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DAVID K. CALDWELL
Editor

A KEY TO THE SPECIES OF OPHIUROIDEA * (BRITTLE STARS) OF THE SANTA MONICA BAY AND ADJACENT AREAS¹

By RICHARD A. BOOLOOTIAN² AND DAVID LEIGHTON³

ABSTRACT: Thirty ophiuroid species occur off the coast of Southern California. The bathymetric range, color in life, habitat, and meristic characteristics are considered. A *dichotomous* key is presented.

Southern California ophiuroids are now well catalogued, although no key to the species existing in any geographically distinct region of the California shore and the continental shelf between La Jolla and Monterey has been previously published.

The pioneer work in the field of Pacific North American ophiuroids was done by Lyman (1861), who listed ten species and later increased the figure to sixteen. Nine species were added to the list by Clark (1911). Neilsen's (1932) résumé of the material collected during the Mortensen Pacific Expedition of 1914-1916 has been invaluable in the composition of this key.

Excellent work has been done on the Japanese ophiuroids by Matsumoto (1917); species occurring in the Nanaimo district were listed by Berkeley (1927); those found in the Philippine seas were presented by Koehler (1922). For those species occurring along the North American coast, Neilsen (1932) prepared a key considering the entire area from the Strait of Georgia to the Gulf of Panama, and Bush (1918, 1921) a key to the ophiuroids of Friday Harbor, Washington. Barnard and Zieshenne (1961) discussed the ophiuroid communities of Southern California coastal bottoms. The only works which are locally applicable are the keys of McClendon (1909) for the San Diego region and May (1924) for Monterey Bay. McClendon's key is the only one useful to investigators in Southern California.

Through the work of the investigators noted above, there are now 40 recognized species of ophiuroids from the North American Pacific coast. Thirty species of ophiuroids are included in this key, ten of which may be collected intertidally.

Materials used in this study were obtained by employing SCUBA for the subtidal forms. Some of the intertidal species were collected by the authors; others were provided by Fred Zieshenne of the Allan Hancock Foundation, University of Southern California.

In this key an attempt has been made to utilize ophiuroid characters which are least subject to variation and which can be observed externally with a hand

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²Department of Zoology, University of California, Los Angeles; and Research Associate in Marine Zoology, Los Angeles County Museum of Natural History.

³Scripps Institution of Oceanography, La Jolla, California.

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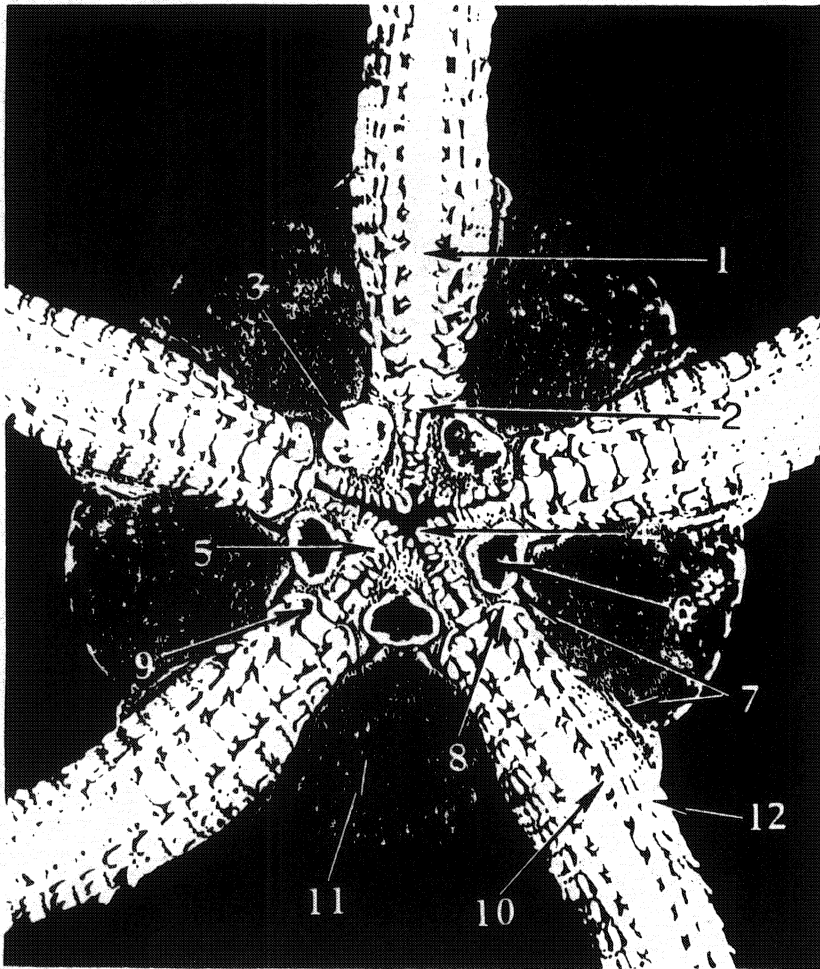


Figure 1. *Ophioderma panamense*. diagnostic parts

- | | |
|---|---|
| 1. oral arm plate <i>ventral arm plate</i> | 7. genital slit |
| 2. angle of mouth <i>1st ventral arm pl.</i> | 8. side arm plate <i>lateral arm plate</i> |
| 3. madreporite | 9. tentacle pore |
| 4. apex of jaw <i>tip of jaw</i> | 10. tentacle scale |
| 5. oral papilla | 11. interbrachial area of disc <i>ventral interradius</i> |
| 6. oral shield | 12. arm spine |

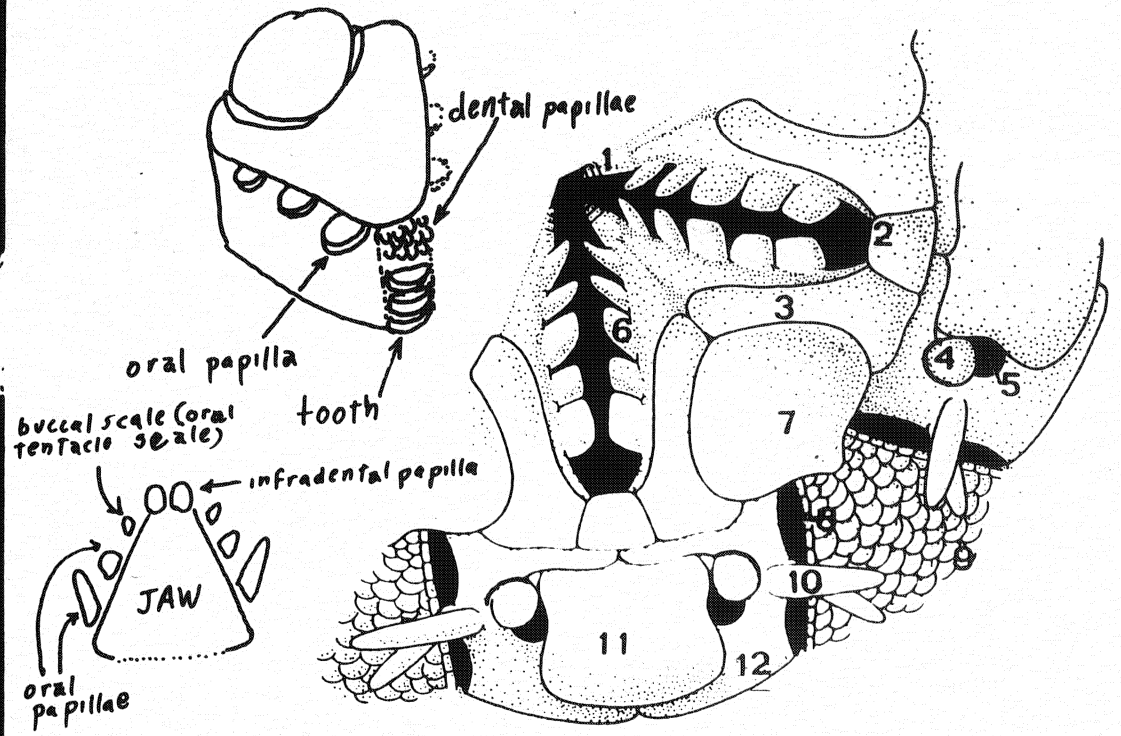


Figure 2. Two-fifths of oral aspect of a diagrammatic disc to show diagnostic parts

- | | |
|---|--|
| 1. teeth | 7. oral shield |
| 2. angle of mouth <i>1st ventral arm pl.</i> | 8. genital slit |
| 3. adoral plate <i>adoral shield</i> | 9. interradial portion of disc |
| 4. tentacle scale | 10. arm spine |
| 5. tentacular pit <i>Tentacle pore</i> | 11. 1st oral arm plate <i>2nd ventral arm pl.</i> |
| 6. oral papilla | 12. side arm plate <i>lateral arm plate</i> |

lens, requiring no dissection of material. Disc-arm ratios, general shape, color, and other potentially ambiguous characters have been avoided.

Oral papillation is a fundamental key character, but whether enlarged oral tentacle scales should be included in the number of oral papillae per jaw in all cases is questionable. Where these structures are obvious, they have been included (see *Ophionereis annulata*). Together with the key we include a table indicating where the specimens may be found (Table 1), as well as a photograph (Fig. 1) and a diagram showing general diagnostic features (Fig. 2). An illustration showing the details of the oral papillae is included for each species.

The key is in no way a natural one, though for the most part, related genera fall closely together.

KEY

I. Both disc and arms covered by a leathery skin; aboral arm plates absent or rudimentary; arms branched (Fig. 3). *Gorgonocephalus eucnemis*

II. Arms never covered by a thickened skin; aboral arm plates present; arms never branched.

A. Aboral disc scaled, though scales may be discontinuous.

1. Oral papillae six or less than six per jaw.

a. Oral papillae two to four (rarely five) per jaw.

(1). Individuals often six-rayed; oral papillae blunt.

(a). Radial shields small, never joining with mate; four smooth spines on each side arm plate; two oral papillae per jaw (Fig. 4). *Ophiactis simplex**

(b). Radial shields large; mates joining distally; five (rarely six) spines with fine serration on each side arm plate; four or five oral papillae per jaw (Fig. 5). *Ophiactis savignyi**

(2). Individuals never six-rayed; oral papillae sharp, numbering two or three per jaw; one apical or subapical and two (occasionally three) distal oral papillae.

(a). One tentacle scale; disc strongly scaled (Fig. 6). *Amphiura diastata*

(b). Two tentacle scales; disc occasionally not scaled centrally (Fig. 7). *Amphiura arcystata*

= *Amphiura diomedea*
Lütken & MTSn.

b. Oral papillae six per jaw; three or occasionally four spines per side arm plate.

(1). Two proximal pairs of oral papillae small; distal pair broad and elongate.

(a). Interbrachial areas granular; radial shields separate or meeting only distally (Fig. 8). *Amphichondrius granulatus*

(b). Interbrachial areas scaled; radial shields in solid contact.
i. Longest arm spines about 1½ times length of arm joint; arms markedly long and narrow (Fig. 9). *Amphipholis pugetana**

ii. Longest arm spines about 1 arm joint in length; arms relatively short (about four times the disc) (Fig. 10). *Amphipholis squamata**

(2). Oral papillae all subequal in size and shape.

(a). Some of the disc scales with free ends prolonged into fine points.

i. Scales of aboral disc few and large (Fig. 11). *Amphiodia (Amphispina) digitata*

ii. Scales of aboral disc numerous and small (Fig. 12). *Amphiodia (Amphispina) urtica*

(b). Disc scales never prolonged into fine points.

i. Disc with a rosette of large scales aborally; tentacle scales (2) unequal in size; plates about mouth inflated (Fig. 13). *Amphiodia psara*

ii. Disc with fine scales; tentacle scales (2) equal in size; plates about mouth not inflated (Fig. 14). *Amphiodia occidentalis*

2. Oral papillae more than six per jaw.

a. Eight oral papillae per jaw (rarely nine).

(1). Spines on disc partially covering scales; oral papillae spinose and globose (Fig. 15). *Amphiacantha amphacantha*
* *Dougalopus amphacantha*

(2). No spines present on disc; most oral papillae heavy though a few are terete. Two tentacle scales in angle of mouth often considered to be oral papillae (10).

(a). Tentacle scales in angle of mouth separate from true oral papillae row; proximal oral papillae heavy and globose; other oral papillae heavy but tapered (Fig. 16). *Amphioplus strongyloplax*

(b). Tentacle scales in angle of mouth closely adjacent to row of true oral papillae; oral papillae tapered and not heavy (Fig. 17). *Amphioplus hexacanthus*

b. Nine or more than nine oral papillae per jaw.

(1). Oral papillae nine to ten; those in angle of mouth curved and pointed (actually tentacle scales). Tentacle scales large and saucer shaped; three arm spines on each side arm plate.

(a). Aboral arm plate large; accessory plates very small. Disc with scattered large scales of lighter pigmentation; arms mottled brown and cream (Fig. 18). *Ophionereis eurybrachyplax*

- (b). Aboral arm plates equaled in size by accessory plates; light spots scattered on disc incorporating several small scales; arms banded (Fig. 19) *Ophioneis annulata**
- (2). Oral papillae more than ten per jaw; tentacle scales often more than one, neither large nor saucer shaped.
 - (a). Arm spines sharp, about one arm joint in length; small notches in disc above arm base edged with small papillae; symmetrical scale situated centrally on aboral disc (Fig. 20). *Ophiura lutkeni*
 - (b). Arm spines not sharp and considerably less than one arm joint in length; disc notches and symmetrical scale absent; oral papillae in even rows.
 - i. Oral papillae partially fused; tentacle pores only on first three oral arm plates; aboral arm plates not divided (Fig. 21). *Ophiomusium jolliensis*
 - ii. Oral papillae not fused; aboral arm plates divided into many smaller plates; arms flattened (Fig. 22). *Ophioplocus esmarki**

B. Scales or plates of aboral disc covered or partially obscured by superficial structures.

- 1. Disc covered by a thickened epidermis. ?
 - a. Velvet-like epidermis covering disc; oral papillae and arm spines small and numerous; adults often over twelve inches in diameter (Fig. 23) *Ophioderma panamense** ← dorsal surface of disc granule-covered
 - b. Smooth or parchment-like epidermis covering disc in interradiar areas; arm spines long, flattened, narrower at base than at end; tentacle scales similar to arm spines and usually held in crossed position on oral surface of arm (Fig. 24). *Ophiopsila californica*
- 2. Disc covered with spines or short stumps.
 - a. Spines of arms held normally to arm axis (unless improperly preserved).
 - (1). Arm spines heavy and flattened; low rounded stumps cover disc; dorsal-most arm spine very short; dental papillae numerous (Fig. 25). *Ophiopteris papillosa**
 - (2). Arm spines rather light and delicate; no oral papillae; disc covered by short spines.
 - (a). Arm and disc spines serrated; seven arm spines on each side arm plate (Fig. 26). *Ophiothrix spiculata**
 - (b). Arm and disc spines rather smooth; five or six arm spines on each side arm plate (Fig. 27). *Ophiothrix rudis**
 - b. Arm spines form small angles with arm axis.

- (1). Arm spines short and blunt; disc fairly heavily covered with branched spines; small supplementary plates partially surround aboral arm plates (Fig. 28). *Ophiopholis bakeri*
- (2). Arm spines rather long and tapered; side arm plates nearly or completely meeting above and below; granules cover most of disc.
 - (a). Oral papillae twelve to fourteen per jaw; some fine scales in evidence on disc.
 - i. Spines of considerable size scattered on aboral disc; shorter stumps and granules cover most of balance of disc; oral arm plates well separated by side arm plates; longest arm spine about three arm joints in length (Fig. 29). *Ophiacantha phragma*
 - ii. Small granules almost completely hiding scales of disc; oral arm plates not widely separated by side arm plates; longest arm spines about five arm joints in length (Fig. 30). *Ophiacantha diplasia*
 - (b). Oral papillae seven to nine per jaw; short spines with fine points cover disc.
 - i. Longest arm spines about two arm joints in length; stumps on disc drawn out to fine (single) points; tentacle scales conical (few scales may show on disc) (Fig. 31). *Ophiacantha normani*
 - ii. Longest arm spines about four arm joints in length; disc with short multi-fid spines; tentacle scales not conical; arm spines serrated (Fig. 32). *Ophiacantha rhachophora*

*Specimens collected intertidally

TABLE I
Various Ecological Aspects of Ophiuroids Discussed in this Paper

Species	Bathymetric Range	Sample Location	Type of Bottom	Reference	Maximum disc diameter	Color
<i>Gorgonocephalus eucnemis</i>	28-93 fathoms	Monterey Bay, California	Gray sand, shells, blue mud, sand (coarse), rock.	May	90 mm.	Reddish tones with brown markings.
<i>Ophiothrix spiculata</i>	lowtide—42 fathoms	Monterey Bay, California & Santa Monica Bay, California	Gray sand, shells, mud, and rock. Holdfasts of <i>Macrocystis</i> .	May & this paper	15 mm.	Variable: blue, green or tan with reddish bands on arms.
<i>Ophiothrix rudis</i>	lowtide—5 fathoms	Palos Verdes, California	Rock and coarse sand.	this paper	11 mm.	Variable: green or tan with reddish bands on arms.
<i>Ophiacantha diplasia</i>	46-80 fathoms	Monterey Bay, California	Coarse sand, green mud, and rock.	May	25 mm.	Disc brown, arms whiter, as dried from alcohol.
<i>Ophiopholis bakeri</i>	26-265 fathoms	Monterey Bay, California	Mud, rock, and sand.	May	10 mm.	Pink or white, dried from alcohol.
<i>Amphiura arcystata</i>	56-156 fathoms	Monterey Bay, California	Mud, rock, and sand.	May	8 mm.	Light orange, brown with white scales, dried from alcohol.
<i>Amphiura diastata</i>	244-253 fathom.	*	Sand and mud.	Clark	*	*
<i>Amphiodia occidentalis</i>	lowtide—15 fathoms	Monterey Bay, California	Sand.	May	11 mm.	Variable, but disc often gray with red markings. Arms yellowish or whitish and spines pink.
<i>Amphiodia urtica</i>	10-100 fathoms	La Jolla, California	Sand or mud.	Nielsen	9 mm.	Disc gray, arms white or straw colored.
<i>Amphiodia digitata</i>	10-100 fathoms	La Jolla, California	Packed sand to "coarse mud."	Nielsen	7 mm.	Whitish yellow, dried from alcohol.

Species	Bathymetric Range	Sample Location	Type of Bottom	Reference	Maximum disc diameter	Color
<i>Amphipholis squamata</i>	lowtide—20 fathoms	La Jolla, California & Departure Bay, Nanaimo	Coralline algae and holdfasts.	Nielsen	8 mm.	*
<i>Amphipholis pugetana</i>	lowtide—44 fathoms	Monterey Bay, California	Mud, and sand or rock.	Clark	*	*
<i>Ophiura lütkeni</i>	11-357 fathoms	Monterey Bay, California	Soft or hard mud, sand or rock, and sandy areas.	Nielsen	7.5 mm.	Yellowish in alcohol.
<i>Ophioplocus esmarki</i>	*	Monterey Bay, California, Santa Monica Bay, California & La Jolla, California	Sand and rock.	Nielsen	9 mm.	White, dried from alcohol.
<i>Ophionereis eurybrachyplax</i>	54-80 fathoms	Monterey Bay, California	Sand and mud or rock.	Nielsen	34 mm.	Dark brown with lighter yellow or white mottlings; annulations on arms.
<i>Ophionereis annulata</i>	lowtide—5 fathoms	California & Panama	Sand and mud or rock.	Clark	21 mm.	*
<i>Ophiopteris papillosa</i>	lowtide—40 fathoms	Monterey Bay, California	Sand and rock.	Ziesenhenné	*	*
<i>Ophiactis savignyi</i>	lowtide—5 fathoms	Panama	Among coralline algae and holdfasts of rock kelp, especially where sand has begun to accumulate.	Ziesenhenné	*	*
<i>Ophiactis simplex</i>	lowtide—5 fathoms	Panama & San Diego, California	Holdfasts of rock kelp.	Clark	*	*
<i>Amphiplus strongyloplax</i>	2-200 fathoms	La Jolla, California & Str. of Georgia	*	Clark	*	*

Species	Bathymetric Range	Sample Location	Type of Bottom	Reference	Maximum disc diameter	Color
<i>Amphioplus hexacanthus</i>	50-88 fathoms	•	Mud, sand, and broken shell.	Zieshenne	•	•
<i>Amphicantha amphacantha</i>	90-100 fathoms	La Jolla, California	•	Nielsen	•	Whitish, dried from alcohol.
<i>Amphichondrius granulatus</i>	10-25 fathoms	La Jolla, California	•	May	4 mm.	Variable: disc reddish brown, pink, or gray; arms white with gray or blackish mottling.
<i>Ophioderma panamense</i>	low tide—15 fathoms	La Jolla, California & Panama	•	May	22 mm.	Salmon red with darker markings.
<i>Ophiomusium jolliensis</i>	167-505 fathoms	La Jolla, California	Clay, mud, and sand.	this paper	30 mm.	Dark brown aborally; tan or yellow orally.
<i>Ophiopsila californica</i>	•	•	•	May	23 mm.	Light brown, arms with whitish or purplish markings.
<i>Ophiacantha phragma</i>	•	•	•	Nielsen	18 mm.	Tan or gray, dark annulation on arms.
<i>Ophiacantha normani</i>	40-987 fathoms	•	Green and brown mud and sand.	May	30 mm.	Light to dark brown. Young with darker annulations on arms.
<i>Ophiacantha rhachophora</i>	63-584 fathoms	•	Sand and broken shell.	Nielsen	7 mm.	Greenish with darker cross bands on arms; oral side yellow.
<i>Amphiodia psara</i>	•	•	•	Nielsen	5.5 mm.	Greenish or yellow with darker annulations on arms.

*No information available

DEFINITIONS OF TERMS

- Aboral*: side opposite the mouth; the dorsal aspect of the animal.
- Aboral arm plates*: superficial plates covering the dorsal portion of each arm joint.
- Aboral plates*: shields or plates situated on either side of an oral shield.
- Angle of mouth*: the distal portion of the slit formed by approximation of any two adjacent jaws.
- Disc*: the central body of an ophiuroid which is sharply marked off from the arms.
- Distal*: occupying a position away from the mouth or away from the center of the disc.
- Genital scales*: scales, usually in orderly rows, bordering the genital slits.
- Genital slits*: slits located interbrachially and orally on the disc (on either side of each arm base) indicating the position of the genital bursae.
- Interbrachial areas*: the oral disc lying between adjacent arms.
- Jaws*: five (or rarely six) triangular structures surrounding the mouth and usually bearing a number of oral papillae laterally and a vertical row of teeth apically.
- Oral*: the ventral surface as opposed to the aboral or dorsal surface; implying direction toward the mouth or on the same surface as the mouth.
- Oral arm plates*: those plates situated on the ventral surface of the arm joint through which pass the podia.
- Oral papillae*: modified spines usually found on the sides of each jaw and bordering the angle of the mouth.
- Oral shield*: a plate, usually comparatively large, situated on the mid-interbrachial line at the base of each jaw.
- Podia*: tube feet projecting through the tentacle pores of the oral arm plates.
- Proximal*: toward the oral-aboral axis; opposed to distal.
- Radial shields*: plates, often large, existing in pairs and located on or approaching the radius of the aboral disc.
- Radius*: an imaginary line drawn from the center of the disc to any arm tip.
- Side arm plates*: those plates covering the lateral aspect of each arm joint and supporting the arm spines.
- Tentacle pores*: a pair of openings in the oral arm plate through which pass the podia or tentacles.
- Tentacle scales*: scales found bordering the tentacle pores which, in some species, completely close the tentacle pore.
- Tooth papillae*: small papillae lying ventrally and about the teeth on the axis of the jaw. (Found in relatively few of the species considered in this key.)

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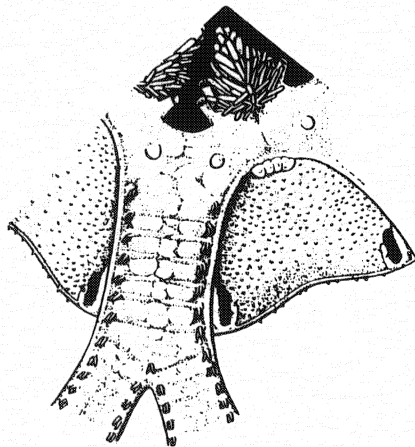


Figure 3. *Gorgonocephalus eucnemis*.

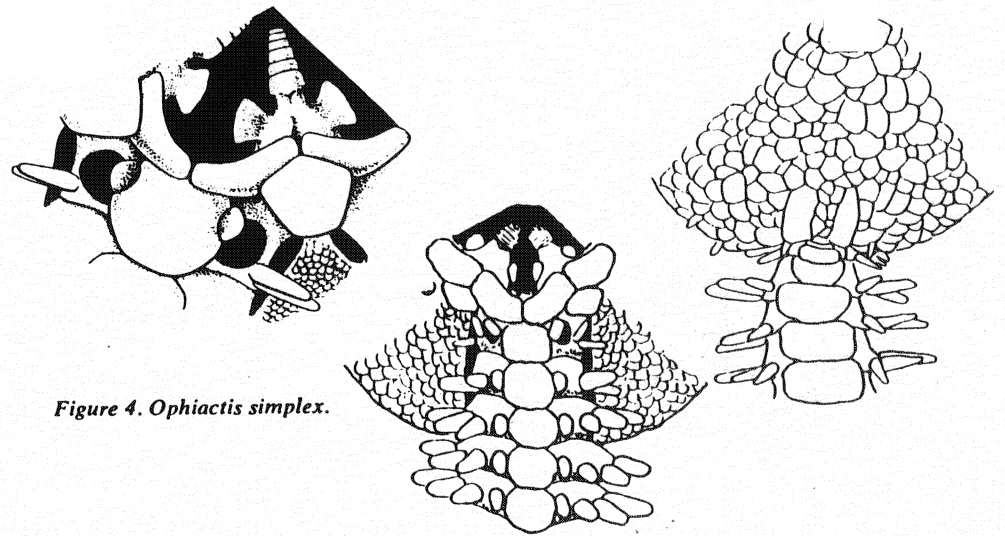


Figure 4. *Ophiactis simplex*.

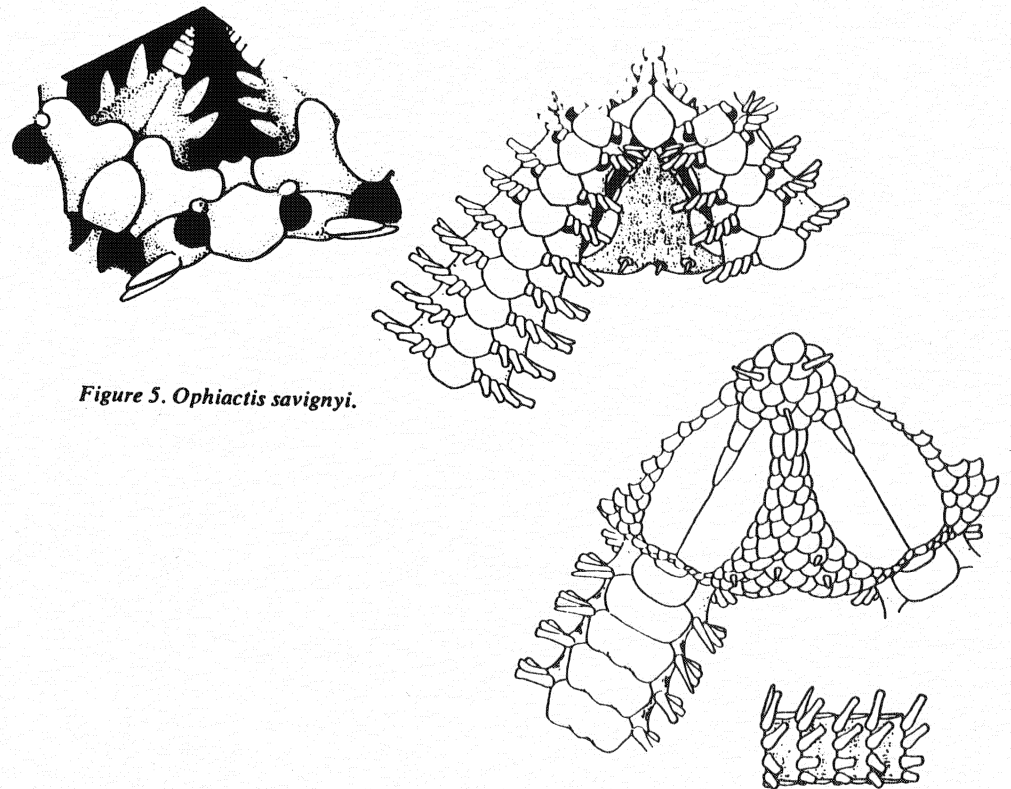


Figure 5. *Ophiactis savignyi*.

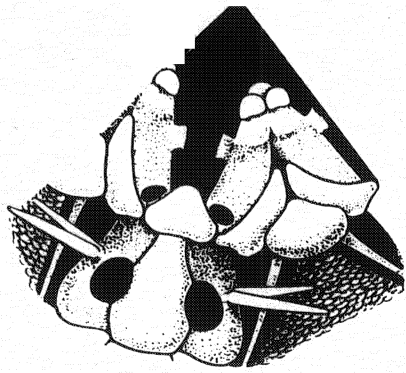


Figure 6. *Amphiura diastata*.

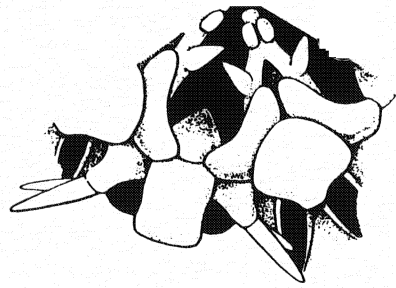
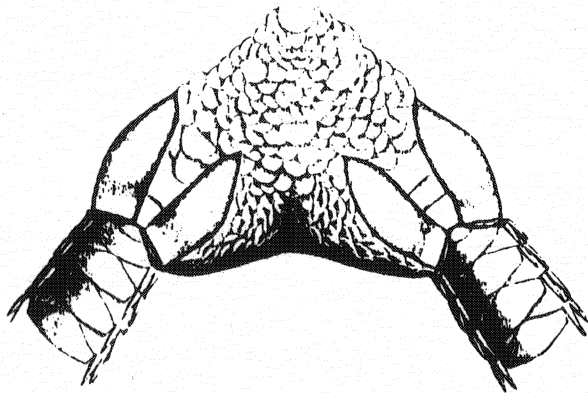
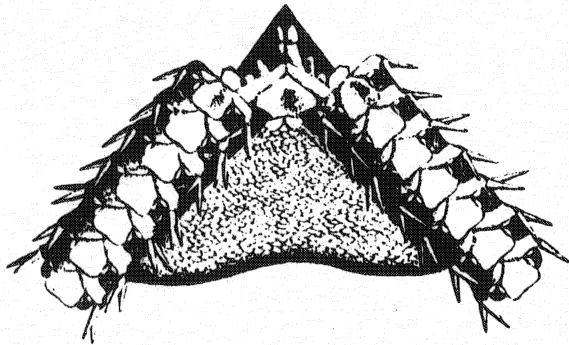


Figure 7. *Amphiura arcystata*.

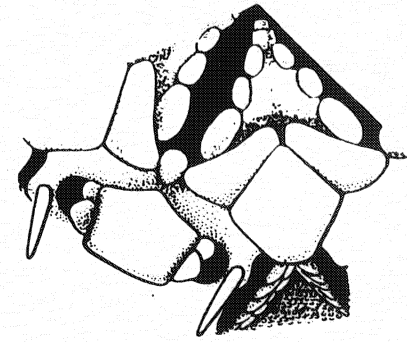
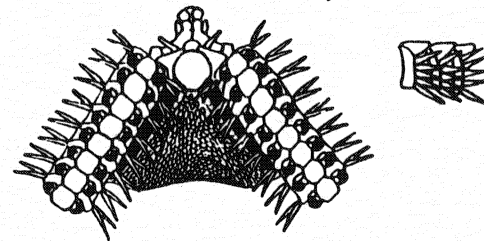
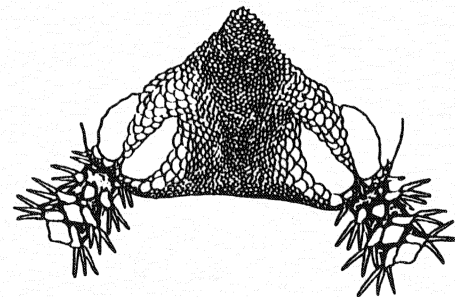
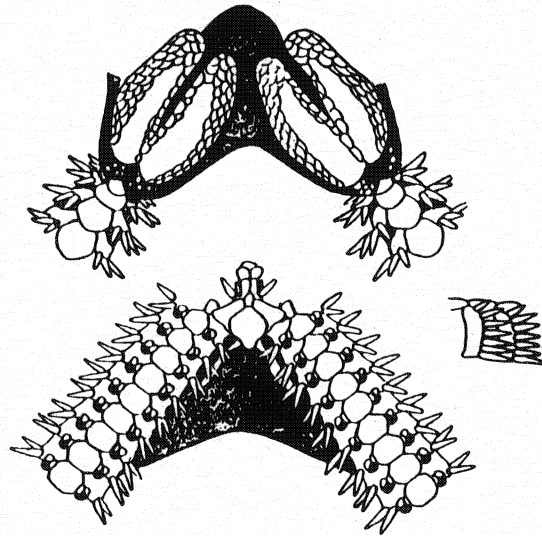
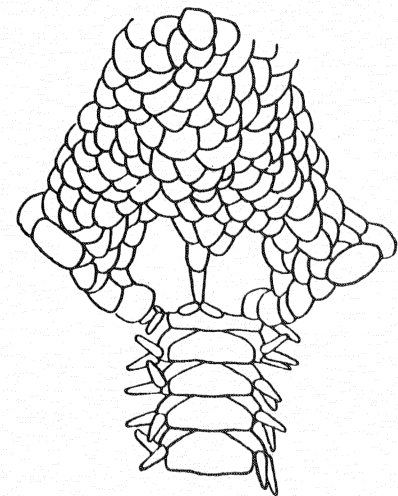
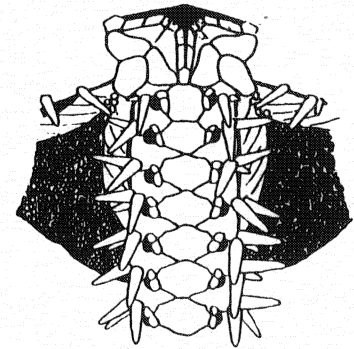


Figure 8. *Amphichondrius granulatus*.



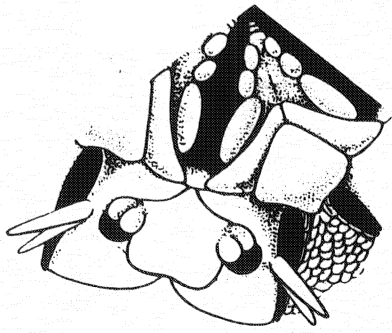


Figure 9. *Amphipholis pugetana*.

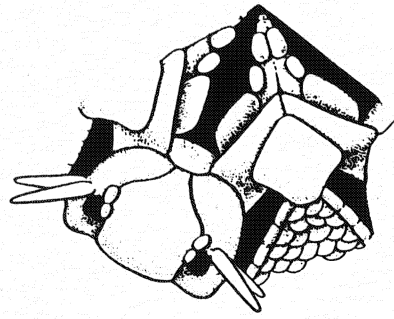


Figure 10. *Amphipholis squamata*.

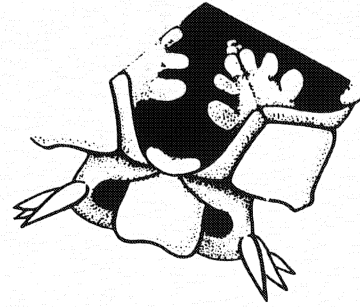


Figure 11. *Amphiodia digitata*.

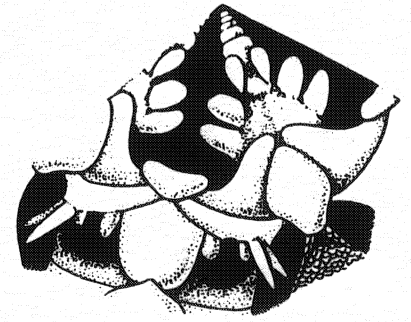
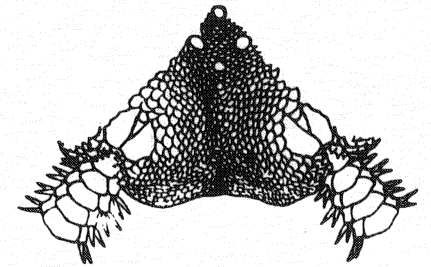
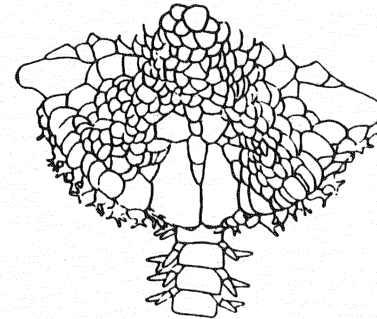
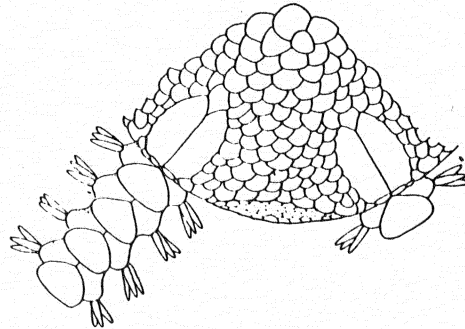
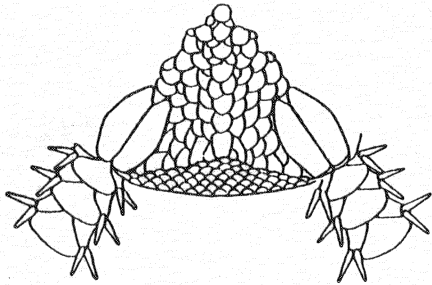
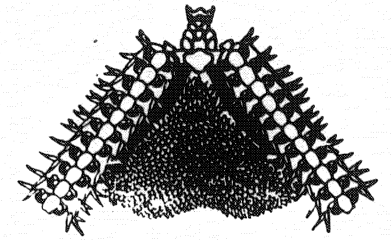
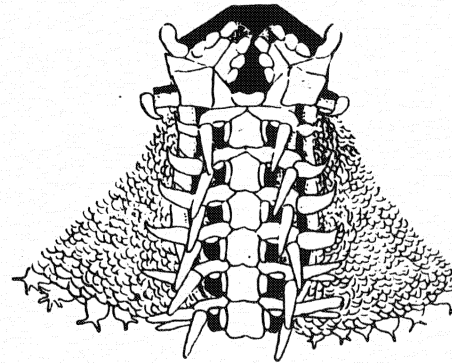
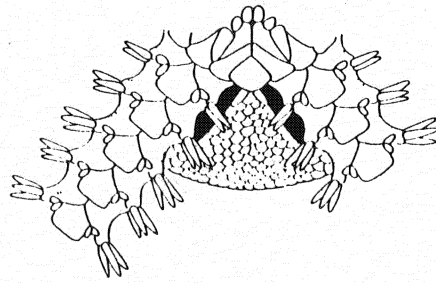
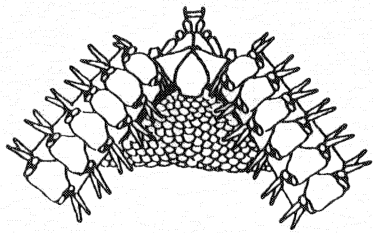


Figure 12. *Amphiodia urtica*.



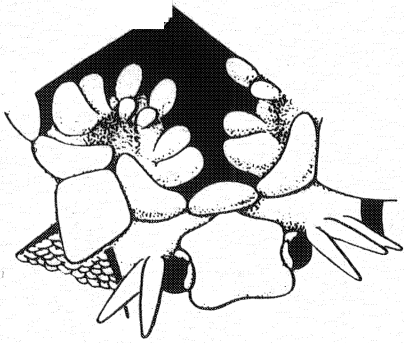


Figure 13. *Amphiodia psara*.

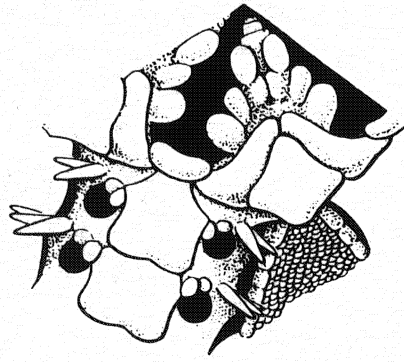


Figure 14. *Amphiodia occidentalis*.

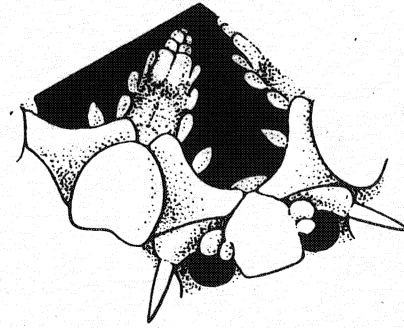


Figure 16. *Amphioplus strongyloplax*.

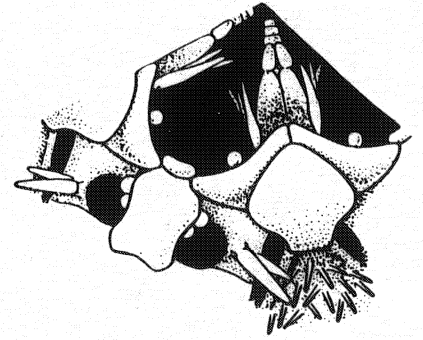
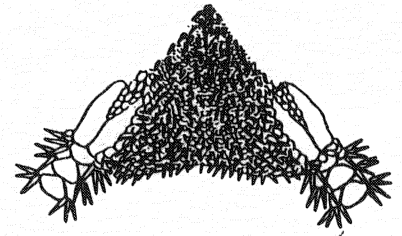
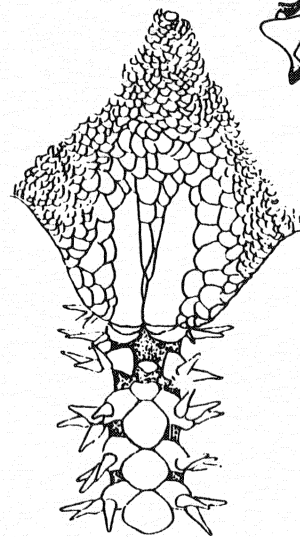
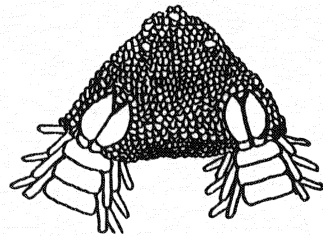
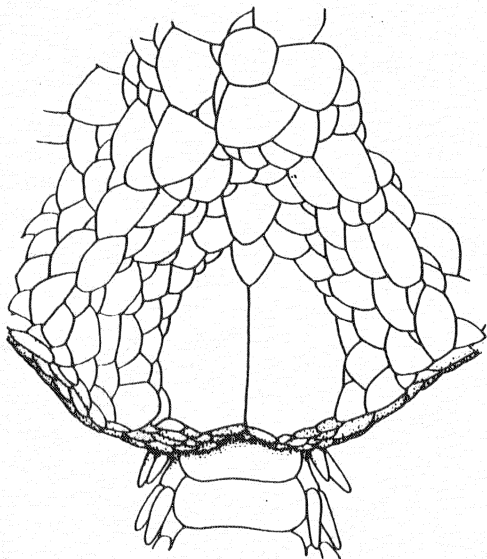
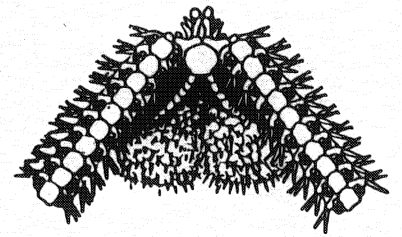
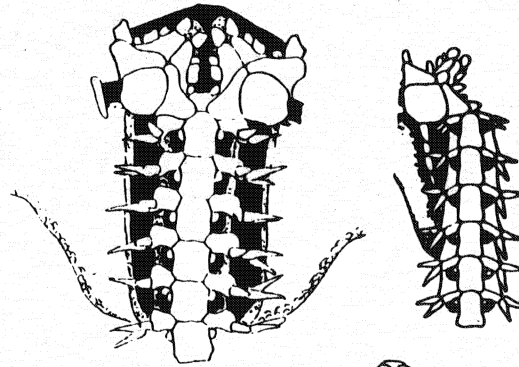
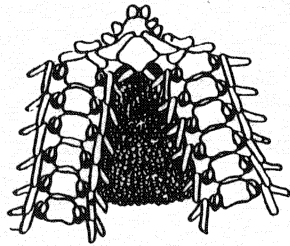
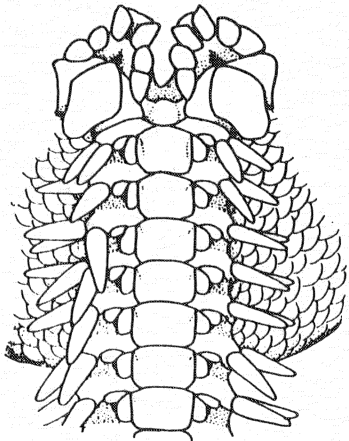


Figure 15. *Amphiacantha amphacantha*.



AMPHIOPLUS HEXACANTHUS, new species.¹¹

Disk lacking. Upper arm plates broadly hexagonal, with rounded corners, twice as wide as long. Arm spines six, about equal to joint; middle ones shortest and one or more terminated by a minute, glassy crossbar. Oral shields oval, longer than wide. Adoral plates large, meeting broadly within. Oral papillæ, four on a side, subequal or apical one largest. Under arm plates squarish or slightly pentagonal, rather wider than long. Tentacle scales, two.

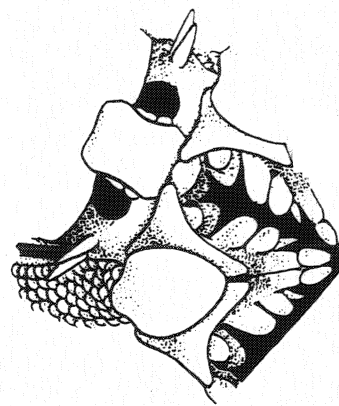


Figure 17. *Amphioplus hexacanthus*.

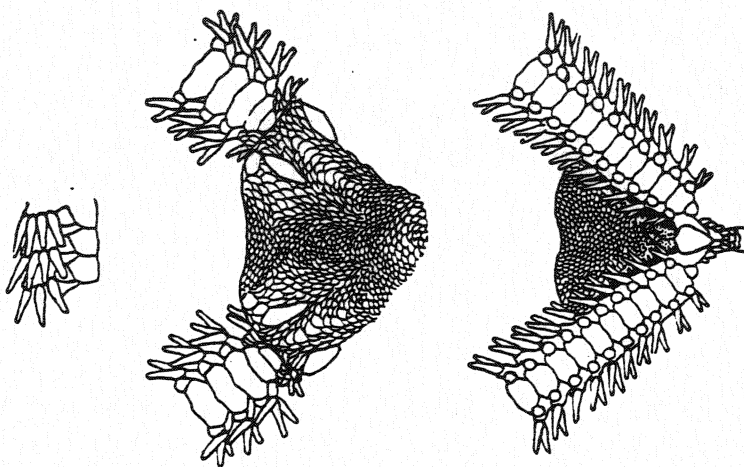


Figure 18. *Ophioneis surbrachyplax*.

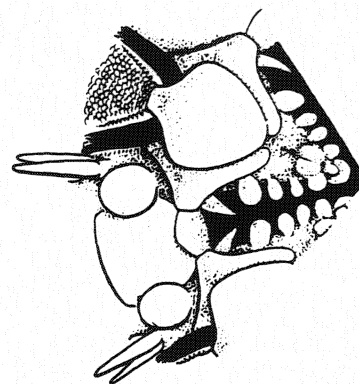


Figure 19. *Ophioneis annulata*.

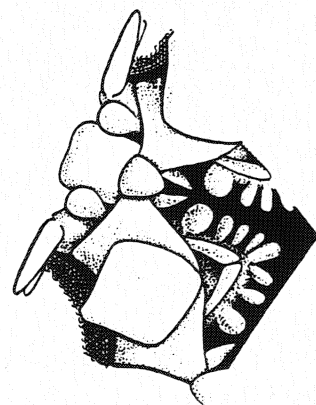
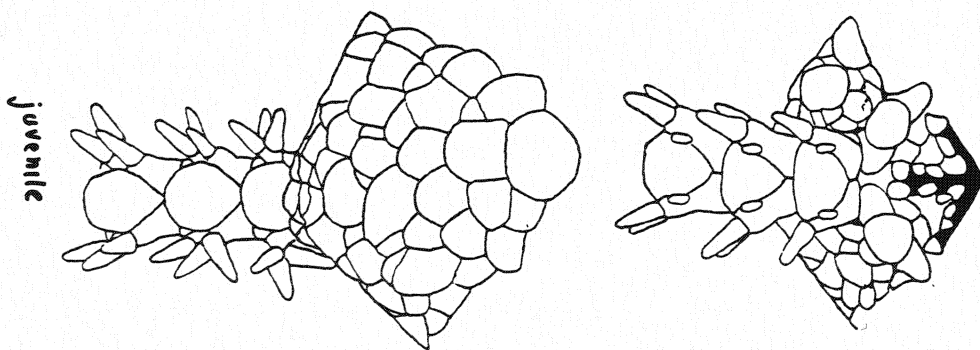
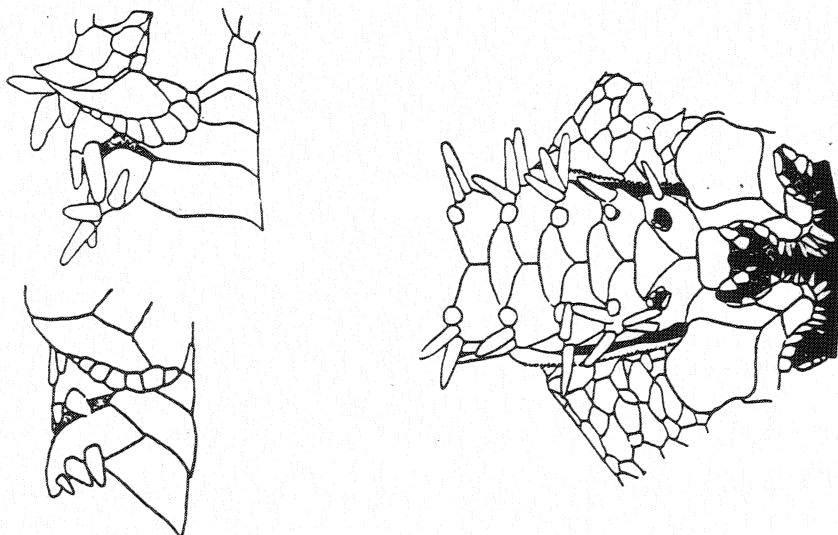


Figure 20. *Ophura lukeni*.



juvenile



Ophiosphalma glabrum

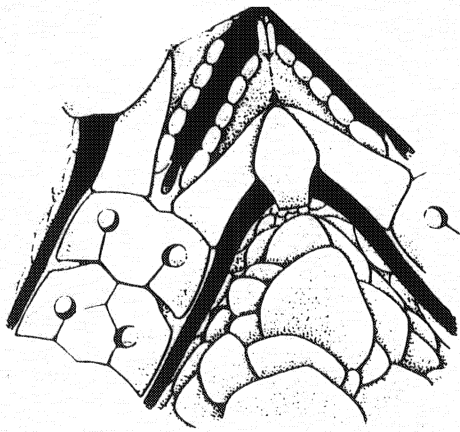


Figure 21. *Ophiomusium jolliensis*.

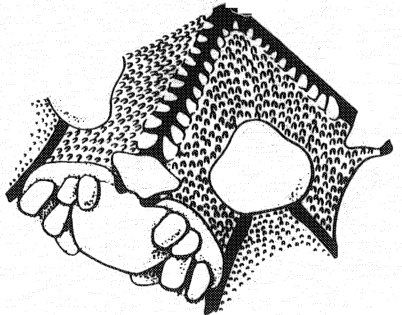
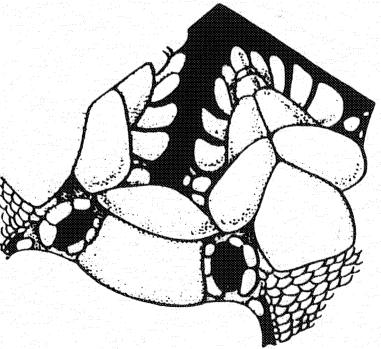
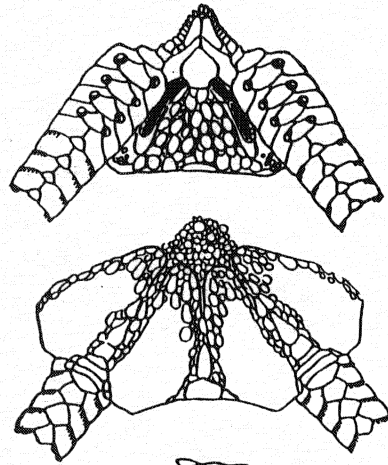
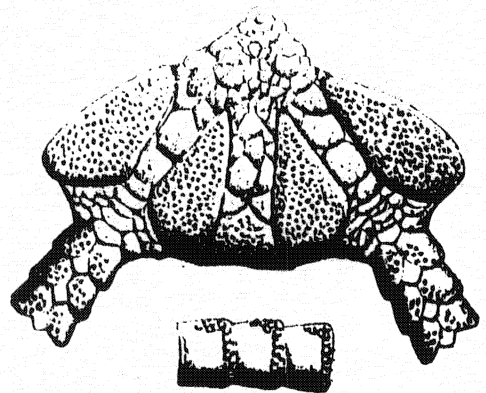
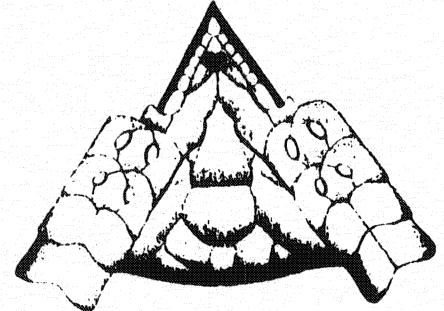
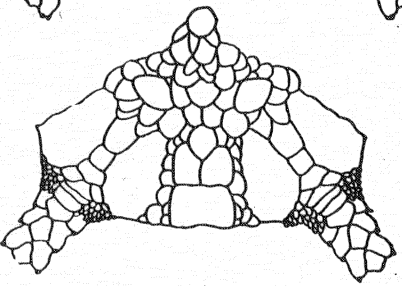
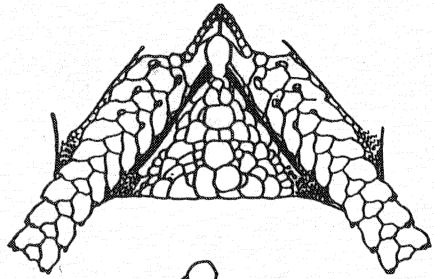


Figure 22. *Ophioplocus esmarki*.

Figure 23. *Ophioderma panamense*.

III

(= *Ophiomusium mutispinum*)



Ophiomusium lymani

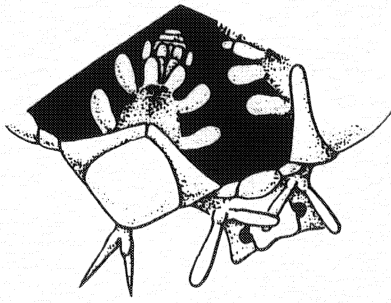
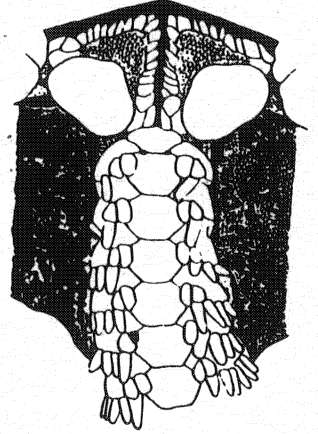
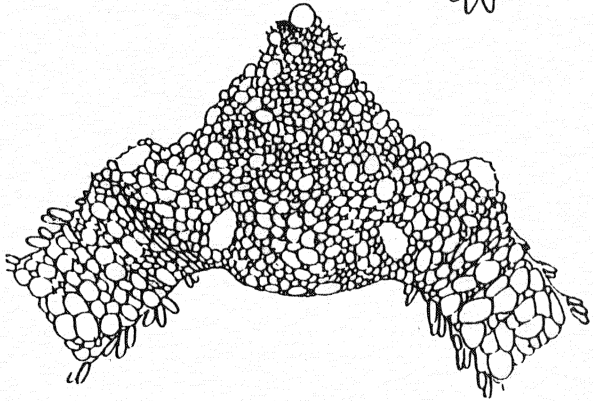
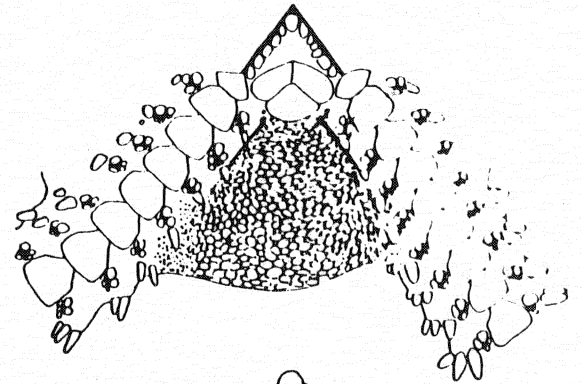


Figure 24. *Ophiopsila californica*.

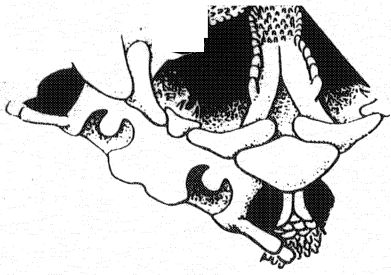


Figure 25. *Ophiopteris papillosa*.

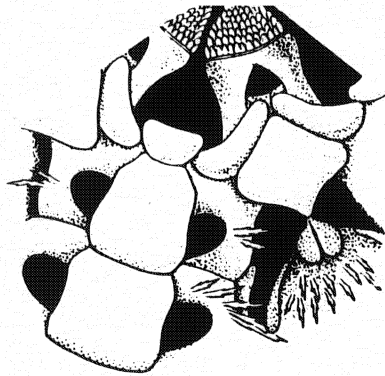


Figure 26. *Ophiothrix spiculata*.

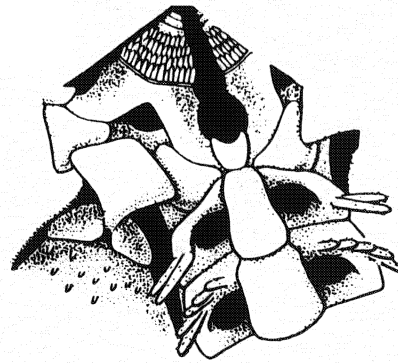


Figure 27. *Ophiothrix rudis*.

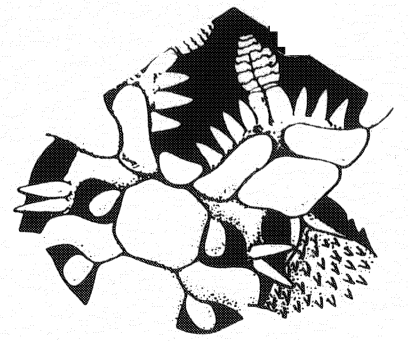
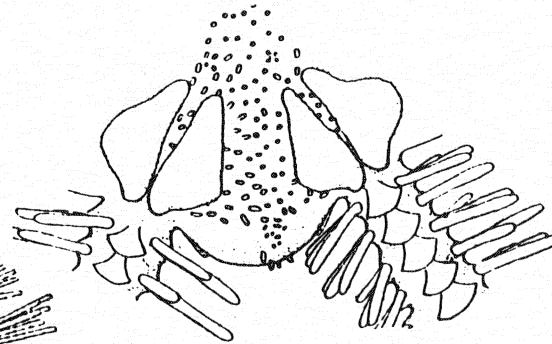
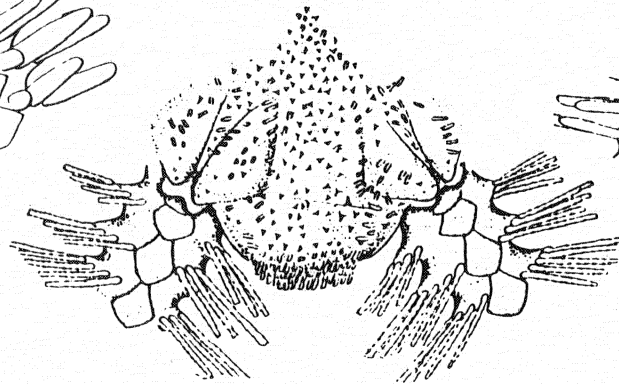
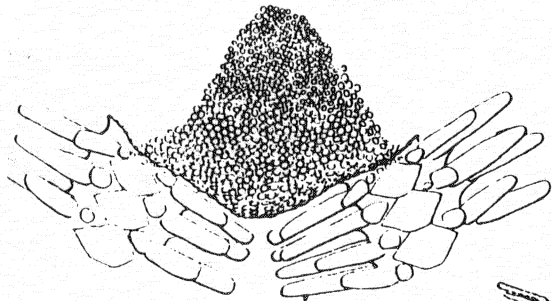
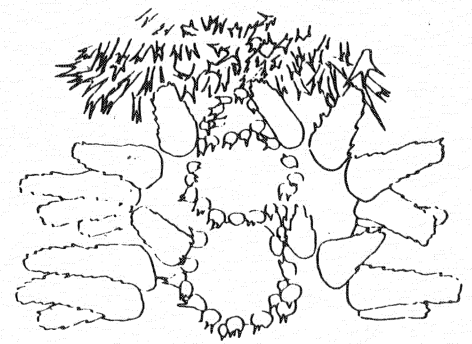
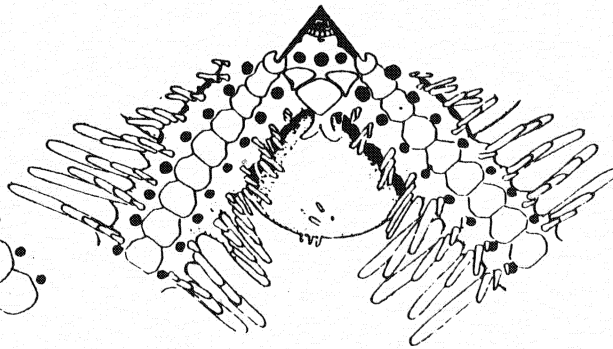
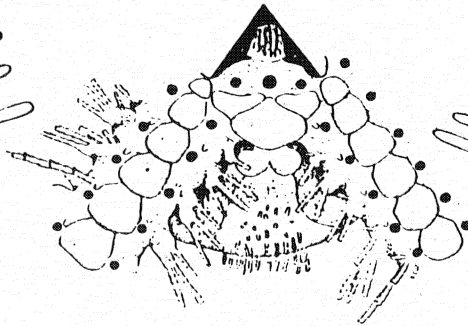
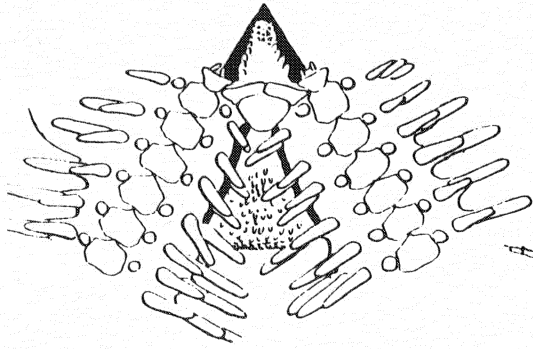


Figure 28. *Ophiopholis bakeri*.



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H.L. Clark (1911)
North Pacific Ophiurans
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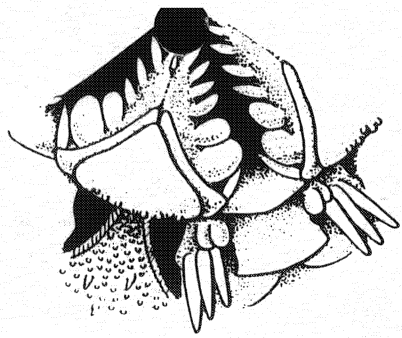


Figure 29. *Ophiacantha phragma*.

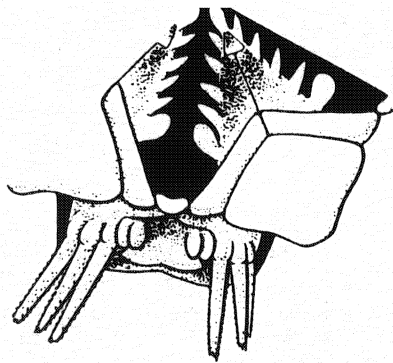


Figure 30. *Ophiacantha diplasia*.

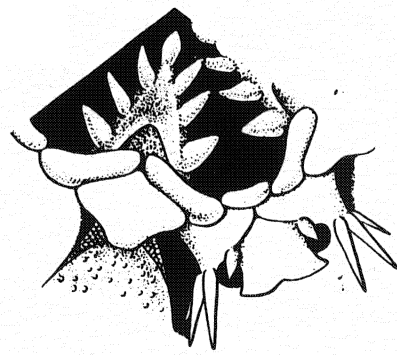


Figure 31. *Ophiacantha normani*.

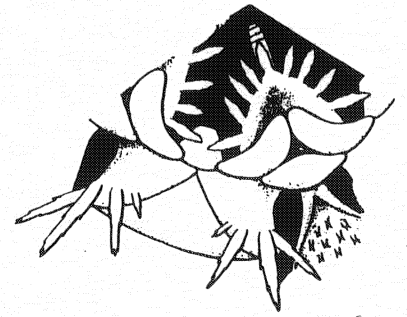


Figure 32. *Ophiacantha rhachophora*.

