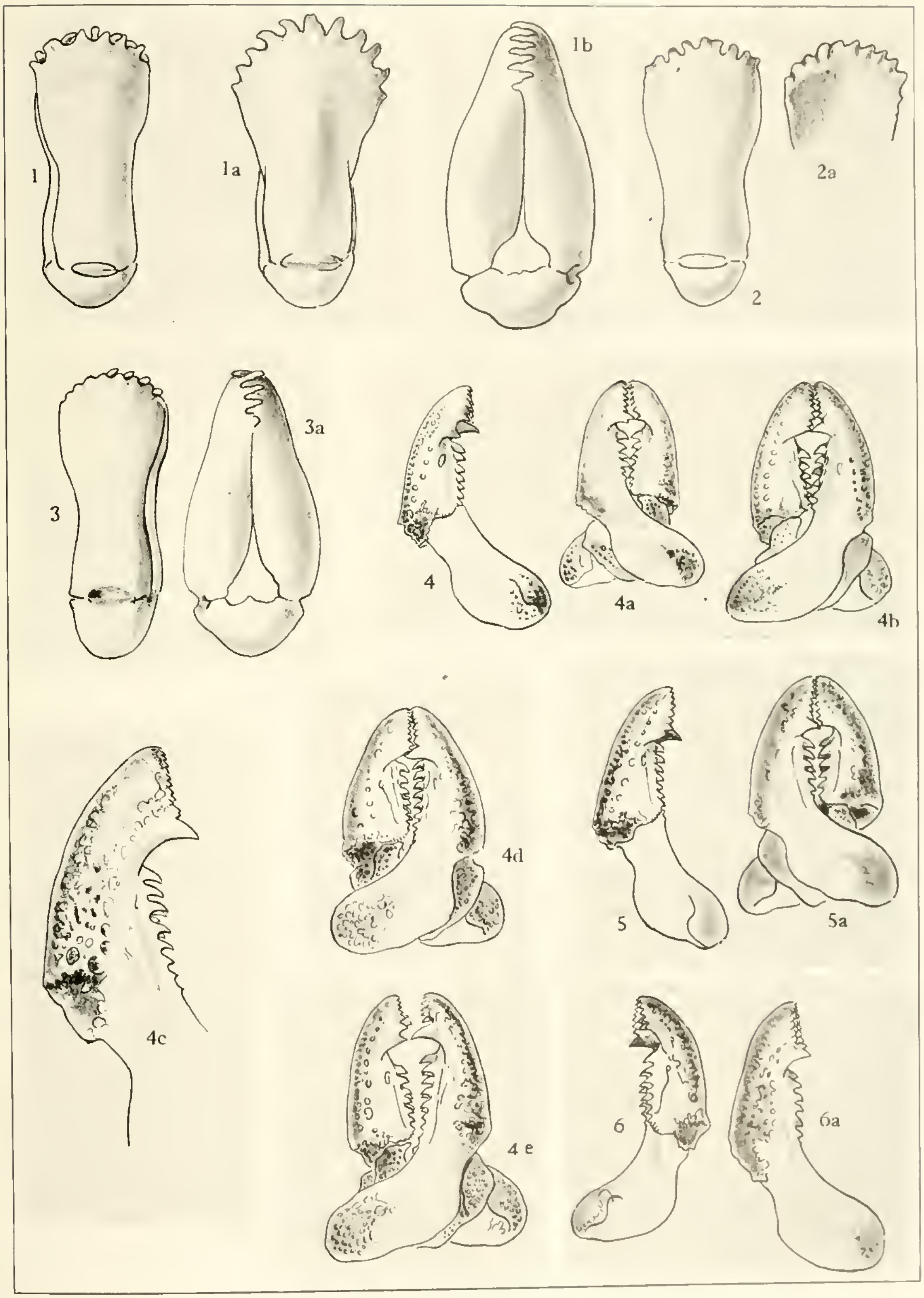
2. *Astrometis sertulifera.* A straight pedicellaria from the type of *Orthasterias dawsoni;* length, 1.6 mm. 2*a*, inner surface of jaw, ×25.

3, 3*a*. *Astrometis californica.* Two views of an intermarginal straight pedicellaria, 1.8 mm. long, ×25.

4. *Astrometis sertulifera,* type specimen. Crossed pedicellaria inner side of jaw, ×100. 4*a* and 4*b*. Same; type. Two dorsolateral pedicellariae 0.32 and 0.36 mm. long, × 100. 4*c*. Same, specimen from La Jolla, outer face of jaw enlarged ×200, showing enlarged lateral tooth of the terminal lip. 4*d*. Same, Tepoca Bay, Gulf of California, 0.39 mm. long. Pedicellariae from this specimen varied from 0.38 to 0.44 mm. long; ×100. 4*e*. Same, La Jolla specimen, 0.43 mm., ×100.

5, 5*a*. Same; dorsal pedicellariae from type of *Orthasterias dawsoni*, 0.39 mm. long, ×100.

6, 6*a*. *Astrometis californica.* Two views of crossed pedicellariae of the type; 6, abactina 6*a* marginal (0.44 mm.); ×100.



1, 2, 4, 5. ASTROMETIS SERTULIFERA. 3, 6. A. CALIFORNICA

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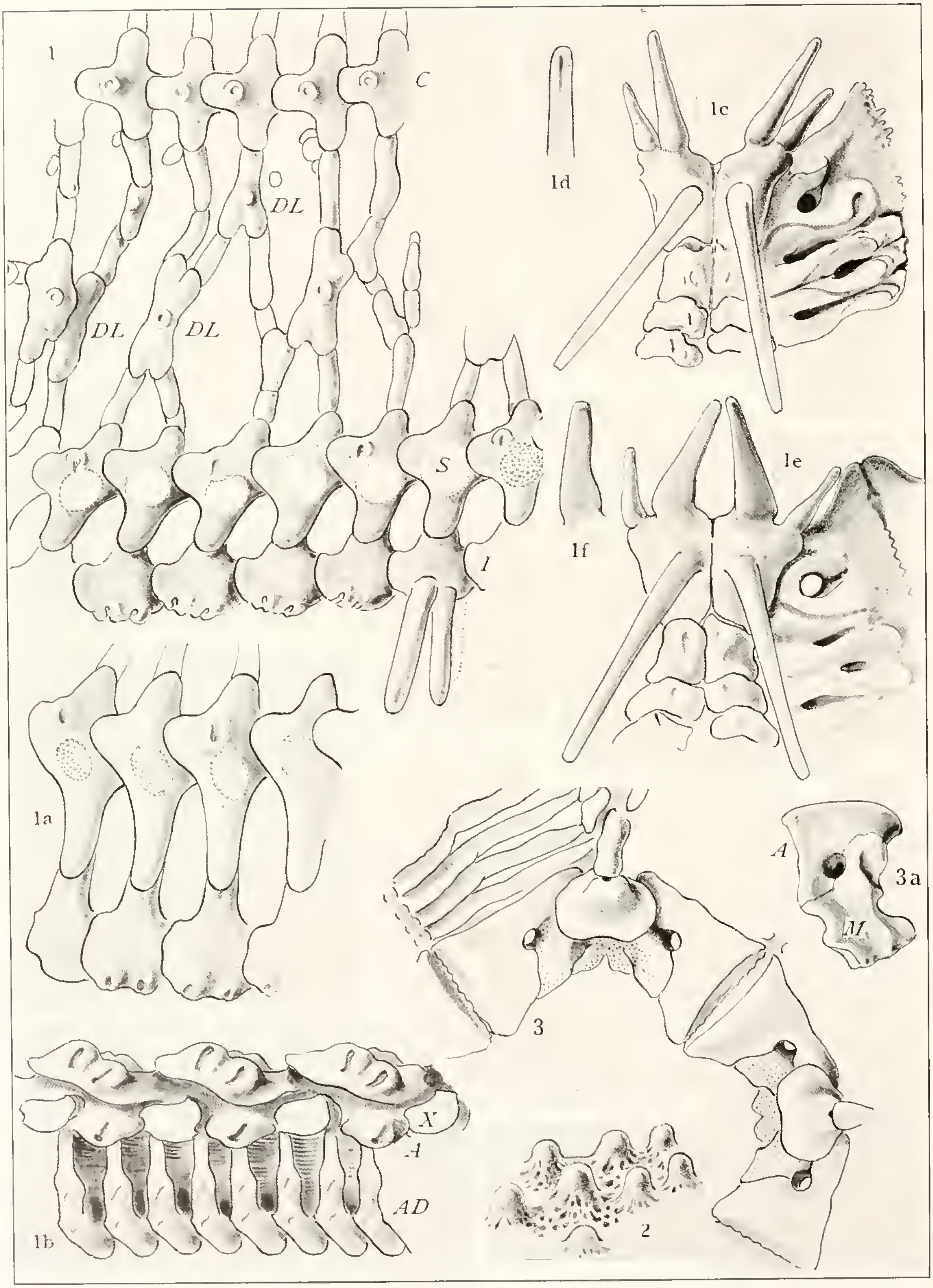


1, 3. Astrometis sertulifera. 2. Sclerasterias heteropaes

For explanation of plate see page facing

PLATE 56

FIG. 1. *Astrometis sertulifera*, No. 38533, U.S.N.M., Santa Margharita Island, L. C. Skeleton of ray near the base (first plate on left is the ninth) showing the carinal plates (*C*), dorso-laterals (*DL*), superomarginals (*S*), and inferomarginals (*I*). The lighter areas on the superomarginals indicate the area of pebbling. Base of ray to left, ×5. 1*a*. Same specimen. Second to fifth supero- and inferomarginal plates, base of ray to left, ×5. 1*b*. Same specimen. Actinal view of 3 inferomarginal plates and corresponding actinal (*A*) and adambulacral plates (*AD*) near base of ray, ×10, *X*, skeletal interval. 1*c*. Same; Tepoca Bay, Gulf of California. Mouth plates and proximal adambulacral and ambulacral plates, ×8. 1*d*. Same specimen. Tip of suboral spine, showing groove, ×15. 1*e*. Same specimen from Half Moon Bay(?), California. Mouth plates, and associated adambulacral and ambulacral plates, ×8. The adambulacral plates have been cleaned. The larger actinostomial spine is flatter than in the 1*c*; ×8. 1*f*. Same specimen. Another actinostomial mouth spine.

2. *Sclerasterias heteropaes*, type. A small portion of the specialized pebbled area of the superomarginal plates, enlarged ×100. The surface of the plate is viewed somewhat in perspective.

3. *Astrometis sertulifera*, La Jolla, Calif., ×10. Portion of actinostomial ring from coelomic side; mouth plates dotted. 3*a*. Same. Side view of crest of first ambulacral (*A*) and mouth plates (*M*) after removal of odontophore.

Plate 57

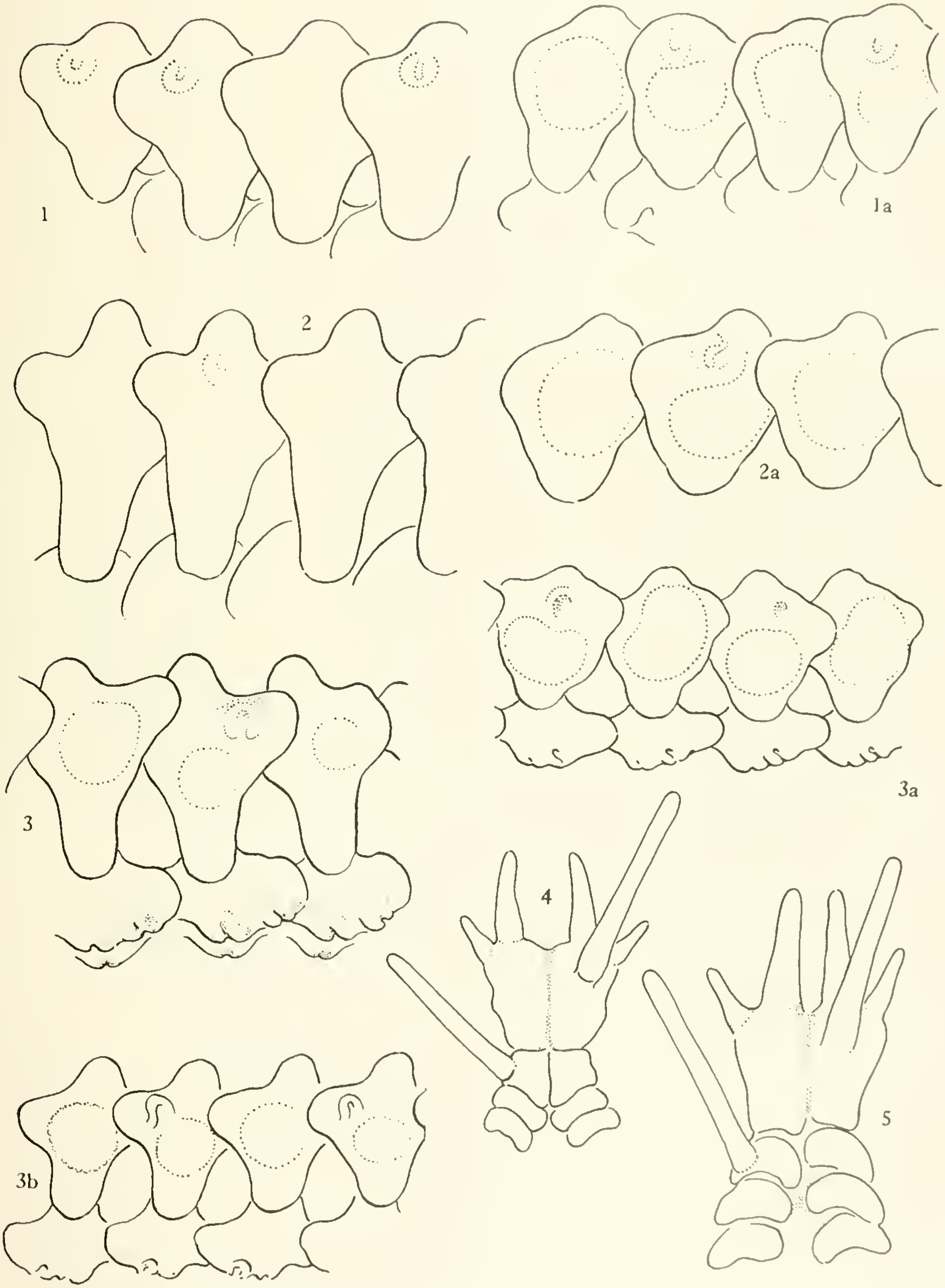
Fig. 1. *Astrometis californica.* Fourth to seventh superomarginal plates; beaded area not indicated; ×10. 1*a*. Same. Twentieth to twenty-third superomarginal plates, beaded area outlined by dots; ×10.

2. *Astrometis sertulifera;* type of *Orthasterias dawsoni.* Fourth to seventh superomarginal plates, beaded area not indicated, ×10. 2*a*. Same specimen; twenty-first to twenty-third superomarginal plates; beaded area outlined; ×10.

3. *Astrometis sertulifera*, specimen from La Jolla, fourth to sixth marginal plates from right to left, ×10. The actinal plates are shown under the inferomarginals. 3*a*. Same specimen. Twenty-seventh to thirtieth superomarginal and inferomarginal plates from right to left, ×10. 3*b*. Same. No. 38533, U.S.N.M. Santa Margharita Island, L. C. (See pl. 56, figs. 1, 1*a*, 1*b*.) Twenty-seventh to thirtieth superomarginal and inferomarginal plates, ×10.

4. *Astrometis sertulifera:* type of *Orthasterias dawsoni.* Mouth plates and proximal adambulacrals; suboral spine shown only on one plate, ×10.

5. *Astrometis californica*, type. Mouth plates and first three pairs of adambulacral plates ×10.



1, 5. ASTROMETIS CALIFORNICA. 2-4. A. SERTULIFERA

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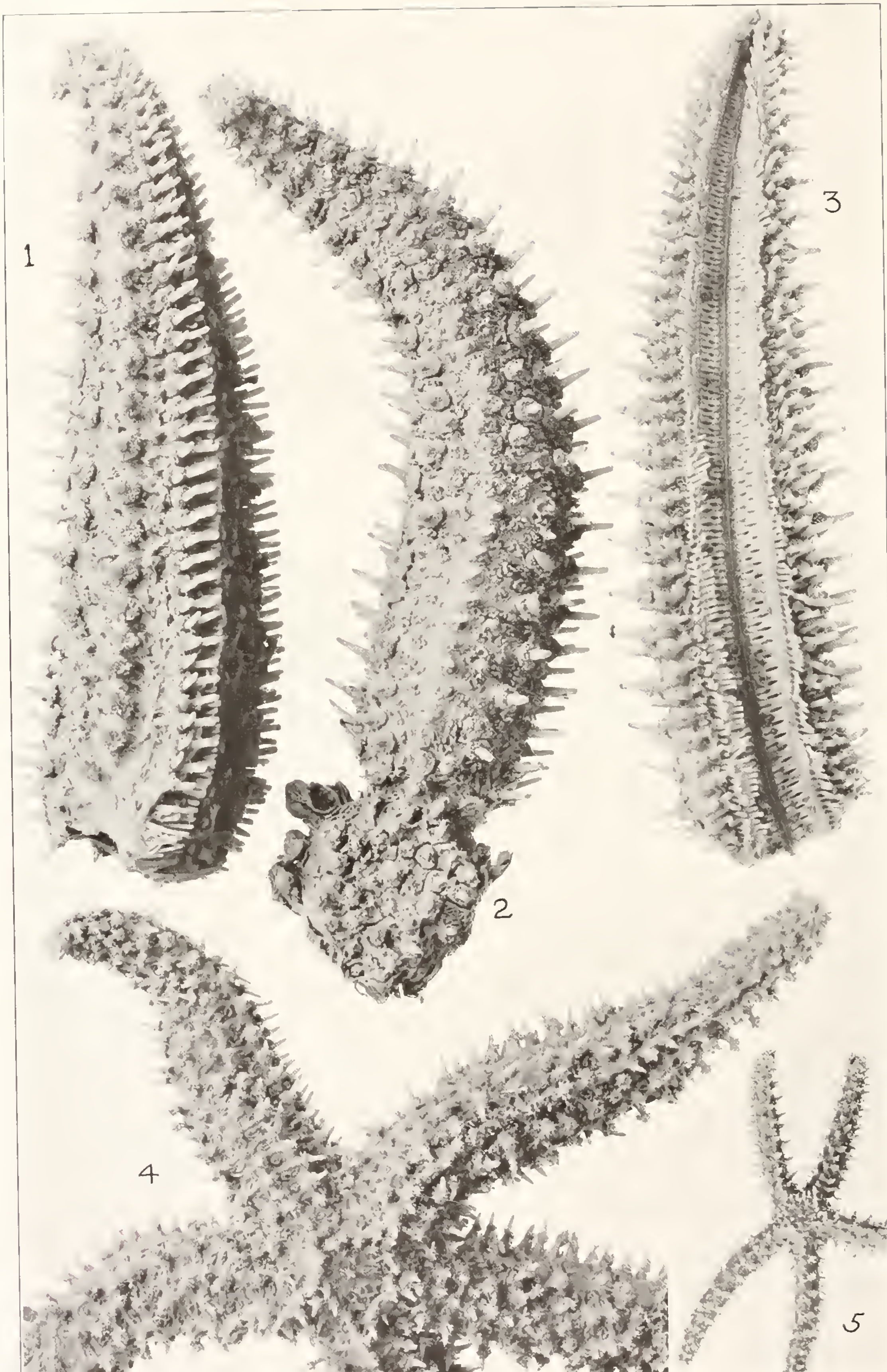


Astrometis sertulifera

For explanation of plate see page facing

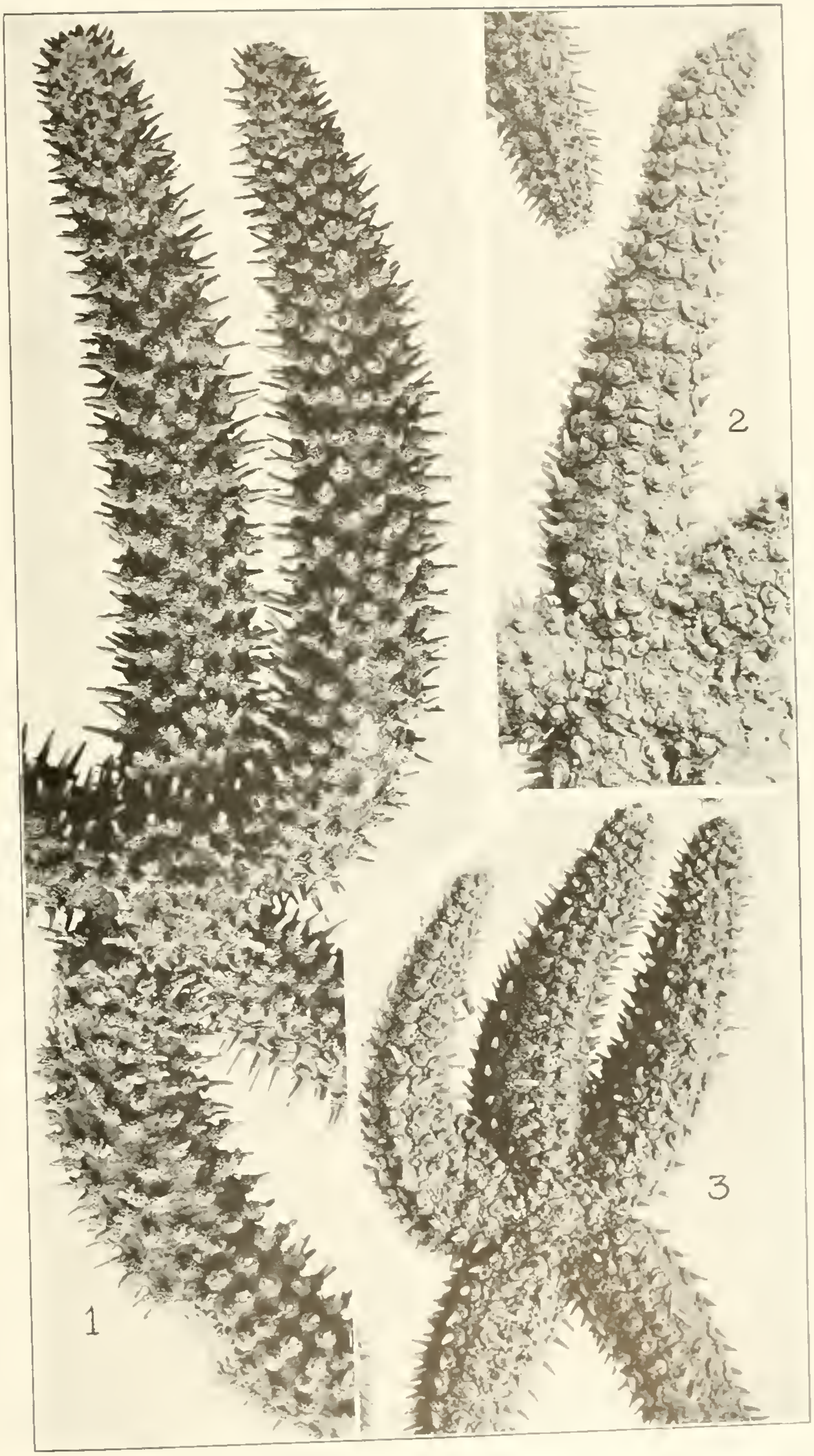
PLATE 58

All figures, *Astrometis sertulifera*

FIGS. 1–3. Santa Margharita Island, L. C., No. 38533, U.S.N.M. Lateral, dorsal, and actinal views of 3 rays of the same specimen; the small disk in 2.
4. Station 3001, Gulf of California, No. 38440, U.S.N.M.
5. Young specimen, La Jolla, Calif.

PLATE 59

FIG. 1. *Astrometis californica* (Verrill), type, enlarged. Yale Museum.
2, 3. *Astrometis sertulifera*, La Jolla, Calif., natural size.



1. ASTROMETIS CALIFORNICA. 2, 3. A. SERTULIFERA

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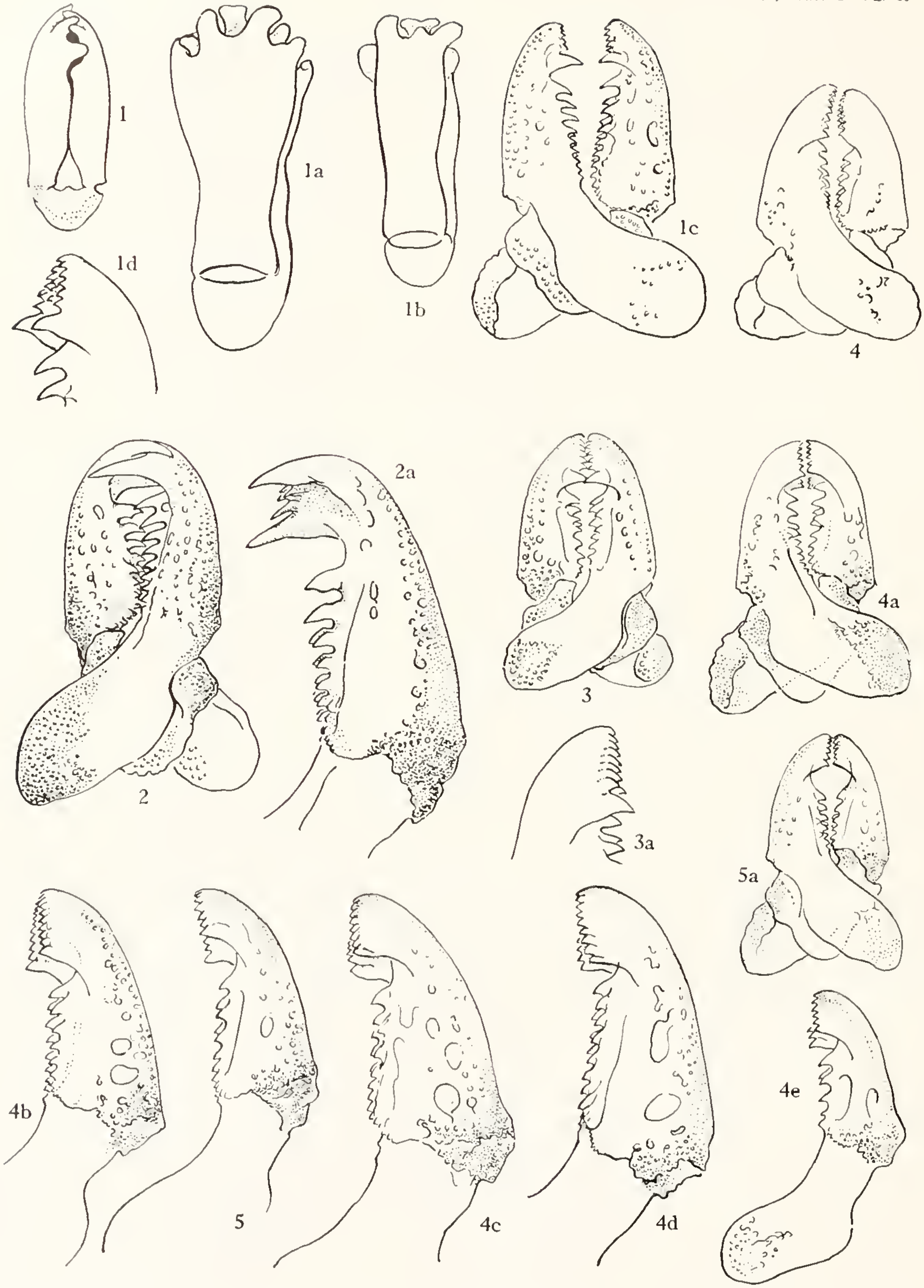


1. Distolasterias stichantha. 2. D. nipon. 3. D. robusta. 4. Lethasterias nanimensis chelifera.
5. L. nanimensis nanimensis

For explanation of plate see page facing

PLATE 60

FIG. 1. *Distolasterias stichantha* (Sladen), type. An abactinal straight pedicellaria, 1.5 mm. long, ×25. 1*a*. Same. An actinal interradial straight pedicellaria, 2.2 mm. long, ×25. 1*b*. Same. An abactinal straight pedicellaria 1.8 mm. long, ×25. 1*c*. Same. An abactinal crossed pedicellaria to show the characteristic terminal teeth; length 0.18 mm., ×100. 1*d*. Same. Tip of a jaw, ×200.

2. *Distolasterias nipon* (Döderlein). An abactinal crossed pedicellaria (Japan), 0.45 mm. long, ×130. 2*a*. Same. A single jaw, ×260, to show the enlarged terminal teeth.

3. *Distolasterias robusta* (Ludwig), type. An abactinal crossed pedicellaria, 0.4 mm. long, ×100. 3*a*. Same. Tip of jaw, ×200, to show enlarged lateral teeth.

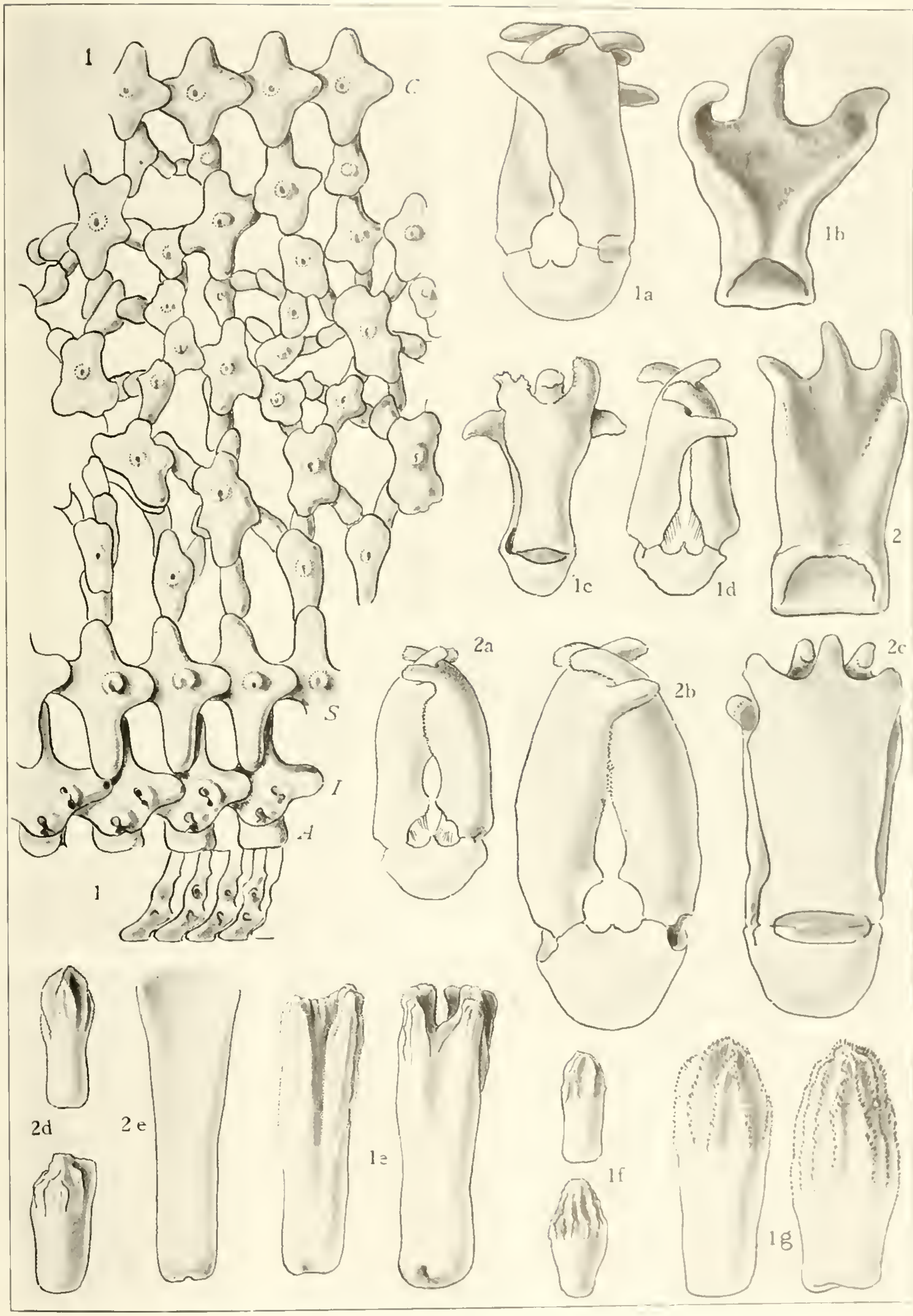
4. *Lethasterias nanimensis chelifera*, station 4795. An abactinal crossed pedicellaria, 0.4 mm. long, ×100. 4*a*. Same, station 2842. Pedicellaria from an inferomarginal spine. 4*b*. Same, station 4796. Single jaw of abactinal crossed pedicellaria, ×200, for comparison. 4*c*. Same. Bering Island, Vega Expedition, ×200. 4*d*. Same, station 5007, Saghalien Island, ×200. 4*e*. Same, young specimen, station 2856, ×200.

5. *Lethasterias nanimensis nanimensis*, station 3464, jaw of an abactinal crossed pedicellaria, ×200. 5*a*. Same. An abactinal crossed pedicellaria 0.39 mm. long, ×100.

Plate 61

Fig. 1. *Lethasterias nanimensis chelifera.* Abactinal skeleton between the carinals and adambulacrals inclusive, near base of ray which is on the right; *C*, carinal plates; *S*, superomarginals; *I*, inferomarginals; *A*, actinal plates; ×5. 1*a*. Same, station 3611. An actinal interradial straight pedicellaria, 1.9 mm. long, ×25. 1*b*. Same. A single jaw for comparison with 2, ×25. 1*c*. 1*d*. Same, station 4796. Two views of an abactinal straight pedicellaria, 1.35 mm. long, ×25. 1*e*. Same, Bering Island, Vega Expedition. Two inferomarginal spines (1.6 and 1.8 mm.) ×10. 1*f*. Same, station 4796. Two abactinal spines, 1.8 mm. long, same scale as 1*e*. 1*g*. Same, station 4796. Two abactinal spines on same scale as 1*c* and 1*d*, ×25.

2. *Lethasterias nanimensis nanimensis*, station 3461. One jaw of 2*b* and 2*c*, for comparison with 1*b*, ×25. 2*a*. Same, station 3464, an actinal straight pedicellaria from near base of ray, 1.6 mm. long, ×25. 2*b* and 2*c*. Same. Two views of a straight pedicellaria from the actinal interradial region, 2.5 mm. long, ×25. 2*d*. Same, station 3464. Two abactinal spines, 2.25 mm. long, ×10. 2*e*. Same specimen; an inferomarginal spine ×10.



1. LETHASTERIAS NANIMENSIS CHELIFERA. 2. L. NANIMENSIS NANIMENSIS

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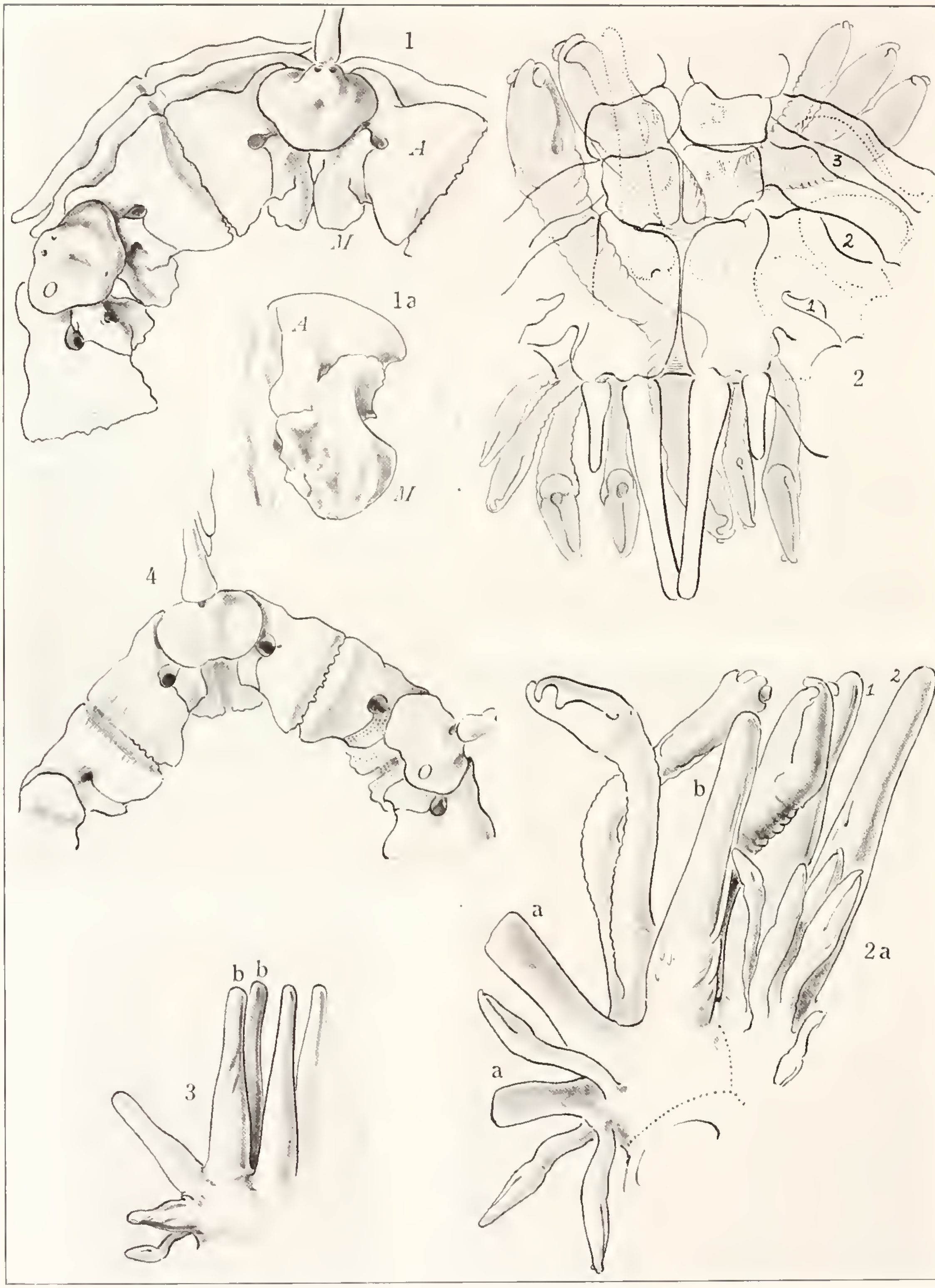

1, 2. LETHASTERIAS NANIMENSIS CHELIFERA. 3. L. NANIMENSIS NANIMENSIS. 4. ORTHASTERIAS KOEHLERI

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PLATE 62

FIG. 1. *Lethasterias nanimensis chelifera*, station 2842, ×5. Portion of actinostomial ring from coelomic side. The odontophores have duplicate sockets as in *Astrostole* and *Megenaster*; *A*, first ambulacral plate; *M*, mouth plates; *O*, odontophore. 1*a*. Side view of the upper part of first ambulacral ossicle *A*, showing attachment to mouth plate, *M*, the odontophore removed.

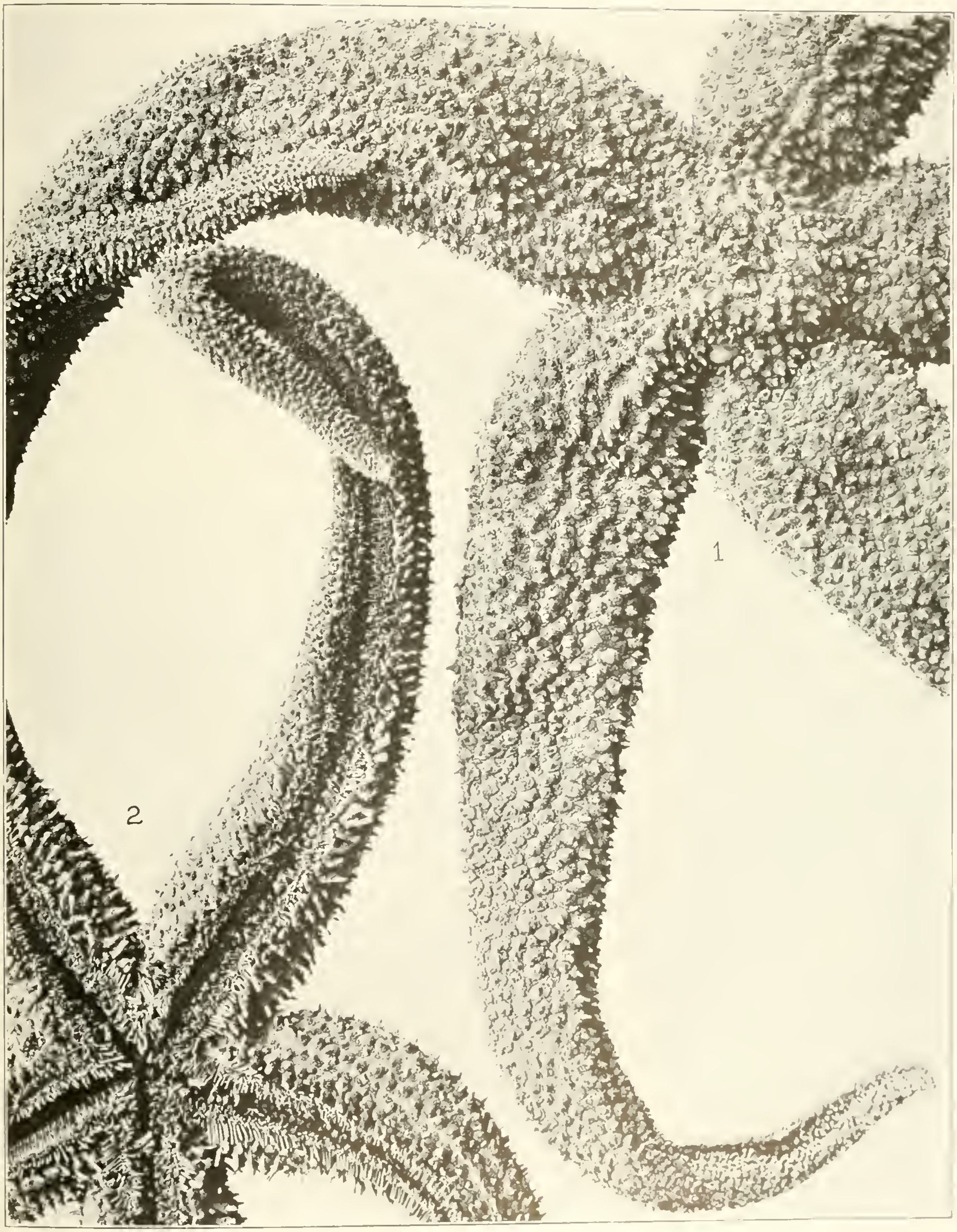
2. *Lethasterias nanimensis chelifera*, station 2842, ×10. Skeleton of mouth angle showing attachment of numerous pedunculate unguiculate pedicellariae. Two adoral adambulacrals are shown above the mouth plates; and on the right, 3 ambulacral plates; 1–3, first ambulacral pores. 2*a*. Same, station 4796, ×10. Side view of mouth plates and 2 adambulacrals, the spines of the other side not indicated; *a*, *a*, actinostomial spines; *b*, suboral spine; 1, 2, first and second adambulacral spines.

3. *Lethasterias nanimensis nanimensis*, station 3461, ×5. Side view of mouth plates and first adambulacral; *b*, *b*, suboral spines of the mouth pair.

4. *Orthasterias koehleri*, station 3464, ×5. Portion of actinostomial ring from coelomic side, one pair of mouth plates under right odontophore (*O*) dotted.

PLATE 63

FIG. 1. *Lethasterias nanimensis chelifera*, station 3282, about seven-eighths natural size.
2. Same, station 4787.



LETHASTERIAS NANIMENSIS CHELIFERA

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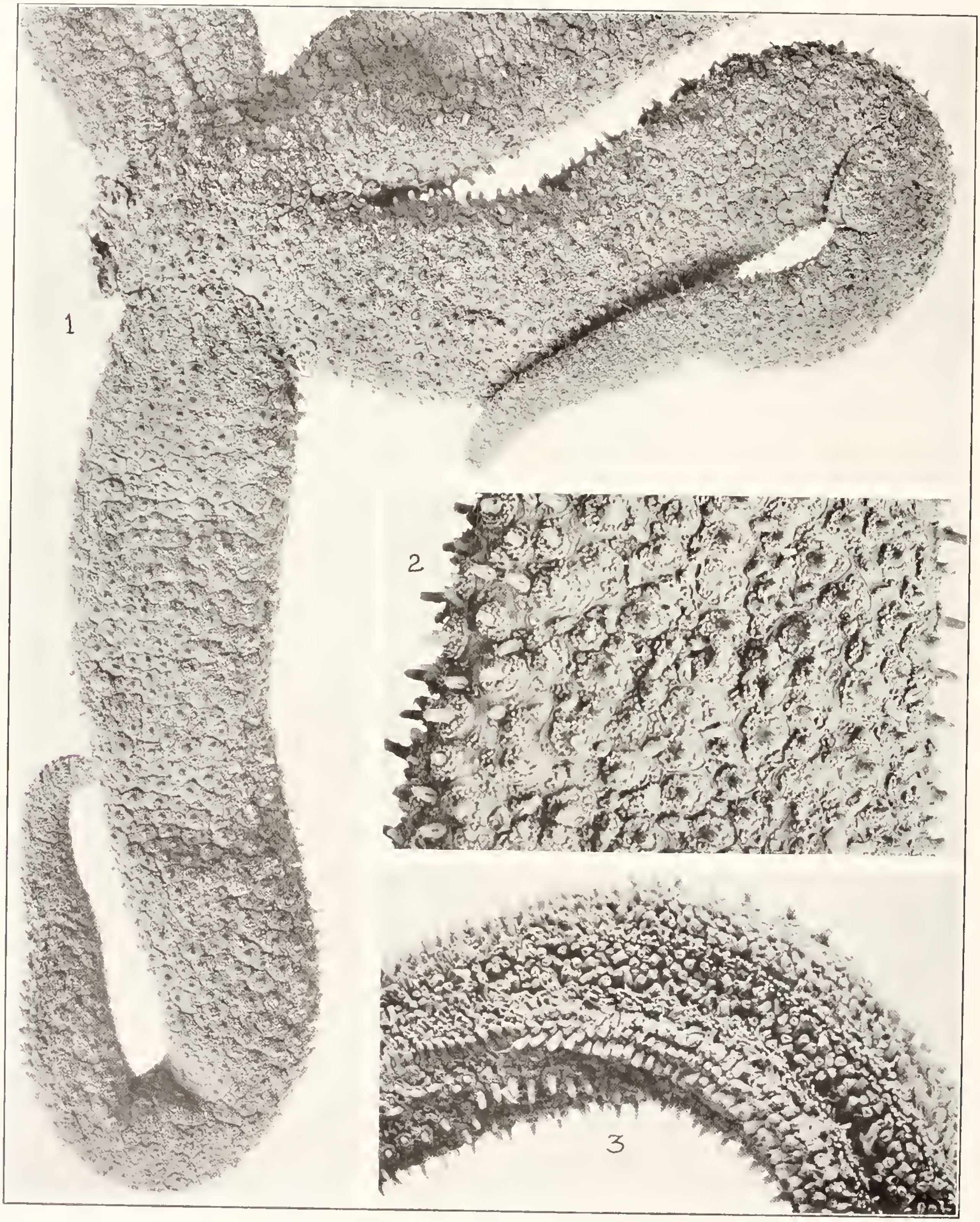


1. LETHASTERIAS NANIMENSIS. 2. L. NANIMENSIS CHELIFERA. 3. ORTHASTERIAS KOEHLERI

FOR EXPLANATION OF PLATE SEE PAGE FACING

PLATE 64

FIG. 1. *Lethasterias nanimensis*, station 3464, $\times 1\frac{1}{5}$.

2. *L. nanimensis chelifera*, station 4787. Small portion of abactinal surface, $\times 2\frac{3}{4}$, to show abundant unguiculate pedicellariae.

3. *Orthasterias koehleri*, station 3466. Actinal surface of ray shown on plate 68, figure 1, to show heavy actinal and inferomarginal spines.

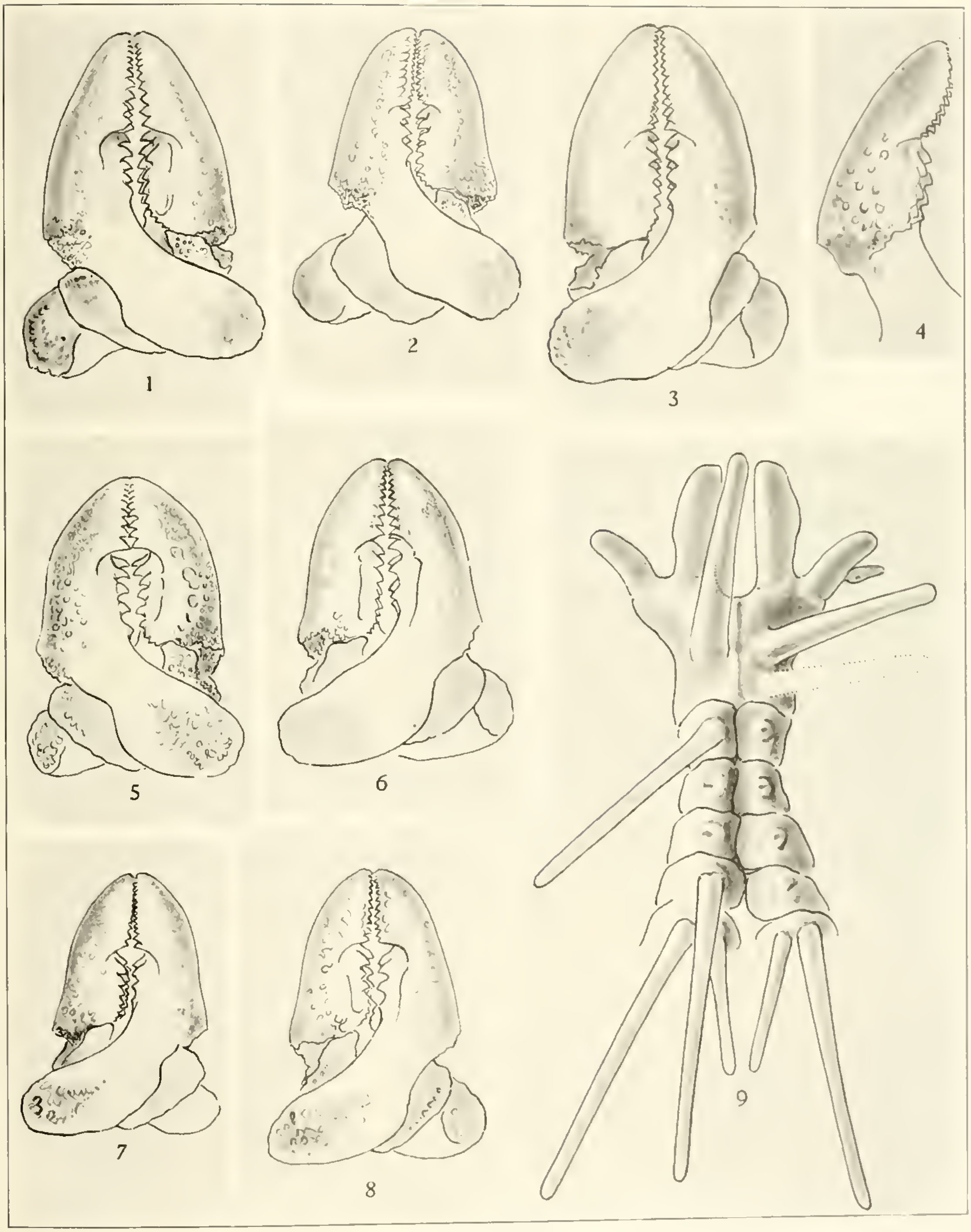
Plate 65

Orthasterias koehleri

Abactinal crossed pedicellariae for comparison, $\times 100$

Fig. 1. Station 4202; specimen described in text (see pl. 68 fig. 2); length 0.48 mm.

2. Type of *Orthasterias columbiana* Ver.; length 0.45 mm.
3. Station 4431, off Santa Rosa Island, Calif.
4. Station 4551, off Point Pinos, Calif. (Pl. 70, fig. 1.)
5. Station 3466, very large specimen (pl. 68, fig. 1); length 0.45 mm.
6. Station 3461, 114 fathoms; length 0.45 mm. Pedicellariae from forma *leptostyla*, station 3445, are similar to this in form, but 0.40 mm. long.
7. Departure Bay, British Columbia; from specimen having a preponderance of abactinal lanceolate straight pedicellariae; length 0.4 mm.
8. Monterey Bay, Calif., low tide (forma *montereyensis*); length 0.45 mm.
9. Mouth plates and oral carina of a specimen from Departure Bay, British Columbia. The marginal mouth spines are rather broader than usual, $\times 10$.



ORTHASTERIAS KOEHLERI

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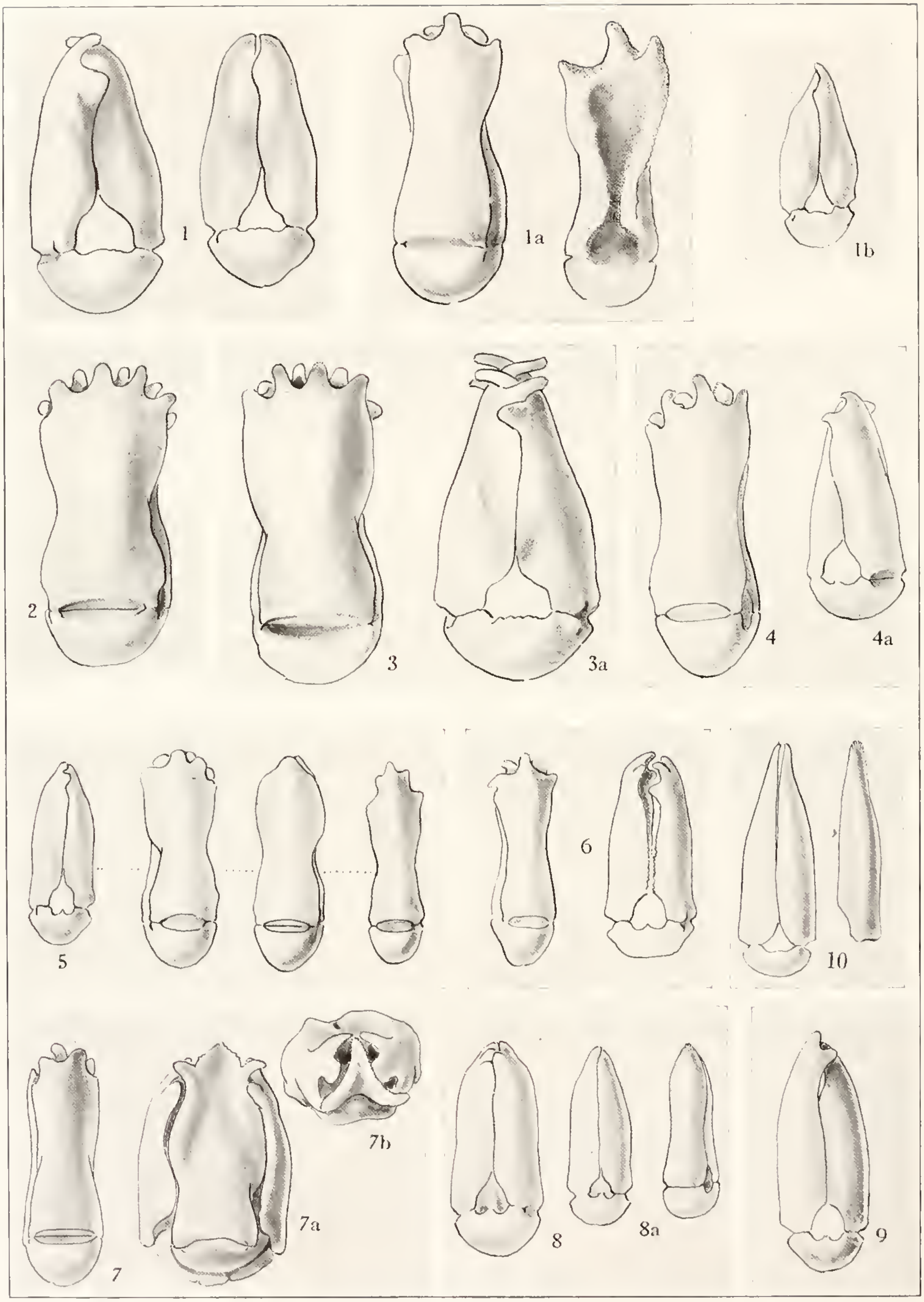


ORTHASTERIAS KOEHLERI

For explanation of plate see page facing

PLATE 66

Orthasterias koehleri

Straight pedicellariae. × 25

FIG. 1. Departure Bay, B. C., abactinal pedicellariae, the longer 1.8 mm. from specimen shown on pl. 69, fig. 2. 1*a*. Same specimen; front view of a pedicellaria and inside of one jaw. 1*b*. Same specimen. Example of a smaller lanceolate form (1.16 mm.) found among the larger type 1, 1*a*, but less commonly.

2. Station 3466; large unguiculate pedicellaria from largest specimen, 1.8 mm. long.

3. 3*a*. Station 4202; two views of a pedicellaria from intermarginal channel (specimen described in text and figured pl. 68, fig. 2).

4. Station 4431; intermarginal pedicellaria, 1.87 mm. long. 4*a*. Abactinal, 0.95 mm.

5. Type of *Orthasterias columbiana*, Yakutat Bay; 4 abactinal pedicellariae, the longest 1.35 mm.

6. Station 3461, 111 fathoms; two views of an abactinal pedicellaria.

7. Monterey Bay (Pacific Grove), low tide; forma *montereyensis*. An abactinal pedicellaria, 1.5 mm. 7*a*, 7*b*. Side and top view of a three-valved pedicellaria from same specimen, abactinal.

8. Departure Bay, British Columbia; specimen having a preponderance of lanceolate pedicellariae (actinal view figured pl. 69, fig. 1); intermarginal, 1.35 mm. 8*a*. Same specimen; two views of a dorsolateral pedicellaria, 1.12 mm.

9. Station 3445, forma *leptostyla*; large furrow pedicellaria, 1.5 mm. long, mentioned in text. The abactinal pedicellariae of this specimen are of the lanceolate type (8*a*).

10. Station 4202 (see 3, 3*a*); furrow pedicellaria from side and a single jaw.

PLATE 67

Orthasterias koehleri

FIG. 1. Actinal view of three inferomarginal plates and adjacent actinal (*A*) and adambulacral plates from a specimen (forma *montereyensis*) taken near Monterey Bay, California; near base of ray which is to left, ×8. 1*a*. Same specimen; skeleton of ray between carinal (*C*) and inferomarginal (*I*) plates, inclusive; base of ray to left, ×4. The proximal superomarginal plates of this specimen are spiniferous on alternate plates only.

2. Forma *leptostyla*, station 4233. A dorsolateral spine, 3 mm., ×8 and tip of same ×20. 2*a*. A dorsolateral spine, 2.1 mm. from specimen from 100 fathoms, Straits of Fuca (station 3445), ×8. 2*b*. Same spine, ×25. 2*c*. Type of forma, station 3443, a dorsolateral spine for comparison, ×8.

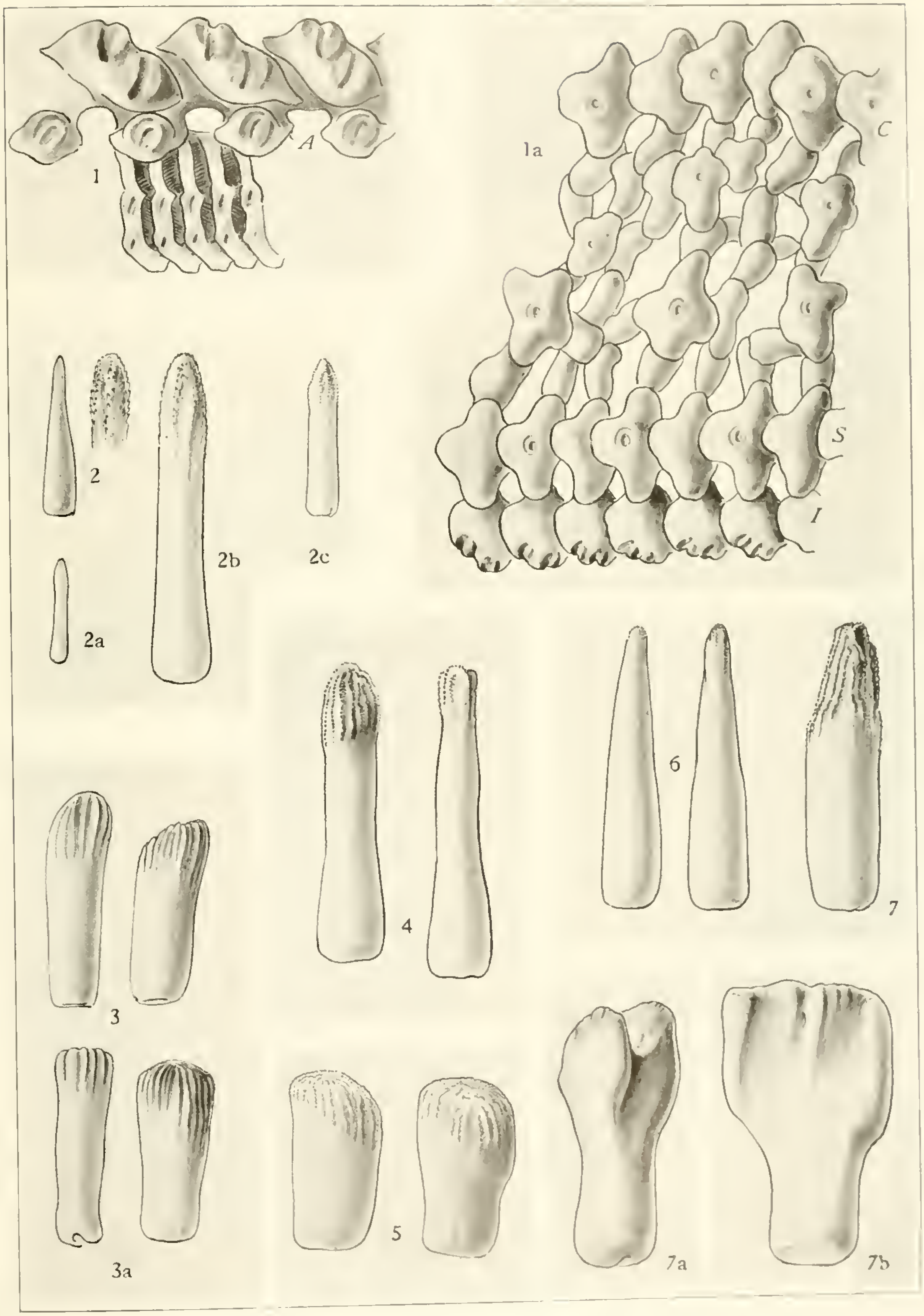
3. 3*a*. Forma *montereyensis*, Monterey Bay and vicinity, abactinal spines, ×8.

4. Forma *koehleri*, station 4202, described in text; two dorsolateral spines 4.5 and 5 mm., ×10.

5. Forma *biordinata*, Port Renfrew, British Columbia; two dorsolateral spines, ×8.

6. Forma *koehleri*, deep water, station 4431; two dorsolateral spines, ×8.

7. Forma *koehleri*, very large specimen, station 3466 (see pl. 68, fig. 1); dorsolateral spine, ×8. 7*a* and 7*b*. Same specimen; inner (7*a*) and outer inferomarginal spines, showing growth due to age.



ORTHASTERIAS KOEHLERI

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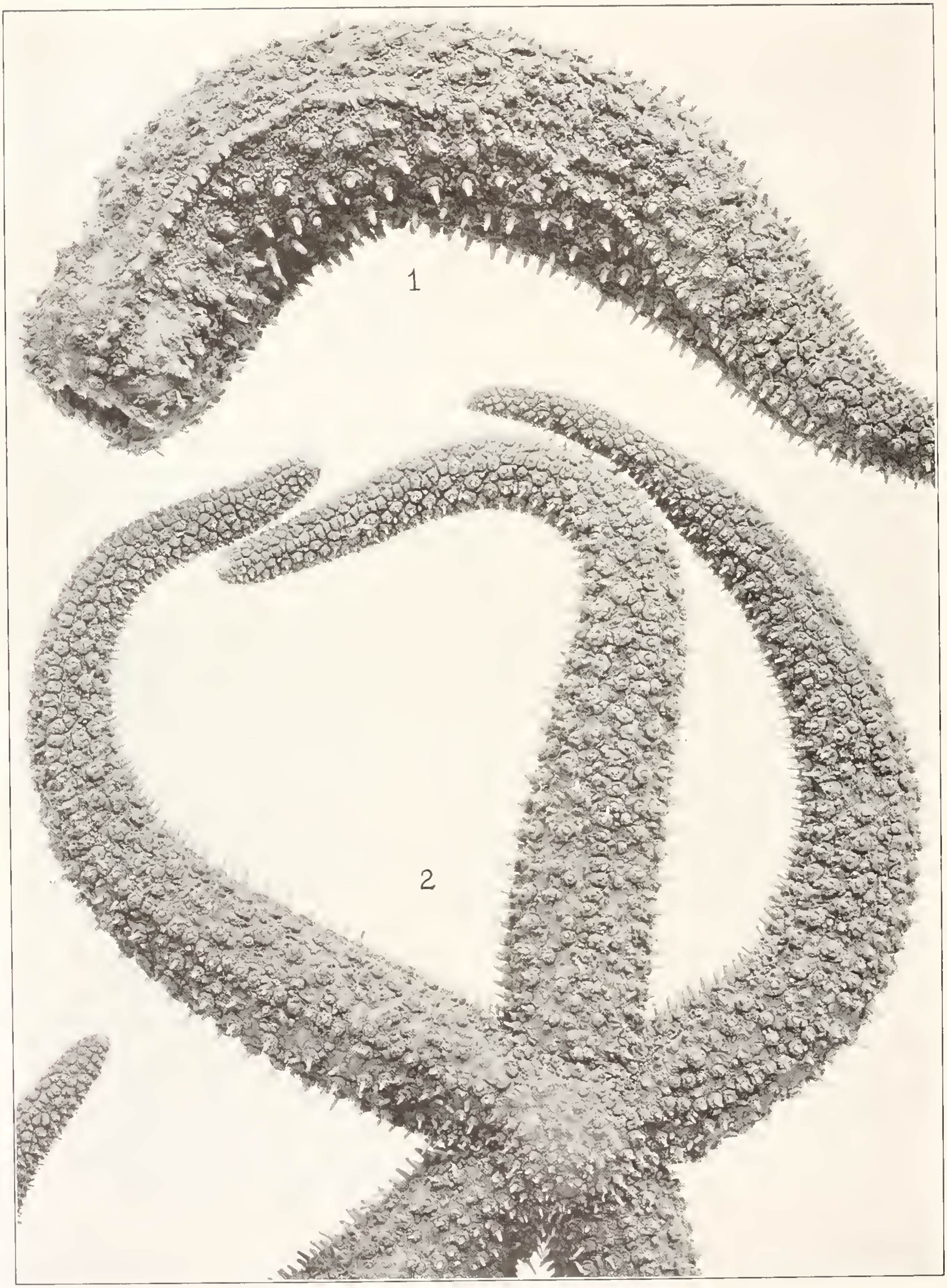

ORTHASTERIAS KOEHLERI

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PLATE 68

Orthasterias koehleri, $\times \frac{7}{8}$

FIG. 1. Station 3466; ray of large specimen having heavy inferomarginal and actinal spines; ray unusually robust.

2. Station 4202; typical example from moderate depth (25–36 fms.). Specimen used for specific description.

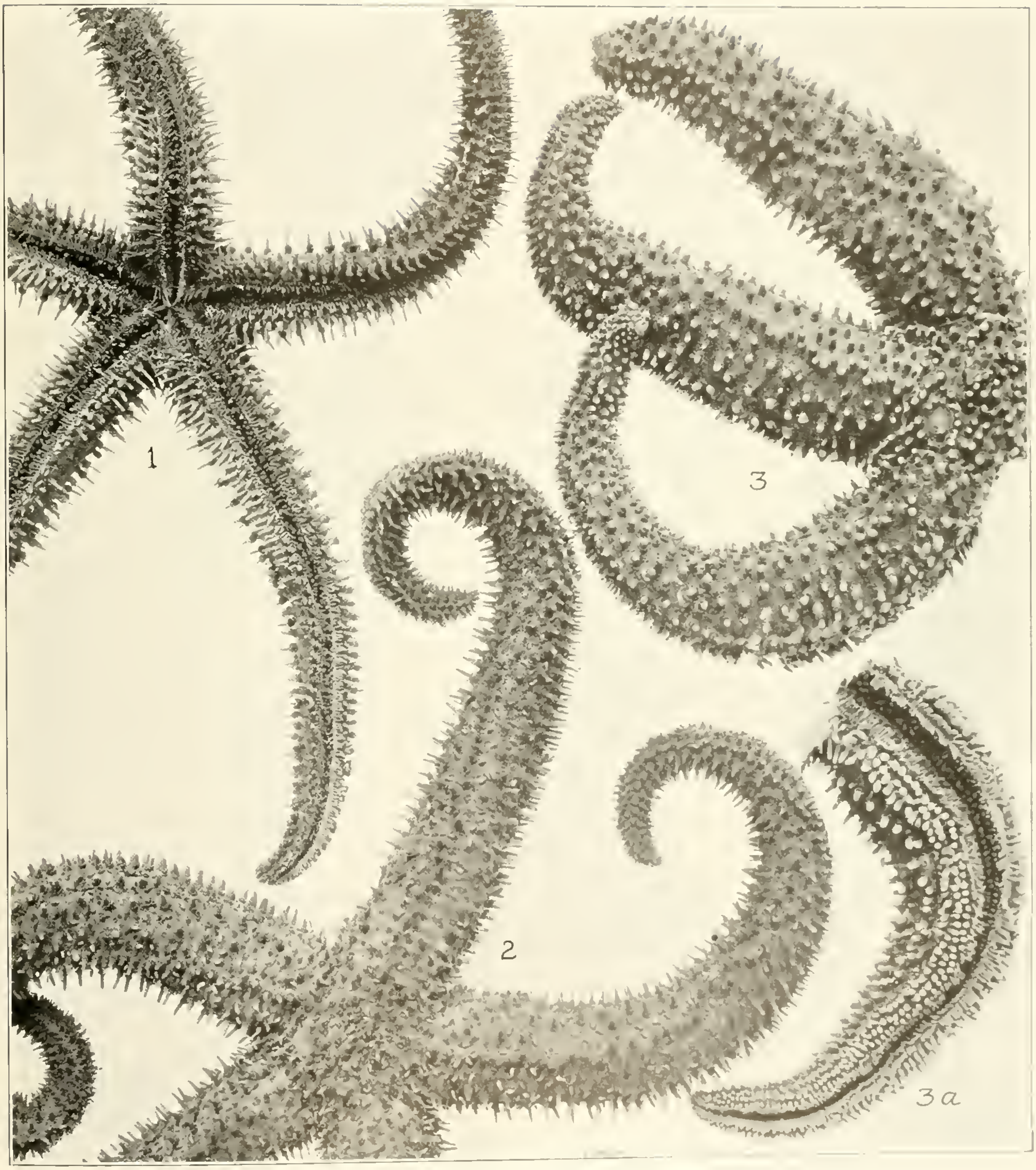
PLATE 69

Orthasterias koehleri, × $\frac{9}{10}$

FIG. 1. Forma *koehleri*, Departure Bay, British Columbia. A subforma with slender lanceolate straight pedicellariae, dried.

2. Forma *koehleri*, Departure Bay, British Columbia. A nearly typical specimen, dried.

3, 3*a*. Forma *biordinata*, Port Renfrew, Vancouver Island (Straits of Fuca), British Columbia; stout-rayed variety.



ORTHASTERIAS KOEHLERI

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ORTHASTERIAS KOEHLERI

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PLATE 70

Orthasterias koehleri, $\times 1\frac{2}{5}$

FIG. 1. Station 4551, off Point Pinos, Monterey Bay, Calif., 56–46 fathoms. Deepwater variety of forma *koehleri*.

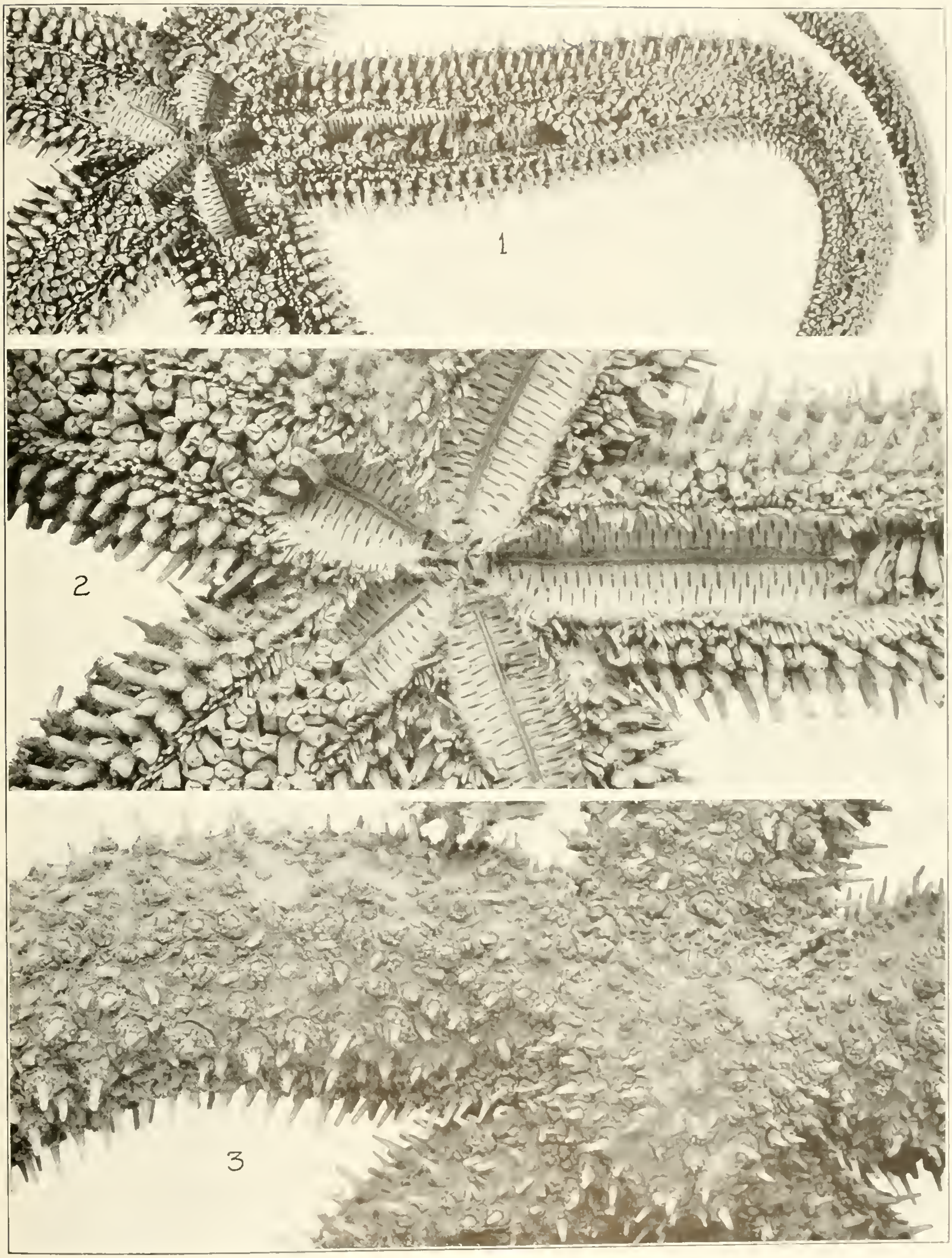
2. Station 3452, Straits of Fuca, 125 fathoms. Variety of forma *koehleri*. (See text under forma *leptostyla*.)

3. Naha Bay, Alaska.

PLATE 71

Orthasterias koehleri, forma *koehleri*

FIG. 1. Actinal view of specimen used for description of species, station 4202, $\times \frac{7}{8}$.
2. Same specimen, $\times 2$.
3. Abactinal view of same specimen, $\times 2$.



ORTHASTERIAS KOEHLERI, FORMA KOEHLERI

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ORTHASTERIAS KOEHLERI, FORMA LEPTOSTYLA

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PLATE 72

FIG. 1. *Orthasterias koehleri*, forma *leptostyla*, type, station 3443, Straits of Fuca, Washington, ×2.

2. Same specimen, actinal, ×1.2.

PLATE 73

FIG. 1. *Lysastrosoma anthosticta.* Marginal and 5 abactinal plates, from proximal half of ray; base of ray to the right; *A*, abactinals; *S*, spiniferous superomarginals; *I*, inferomarginals; *AD*, adambulacrals; secondary marginals shown between the superomarginals; ×10.

1*a*. Same. Marginal plates from near tip of ray showing absence of connections; lettering as in 1; base of ray to the left; ×10.

1*b*. Same. Diagram of plates of mouth angle. 1–4, first 4 superomarginals; I–III, first 3 inferomarginals; *i*, probable primary interradial plate; *M*, mouth plate; *AD*, first, enlarged adambulacral plate; ×10.

1*c*. Same. Abactinal spinelet, ×50.

1*d*. Same. Two inferomarginal plates (*I*) showing the sheath common to two spines, and above, 2 superomarginal spines; below, 5 adambulacral spinelets (*AD*) with attendant pedunculate straight pedicellariae; *P* intermarginal papulae; near base of ray, ×10.

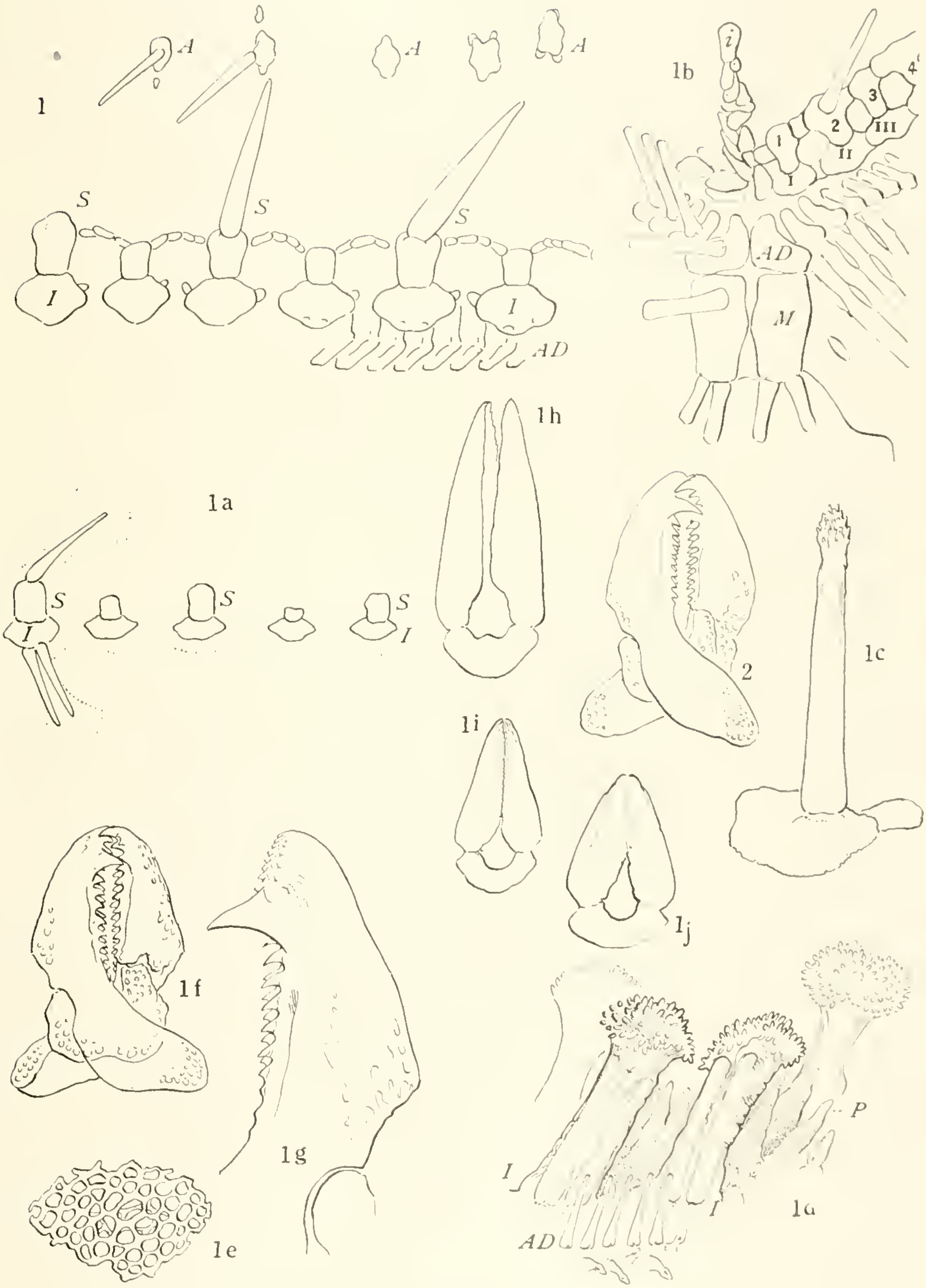
1*e*. Same. Vestigial platelet from abactinal integument, ×200.

1*f*. Same. Abactinal crossed pedicellaria, 0.21 mm., ×200.

1*g*. Same. Portion of a jaw enlarged ×400, to show charactersitic enlarged tooth.

1*h*, 1*i*, 1*j*. Same. Straight pedicellariae. 1*h*, abactinal, 0.45 mm. long ×100; 1*j*, abactinal 0.11 mm. ×200, one of the tiny kind; 1*i* from adambulacral plates, 0.27 mm. ×100.

2. *Lysastrosoma desmiora* Clark; abactinal crossed pedicellaria, 0.27 mm. long, ×150.



1. Lysastrosoma anthosticta. 2. L. desmiora

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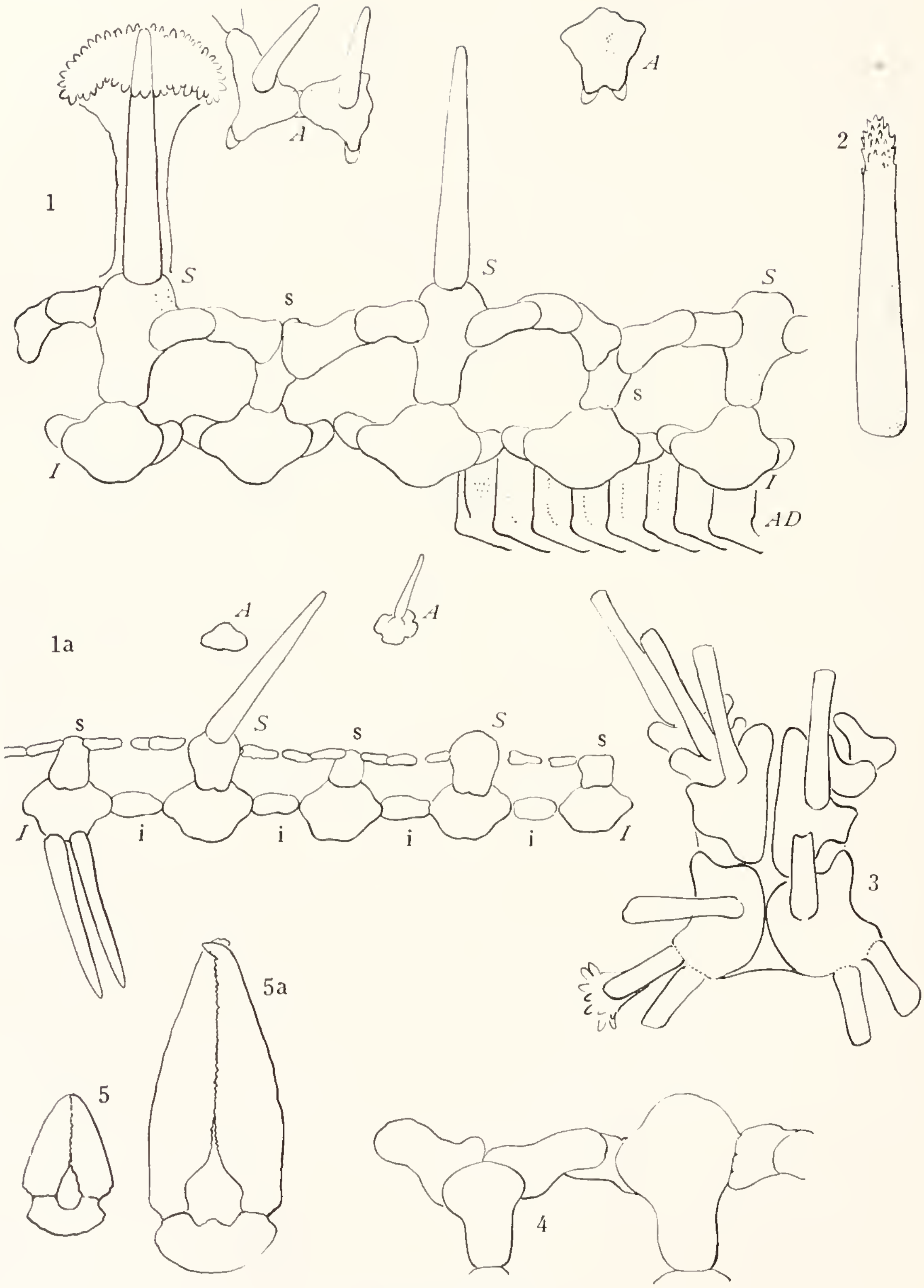

LYSASTROSOMA DESMIORA

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PLATE 74

All figures *Lysastrosoma desmiora* Clark

FIG. 1. Marginal skeleton and 3 adjacent abactinal plates (*A*); *S S S*, ninth, eleventh and thirteenth spiniferous superomarginal plates; *s s*, alternate unarmed superomarginals; secondary superomarginals shown between; *I*, inferomarginals; *AD*, adambulacral plates; base of ray to left; ×10.

1*a*. Marginal skeleton and two adjacent abactinal plates (from near end of ray), lettering as in 1; note the single intermediate inferomarginal ossicles (*i*) between any 2 plates, instead of 2 as in 1; base of ray to left, ×10.

2. Abactinal spinelet, ×25.

3. Mouth plates and first 3 adambulacral plates of either ray, the first plate much specialized, ×10.

4. Inner surface of ninth and tenth superomarginal plates, tenth to the left, ×12.

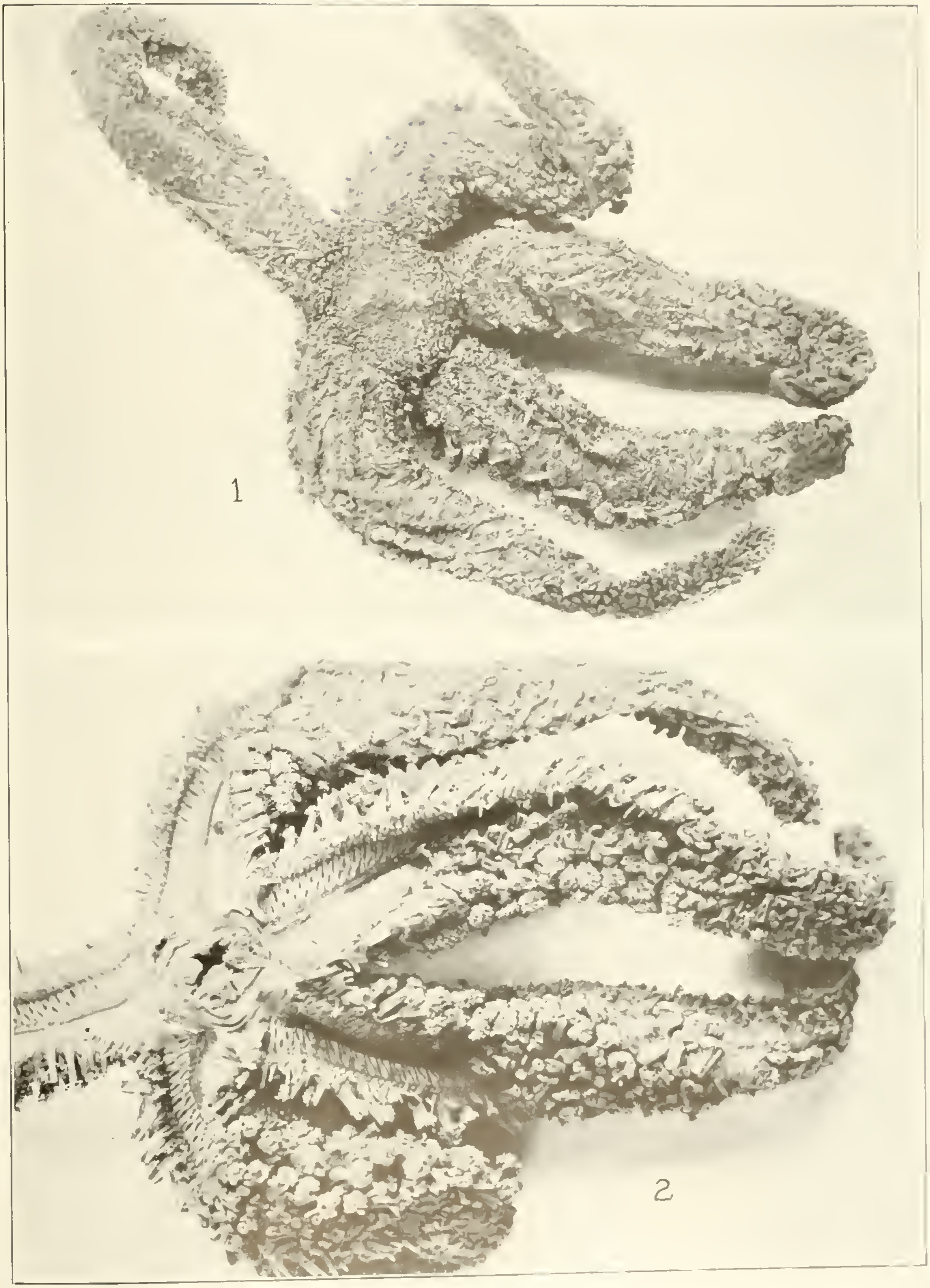
5. Abactinal straight pedicellaria, 0.22 mm., ×100.

5*a*. Interbrachial straight pedicellaria, 0.54 mm., ×100.

PLATE 75

Lysastrosoma anthosticta, type

FIG. 1. Abactinal view enlarged.
2. Actinal view enlarged.



LYSASTROSOMA ANTHOSTICTA

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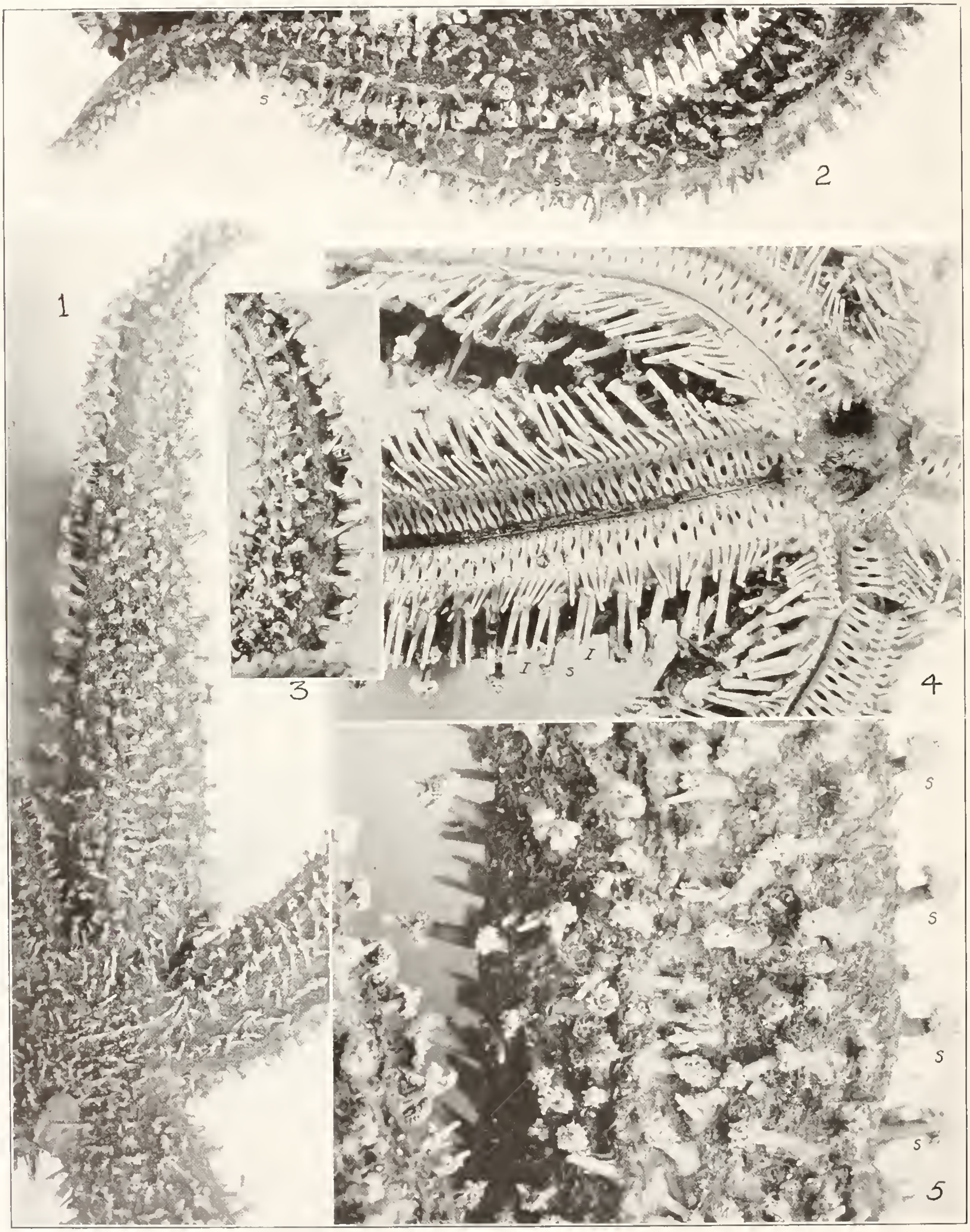

LYSASTROSOMA DESMIORA

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PLATE 76

Lysastrosoma desmiora type

FIG. 1. Abactinal view, $\times 1\frac{3}{4}$.

2, 3. Side view of three rays, $\times 1\frac{3}{4}$; *S*, superomarginal spines.

4. Actinal view, $\times 2\frac{1}{3}$; *S*, superomarginal spines; *I*, inferomarginal spines.

5. Portion of abactinal surface, $\times 5$; *S*, superomarginal spines.

Plate 77

All figures from living specimens of *Pycnopodia helianthoides*, Monterey Bay, Calif.

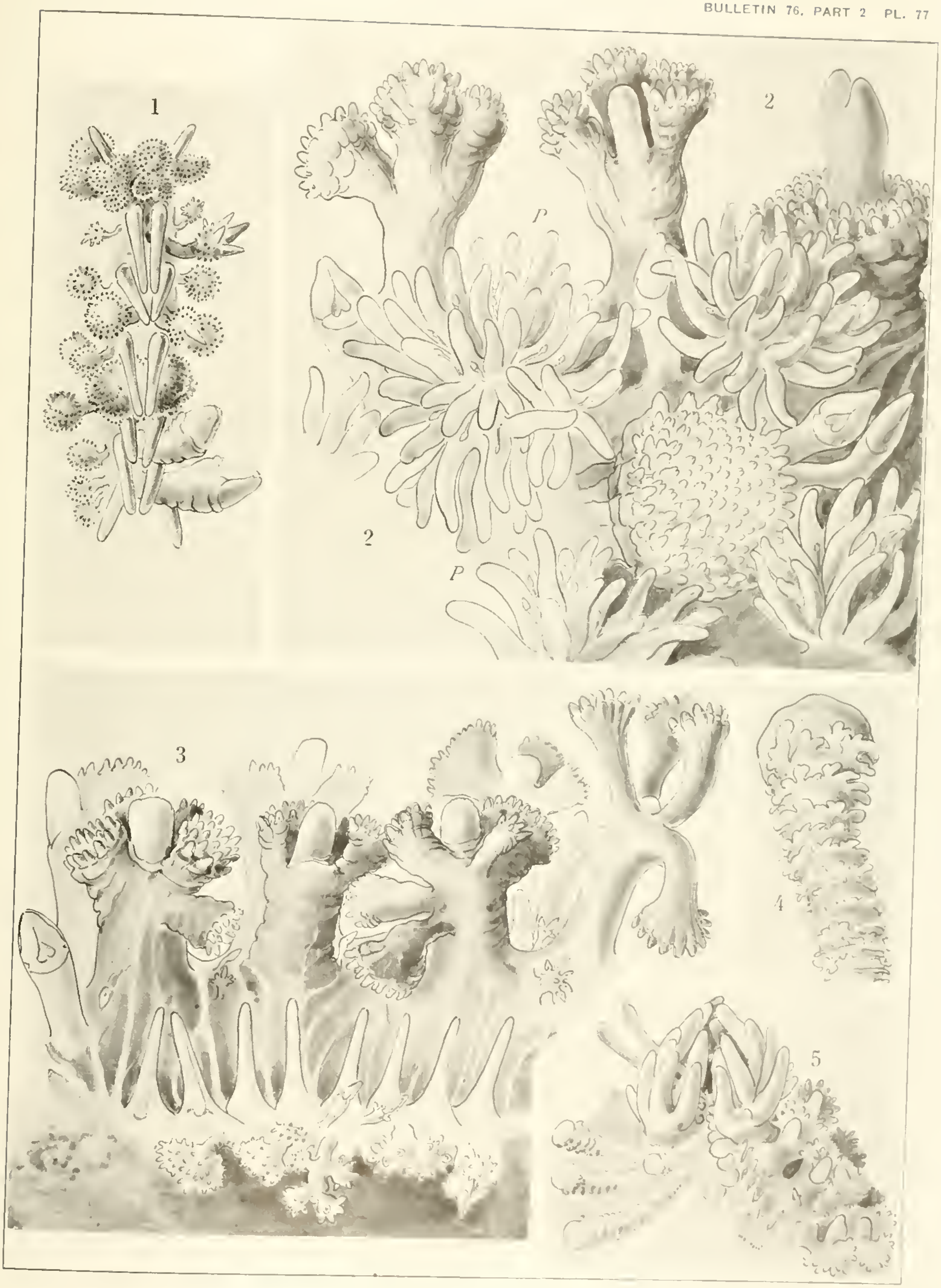
Fig. 1. Oral angle. Showing the mouth plates at top, and five pairs of adambulacral plates of the adoral carina, with their clusters of straight pedicellariae. The peduncles are in a state of contraction; ×7.

2. Three superomarginal spines, and below a small portion of the abactinal surface at middle of ray, showing the large compound papulae (*P*) with their attendant dwarf and giant straight pedicellariae. The sheaths of the three marginal spines, carrying crossed pedicellariae are shown expanded and contracted. The abactinal sheath of crossed pedicellariae in the midst of the four groups of papulae is without a central spine. Enlarged about eight times.

3. Actinal surface of a ray showing the inferomarginal and adambulacral spines and the mobile clusters of pedicellariae in various postures. Note the differentiated ciliated channels traversing the skin, ×8.

4. A tube-foot enlarged, showing the expanded integumentary lappets.

5. Actinal view of a terminal plate and adjacent portion of ray. The actinal terminal spines cover the bright red "ocular" organ here shown in solid black.



PYCNOPODIA HELIANTHOIDES

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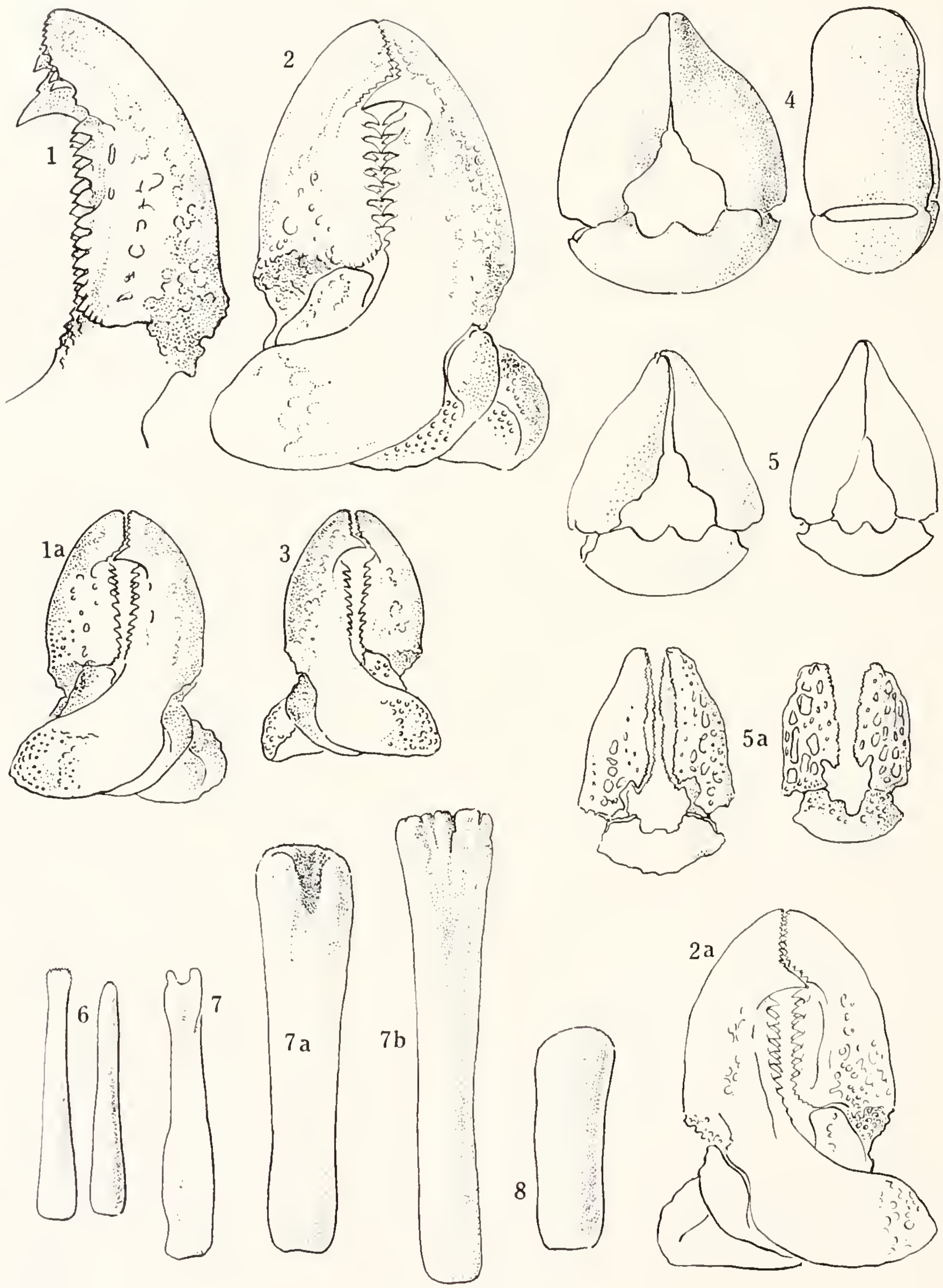

PYCNOPODIA HELIANTHOIDES

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PLATE 78

All figures *Pycnopodia helianthoides*

FIG. 1. Crossed pedicellaria, Unalaska, ×200. *1a.* Same, 0.45 mm. long, ×100.

2. Crossed pedicellaria, Monterey Bay, Calif., 0.36 mm. long, ×200. *2a.* Same, from young specimen, 0.29 mm., ×200.

3. Crossed pedicellaria, Departure Bay (Nanaimo), British Columbia, 0.37 mm., ×100.

4. Abactinal giant straight pedicellariae, Karluk, Kadiak, 1.75 mm., ×25.

5. Abactinal straight pedicellariae, Monterey Bay, Calif.; length 1.5 and 1.4 mm., ×25.

5a. Small straight pedicellariae from the furrow clusters, the larger 0.18 mm. long, ×200.

6. Superomarginal (left) and abactinal spine; from small specimen, station 4222, ×10.

7. Abactinal spine from large Unalaskan specimen.

7a. Inferomarginal spine from same.

7b. Superomarginal from same; all ×10.

8. Abactinal spine, ×10, of specimen from Monterey Bay.

PLATE 79

All figures *Pycnopodia helianthoides*

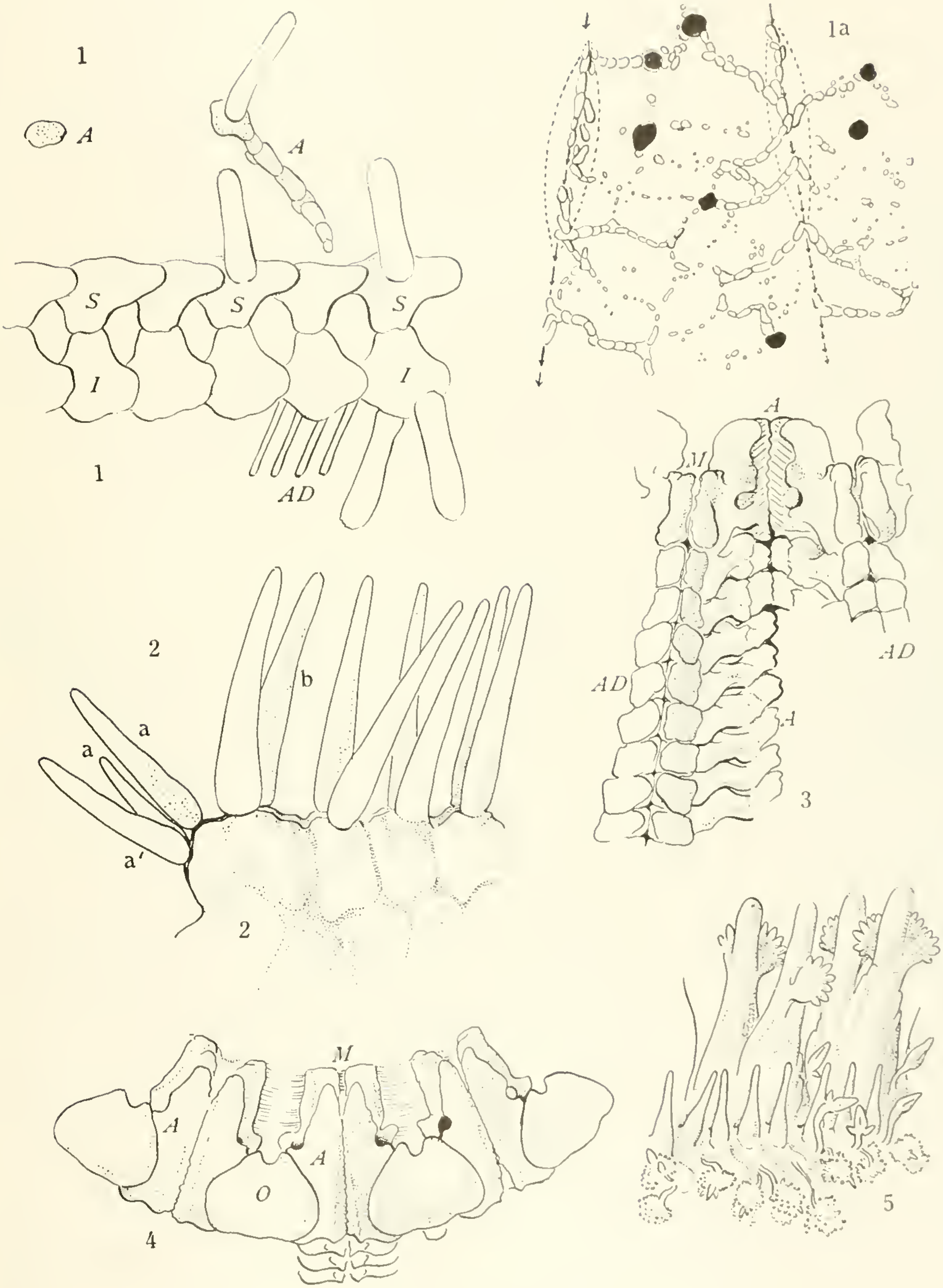
FIG. 1. Marginal and abactinal plates of a small specimen from Monterey Bay, enlarged, seen from side. *A*, abactinal; *S*, *S*, *S*, spiniferous superomarginals; *I*, inferomarginals; *AD*, actinal surface of four adambulacral plates projected upon lateral view to show relative size; base of ray to right. 1*a*, Abactinal skeleton made up of small obsolescent plates seen from coelomic side of radial area near periphery of disk, ×3. The two lines of arrows indicate the position of two membranous interbrachial septa which would lie at right angles to plane of drawing. The inner free vertical edge of these septa is at the two uppermost arrows, and the plates within the elliptical area enclosed by dotted lines fortify the upper part of the septum rather than the dorsal wall. Solid black plates are spiniferous.

2. Mouth plate and three adambulacrals seen from side ×5; Unalaska. *a*, *a*, actinostomial spines of the farther, hidden mouth plate; the nearer plate having only one, a^1; *b*, suboral spine of the farther plate.

3. Actinal view of two pairs of mouth plates and part of adjacent adoral carina, ×3; *A*, ambulacral plates; *AD*, adambulacrals; *M*, mouth plates.

4. Dorsal or coelomic view of a portion of a cleaned actinostomial ring including three radii, ×5. *A*, ambulacral plates; *M*, mouth plates; *O*, odontophore.

5. Actinal view of two inferomarginal and eight adambulacral plates of a partly dried alcoholic specimen from Nanaimo, British Columbia, ×5.



PYCNOPODIA HELIANTHOIDES

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PYCNOPODIA HELIANTHOIDES

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PLATE 80

Pycnopodia helianthoides; abactinal view of a small specimen, natural size; *ped*, pedicellariae left by a sea urchin (*Strongylocentrotus*), which had been attacked by the sea star.

PLATE 81

Fig. 1–3. *Sclerasterias heteropaes* six-rayed, fissiparous young from station 4431, $\times 3\frac{1}{5}$. Three new rays are appearing symmetrically after the animals have divided in two. In figure 1 the longest radius is 10 mm.

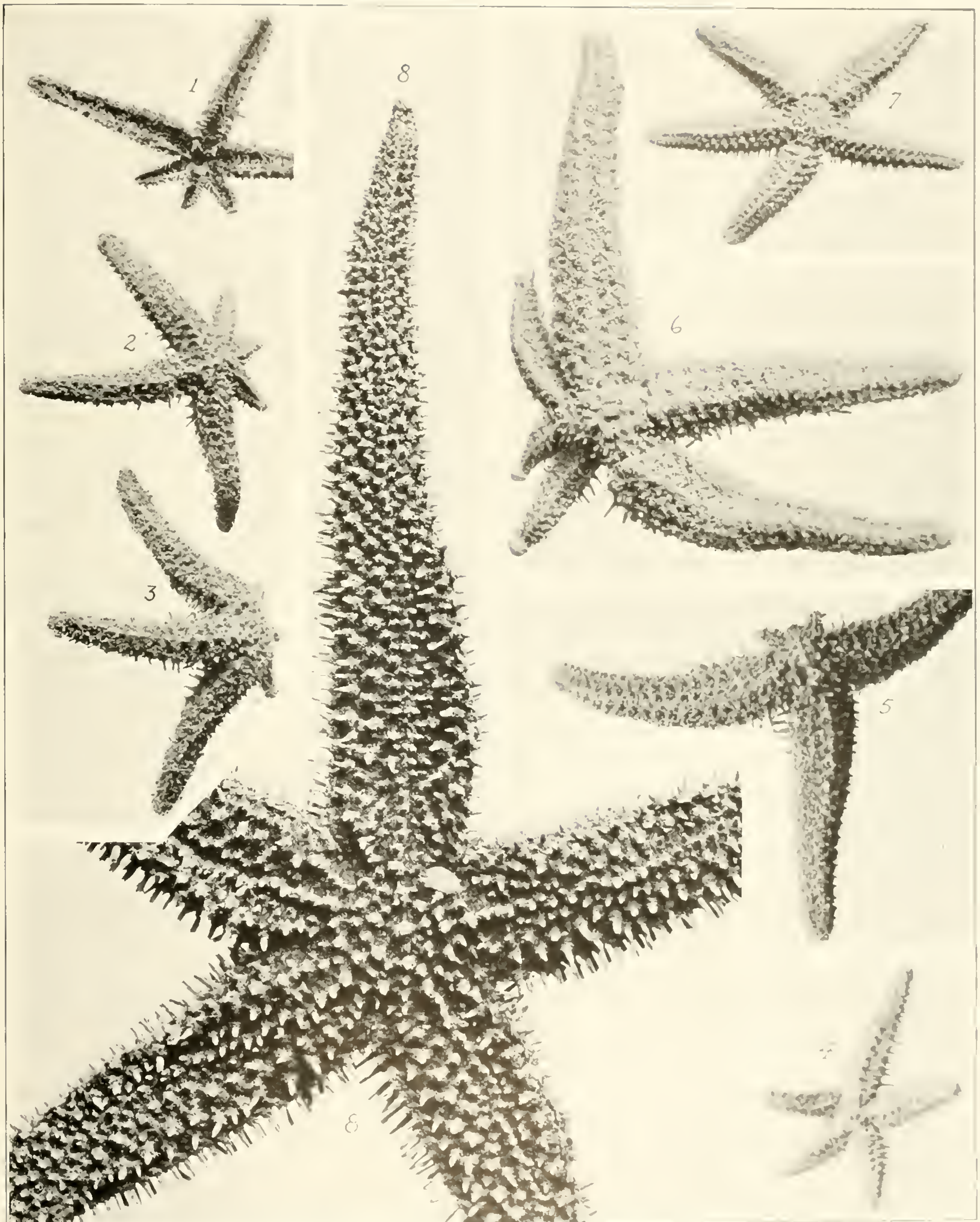
4. *Sclerasterias heteropaes*, a five-rayed young from station 4416, $\times 3\frac{1}{5}$. From the same haul was taken a small symmetrical six-rayed specimen with equal radii. (R 7.5 mm.)

5. *Sclerasterias heteropaes*, station 4328; six-rayed young with three very small regenerating rays; longest radius, 15 mm., $\times 3\frac{1}{5}$.

6. *Sclerasterias alexandri*, station 3397, off Panama, 85 fathoms; young in six-rayed stage with three regenerating rays, $\times 3\frac{1}{5}$. Referred to in the text.

7. *Sclerasterias euplecta*, station 4046, west coast of Hawaii, 117 fathoms; symmetrical five-rayed young, longest radius 8 mm.

8. *Distolasterias nipon*, Peter the Great Bay, near Vladivostok, 1926; collected by the Pacific Marine Station. One of the types of *D. tricolor* Djakonov (now in Museum of Comparative Zoölogy). Radius shown, 127 mm.



1-5. SCLERASTERIAS HETEROPAES. 6. S. ALEXANDRI. 7. S. EUPLECTA. 8. DISTOLASTERIAS NIPON

FOR EXPLANATION OF PLATE SEE PAGE FACING

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INDEX

The following index contains the names of the families, genera, species, and subspecies of Asteroidea which occur in this memoir. Two kinds of type are used for names, roman and italic; the former indicates valid names, the latter synonyms. But when a species name follows a genus name that is a synonym of another genus name, both the genus and species names of the combination are italicized, although the species may be valid. Two kinds of type are used in the figures referring to the pages; the heavy-faced type indicates the pages on which descriptions may be found. Names occuring in the explanation of plates have not been indexed

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