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THREE NEW SPECIES OF STOLIDOBRANCH ASCIDIANS (CHORDATA: ASCIDIACEA) FROM THE CALIFORNIA CONTINENTAL SHELF

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ABSTRACT: Three new species of solitary stolidobranch ascidians are described from the California continental shelf region from Point Conception to Point San Luis. *Molgula napiformis* was collected from soft sediment at 90-92 m. It is distinguished from other northeast Pacific species of *Molgula* by a constellation of characters that includes a very long, branching posterior stolon (presumably used for anchoring in the substrate); the placement of the siphons; gonad shape; and the tubular opening of its dorsal tubercle. *Boltenia polyplacoderma* was collected from rock surfaces at 91-117 m. It is unlike any other species of *Boltenia* in that the anterior and lateral tunic surfaces are divided into annulated flat plates that increase in number as the animal grows. *Styela tesseris*, collected from rocks at 61-88 m, is easily distinguished from other northeast Pacific species of *Styela* by the tessellated tunic pattern, especially when this trait is considered along with all the other body characters. A list of all the ascidians collected is given with their depths and localities. In addition, the ascidian assemblages that were present at 11 of the 18 hard-substrate stations sampled are enumerated.

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INTRODUCTION

Although the intertidal and shallow subtidal ascidian fauna is well known for the Pacific coast from Alaska to Mexico and even for much of South America (Van Name 1945), the deeper water species have rarely been sampled. Of the 14 species collected by dredging off the California coast in 1904, nine were new species, indicating that this area was not well known (Ritter 1907). Between 1983 and 1988 the U.S. Department of the Interior Minerals Management Service (MMS) sponsored a major collecting effort of the benthic invertebrate fauna of the Santa Maria Basin and western Santa Barbara Channel (Blake and Lissner, in press). During this project, some of the same localities that had been sampled by Ritter in 1904 were examined by box corer and manned submersible. Ascidians were found at 11 of the 18 hard-substrate stations and at four of the 136 soft-substrate stations. Twenty species of ascidians were collected; six of these are the same species collected by Ritter, 11 are described species not previously recorded from this area, and three are undescribed species (Lambert, in press).

In addition to the following descriptions of these three new stolidobranch species, a list of all the ascidians collected during the MMS project, with their depth and locality, is given in Table 1. The ascidian assemblages at the 11 hard-substrate stations that included ascidians are listed in Appendix A.

Table 1. Ascidians collected during the MMS Phase I and Phase II Monitoring Program in the Santa Maria Basin.

	Depth (m)	Location
Order Aplousobranchia		
Family Didemnidae		
1. *Didemnum carnulentum* var. *lacteolum*	61.5–73	Goleta Pt. to Pt. Arguello
2. *Tridemnum opacum*	61.5	Pt. Arguello
Family Polycitoridae		
3. *Distaplia occidentalis*	87	Purisima Pt.
4. *Eudistoma carolinense* (?)	86–98	Purisima Pt.
Family Synoicidae		
5. *Aplidium californicum*	61.5	Pt. Arguello
6. *Aplidium spauldingi*	97	Purisima Pt.
7. *Aplidium* sp.	97	Purisima Pt.
8. *Euherdmania claviformis*	117	Pt. Buchon
Order Phlebobranchia		
Family Ascidiidae		
9. *Ascidia* sp.	98.5	Purisima Pt.
Family Rhodosomatidae		
10. *Chelyosoma columbianum*	54–231	Goleta Pt. to Pt. Buchon
11. *Corella* sp.	231	Pt. Conception
Order Stolidobranchia		
Family Molgulidae		
12. *Molgula napiformis*	90–92	Purisima Pt. to Pt. San Luis
13. *Molgula regularis*	105	Purisima Pt.
Family Pyuridae		
14. *Boltenia polyplacoderma*	91.5–117	Pt. Conception to Purisima Pt.
15. *Halocynthia igaboja*	88–231	Pt. Conception to Pt. Buchon
16. *Pyura haustor*	97–231	Pt. Conception to Pt. Buchon
17. *Pyrua* sp.	61.5–97	Pt. Arguello
Family Styelidae		
18. *Styela gibbsii*	61.5	Pt. Arguello
19. *Styela milleri*	69–117	Goleta Pt. to Pt. San Luis
20. *Styela tesseris*	61.5–88	Pt. Arguello to Purisima Pt.
21. *Styela* sp.	69–73.5	Goleta Pt.

Materials and Methods

The three new species described in this paper were collected from the Santa Maria Basin and western Santa Barbara Channel's outer continental shelf during the 1983–86 Phase I assessment of long-term changes in biological communities in these areas by the U.S. Department of the Interior Minerals Management Service and the 1987–89 Phase II monitoring program by the same agency (Blake and Lissner, in press). *Molgula napiformis* n. sp. was collected from soft sediments by box corer, with the sediment sieved through a 0.1 mm mesh sieve. The rocks from which *Boltenia polyplacoderma* n. sp. and *Styela tesseris* n. sp. were taken were collected by manned submersible.

After collection, the animals were preserved in 10% sea water formalin and later transferred to 70% isopropyl alcohol. Some of the animals

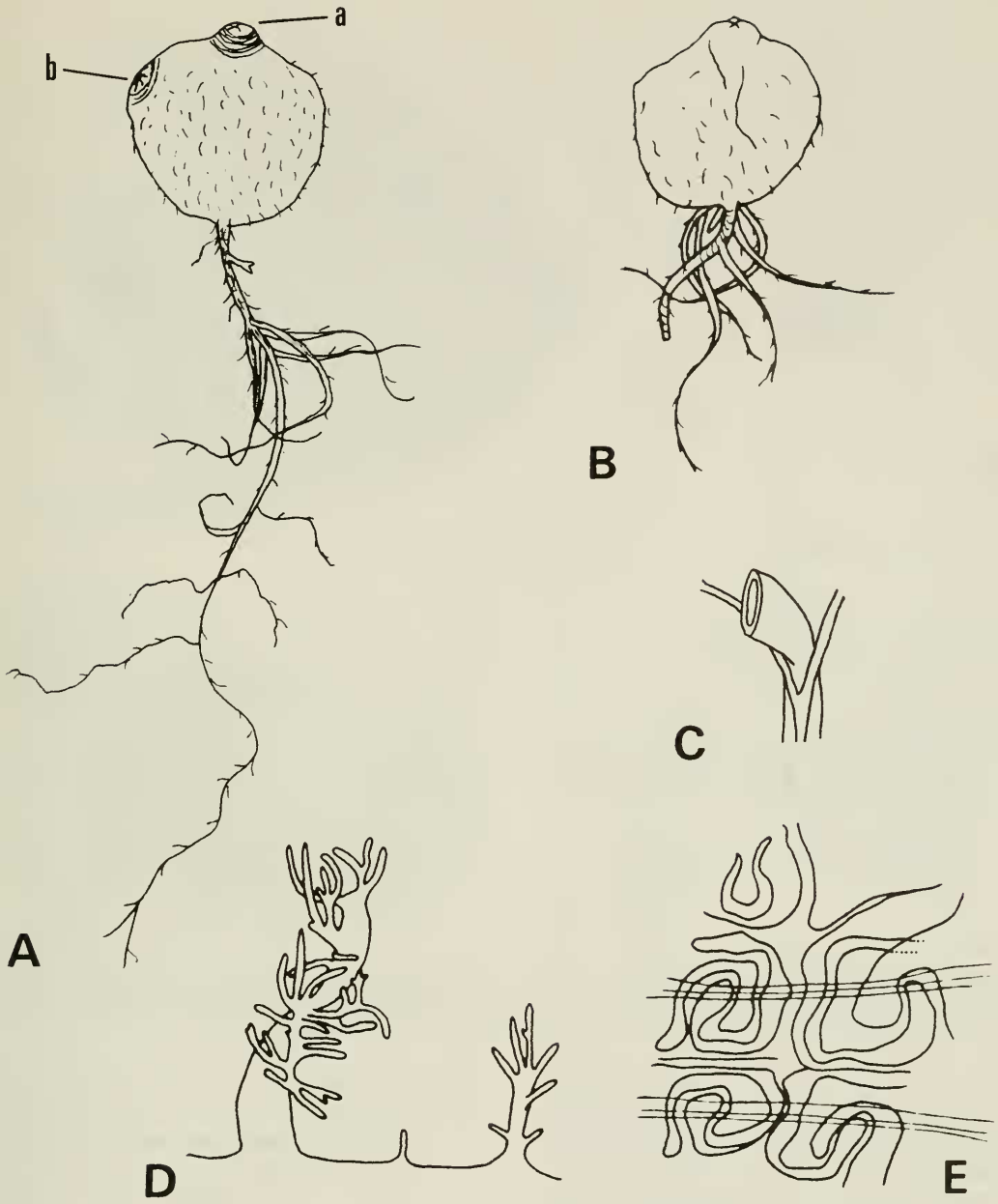

FIGURE 1. *Molgula napiformis* n. sp. A, B, whole animals, left side, ×13 (a—atrial siphon, b—branchial siphon); C, dorsal tubercle between the peripharyngeal bands; D, three branchial tentacles, ×65; E, detail of branchial sac. C–E greatly enlarged.

were placed in glycerin to clear them for microscopic examination and to prevent movement during the execution of the drawings; they were then returned to 70% isopropyl alcohol. Drawings were made with a camera lucida mounted on a stereozoom-dissecting microscope.

DESCRIPTION OF SPECIES

Molgula napiformis n. sp.

(Figs. 1, 2)

HOLOTYPE.—MMS Phase II, Santa Maria Basin, soft substrate, sta. R-4, cruise 2-5 (34°43.01'N, 120°47.39'W) M/V

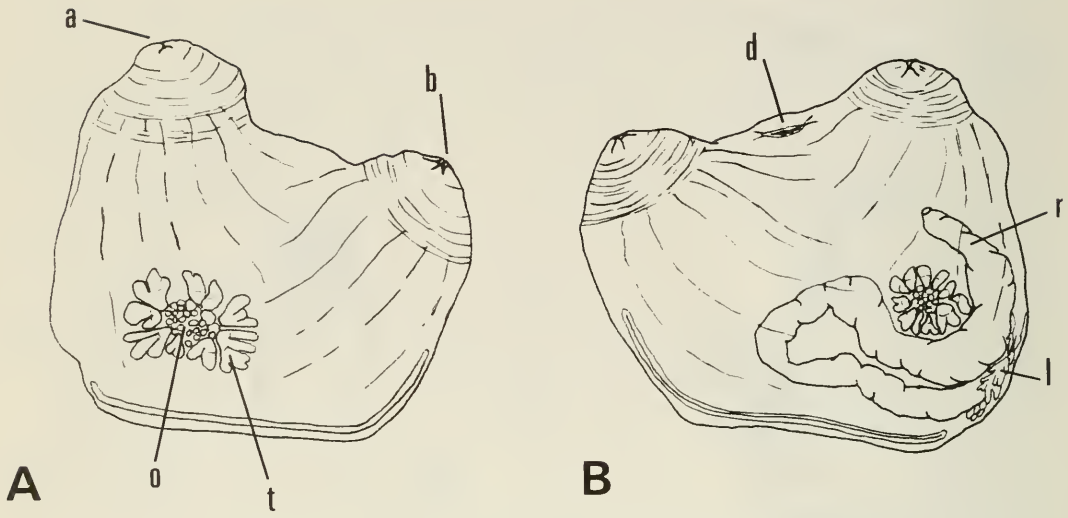

FIGURE 2. *Molgula napiformis* n. sp. A, right side of animal removed from tunic; B, left side (a—atrial siphon, b—branchial siphon, d—dorsal ganglion, l—liver, o—ovary, r—rectum, t—testis). ×30.7.

Aloha at 92 m, coll. May 1988, U.S. National Museum of Natural History, catalog #20008.

PARATYPES.—MMS Phase II, Santa Maria Basin, soft substrate, coll. by M/V Aloha: sta. R-1, cruise 2-4 (35°05.83′N, 120°49.16′W) at 91 m, 3 specimens coll. Jan. 1988, Santa Barbara Museum of Natural History #35608; sta. R-4, cruise 2-5 (34°43.01′N, 120°47.39′W) at 92 m, 5 specimens coll. May 1988, U.S. National Museum of Natural History, #20009; sta. R-8, cruise 1-2 (34°55.30′N, 120°45.87′W) at 90 m, 1 specimen, coll. Jan. 1987, California Academy of Sciences, #086764.

DESCRIPTION.—Animals are almost spherical, 2–3 mm in diameter. The clear transparent tunic is covered with short hairs to which numerous sand grains firmly adhere. An extremely long, branched, root-like posterior process with long hairs projects from the posterior end of the tunic; additional long hairs may or may not be present around the main process. On one specimen the process, or stolon, is about 4 times longer than the animal and greatly branched; it gradually tapers to a very fine hair at its terminus. The siphons are very short and widely separated; the branchial siphon is more noticeable on the tunic surface than the atrial siphon and produced into 6 pointed processes, while the atrial siphon is square. In the 7 specimens examined the location of the siphons is identical; the atrial siphon is anteriormost and at the opposite end of the animal from the stolon, while the branchial siphon is located back about one-third of the body length. The dorsal tubercle contains a narrow oval opening. In the largest animal examined (3 mm in diameter) there are 7 branchial folds on the left side of the branchial sac and 6 on the right side; some of the folds are not distinct in the smaller, 2 mm individuals. There are three longitudinal vessels per fold. The infundibula are large, with only one row of them between each of the rudimentary branchial folds. All the animals examined are more or less immature, so the adult number of infundibular spirals was not determined. The dorsal lamina is a smooth membrane. The largest specimen has 8 large branchial tentacles, long and slender and variably branched; additional small tentacles of various sizes occur between the largest ones and were difficult to count. The mantle contains widely spaced longitudinal muscles radiating from the siphons over the body and overlapping slightly; circular muscles are well developed only on the siphons. The intestine and the stomach with its attached lobed liver are on the left side; the kidney is not developed. The left gonad lies in the secondary intestinal loop. The gonads are oval in outline, with branched or unbranched testes surrounding each ovary.

ETYMOLOGY.—The specific epithet *napiformis* is derived from the Latin term *napus* describing the shape of a turnip root, which the body and long branched stolon of this ascidian resemble.

REMARKS.—This species differs from *Molgula pugetiensis* (1) in possessing a very long, branched tunic stolon and secondary processes in addition to the numerous short tunic hairs; (2) in the siphons being farther apart and shorter; and (3) in

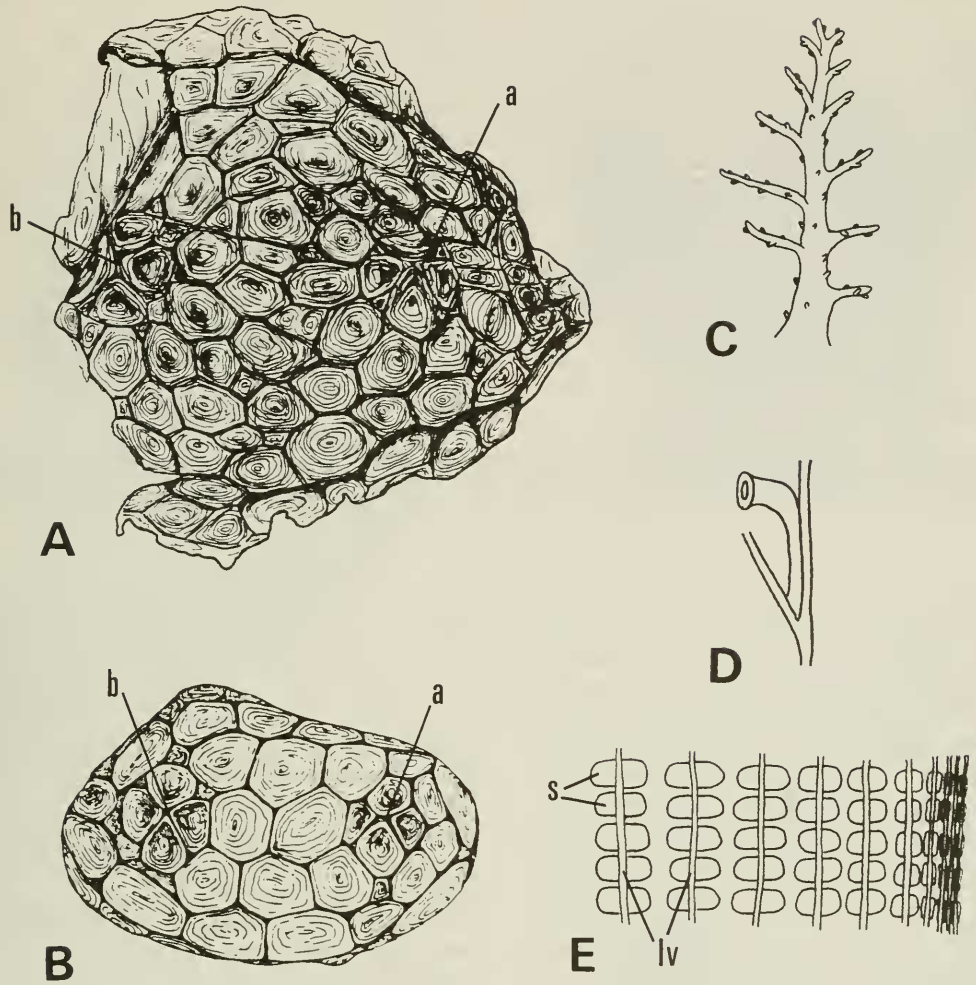

FIGURE 3. *Boltenia polyplacoderma* n. sp. A, anterior surface of tunic of holotype, ×7.2; B, anterior tunic surface of juvenile paratype, ×10; C, branchial tentacle, ×66; D, dorsal tubercle (side view) between the peripharyngeal bands, greatly enlarged; E, detail of branchial sac, ×56 (a—atrial siphon, b—branchial siphon, lv—internal longitudinal vessels, s—stigmata).

the body being attached ventrally which results in the endostyle appearing to be posterior.

Boltenia polyplacoderma n. sp.

(Figs. 3, 4)

HOLOTYPE.—002-BRA-01-TX, Santa Maria Basin (34°11.377′N, 120°29.318′W to 34°11.289′N, 120°28.774′W) at 116 m, 1 specimen coll. Jul.–Aug. 1984. Santa Barbara Museum of Natural History, #35607.

PARATYPES.—016-BRA-01-TX, 2 specimens (34°46.544′N, 120°50.197′W to 34°45.912′N, 120°49.726′W) at 98 m. U.S. National Museum of Natural History, #20010. 013-BRA-04-TX (34°42.570′N, 120°47.899′W to 34°42.107′N, 120°48.253′W) at 98 m, 2 specimens; California Academy of Sciences, #086765. 014-BRA-02-TX (34°43.589′N, 120°49.093′W to 34°42.826′N, 120°48.37′W) at 104 m, 1 specimen; California Academy of Sciences, #086766. All paratypes were collected during Jul.–Aug. 1984.

DESCRIPTION.—The body is very flattened anteroposteriorly. The tunic is rather thin but composed of thickened, irregular, polygonal flat-topped plates, each plate with numerous, closely spaced annulations. The plates are straight-sided with 3–8 sides of unequal lengths. Each polygon is set off from the others by a narrow groove in the tunic, but the plates abut closely, especially in contracted regions. The inner surface of the tunic is covered by a continuous, thin sheet of white, fibrous material. The apertures are 4-sided

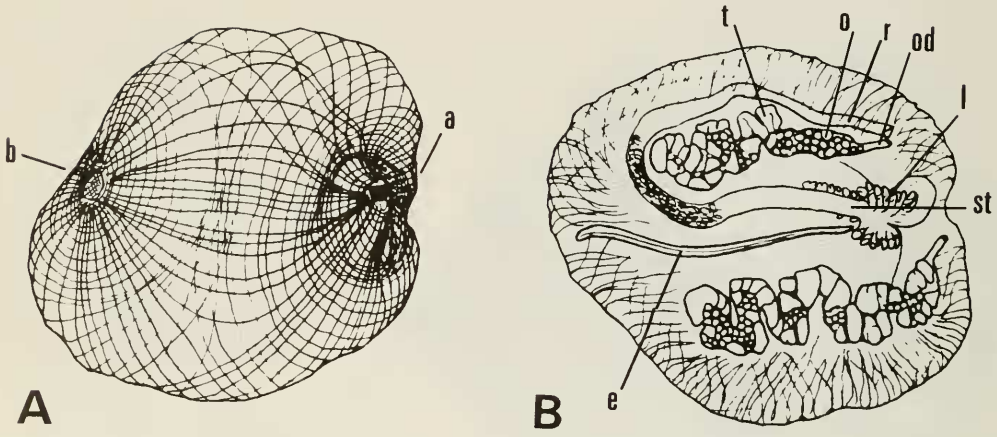

FIGURE 4. *Boltenia polyplacoderma* n. sp., body removed from tunic, ×8.7. A, anterior surface of mantle showing the siphons and musculature; B, posterior view of body, showing digestive and reproductive organs (a—atrial siphon, b—branchial siphon, e—endostyle, l—liver, o—ovary, od—oviduct, st—stomach, r—rectum, t—testis).

and are formed by 4 main triangular plates with smaller plates forming between the bases of the larger ones in the larger animals (compare Fig. 3A, B). The mantle muscles are very regular and robust, the longitudinally radiating ones deeper and the circular ones around each aperture more superficial, creating a beautifully regular meshwork. The dorsal tubercle has a narrow, oval opening at the end of a long tube, opening to the right between the peripharyngeal bands. There are about 18 branched oral tentacles, mostly of 2 alternating sizes. The larger tentacles are alternately branched, the branches containing tiny protruberances. In addition, very small projections occur on the trunk of the main tentacles between the branches. Probably the tentacles would be more branched in larger animals. The branchial sac contains 6 branchial folds on each side, of unequal size; the second (counting from the dorsal lamina) is rudimentary, visible mainly as a region of more closely spaced internal longitudinal vessels. The internal longitudinal vessels are numerous, with about 5 between branchial folds and about 8–12 on each fold. There are 10–12 rows of stigmata between the transverse vessels. Characteristic of this genus, the stigmata are arranged with their long axis running dorso-ventrally in the branchial sac. The stigmata are fairly short and broad, each one crossed at its midpoint by a very thin parastigmatic internal longitudinal vessel. The dorsal lamina is cleft into a series of closely spaced languets. An unidentified notodelphyid copepod was found in the branchial sac. The stomach is long and tubular, with no external grooves or plications. Small lobes of the hepatic gland are visible at the anterior end of the stomach. The intestine is long, tubular, and recurved; the anus margin is slightly lobed. There is one gonad per side, the left one completely within the gut loop. Each ovary is long and slender, with the numerous irregularly lobular testes arranged alongside most of the length of the left ovary and along the entire length of the right ovary.

The sizes of the specimens in this collection range from 3 mm in width to 10 mm as measured across the siphons. All are very flattened, no more than 4 mm measured anteroposteriorly. The gonad is fairly well developed in the larger animals, though it is not possible to say if they are mature.

ETYMOLOGY.—The specific epithet *polyplacoderma* (Gr. *plakos,* a flat tablet; Gr. *derma,* skin) aptly describes the numerous characteristic tunic plates that distinguish this species.

REMARKS.—The most striking difference between *Boltenia polyplacoderma* and the other species of *Boltenia* is the large number of plates on the anterior and lateral regions of the tunic. This species could even be confused with species of *Chelyosoma* were it not for the square 4-sided apertures, branchial folds, branched oral tentacles, and dorso-ventrally arranged stigmata. The tunic pattern resembles that of the European *Pyura tessellata,* so a reexamination was made of several specimens kindly provided by Dr. Ib Svane of the Kristineberg Marine Station, Swe-

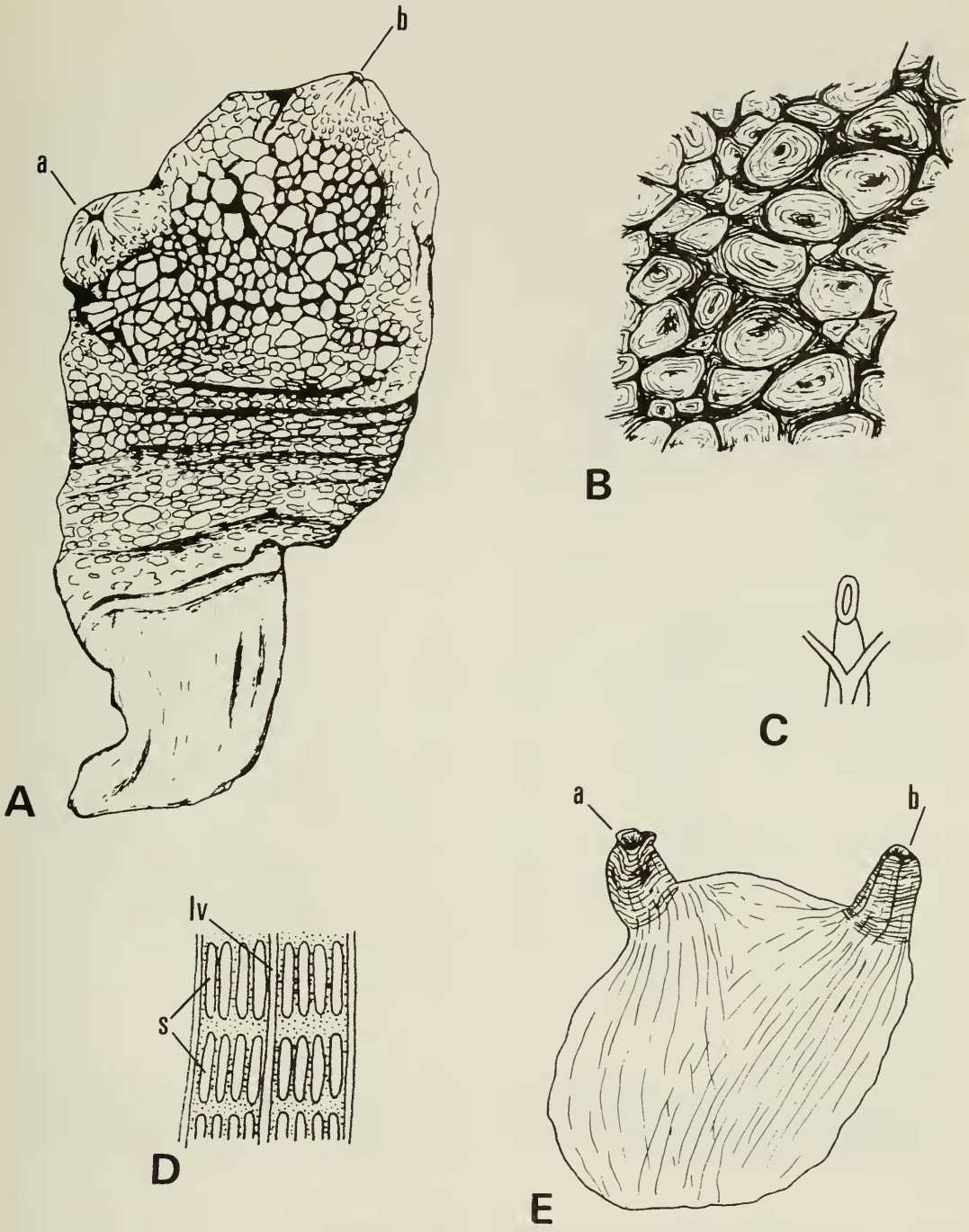

FIGURE 5. *Styela tesseris* n. sp. A, whole animal, right side, ×6.5; B, detail of tunic, ×22; C, dorsal tubercle, greatly enlarged; D, small piece of branchial sac, ×40; E, body removed from tunic, right side, ×6.8 (a—atrial siphon, b—branchial siphon, lv—internal longitudinal vessel, s—stigmata).

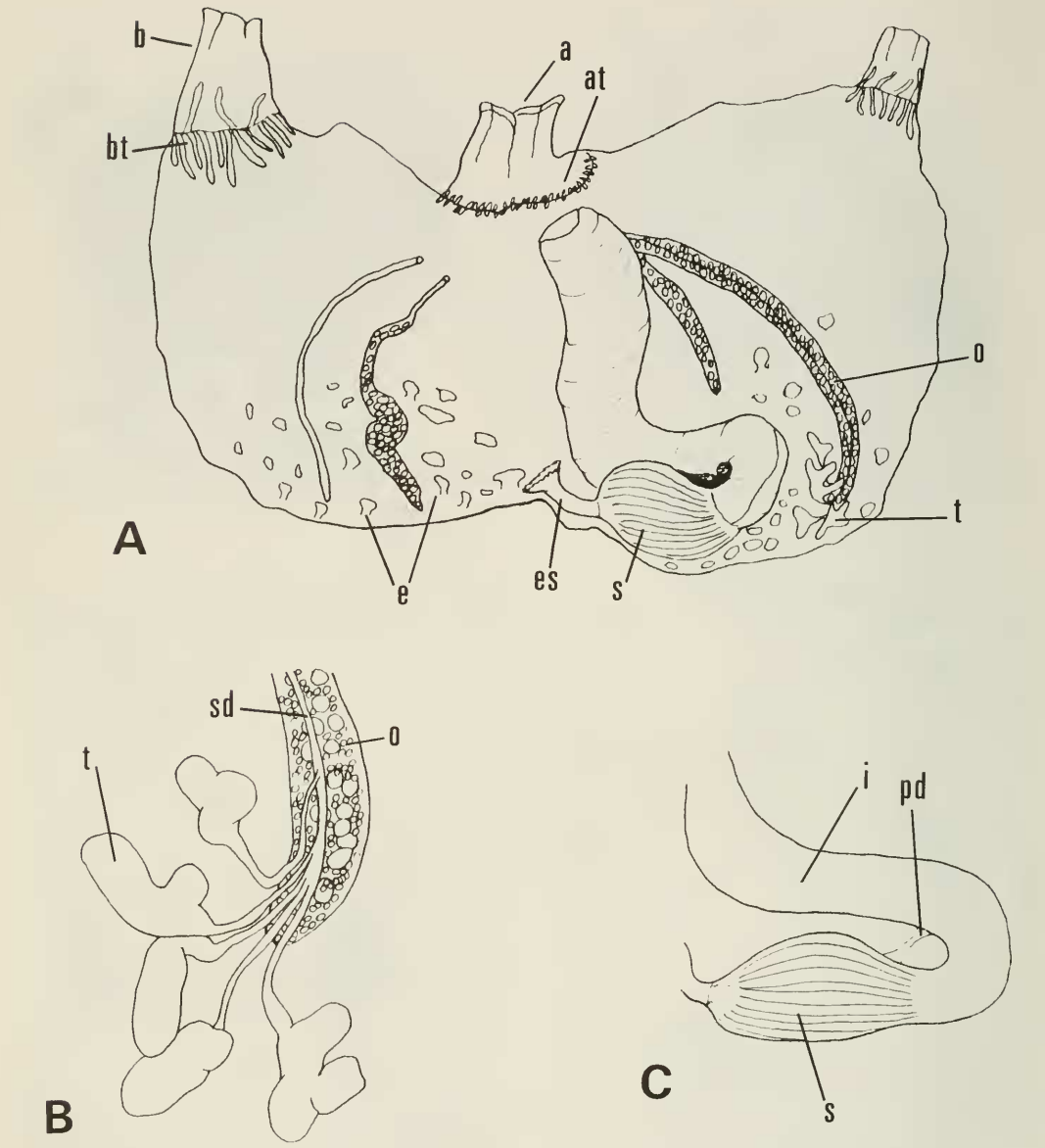

FIGURE 6. *Styela tesseris* n. sp. A, animal opened mid-ventrally to show internal anatomy, ×9; B, enlarged detail of gonad; C, detail of stomach and anterior intestine showing the delicate connection between them (a—atrial siphon, at—atrial tentacles, b—branchial siphon, bt—branchial tentacles, e—endocarps, es—esophagus, i—intestine, o—ovary, pd—pyloric duct, s—stomach, sd—sperm duct, t—testis).

den. The stigmata in *P. tessellata* are oriented longitudinally as in the other *Pyura* spp. *Pyura tessellata* has only four branchial folds per side in the branchial sac, a much thicker tunic, and the body is compressed laterally, while *Boltenia polyplacoderma* has six branchial folds per side and is flattened antero-posteriorly.

Styela tesseris n. sp.

(Figs. 5, 6)

HOLOTYPE.—021-BRA-02-TX, Santa Maria Basin (34°47.335′N, 120°45.903′W to 34°47.548′N, 120°46.123′W) at 87 m, on rock, Jul.–Aug. 1984. U.S. National Museum of Natural History, #20011.

PARATYPE.—006-BRA-02-TX, Santa Maria Basin (34°30.246′N, 120°35.555′W) at 61 m, on rock, one specimen

coll. Jul.–Aug. 1984. U.S. National Museum of Natural History, #20012.

DESCRIPTION.—Both specimens are immature. The holotype is 15 mm long and 8 mm wide as measured across the siphons, and the paratype is 2 mm long. The animals are flattened laterally. The tunic has a very distinctive, irregularly tessellate pattern, with flat-topped plates raised and separated from one another by furrows over the entire tunic except adjacent to the siphonal openings, where the tunic is smooth. The pattern resembles a mosaic tilework, with a narrow groove between each tile. The tunic between the tessellations is flexible and changes shape as the tunic is bent or moved. The plate-like tunic thickenings may overlap at their edges in contracted areas of the tunic. The furrow between each raised area presumably allows for expansion and contraction of the body. The tunic is thick, with a thick and uniformly smooth inner white layer; the tessellations are superficial and do not penetrate to this white layer. At the posterior end of both animals the tunic forms a wide, short, laterally flattened stalk; no body parts extend into this basal region of tunic. Small scattered sand grains are embedded superficially in the tunic. The tessellations are largest and most pronounced anteriorly; posteriorly they become progressively smaller, flatter, and less distinct. They appear to be oriented in rows running more or less across the tunic dorsoventrally, especially in the more posterior region; however, there are none on the stalk. Both siphons are square, the branchial one terminal and the atrial one situated slightly posterior. On the mantle, numerous very fine longitudinal muscles extend the full length of the body. Only a few longitudinal muscles occur on the siphons, where the deeper, circular muscles predominate. The opening of the dorsal tubercle is a simple oval slit. There are about 40 long, slender, unbranched oral tentacles, mostly of 2 alternating sizes, and a large number of very tiny, simple atrial tentacles. The dorsal lamina is a wide, flat membrane. The branchial sac has 4 folds per side, with the following numbers of internal longitudinal vessels; numbers in parentheses refer to vessels on the folds. Right side, counting from the dorsal lamina to the ventral endostyle: 6 (6) 3 (6) 3 (6) 5 (5) 3; left side, starting from the dorsal lamina: 2 (6) 3 (6) 3 (6) 3 (6) 3. On the flat areas of the sac there are 4 stigmata between the internal longitudinal vessels; each stigma is crossed at its mid-point by a very thin parastigmatic transverse vessel.

The stomach is elongate, with about 23 longitudinal folds or ridges. The proximal part of intestine folds back alongside the stomach, while its distal portion curves anteriorly toward the atrial siphon. There is no hepatic gland. In the larger animal there are two thin-walled gastrointestinal connections (pyloric ducts) located within the first intestinal curve; one is much wider than the other. There is a single pyloric duct in the smaller animal. The larger specimen has two long, tubular ovaries on each side, with a few irregularly lobed testes grouped around the posterior end of the left anterior ovary, which is the most fully developed. The individual sperm ducts appear to coalesce to form a common sperm duct that runs along the surface of the ovary to end near the mouth of the oviduct, close to the base of the atrial siphon. The right anterior ovary is the least developed and has no eggs. No gonads are apparent in the smaller specimen. Numerous endocarps of various sizes are attached to the atrial body wall around the posterior regions of the gonads and stomach.

ETYMOLOGY.—The specific epithet *tesseris* describes the tunic pattern. The term is derived from the Greek *tessera,* a small tablet usually with four sides but sometimes with five or six, used in making mosaics; a decorative pattern made with small pieces of such shape (Onions 1966).

REMARKS.—The most obvious way in which this new species differs from all the described northeast Pacific species of *Styela* is by the tessellated pattern of its tunic. This species most closely resembles *Styela atlantica,* which is also a deeper water form, though never recorded from the Pacific. *Styela tesseris* differs from *S. atlantica* in the tessellated tunic, the fewer internal longitudinal vessels on and between the folds in the branchial sac, and the rather wide dorsal lamina even in these immature specimens. In addition, the dorsal tubercle in this species is an oval slit without *S. atlantica*'s inrolled horns.

DISCUSSION

This project is the only sampling of continental shelf areas off the California coast since 1904 in which the ascidians have been identified. Table 1 gives a complete listing of the ascidians collected, with their depth and locality. *Aplidium* sp. and *Styela* sp. are different from the other listed species of those genera, but because of their condition or immature stage it was not possible

to identify them to species. *Pyura* sp. is a juvenile and is probably *P. haustor*; it was not included in the total species count as a separate species. Of the 20 species collected, therefore, three are new. Six of the 16 taxa identified to species are the same as those collected by Ritter in 1904 (Ritter 1907). Of the 14 species collected in 1904, four came only from abyssal depths (1,828–4,207 m) and were not found during the present MMS project. These four may or may not occur at shallower levels, leaving only four species from Ritter's (1907) 14 as ones that he found but we did not at similar depths during this project.

Rock samples were collected by manned submersible at 12 of the 18 hard-substrate stations; ascidians were found on rocks at 11 of these stations. Appendix A lists the combined assemblages on all the rocks analyzed at each station. This collection of ascidians from the western Santa Barbara Channel and Santa Maria Basin demonstrates that the rich diversity of ascidians that occurs in shallow California waters (Abbott 1975; Fay and Vallee 1979; Abbott and Newberry 1980) also occurs in deeper continental shelf areas. Some of the species listed here occur in both shallow and deep water; others appear to be limited to deeper habitats. Future collections in this region will likely disclose additional undescribed species of ascidians.

Acknowledgments

I thank Andrew Lissner and James Blake of Science Applications International Corp. for the opportunity to examine this ascidian collection, Leslie Harris and Gordon Hendler for the loan of specimens from the Los Angeles County Museum of Natural History, Ib Svane for the specimens of *Pyura tessellata* from Sweden, and my husband Charles for his help and encouragement during all aspects of this work. I am grateful for the many significant improvements made to the manuscript by Todd Newberry and two other anonymous reviewers. Publication costs were funded by the Southern California Association of Marine Invertebrate Taxonomists.

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Appendix A

Ascidian hard substrate assemblages by station number. Number in parentheses refers to number of rocks sampled.

01 (3) *Chelyosoma columbianum, Didemnum carnulentum* var. *lacteolum, Styela milleri, Styela* sp.
02 (1) *Boltenia polyplacoderma, Chelyosoma columbianum*
04 (2) *Chelyosoma columbianum, Corella* sp., *Halocynthia igaboja, Pyura haustor*
06 (2) *Aplidium californicum, Chelyosoma columbianum, Didemnum carnulentum* var. *lacteolum, Halocynthia igaboja, Pyura* sp., *Styela gibbsii, Styela tesseris, Tridemnum opacum*
13 (7) *Aplidium* sp., *Ascidia* sp., *Boltenia polyplacoderma, Chelyosoma columbianum, Eudistoma carolinense* (?), *Halocynthia igaboja, Pyura haustor, Pyura* sp., *Styela milleri*
14 (4) *Boltenia polyplacoderma, Chelyosoma columbianum, Molgula regularis, Pyura haustor, Styela milleri*
16 (5) *Aplidium spauldingi, Ascidia* sp., *Boltenia polyplacoderma, Chelyosoma columbianum, Halocynthia igaboja, Pyura haustor*
20 (4) *Chelyosoma columbianum, Halocynthia igaboja, Pyura haustor, Styela milleri*
21 (4) *Chelyosoma columbianum, Distaplia occidentalis, Eudistoma carolinense* (?), *Halocynthia igaboja, Styela tesseris*
25 (1) *Chelyosoma columbianum, Corella* sp., *Styela milleri*
27 (2) *Aplidium californicum, Chelyosoma columbianum, Eulherdmania claviformis, Halocynthia igaboja, Pyura haustor*