CONTRIBUTIONS FROM THE BIOLOGICAL LABORATORY OF THE U. S. FISH COMMISSION AT WOODS HOLE, MASSACHUSETTS.

THE ECHINODERMS OF THE WOODS HOLE REGION.

BY

HUBERT LYMAN CLARK,

Professor of Biology, Olivet College.

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As used in this report, the Woods Hole region includes that part of the New England coast easily accessible in one-day excursions by steamer from the U. S. Fish Commission station at Woods Hole, Mass. The northern point of Cape Cod is the limit in one direction, and New London, Conn., is the opposite extreme. Seaward the region would naturally extend to about the 100-fathom line, but for the purposes of this report the 50-fathom line has been taken as the limit, the reason for this being that as the Gulf Stream is approached we meet with an echinoderm fauna so totally different from that along shore that the two have little in common. This deep-water fauna, characterized by such species as *Antedon dentata*, *Schizaster fragilis*, *Astropecten americanus*, etc., is exceedingly interesting, but unfortunately too little is known about it at present to make a report in any degree satisfactory or complete. This paper, therefore, concerns itself only with the shallow-water species, all included herein having been taken in less than 40 fathoms, and, with one or two exceptions, in less than 15. No species is included which has not been actually taken within the above-mentioned limits.

The purpose of this article is not merely to aid students and collectors at Woods Hole to identify the echinoderms which they find, but also to furnish descriptions and figures of such accuracy that students of echinoderms elsewhere may be able to determine beyond question whether the species which they collect are identical with those occurring at Woods Hole. At present very few of the common littoral echinoderms of America are described in such a way as to make their positive identification possible by one not a specialist, and good figures are even more rare. Particularly is this true of the asteroids and holothurians. Thanks to Lyman and Alexander Agassiz, ophiuroids are well described, and echinoids well figured. In both these cases, however, the publications referred to are not only inaccessible to the average student, but are out of print. It therefore seems wise to gather into one report all the echinoderms of this region.

The only previous list is that of Verrill (1873*b*), who names 22 species, 5 asteroids, 5 ophiuroids, 4 echinoids, 7 holothurians, and 1 crinoid. The latter, however, and one of the ophiurans (*Amphiura abdita* Verrill), have never been taken within the Woods Hole limits, nor is it probable that either occurs there. Of the 5 starfishes, 2 are undoubtedly identical (*Asterias forbesi* and *arenicola*), so there are really only 19 bona fide Woods Hole species in the list. During the past four summers 5 other species (2 starfishes, 1 brittle star, and 2 holothurians) have been collected within the above-given limits, so that now 24 species are properly credited to Woods Hole, more than one-third of which are holothurians.

The number of species listed is small, but includes representatives of two quite distinct faunas, making the region one of much interest. The southern and western portions of the region mark the northern limit of several distinctively southern species (such as *Mellita pentapora*, *Ophiura brevispina*, *Thyone briareus*), while the northern and eastern portions mark the southern limit of several distinctly northern species (*Solaster endeca*, *Ophioglypha robusta*, *Cucumaria frondosa*.[a]) It is interesting to note that not fewer than 9 of our 24 species occur on the northern shores of Europe, while 4 occur in Bermuda and the West Indies. Only 10 can be called common in the Woods Hole region, and 4 of these common only in very restricted areas, so that, unless the exact locality is known, the chances are against collecting more than a half-dozen species. Moreover, the common species vary greatly in their abundance from year to year, a species easily found one summer being looked for in vain the next season. For example, the starfish *Asterias forbesi* was very abundant in Woods Hole harbor in 1895; in 1899 it was almost wanting and only small specimens occurred; in 1902 it was again abundant. Similar facts could be given regarding the common sea-urchin, *Arbacia*, and the small red starfish, *Cribrella*.

The best collecting grounds for echinoderms in this region are undoubtedly on the shoals east of Chatham and Nantucket. On the fishing ground known as Crab Ledge, off Chatham, in about 17 fathoms of water, we collected on August 22, 1902, 4 species of starfish, 3 brittle stars, 1 sea urchin, and 1 holothurian. Southeast of the Round Shoal light-ship, and about 8 miles off Sankaty Head, Nantucket, in 12 fathoms, August 13, 1902, we collected 4 species of starfish, 2 brittle stars, 3 sea urchins, and 1 holothurian. Of the 9 species at Crab Ledge, 3 were not taken at Sankaty, while of the 10 species of the latter station, 4 were not found at Crab Ledge; more than half of all the species of this region were therefore taken at these two stations, and 2 other species are known to occur there. In Vineyard Sound, including the deep water off Gay Head, 15 species have been taken, but at least 8 of these are rare and very seldom occur in the sound. At no one station have more than 6 species been taken. In Buzzards Bay, including the deep water off Cuttyhunk, only 8 species occur, and 1 of these is extremely rare.

From the point of view of human economy, the echinoderms of the Woods Hole region are of little importance. None of the 24 species is directly valuable for any purpose. The large *Cucumaria frondosa* has occasionally been used as food, and no less an authority than Dr. William Stimpson recommends it, but it is too rare in the Woods Hole region to be of any use. The starfish, *Asterias forbesi*, is of commercial significance wherever oysters are cultivated, because of its destructiveness to that

[a] The recorded occurrence of this species on the Florida reefs is not beyond question; but, even if correct, there is no doubt that the shoals east of Nantucket are the southern limit of the species as a littoral form.

mollusk; but this whole subject has been so thoroughly investigated and reported by Mead ('99) that there is no reason to discuss it here. As food for fishes some of the echinoderms deserve mention, particularly *Echinarachnius parma* and *Ophiopholis aculeata*, which, in spite of their most unprepossessing appearance from a gastronomic point of view, and their firm, calcareous skeletons, seem to be important items of food with the cod and some other fishes. The tilefish is known to feed very largely on a species of brittle star, *Amphiura*, its stomach often being completely distended with them. The smaller holothurians are also frequently eaten by fishes, though it is at least an open question how important an article of diet they may be.

For the proper study of echinoderms, especially for purposes of identification, freshly killed material is the best. Alcohol is the best preservative, and should be used quite strong. Formalin is worthless, tending to make the tissues swell and become slimy, and dissolving the calcareous parts. All echinoderms are very susceptible to Epsom salts ($MgSO_4$), and it is probably the best available narcotic. In most cases it is not necessary to take any precautions, and the salt may be added to the sea water at once in considerable quantity. With some holothurians, however, more care is needed, and the salt should be added to the water a little at a time. Once thoroughly stupefied, echinoderms of all classes, except holothurians, can be killed nicely expanded by putting them into alcohol, 50 per cent or stronger. Some holothurians, especially *Thyone briareus*, are more difficult to kill satisfactorily, and hot water or acid reagents serve the purpose better, as a rule. Of course, when it is desired to identify the specimen, acid reagents should carefully be avoided, for the calcareous parts of all echinoderms are essential to accurate identification, and especially is this true of holothurians. Starfishes, brittle stars, and sea urchins are much more easily identified from well-dried specimens than from the best alcoholic ones, all important specific and most generic characters being based on calcareous parts. To prepare dry starfishes or brittle stars, they should be thoroughly narcotized, then placed in fresh water for a short time, then in strong alcohol for twenty-four hours, more or less, according to size, then dried as rapidly as convenient. The colors of many species are readily washed out in alcohol or even in fresh water, so that specimens prepared in the manner just described rarely retain a natural color. It is said the color may be preserved very satisfactorily by killing in 50 per cent alcohol and drying rapidly by artificial heat. Sea urchins may be prepared in a similar manner, but care must be taken to see that the interior of the animal is thoroughly soaked in strong alcohol before drying. Most of the specific characters of all echinoderms, except holothurians, are easily seen with a hand lens, and usually with the unaided eye, even in young and small specimens. But for the proper identification of holothurians, a compound microscope is essential, as the minute particles of lime in the skin furnish the most important specific characters. To examine these all that is necessary is to cut out a small piece of the thin body wall, and after soaking it in water a few minutes, clear and mount in glycerin. If the body wall is thick, only the surface layer should be taken, and it should be treated with caustic potash (10 per cent or stronger) before being washed in water and cleared in glycerin. The same treatment is desirable when the body wall is heavily pigmented, or when the calcareous particles are extremely numerous and crowded into more than one layer. It is sometimes necessary to leave the piece of skin in caustic potash for several days, especially if the specimen has been in alcohol for some time.

The illustrations for the present report were made—in all but one instance, *Trochostoma oölíticum*—from specimens taken in the Woods Hole region. The figures showing the external appearance of the different species, and the denuded tests of the sea urchins, are from photographs made by Mr. J. D. Figgins. So far as possible, these photographs were from living or freshly killed specimens, and are represented natural size. It is due entirely to Mr. Figgins's patience and persistence that the results have been so generally satisfactory, and it gives me pleasure to express my sincere thanks to him. The other figures are from drawings, and are intended to show those characters which are of importance in the identification of species.

In the choice of names, I have endeavored to make as few changes as possible from those in common use, but pre-Linnæan names have been rejected, as no good reason has ever been given for introducing them into modern literature. The name of each species is followed by that of its describer; if, however, that describer did not place the species in the genus in which it is now included, his name is inclosed in parentheses. There is no good reason for appending the name of the writer who placed the species in its present genus, and the custom is bad in its effects. Popular names are given where any are in common use, but none has been coined for any of the less-known species. No attempt has been made to give a complete synonymy, but the names used in the most important papers dealing with the echinoderms of the New England coast, and in standard works on the various classes, are given under each species. A bibliography also is appended, in which the titles of such works will be found, and there is an index to all names, including synonyms.

The work upon which this report is based has been carried on exclusively in the laboratory of the United States Fish Commission at Woods Hole, in part during the summers of 1898, 1899, and 1900, but particularly in 1902. It gives me pleasure to acknowledge my indebtedness to the Commissioner, Hon. George M. Bowers, for the opportunity thus given me, and to Dr. H. M. Smith, who, as director of the Woods Hole laboratory, has afforded me every facility for carrying on my investigations. Like all other workers at the Woods Hole station, I am under special obligations to the veteran collector of the Commission, Mr. Vinal N. Edwards, who has supplied me with many important data concerning the local distribution and habits of echinoderms. Mr. George M. Gray, of the Marine Biological Laboratory, has also assisted me with information and specimens.

ECHINODERMATA.

Radially symmetrical animals, with a well-developed water-vascular system.

Key to the classes of Echinodermata of the Woods Hole region.

Body more or less flattened dorso-ventrally, with the mouth at the center of the lower surface; external skeleton well developed.
Body with the radii extended as more or less elongated arms.
Arms unjointed, with a longitudinal furrow on the lower side, in which are the numerous tube feet.....ASTEROIDEA
Arms made up of numerous joints, without a longitudinal furrow on the lower side.....OPHIUROIDEA
Body hemispherical or discoidal, without extended radii.....ECHINOIDEA
Body more or less elongated, with the mouth at the anterior end, surrounded by a circle of tentacles; no well-developed external skeleton.....HOLOTHURIOIDEA

ASTEROIDEA.

STARFISHES.

Of the 6 starfishes which occur in the Woods Hole region, no fewer than 4 belong to the large and widely distributed genus *Asterias*, the species of which are, even to the present day, greatly confused. For this reason it is impossible to avoid the use of some technical terms in the artificial key, as well as in the descriptions, although the endeavor has been made to have the descriptions as clear and free from technicalities as possible.

Following are the terms used which do not carry their own meaning:

Abactinal=aboral; opposite the mouth; the upper surface.

Actinal=oral; the lower surface.

Adambulacral spines=the spines borne on the plates which form the margin of the actinal longitudinal furrow on each arm.

Ambulacral furrow=the actinal longitudinal furrow on each arm.

Madrepore plate=the more or less prominent somewhat circular body situated abactinally in one of the interradii.

Oral plates=the skeletal plates, especially the adambulacral plates, immediately surrounding the mouth.

Papulæ=the tentacle-like outgrowths of the body wall which project between the meshes of the skeleton and contain prolongations of the body cavity.

Papular areas=spaces occupied by papulæ between the meshes of the skeleton.

Pedicellariæ=the minute forcep-like modified spines, consisting of two hard jaws moved by muscles, and occurring in many starfish, especially on the abactinal surface, and at the base of the large spines.

It must be added, moreover, that no description or figures will serve to distinguish positively very young individuals of our 4 species of *Asterias*. The young of *forbesi* seem to be the first to show the specific characters, and individuals 15 mm. in diameter can generally be recognized without much trouble. The young of *vulgaris*, *tenera*, and *austera* resemble each other so closely when less than 10 mm. in diameter that it is practically impossible to separate them positively, but when 15 mm. in diameter they can usually be distinguished from each other on careful comparison, and by the time they have reached a diameter of 20 mm. the specific characters are generally quite marked. It must be borne in mind, however, as shown by Mead ('99), that the age of a starfish is not shown by its size, and, furthermore, that spines and pedicellariæ increase in number as the age increases. Thus some small but old specimens may have the specific characters well defined, while others much larger but younger may have them barely indicated.

Key to the Asteroids of the Woods Hole region.

Rays rough and spiny, since the meshes of the skeletal network are coarse and bear prominent spines, singly or in groups of 3 or 4; pedicellariæ numerous; feet in 4 longitudinal rows in each furrow.

Adults usually over 100 mm. in diameter; papulæ numerous in small groups.

Rays tending to be cylindrical and blunt; skeleton quite firm; spines rather few and coarse; pedicellariæ on adambulacral spines short and blunt; madrepore plate usually bright orange.—ASTERIAS FORBESI

Rays tending to be somewhat flattened and acuminate; skeleton open and rather soft; spines numerous, tending to form a noticeable median longitudinal row on the abactinal side of each ray; pedicellariæ on adambulacral spines numerous, long, slender, and sharp; madrepore plate pale.....ASTERIAS VULGARIS

Adults usually much less than 80 mm. in diameter; papulæ few, 1, 2, or 3 in a place.

Rays tending to be cylindrical and tapering; skeleton moderately firm, with numerous spines; pedicellariæ very numerous, especially on actinal surface, forming wreaths, generally very noticeable, on the spines there.....ASTERIAS TENERA

Rays decidedly flattened, rather wide and blunt; skeleton coarse and very firm; spines few; pedicellariæ on adambulacral spines few and blunt, but a prominent series of them just within the edge of the ambulacral furrow.....ASTERIAS AUSTERA

Rays rather smooth, since the meshes of the skeletal network are fine and bear numerous very small, delicate spines; no pedicellariæ; feet in 2 rows—

With 5 or 6 rays.....CRIBRELLA SANGUINOLENTA

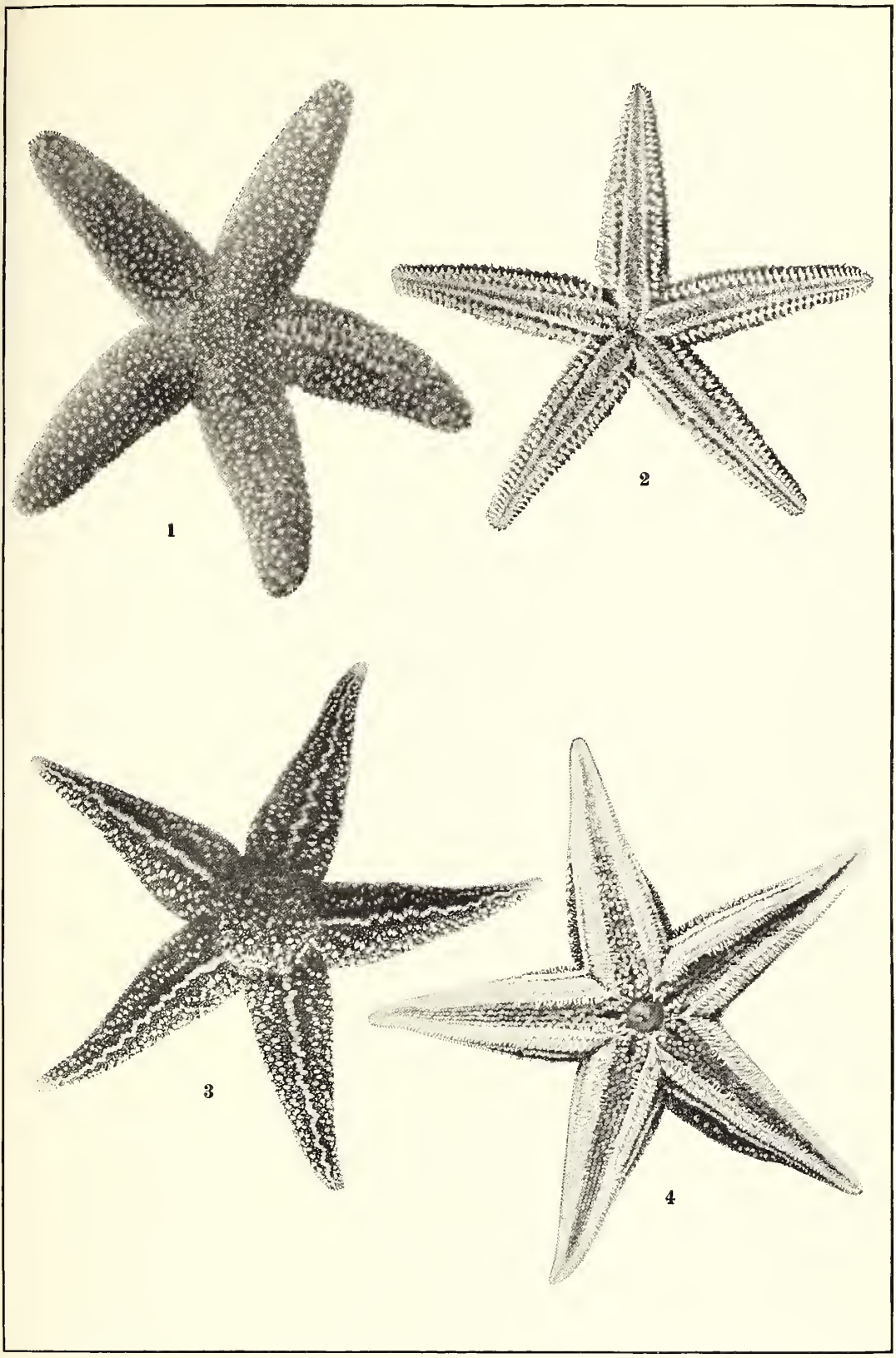
With 9 to 11 rays.....SOLASTER ENDECA

1. Asterias forbesi (Desor). *Common starfish.* (Pl. 1, figs. 1, 2; pl. 4, figs. 14, 15.)

Asteracanthion forbesi Desor, 1848.
Asterias arenicola Stimpson, 1862.
Asteracanthion berylinus A. Agassiz, 1863.
Asterias forbesii Verrill, 1866 et seq.

Description.—Rays normally 5, occasionally 6, rarely 4 or 7. R=75 to 130 mm., r=10 to 25 mm., R=4.5 to 8 r. Breadth of ray, near base, 15 to 30 mm., R=3.5 to 5 br. Rays stout, blunt, and somewhat rounded at the tip, abactinal surface normally arched. Disk moderate or large, often highly arched. Interbrachial arcs rather acute. Abactinal area covered with stout plates, closely soldered together into a firm skeleton, with no constantly regular arrangement. These plates carry single prominent spines, 1 to 2 mm. high, which are usually blunt and minutely rough or thorny at the tip, but in young individuals may be quite sharp. About the base of these large spines are often grouped 2 to 4 smaller ones, 0.5 to 1 mm. high, also blunt. All the spines are more or less fully encircled about midway between base and tip with a cluster of very small, blunt pedicellariæ. Scattered more or less freely all over the abactinal surface are pedicellariæ a little less blunt and somewhat larger. Sides of rays well rounded, but oftentimes with a well-defined longitudinal arrangement of spines, about halfway between actinal and abactinal surfaces. Below this row is a space of very variable width which is usually free from spines but bears a few scattered pedicellariæ. Beneath this space, and well on to the actinal surface of the ray is a prominent longitudinal series of plates, each of which bears an obliquely arranged pair or trio of very prominent spines (like those of the abactinal surface, and wreathed by pedicellariæ in the same way), of which the most distal is nearest the ambulacral furrow. This series is usually clearly defined, but in some individuals it is more or less irregular. Between it and the adambulacral spines is a longitudinally extended space, which may be perfectly open and occupied by only a few pedicellariæ, but in many specimens is obliterated by a single series of large spines, which are more or less square cut or even clavate at the end, and are often slightly beveled on one side. The presence or absence of this row is not a matter of size, but it is very probably a matter of age, though that is not yet proved. Adambulacral plates with 1 or 2 (usually 2) rather long (2 to 4 mm.), somewhat flattened and slender spines square cut or blunt at the end, and many of them, especially near the mouth, bearing small blunt pedicellariæ, though these are often wanting in young individuals. In a specimen with R=24 mm. there are about 60 adambulacral plates on each side of the ambulacral furrow; in one with R=67 mm. there are about 100; and in one with R=80 mm. there are about 130. Oral spines not peculiar. Papular areas variable in size, but usually large, with numerous papulæ, generally 5 or more in each group. Madrepore plate of moderate size, 2 to 5 mm. in diameter, with numerous narrow furrows, and not surrounded by any special circle of spines. Tube feet quadriserial, crowded. Color in life very variable; the most common shades are brown, purple, orange, green, and bronze. Spines generally light and madrepore plate usually bright orange-red. After death the bright tints are generally lost and in preserved specimens the madrepore plate is usually yellow or brown.

Range.—Maine to the Gulf of Mexico, rare or local north of Cape Ann; low water to 27 fathoms.



Figs. 1, 2. *Asterias forbesi* (small specimen, natural size).—1. Aboral view. 2. Oral view.
Figs. 3, 4. *Asterias vulgaris* (small specimen, natural size).—3. Aboral view. 4. Oral view.

Remarks.—This is the common starfish of the Woods Hole region. It occurs abundantly in the harbor, in Vineyard Sound, and in Buzzards Bay. It was originally described from the shoals of Nantucket, but we did not find any off Sankaty Head or Crab Ledge. It is most common near low-water mark, but occurs down to 18 or 20 fathoms. The habits have been observed and described so well by Mead ('99) that any account of them here would be superfluous. The larval stages and development of this species have been described by Agassiz ('77), but curiously enough little has been done on the embryology during the past twenty-five years. The young stars occur in great abundance on the eelgrass in the Eel Pond at Woods Hole during August. The great variety of color in the adults has yet to be explained; it is apparently not associated with age or sex, nor has its correlation with the environment been proved.

2. Asterias vulgaris Verrill. *Northern starfish.* (Pl. 1, figs. 3, 4; pl. 4, figs. 16, 17.)

Asterias rubens Gould, 1841.
Astevacanthion rubens Desor, 1848.
Asteracanthion violaceus Stimpson, 1853.
Asteracanthion rubens Stimpson, 1853.
Asteracanthion pallidus A. Agassiz, 1863. No description.
Asterias vulgaris Packard, 1863. No description.
Asterias vulgaris Verrill, 1866 et seq.
Asterias stimpsoni Verrill, 1866 (pars.).
Asterias pallida Goto, 1898.

Description.—Rays normally 5, rarely 4 or 6. R=75 to 150 mm. or even more, specimens 425 mm. in diameter being reported from Nova Scotia, r=9 to 30 mm., R=4.5 to 8.5 r. Breadth of ray near base, 15 to 30 mm., R=3.5 to 5 br. Rays more or less flattened, the sides somewhat vertical, tapering to a more or less acuminate point. Disk usually rather large, sometimes considerably arched. Interbrachial arcs somewhat acute. Abactinal area covered by a network of narrow plates with large meshes, not forming a very firm skeleton. Almost always there is a median longitudinal series on the arm, with large papular areas (sometimes 4 or 5 mm. across) on each side. All the plates bear blunt spines 1 or 2 mm. high, usually singly but occasionally 2 or 3 together. The spines are rough or minutely thorny at the tip, and are encircled by a more or less complete wreath of pedicellariæ, which are remarkably blunt. Pedicellariæ scattered over abactinal surface much larger and quite acute. Along side of ray a very well-marked lateral series of spines, below which is a longitudinally extended area of greater or less extent quite free from spines, but with numerous pedicellariæ. The lateral series varies greatly in position, in some specimens being quite near the abactinal surface, while in others it may be scarcely visible when seen from above. It is made up of plates bearing 2 spines, side by side, so that there is apparently a single line of spines. In older specimens, however, there is often a third spine beneath the distal one of each pair, and frequently a fourth spine occurs above or beside the proximal one. Well down on the actinal surface of the ray is another series of spines, the largest and most prominent of all. These are usually over 2 mm. in length and are often 3 or 4 mm. long; they are very blunt, even square cut or clavate, in some specimens deeply so. Three spines form an oblique row on each plate, the most distal being nearest to the ambulacral furrow. Although these spines bear pedicellariæ, often in great numbers, they are not so nearly wreathed by them as are the abactinal spines. Adambulacral plates with 1 or 2 (usually 2) rather long (2 to 4 mm.) somewhat flattened slender spines, pointed, square cut or clavate at the end, most of which carry from 1 to 6 long, slender and very acute pedicellariæ (fig. 17). A few small pedicellariæ occur on the adambulacral plates within the furrow. The acute pedicellariæ on the adambulacral spines are present even in very small individuals (15 to 20 mm. in diameter). Adambulacral plates are more numerous in this species than in any of the other forms of *Asterias* occurring at Woods Hole. In a specimen with R=18 mm. there are 65 or more plates on each side of the furrow; in another with R=24 mm. there are about 75; in another with R=37 there are only about 110; in another with R=107 there are not less than 170. Oral spines not peculiar. Papular areas generally large, with 3 or more papulæ in each group. Madrepore plate of moderate size, 2 to 5 mm. in diameter, with numerous narrow furrows, and not surrounded by any special circle of spines. Tube feet quadriserial, crowded. Color in life very variable; the most common shades are yellow and purple, but cream-colored, yellow-brown, brown, orange, pink, and even bright red individuals occur. Spines generally light, and madrepore plate light yellowish.

Range.—Labrador to Cape Hatteras; but south of the Woods Hole region rarely seen in shallow water; low water to 358 fathoms.

Remarks.—Although less common than *A. forbesi*, this species occurs in abundance in many places near Woods Hole. In the harbor it is occasionally found with *A. forbesi*, and specimens have been

described to me which were apparently hybrids between the two species; but I have never seen such, nor any individuals, however small, which could not readily be assigned to the proper species. Even when only 10 mm. in diameter, *forbesi* has a much stouter appearance. Young specimens of *vulgaris* were taken in August off Gay Head and Cuttyhunk, as well as at Crab Ledge, and off Sankaty Head. Most of the adults taken in the Woods Hole region are less than 180 mm. in diameter. The best specimens that we collected were taken at Crab Ledge. The habits and development of *vulgaris* do not seem to differ essentially from those of *forbesi*, though some slight differences in the early stages have been noted by Alexander Agassiz ('77). The larval stages have been well described by Field ('92), and further points have been carefully investigated by Goto ('98). As in the case of *forbesi*, the great variety of color does not seem to be associated with either age, sex, or environment. All of the earlier writers regarded this species as identical with *Asterias rubens* of Europe. Stimpson, early in 1863, first suggested in a private letter that it might prove distinct, and proposed the name *vulgaris*, but he gave no description. Later in the same year Alexander Agassiz proposed the name *pallidus*, but gave no adequate description. Still later Packard used the name *vulgaris* Stimpson, in a published list, but he also failed to give a description. Finally, in 1866, Verrill published a description under the name *vulgaris* Stimpson. Clearly, however, Stimpson's name is the barest kind of a *nomen nudum*, and Verrill is properly the describer of the species. Whether it is really distinct from *Asterias rubens*, however, has never yet been proved, and Verrill ('76) now thinks they may prove identical.

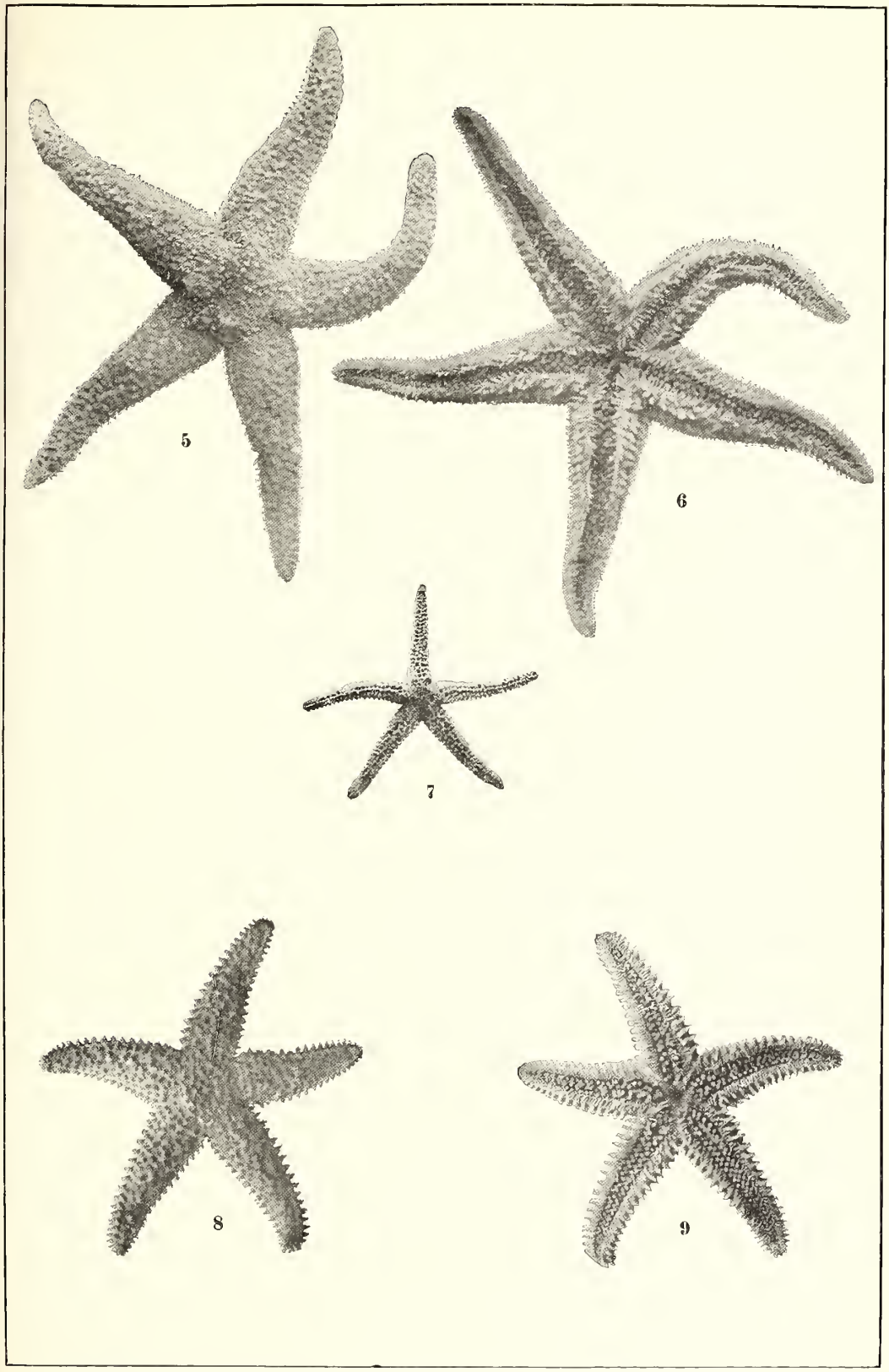
3. Asterias tenera, Stimpson (pl. 2, figs. 5–7; pl. 4, figs. 20, 21).

Asterias tenera Stimpson, 1862, p. 269.
Asterias compta Stimpson, 1862, p. 270.
? *Asteracanthion flaccida* A. Agassiz, 1863.
Leptasterias compta Verrill, 1873.
Leptasterias tenera Verrill, 1874.
Asterias (*Leptasterias*) *compta* Sladen, 1889.

Description.—Rays 5, rarely 4 or 6. R=30 to 40 mm., r=4 to 7 mm., R=6 to 7 r. Breadth of ray near base, 5 to 10 mm., R=4 to 6 br. Rays not flattened, nearly terete, slender and pointed. Disk small. Interbrachial arcs acute. Abactinal area covered by a fine network of narrow plates with rather large meshes, forming an open but fairly firm skeleton, with no clearly defined median row on the ray. All the plates carry prominent, though rather delicate, spines about 1 mm. long, more or less rough and pointed at the tip. These spines, except on the disk, are encircled at or near the base by more or less complete wreaths of blunt pedicellariæ; the contrast between disk and rays in this respect is often marked. Pedicellariæ most numerous near the tip of the ray. On sides and actinal surface of rays, the spines are somewhat larger and tend to form longitudinal series of single spines placed side by side. There are generally four such series quite clearly defined, of which the one nearest the ambulacral furrow consists of the largest spines. In all the series the spines are more or less densely wreathed with pedicellariæ which become more numerous approaching the ambulacral furrow or passing toward the tip of the ray. Adambulacral plates with 1 or 2 slender spines 2 mm. long; at middle of ray plates carrying 1 spine tend to alternate regularly with those carrying 2, but at both base and tip of ray the plates more frequently bear a single spine. Adambulacral spines with numerous pedicellariæ which often form wreaths about the spines near the middle. Similar pedicellariæ also occur on the adambulacral plates within the furrow. Adambulacral plates rather less numerous than in *vulgaris;* a specimen with R=18 mm. has about 60 plates on each side of the furrow; another with R=24 has about 68 plates, and in one with R=37 there are about 100. Oral spines not peculiar. Papular areas of moderate size, with few papulæ, usually 1 or 2, in each area. Madrepore plate small, with few, rather wide furrows, surrounded by an imperfect circle of 6 or 8 spines. Tube feet quadriserial, but not crowded. Color in life varying from purplish-pink to nearly white, the smallest ones having the least color; madrepore plate and spines nearly white.

Range.—Nova Scotia to New Jersey; in 14 to 85 fathoms.

Remarks.—This small starfish is very common off Sankaty Head, but we did not collect any specimens at Crab Ledge, nor has it been taken in Vineyard Sound. Verrill ('73) records it from south of Marthas Vineyard in 20 to 25 fathoms. A careful study of Stimpson's ('67) original descriptions of *tenera*, based on 20 specimens from Massachusetts Bay, and *compta*, based on a single individual 3 inches in diameter, has convinced me that the two forms are identical, and this belief is confirmed by a comparison of numerous specimens, undoubtedly *tenera*, taken off Sankaty Head, with 2 large specimens (72 mm. in diameter) labeled *compta* in the collection of the Fish Commission from outside the Woods



Figs. 5–7. *Asterias tenera* (natural size).—5. Large specimen; aboral view. 6. Large specimen; oral view. 7. Young; aboral view.
Figs. 8, 9. *Asterias austera* (adult, natural size).—8. Aboral view. 9. Oral view.

Hole region. The latter were probably identified by Verrill. Sladen ('89) expressed his suspicion that *tenera* and *compta* were identical, but owing to lack of material withheld his decision. Verrill ('95) thinks *tenera* is a poorly nourished, slender variety of *compta*, but the name *tenera* has precedence. The group of starfish (regarded as a genus by Verrill and a subgenus by Sladen) called *Leptasterias*, and including *tenera* and one or two other forms, does not seem to rest upon characters of sufficient importance and constancy to warrant recognition. Very little is known of the habits or development of *Asterias tenera*, though the latter is said to be without metamorphosis, the young being cared for by the mother, to whom they are attached. Whether this species is really distinct from *Asterias mülleri* of Europe remains to be proved.

4. Asterias austera Verrill. (Pl. 2, figs. 8, 9; pl. 4, figs. 18, 19.)

Asterias austera Verrill, 1895.

Description.—Rays 5. R=24 to 35 mm., r=6 to 10 mm., R=3.5 to 4 r. Breadth of ray near base 6½ to 10 mm., R=3.5 br. Rays rather short, wide, and depressed, somewhat angular from the prominent row of lateral spines. Interbrachial arcs rather acute. Abactinal area covered with rather stout plates, apparently with no regular arrangement, the median radial series being very zigzag. These plates are very thick, though the width is quite variable. They carry short, very blunt spines, considerably less than 1 mm. in length. Spines of the median radial series sometimes noticeably larger than the disk spines. Each spine is encircled at the base by a few small, blunt pedicellariæ, usually from 4 to 10 in number, but these are often wanting on the disk. Occasional isolated pedicellariæ of much larger size occur scattered here and there on the abactinal framework. Sides of ray practically vertical, the upper edge being marked by a series of 18 to 28 large stout plates, which start at the level of the disk, abactinally, and run distally with a downward slope, so that the side of the ray is almost twice as high at base as at tip. Each of these plates carries a prominent, stout, blunt spine, about 0.7 of a mm. long, encircled at base by a cluster of 8 to 15 small pedicellariæ on the upper and outer side. Between the two series of spines the lateral surface of the ray is free from projections of any kind, except occasionally a few large pedicellariæ. Between the actino-lateral series and the adambulacral plates there is apparently only a single row of plates, and these are usually confined to the basal half of the ray. They often bear stout spines nearly 1 mm. long, which are apparently opposite and not alternate with the spines of the actino-lateral series. They have no cluster of pedicellariæ at the base, but sometimes bear one or two small pedicellariæ near the tip. Adambulacral plates with one or two nearly cylindrical blunt spines, considerably over a mm. in length; they do not alternate alike even on the two sides of the same ray. These spines are mostly free from pedicellariæ, but rarely a small blunt one is present near the tip. Within the ambulacral groove, however, above the bases of the spines, are numerous small pedicellariæ. These are sometimes specially prominent on the oral plates. Adambulacral plates rather few; a specimen with R=18 has only 49 on each side of the furrow, and my largest, with R=24, has only 60. Madrepore plate of medium size, with few, wide furrows, and surrounded by a rather incomplete circle of 6 to 8 spines. Tube feet quadriserial, but not at all crowded. Color in life white, cream color, or yellowish, more or less marked abactinally by dark green, purple, or reddish. Digestive cœca often show through the abactinal surface, especially in small individuals (as in young *vulgaris* and *tenera*), adding much to their beauty.

Range.—Georges Bank and off Cape Cod; Crab Ledge, off Chatham, Mass.; 17 to 35 fathoms.

Remarks.—After some hesitation I have referred a small star-fish, of which we took 12 specimens at Crab Ledge, to Verrill's species *austera*, although, owing to the brevity of his description and the lack of figures, there is some room for doubt; but the largest specimens answer very well to his description, and as he reports his species from off Cape Cod in 33 to 35 fathoms, it is highly probable that the species here described and figured is *austera*. It is a handsome little star-fish, and seems to be common at Crab Ledge. We did not find it elsewhere. Nothing is known of its habits or development.

5. Cribrella sanguinolenta (O. F. Müller). (Pl. 3, figs. 10, 11; pl. 4, fig. 22.)

Asterias sanguinolenta O. F. Müller, 1776.
Asterias pertusa O. F. Müller, 1776.
Asterias oculata Pennant, 1777.
Asterias spongiosa Fabricius, 1780; Gould, 1841; Desor, 1848.
Linckia oculata Forbes, 1839; Stimpson, 1853.
Cribella oculata Forbes, 1841.
Linckia pertusa Stimpson, 1853.
Cribrella sanguinolenta Lütken, 1859; Verrill, 1866 et seq.
Cribrella oculata Al. and E. C. Agassiz, 1865; Sladen, 1889.

Description.—Rays normally 5, occasionally 6. The proportions vary to an extraordinary degree. R=30 to 60 mm., r=6 to 13 mm., R=2.5 to 5.5 r. Breadth of ray near base, 10 to 14 mm., R=2.4 to 5.4 br. Rays varying from nearly cylindrical to long conical, but usually with a rounded tip, and not flattened. The basal part is oftentimes swollen and then contracted close to the disk, which is of very variable size. Interbrachial arcs are sometimes rounded, but more often acute. Abactinal surface covered by a network of plates, which form a more or less firm skeleton, according to the size of the meshes, these ranging from under 0.5 mm. to over 1.5 mm. As a rule these plates have no regular distribution, but in some specimens there is, on the sides of the ray, an approach to a transverse arrangement, either in vertical or oblique rows. Upon the plates are numerous minute spines, which differ greatly in size and form in different individuals. They are sometimes very delicate and sharp, sometimes stout and blunt, and the length varies from 0.2 to 0.5 mm. These spines occur singly, or more often in groups of from 2 to 12, and as they are so small, so numerous, and of such nearly uniform length (in any one specimen) the surface of the ray does not appear spinulose in the living animal. On the actinal surface the plates tend to form longitudinal rows, especially near the base of the rays, and there is almost invariably one well-defined row just outside the adambulacral plates. The latter are not very numerous, a ray 42 mm. long having only about 65 on each side of the furrow. The armature of the adambulacral plates is made up of 10 to 12 blunt spines, of which 1 is on the side of the plate, well up in the furrow, while the remainder are on the face of the plate. Although they vary considerably in size, in different specimens, the arrangement, on the whole, is fairly constant. The furrow spine is very slender, but is sometimes quite long, over 0.5 mm. Of the others, that nearest the furrow is the largest (1.5 mm.) and usually stands more or less alone. Behind, or outside of it, are 1 or 2 a trifle smaller, and the remainder, arranged more or less irregularly in pairs, diminish rapidly in size, so that those on the outer edge of the plate are of about the same size as the spines on the adjoining plates. In young individuals the adambulacral spines tend to form a narrow, transverse series on the plate, continuous with the transverse series on the sides of the ray, but in adults such an arrangement is obscured, if not obliterated. Oral spines long, but not peculiar. Papular areas small, with usually 1 papula, sometimes 2 or 3. Madrepore plate small, with few wide furrows, the ridges between which frequently bear spines. Feet biserial. Color in life, abactinally usually bright red, with a slight orange cast, the actinal surface deep yellowish. There is, however, more or less variety. In some specimens the red is faded in spots to yellowish, or even the whole abactinal surface to orange, yellow, or cream color; in other specimens the red is deepened to purple, often of a very rich shade, while again the purple is faded to lavender or nearly white.

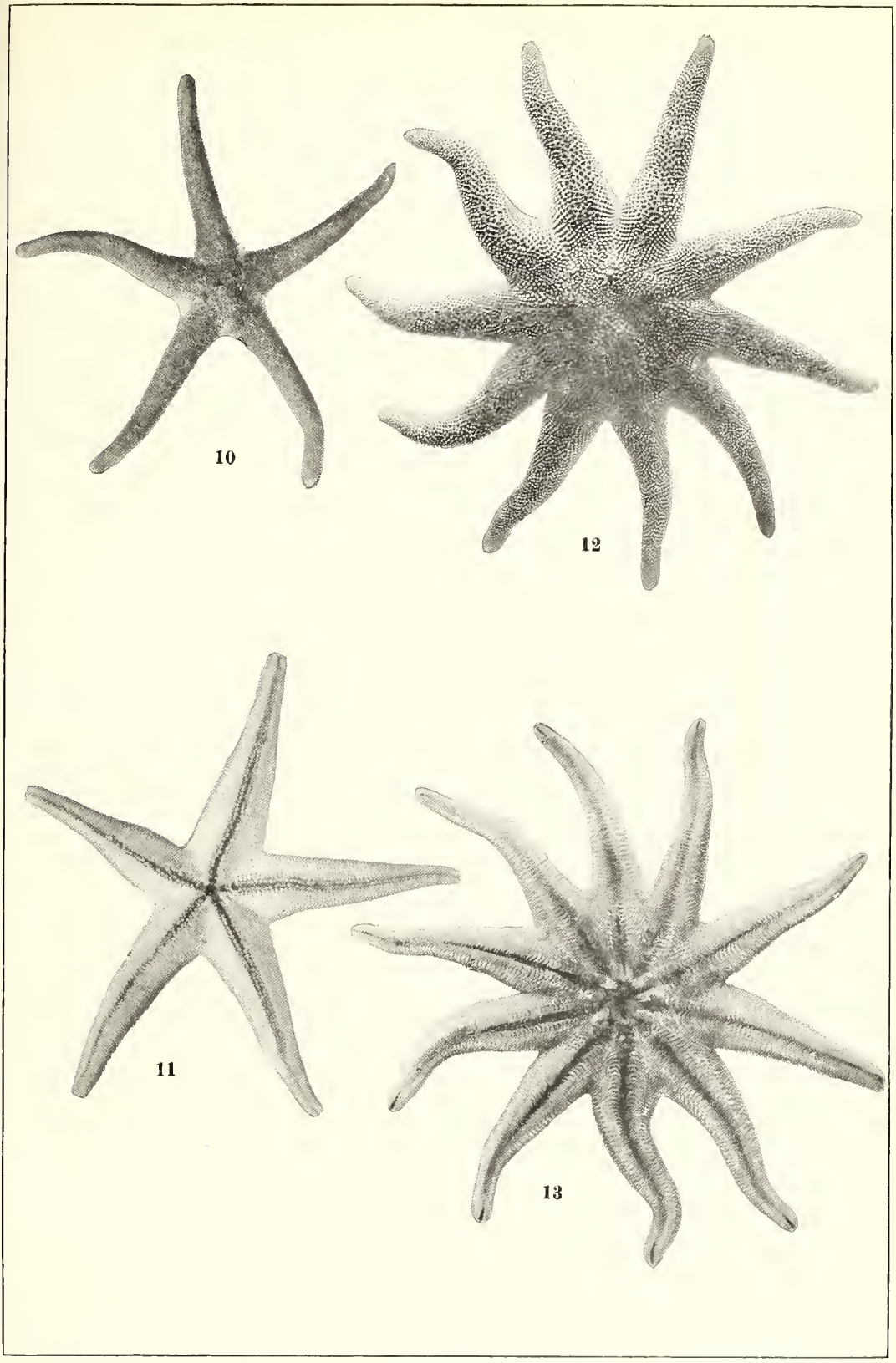
Range.—Greenland and Labrador to Connecticut, off New Jersey, and even Cape Hatteras; littoral only as far south as the Woods Hole region; northward it is common from low water to 220 fathoms, while southward specimens have been reported from 1,350 fathoms. Also Spitzbergen, Nova Zembla, and Iceland to Great Britain and northwestern France. Northwestern coast of Asia (Brandt), Bering Sea (Ludwig).

Remarks.—The abundance of this star-fish in Woods Hole Harbor varies greatly in different years, and although it is often common the specimens are always small. Much the finest specimens found in this region come from Crab Ledge, where the species is very common, and exhibits the greatest variety of form and color. Careful measurements were made of 142 specimens to see whether there was any tendency to diverge into two or more forms, but none appears. While some specimens have the breadth of the ray over 36 per cent of the length, others have it only 18 per cent, while the majority range about 28 per cent. The curve of variation falls off quite uniformly in both directions. Nor could I find that the diversity of either form or color was in any way correlated with age, sex, or environment. This species breeds in the early spring; the eggs are large and contain much yolk; development is abbreviated, but is still imperfectly known.

6. Solaster endeca (Retzius). (Pl. 3, figs. 12, 13; pl. 4, fig. 23.)

Asterias endeca Retzius, 1783.
Solaster endeca Forbes, 1839.

Description.—Rays usually 10 or 11, frequently 9, occasionally 7, 8, 12, or 13. R=75 to 150 mm., r=25 to 50 mm., R=3 r. Breadth of ray near base 12 to 30 mm., R=5 to 6 br. Rays arched abactinally, flattened actinally, regularly tapering, bluntly pointed. Disk large, generally highly arched; in a specimen with R=106, the disk is 35 mm. high. Interbrachial arcs rather rounded. Abactinal surface covered with a very close net-work of plates, making a firm skeleton. These plates



Figs. 10, 11. *Cribrella sanguinolenta* (natural size).—10. Slender-armed form; aboral view. 11. Stout-armed form; oral view.
Figs. 12, 13. *Solaster endeca* (small specimen, natural size).—12. Aboral view. 13. Oral view.

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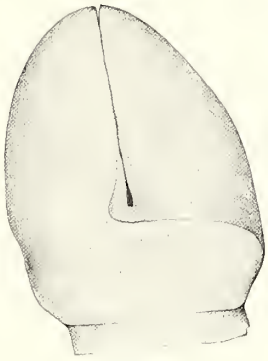

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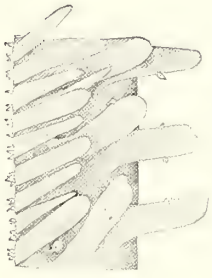

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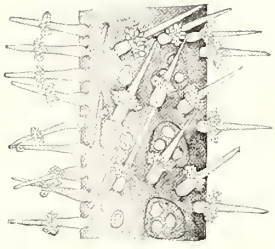

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Figs. 14, 15. *Asterias forbesi.*—14. Part of oral surface of one side of ray near middle (× 2½). 15. Large pedicellaria from oral side (× 75).
Figs. 16, 17. *Asterias vulgaris.*—16. Part of oral surface of one side of ray near middle (× 2½). 17. Large pedicellaria from oral side (× 75).
Figs. 18, 19. *Asterias austera.*—18. Part of oral surface of one side of ray near middle (× 5). 19. Large pedicellaria from oral side (× 75).
Figs. 20, 21. *Asterias tenera.*—20. Part of oral surface of one side of ray near middle (× 5). 21. Large pedicellaria from oral side (× 75).
Fig. 22. *Cribrella sanguinolenta.* Part of oral surface of one side of ray (× 6).
Fig. 23. *Solaster endeca.* Part of oral surface of one side of ray (× 6).

bear low columnar elevations, each of which is crowned with a group of from 10 to 12 (more or less) delicate spines, 0.3 to 0.5 mm. in length. These spines are so short, and of such nearly uniform length, that the general impression in the living starfish is that of an almost smooth surface. In some specimens the spines radiate slightly from the top of the column while in others they are very closely erect. Along the sides of the rays, the columns tend to form longitudinal series, and 4 or 5 such series are sometimes well defined. On the actinal surface there is a well-marked series of plates forming a lateral margin to the ray. On the distal portion of the ray these plates are in contact with the adambulacral plates, but as the disk is approached, they diverge and form a margin for the actinal surface of the disk. The plates carry transverse ridge-like elevations, 0.5 mm. high (more or less), which are crowned by a group of 12 to 25 small spines, of nearly uniform length, arranged in a more or less perfectly double series. Actinal, interradial spaces, closely covered with plates, bearing low columnar or ridge-like elevations, crowned with clusters of spines somewhat larger than those of the abactinal surface. These clusters have a more or less definite arrangement, tending to form rows parallel to the adambulacral plates. The row adjoining the latter runs out about halfway to tip of ray, while the others are successively shorter, the interradial series being the shortest. Adambulacral plates with 2 series of spines, one in the furrow, and one on the face of the plate. Furrow series of 3 spines in a row parallel to the furrow; 1 (or even 2) of these spines is often absent, but when all are present, the middle one is the longest (a little over 1 mm.), while the distal one is generally the shortest. Near the mouth these furrow spines are usually more or less fused at the base. Spines on face of plate somewhat pointed, 6 to 8 in number, 1 to 2 mm. long, arranged in a single curved transverse series, concavity of curve away from mouth; largest spine nearest furrow. Oral plates very prominent, bearing along the margin a series of 14 to 18 spines, of which those at the oral end of the plate are much the largest (2 to 6 mm. long), the next 1 or 2 pairs a little smaller, and the remainder markedly smaller. On the face of each plate is a ridge on which are borne 3 to 12 spines of very variable length; the longest are nearest the oral end of the plate and may be 2 to 3 mm. long. Papulæ small, and generally single. Madrepore plate small, with numerous fine furrows. Feet biserial. Color in life, abactinally, dark red or deep rose-purple, rarely orange or dull yellowish; actinally, orange or yellowish of some shade.

Range.—Greenland and Newfoundland to Crab Ledge, off Chatham, Mass., low water to 150 fathoms; also on the coasts of Great Britain and Northern Europe; possibly circumpolar.

Remarks.—This very striking and easily recognized northern starfish just enters the Woods Hole region, as we found it not uncommon on Crab Ledge. Of the 9 specimens we took, 4 have 10 rays, and 5 only 9. Both the largest specimen (220 mm. in diameter in life) and the smallest (40 mm.) are among the 9-rayed individuals. Little is known of the habits, and nothing of the development, of this species.

OPHIUROIDEA.

BRITTLE STARS, SAND STARS, SNAKE STARS, OR SERPENT STARS.

The ophiuroids are a very large class, and the separation of nearly allied species is a task sufficient to test the skill of a specialist; but the Woods Hole region contains only 5 species, and these are so unlike each other that even a beginner can easily distinguish them. The terms which are used in describing a brittle star usually carry their own meaning, so that it is only necessary to introduce here a few of the less easily understood names:

Adoral plates.—A pair of plates on the face of each of the 5 jaws, beside or in front of the oral shield.
Oral papillæ.—Teeth-like projections along the edges of the jaws.
Oral shield.—The large plate on the face of each jaw, near the base.
Radial shields.—A pair of plates on the upper side of the disk, at the base of each arm; sometimes very prominent, again wholly covered.
Tentacle scales.—Small scales on the lower side of the arm, on each side of the under-arm plate; 1, 2, or several at the base of each tentacle.
Tooth papillæ.—Small teeth-like projections at the point of each jaw.

Key to the Ophiuroids of the Woods Hole region.

Arms simple, unbranched.
- Arm spines short, small, and more or less appressed to the arm.
  - Arms nearly terete; disk covered with a fine granulation ..... OPHIURA BREVISPINA
  - Arms flattened; disk covered with scales ..... OPHIOGLYPHA ROBUSTA
- Arm spines prominent, at a marked angle with the arm.
  - Upper-arm plates surrounded by a series of small plates; arm spines 5 to 6 ..... OPHIOPHOLIS ACULEATA
  - Upper-arm plates not surrounded by small plates; arm spines 3 ..... AMPHIPHOLIS SQUAMATA

Arms dichotomously branched ..... GORGONOCEPHALUS AGASSIZII

1. Ophiura brevispina Say. (Pl. 5, figs. 28–30; pl. 7, figs. 37, 38.)

Ophiura brevispina Say, 1825.
Ophioderma olivaceum Ayres, 1852.
Ophioderma serpens Lütken, 1856.
Ophiura brevispina Lyman, 1860 and 1882.
Ophiura olivacea Lyman, 1865; Verrill, 1873.

Description.—Arms normally 5, occasionally 4, rarely 6, of moderate length, nearly terete, but flattened on the oral side. Diameter of disk, 10 to 15 mm. Length of arm, 40 to 60 mm.; breadth of arm at base, $2\frac{1}{2}$ to 3 mm. Arm spines 7 to 8, shorter than the arm joints, approximately equal, or the lowest shortest, closely appressed to the arm. Disk more or less perfectly pentagonal, covered with granules of nearly uniform size, about 100 to 180 to a square millimeter, completely concealing the radial shields. At the base of each arm the granulation extends out on each side, so that the first 3 upper-arm plates form a narrow ridge running in toward the center of the disk. On each side of the third plate is a group of about 10 little scales. Upper-arm plates broadly in contact with each other; at the base of the arm they are nearly oblong, twice as wide as long, but as the tip is approached they become more rounded on the sides, the outer edge becoming curved, the inner markedly narrowed. Under-arm plates broadly in contact, nearly square with rounded corners, usually somewhat longer than wide. First under-arm plate much wider than long, with rounded sides; second much longer. Tentacle scales 2, of which the inner is nearly half the length of the under-arm plate, while the outer is about half as long and covers the base of the lowest spine. Oral shields oval, plainly longer than wide. Adoral plates small, lying entirely at sides of oral shields, roughly triangular, with rounded corners. All of the oral surface granulated as above, except the oral shields and adoral plates. Oral papillæ about 7 on each side of each jaw, of which the one next to the under-arm plate is small, often wanting, while the next one is the widest and largest of all. Teeth 5, blunt, the lowest the smallest. No tooth papillæ. In each interbrachial space there are 4 genital openings. Color very variable, but never very bright; some shade of green or brown is the most frequent; the disk is generally mottled or spotted, and the arms frequently banded with alternate rings of light and dark shades. More or less uniform olive green is a frequent color, uniformly brown specimens being less frequent; nearly black specimens are occasionally found.

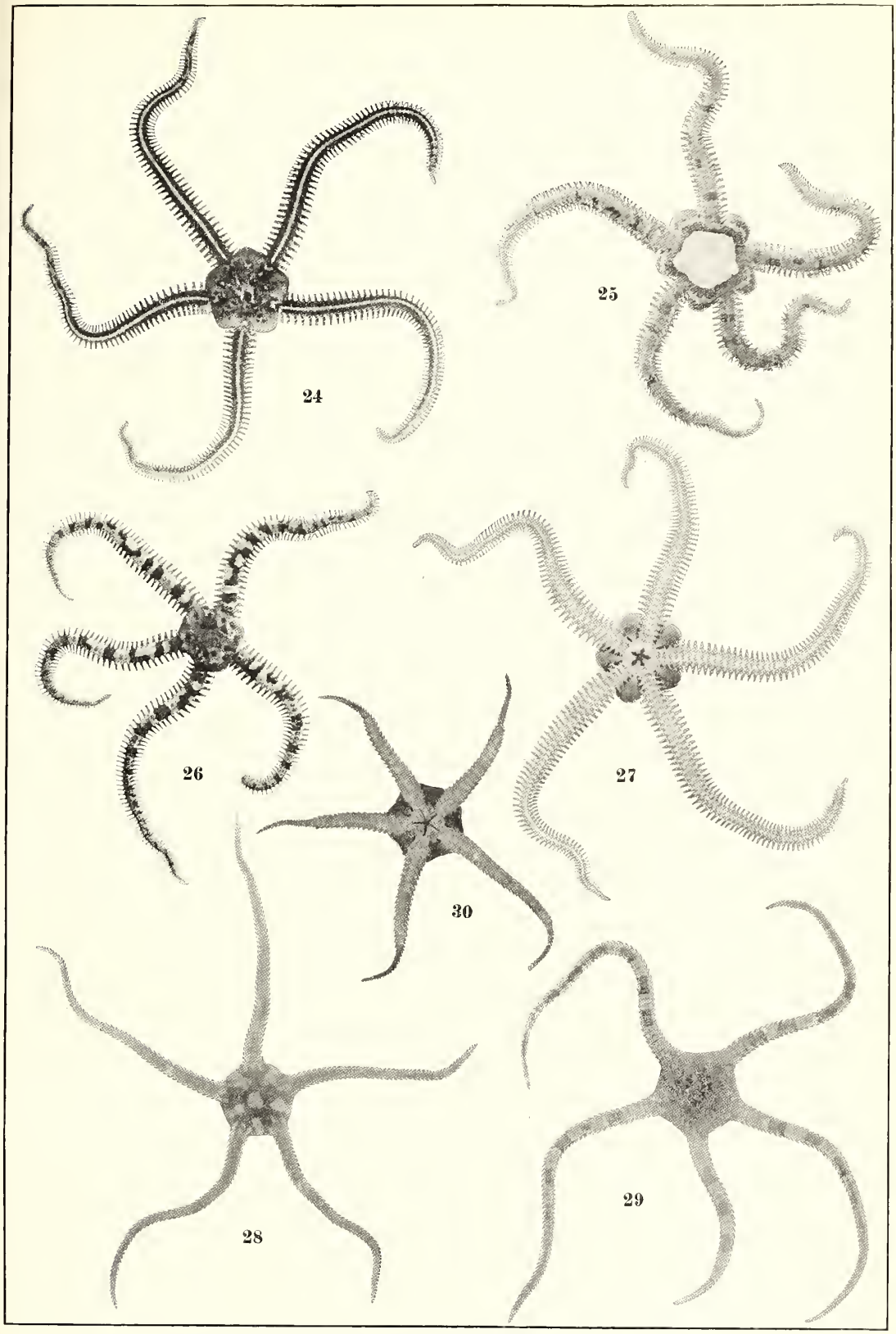
Range.—North Falmouth, Mass., to Bahia, Brazil, low water to 122 fathoms.

Remarks.—This very widely distributed brittle star reaches its northern limit in Buzzards Bay. It is abundant in about 1 fathom of water, on a bottom covered with eel grass, in North Falmouth Harbor, and has been taken in similar situations in Marion, New Bedford, and Dartmouth, Mass., on the other side of the bay. It also occurs at Sag Harbor, Long Island. The habits, movements, and development have been so well described by Grave (1900) that it is unnecessary to discuss them here. Verrill ('99) considers the northern form of this species as separable from the form occurring from Florida southward, and would regard it as a variety *olivacea*.

2. Ophioglypha robusta (Ayres). (Pl. 6, figs. 31, 32; pl. 7, 39, 40.)

Ophiolepis robusta Ayres, 1851.
Ophiura fasciculata Forbes, 1852.
Ophiura squamosa Lütken, 1854.
Ophioglypha robusta Lyman, 1865.
Ophioglypha tenorii Ljungman, 1866.

Description.—Arms 5, finely tapering. Diameter of disk, 7 to 10 mm. Length of arm, 24 to 35 mm.; breadth of arm at base 1 to 1.5 mm. Arm spines 3, rounded and acute, the upper one largest, nearly 1 mm. long; at tip of arm the lowest spine is flattened and bears 1 or 2 small hooks. Disk rounded or slightly pentagonal, covered with small, irregular scales, 4 or more to the square millimeter; in young specimens, the plates at center of disk show more or less definite arrangement. Radial shields inconspicuous, about as broad as long, barely touching without. The disk is notched in each radius



Figs. 24-26. *Ophiopholis aculeata.* Aboral view (natural size).
Fig. 27. *Ophiopholis aculeata.* Oral view (natural size).
Figs. 28, 29. *Ophiura brevispina.* Aboral view (natural size).
Fig. 30. *Ophiura brevispina.* Oral view (natural size). Shows regenerating arms.

by the upper-arm plates, and on the side of the notch are 7 or 8 short conical projections or papillæ. This series is continuous with another one of 12 small, flat papillæ along the genital slit. Just outside the disk notch are small papillæ on each side of the upper-arm plate. In young specimens all or nearly all of these papillæ may be wanting. Upper-arm plates rounded distally, more or less pointed proximally, separated by the side-arm plates on the distal part of the arm in adults, on the whole length of the arm in the young. First under-arm plates oval or triangular with rounded corners; the remainder broader than long, the distal edge slightly convex, the proximal with a little point. Side-arm plates strongly developed, completely separating the under-arm plates. Tentacle scales small and with rounded ends, 7 to 9 for the mouth tentacles, 3 or 4 for each of the first two arm tentacles, and 1 for each tentacle thereafter. Oral shields somewhat broader than long, pointed within, and broadly curved on the outer side; 1.5 mm. wide, more or less. Adoral plates long and narrow, lying along the inner sides of oral shields, and meeting within. Oral papillæ 3 or 4 on each side of each jaw, one or more of them at the point of the jaw; outermost one broadest. Teeth 5 or 6, equal, sharp and flat. No tooth papillæ. Interbrachial spaces with small scales, and 1 pair of genital slits. Color in life variable, but not bright; generally some shade of gray, more or less variegated with brown, reddish, or black; radial shields usually distinctly lighter; arms often banded with gray and greenish.

Range.—Greenland to Crab Ledge, off Chatham, Mass.; and possibly in deep water to Porto Rico. (Fish Hawk collection, 1899.) Also from the Arctic Ocean to Denmark. Alaska? Possibly circumpolar. Low water to 150 fathoms.

Remarks.—This is another of the northern echinoderms which just comes within the northeastern border of the Woods Hole region. Amidst the gravel and broken shells brought up in the dredge on Crab Ledge we found 4 small specimens of this species, the largest with the disk only 3 mm. across. The figure on plate 6 is taken from this specimen, enlarged. Apparently nothing is known of the habits or development of the species.

3. Ophiopholis aculeata (Linnæus). *Daisy Brittle-Star.* (Pl. 5, figs. 24–27; pl. 7, figs. 41, 42.)

Asterias aculeata Linnæus, 1767. Müller, 1776.
Ophiura bellis Fleming, 1828.
Ophiocoma bellis Forbes, 1839.
Ophiolepis scolopendrica Müller & Troschel, 1842.
Ophiocoma aculeata Desor, 1848.
Ophiopholis aculeata Gray, 1848. Verrill, 1866 and 1873. Lyman, 1882.
Ophiopholis scolopendrica Stimpson, 1853.
Ophiopholis bellis Lyman, 1865.

Description.—Arms, 5; rather wide and flat. Diameter of disk, 15 to 20 mm. Length of arm, 60 to 80 mm. Breadth of arm at base, without spines, 3 to 4 mm.; with spines, 6.5 to 8 mm. Arm spines, 5 or 6, of which the two middle ones are the largest (1 to 1.5 mm. long by 0.3 to 0.6 mm. wide), the upper one or two slightly, the lower two considerably, smaller, the lowest spine smallest of all; these spines are borne on a prominent vertical ridge on each side arm plate and stand at nearly a right angle to the arm. In adults these spines are very blunt, but in young individuals they are slender and acute. Beginning rather more than halfway out on the arms, the lowest spine becomes bent at the tip until finally it is little more than a sharp-pointed hook, usually with 1 or 2 minute teeth on the concave side. Disk circular, often bulging considerably between the arms, scaled, but more or less covered by a coat of very unequal granules, which are small and spheroidal near the center of the disk, and become much more prominent and spine-like on the interbrachial portions. In very few cases, however, does the granular coat cover the disk with even approximate uniformity. In the very great majority of specimens, from 6 to 36 more or less circular scales or plates are left bare, and as these are always symmetrically arranged, the disk has a very ornate appearance. In the center is 1 plate, around which are grouped 5 others, placed radially; there are then 10 sets of 1, 2, or rarely 3 somewhat smaller plates, lying in rows radiating from the center, 5 radial and 5 interradial. In extreme cases the radial shields may also be left partially bare. Some or all of the plates are surrounded by definite circles of small granules. Upper arm plates nearly elliptical, about twice as wide as long; in large specimens those near the base of the arm are broken into two pieces. Each plate is surrounded by a single series of about 12 very large, somewhat angular, flat grains; but between any two adjoining upper arm plates there is only 1 row of these grains, so that those which serve as an anterior border for one plate are also the posterior border of the next distal plate. In some specimens, as the tip of the arm is approached, the bordering grains become more numerous and nearly circular, while in other specimens they are less numerous, so that the upper arm plates come in direct

contact. Under arm plates nearly rectangular, but with rounded corners and slightly concave sides; except the first 1 or 2 they are distinctly wider than long. Tentacle scales single, large, oval, more than half the length of the under arm plate. Oral shields more or less elliptical, much wider than long, the outer side often flattened; the madrepore plate is usually distinctly longer and larger than the others. Adoral plates large, more or less rounded at each end, on the inner side of the oral shields, but not meeting within. Oral papillæ, 3 or 4 on each side of each jaw, wide, flat, and thin edged, of approximately equal size. Teeth about 12, narrowest above, the broad, lower ones sometimes broken in two. No tooth papillæ. Interbrachial spaces loosely covered with plates, each of which bears 1 to 3 large granules or small blunt spines; in each space there is 1 pair of genital slits. Color extraordinarily variable; no two specimens seem to be colored just alike; shades of brown, red, yellow, purple, and green are most common; unicolor specimens are very rare, the disk being always blotched, or marked in some regular pattern, while the arms are banded or longitudinally striped; actinal surface generally light, most often yellowish.

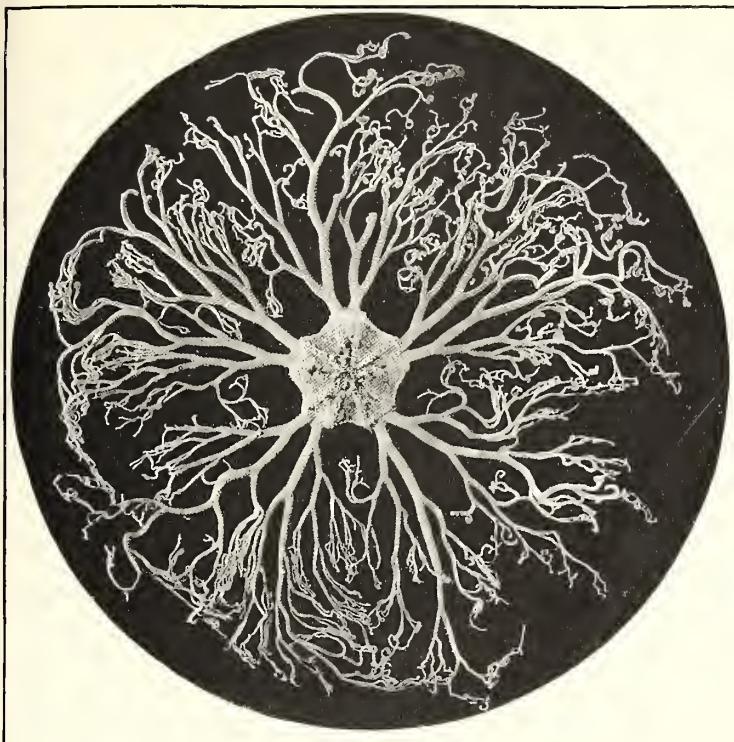
Range.—Greenland to New Jersey, low water to 1,000 fathoms; rare or local south of Cape Cod; also Iceland and Spitzbergen; along the coasts of Great Britain and northern Europe to Ireland and the English Channel. Bering Sea (Ludwig).

Remarks.—Although this beautiful ophiuran has been known to occur in the colder waters off Gay Head and Watch Hill and in 38 fathoms even off the coast of New Jersey, it has always been regarded as a rarity south of Cape Cod. The reported cases of its occurrence in Vineyard Sound are almost certainly cases of mistaken identification. In 1894 Mr. Vinal Edwards took a number of very fine specimens on some fishing banks about 15 miles ESE. of Sankaty Head, Nantucket, in 24 fathoms. In 1902 we took hundreds of specimens off Sankaty Head in 12 fathoms and on Crab Ledge in 17. Those taken off Sankaty Head were all small, very few having a disk diameter of over 7 mm. and none over 10, while the specimens from Crab Ledge were of good size, many being over 15 mm. across the disk. Next to the remarkable variety of color, which is really beyond description, the most extraordinary thing about these brittle-stars is the way in which even large specimens secrete themselves in cavities and crannies, among rocks, shells, and barnacles. They are eagerly sought as food by codfish, and their colors and habits are doubtless protective. The development of this species has been partially described by Fewkes ('86).

4. Amphipholis squamata (Delle Chiaje). (Pl. 6, figs. 33, 34; pl. 7, figs. 43, 44.)

Asterias squamata Delle Chiaje, 1828.
Ophiura neglecta Johnston, 1835.
Ophiocoma neglecta Forbes, 1841.
Ophiolepis squamata Müller and Troschel, 1842.
Ophiolepis tenuis Ayres, 1851.
Amphiura tenera Lütken, 1859. Lyman, 1865.
Amphiura tenuis Lyman, 1860.
Amphiura elegans Norman, 1865.
Amphipholis lincata Ljungman, 1871.
Amphipholis elegans Lütken, 1871. Verrill, 1873 et seq.

Description.—Arms 5, slender, of moderate length, 2.5 to 4.5 times the diameter of the disk, which is from 3 to 5 mm. Length of arm 12 to 20 mm. Breadth of arm at base, without spines, 0.5 to 0.8 mm. Arm spines 3, blunt, nearly equal, the upper a little the stoutest; more slender and acute in the young. Disk nearly circular, rather flat, covered with scales of nearly uniform size, 20 or more to the square millimeter. Radial shields conspicuous, narrow (about 3 times as long as broad), in close contact with each other, barely separated at each end. Margin of disk rather sharply defined by a line where the edges of the scales on the interbrachial spaces meet the scales of the disk. Upper arm plates mostly wider than long, with the outer edge slightly curved, the inner edge and sides forming a common curve; all except the first 2 or 3 separated by the side arm plates. In the young, the upper arm plates are more widely separated, and are nearly pointed on the inner edge. Under arm plates about as long as broad, the outer edge nearly straight, the sides straight, or reëntteringly curved, the inner edge pointed; all are separated by the side arm plates. Tentacle scales 2, quite large. Oral shields of medium size, wider than long, rounded without, but pointed within. Adoral plates rather large, meeting within. Oral papillæ 3 on each side of each jaw, the basal one very much the widest, the other 2 small and nearly equal; when pressed together the oral papillæ can completely close the mouth slit. No tooth papillæ. Teeth 5, flat and thin, the lowest the smallest. Interbrachial spaces more finely scaled than disk, with 1 pair of genital slits. Color in life quite uniformly brownish or gray,



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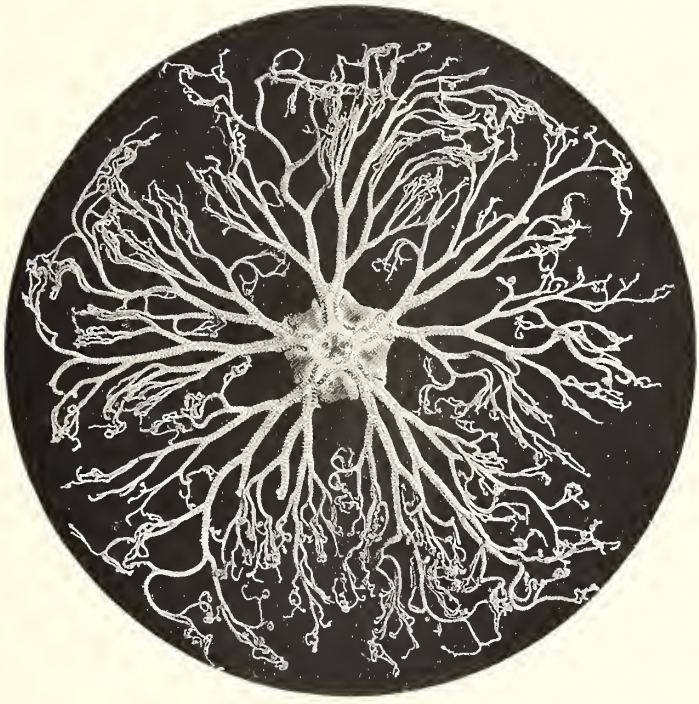

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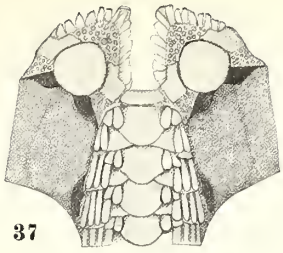
Figs. 31, 32. *Ophioglypha robusta.* Broken young one from Crab Ledge.—31. Aboral view (× 2). 32. Oral view (× 2).
Figs. 33, 34. *Amphipholis squamata* (adult, natural size).—33. Aboral view. 34. Oral view.
Figs. 35, 36. *Gorgonocephalus agassizii* (one-fourth natural size).—35. Aboral view. 36. Oral view.



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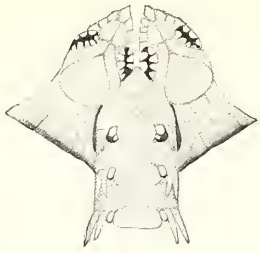

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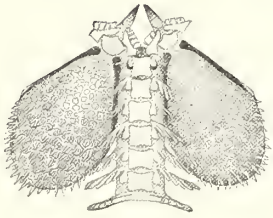

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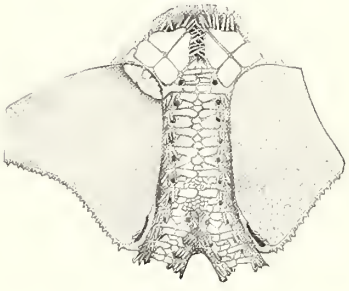

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Figs. 37, 38. *Ophiura brevispina.*—37. Oral view of base of arm, with adjacent parts (× 5). 38. Side view of three arm joints, to show arm spine (× 5).

Figs. 39, 40. *Ophioglypha robusta.*—39. Oral view of base of arm, with adjacent parts (× 10). 40. Side view of three arm joints, to show arm spines (× 10).

Figs. 41, 42. *Ophiopholis aculeata.*—41. Oral view of base of arm, with adjacent parts (× 5). 42. Side view of three arm joints, to show arm spines (× 5).

Figs. 43, 44. *Amphipholis squamata.*—43. Oral view of base of arm, with adjacent parts (× 10). 44. Side view of three arm joints, to show arm spines (× 10).

Figs. 45–47. *Gorgonocephalus agassizii.*—45. Oral view of base of arm, with adjacent parts (× 2). 46. Side view of arm joints near middle of arm (× 2). 47. Side view of arm joints near tip of arm (× 10).

more or less finely mottled with whitish, the lower surface yellowish. Outer ends of radial shields almost always very light, giving the appearance of a white spot at the base of each arm. Very young individuals have the disk bright orange.

Range.—Arctic Ocean to New Jersey, low water to 60 fathoms. Also on the coast of Europe well into the Mediterranean. Lyman reports specimens even from near the Cape of Good Hope, 98 fathoms, and near Australia, 120 fathoms, but these probably represent species which in life would show marked differences from *squamata*.

Remarks.—This is the commonest and most widely distributed of the ophiurans in the Woods Hole region. It is common in Vineyard Sound, especially just east of Nobska, and is reported abundant at Newport. We also took it at Crab Ledge and off Sankaty Head, and specimens were brought in from Ram Island and the Eel Pond at Woods Hole. The latter were very small, and were found on the eel grass. I am indebted to Dr. H. F. Perkins for one of these, a beautifully stained and mounted specimen with disk half a millimeter in diameter. Adults occur on rocky or shelly bottom and generally are found in the interstices and cavities of the stones and shells. The breeding season is in the summer, and in July and August the adults nearly always contain eggs or young, for, as is well known, this species is viviparous. Often one of the interbrachial spaces will be found swollen and of a slightly pink shade. If opened, it will be seen to contain the bright pink eggs of a parasitic crustacean. The eggs of the brittle star are yellow, orange or reddish. The development of this species is without metamorphosis and has been studied in part by several observers in Europe and by Fewkes ('87) in this country, but much still remains to be done. Fewkes's paper contains interesting notes on the breeding and other habits of adults.

5. Gorgonocephalus agassizii (Stimpson). "*Basket Fish*"; "*Spider.*" (Pl. 6, figs. 35, 36; pl. 7, figs. 45–47.)

Euryale scutatum Gould, 1841 (not of Blainville).
Astrophyton agassizii Stimpson, 1853.
Gorgonocephalus agassizii Lyman, 1882.

Description.—Arms 5, dividing dichotomously, but unequally, 11 to 15 times, and perhaps more; branches of unequal length, and alternating, so that if the left-hand branch of the first fork is the longer, the right-hand branch will be longer at the next fork, the left hand at the third, the right hand at the fourth, and so on. Disk 40 to 80 mm. in diameter; length of arm 140 to 280 mm.; breadth of arm at base 8 to 10 mm.; at first fork 10 to 18 mm. True arm spines wanting (Lyman). Disk more or less flattened, with radial shields very prominent as raised ridges, covered with a thick skin, which is usually quite smooth, but often bears granules or low blunt spines, sometimes in large numbers, especially at the center of the disk. Margin of disk sharply defined by a band of plates connecting the outer ends of the radial shields. The latter are long and narrow and nearly meet at center of disk; although sometimes nearly smooth, they usually bear numerous knobs or thick, blunt spines, a millimeter high, more or less. Upper surface of arms beautifully curved; on the last few subdivisions there is a faint longitudinal groove; the surface may be smooth near the base and along the sides for some distance, though generally covered with coarse granules which are at first irregularly disposed, but after about the second or third fork begin to form incomplete rings about the arm. After about the sixth fork the granules are confined almost wholly to these rings, which soon become raised ridges, about 2 granules wide. Undersides of arms nearly flat, smooth, the numerous small, irregular underarm plates quite evident in dry specimens. Tentacle scales usually 3, sometimes 4, at base of arm 2 or 1; the first tentacle pore has none. These scales are spine-like, and about a millimeter long. Near the tips of the arms there are only 2 or even 1, but there they assume the form of little, toothed hooks. No oral shields or adoral plates, but the jaws are surrounded by a wide circle of calcareous plates connecting the bases of the arms. Teeth, teeth papillæ, and mouth papillæ, all alike and spiniform, about 20 in number on each jaw, and about 2 mm. long. Interbrachial spaces nearly triangular with a rounded point inward, covered with a thick, smooth, or more or less granular skin, and containing a single pair of genital openings near their outer edges. At the inner point of one of the interbrachial spaces is the single, large madrepore plate, which is wider than long. Color in life, disk and interbrachial spaces brown, of variable shade, but usually dark; radial shields often lighter; arms cream color, yellow, brownish-yellow, or reddish; some specimens have a very strong reddish cast.

Range.—Arctic Ocean and Gulf of St. Lawrence to Crab Ledge, off Chatham, Mass., and perhaps even on Nantucket Shoals. Also reported from Vadsö, Norway. Low water to 800 fathoms.

Remarks.—This remarkable animal is one of the rarest of the Woods Hole Echinoderms, and its right to a position in this list is based on the reported capture of specimens by codfishermen near Nantucket Shoals and at Crab Ledge. We failed to find it at the latter place, although trustworthy fishermen have assured Mr. Edwards and myself that it is common there, "if you get into deep enough water." It is very abundant off Race Point, Provincetown, Mass., in 35 fathoms, where, in August, 1902, I brought up 123 fine specimens in a single haul of a small dredge. At that place the basket fish breeds during the latter part of August, and these specimens were full of the ripe reproductive cells. It is called by the fishermen "spider," and the particular spot where it occurs is known locally as the "spider ground." Almost nothing is known of the habits and absolutely nothing of the development of this remarkable ophiuran. Young specimens with the arms only once forked have the disk covered with scales, and are said to resemble *Ophiopholis*. One of the specimens taken at Provincetown had 5 madrepore plates, but dissection showed that there was only 1 stone canal. The history of the discovery of the basket fish, and its original description, are very interesting, and are given very fully by Lyman ('65).

ECHINOIDEA.

SEA-URCHINS, SAND-DOLLARS, CAKE-URCHINS, SAND-CAKES, ETC.

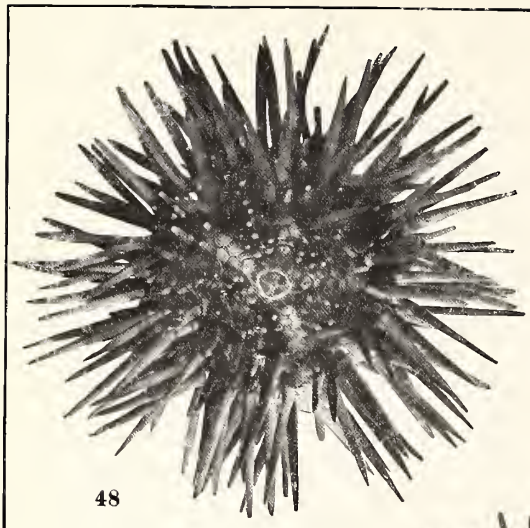
The echinoids are less represented in the Woods Hole region than any other class, for there are only 4 species known to occur, and of these 1 is extremely rare, and 1 is found only in deep, cold water. The 4 are so unlike each other that there is no danger of confusing them; but it must be borne in mind that the young are often unlike the adults, for not only do the primary spines increase in number with age, but the number and arrangement of the poriferous plates also undergoes a marked change in many cases. In the cake-urchins (clypeastroids), moreover, there is a marked change in the shape of the test, position of the anus, number and appearance of lunules, etc., as the animal increases in size. The following terms, used in the descriptions, require some explanation:

Abactinal system=the group of plates forming the apex of the test (or near it) including the genital and ocular plates, and in true urchins the anal plates also.
Ambitus=the line of largest horizontal circumference of the test.
Buccal plates=a circle of plates on the peristome around the mouth.
Branchial incisions=notches in the edge of the peristome, between the ambulacra and the interambulacra.
Coronal plates=any vertical series of plates running from the abactinal system to the peristome.
Genital plates=the five large plates terminating the interambulacra abactinally.
Imperforate tubercles=tubercles the top of which is not centrally depressed or vertically perforated.
Lunules=slit-like openings piercing the test from abactinal to actinal surface.
Miliary spines=the smallest spines of the test, usually on very insignificant tubercles.
Ocular plates=the five plates terminating the ambulacra abactinally.
Peristome=the portion of the actinal surface surrounding the mouth, covered with a membrane.
Petals=the figures formed by the poriferous zones of the ambulacra, of flat or irregular echinoids.
Poriferous zones=the vertical areas occupied by the pores through which the feet pass.
Primary spines=the large spines situated on the largest tubercles of the test.
Secondary spines=spines intermediate between primaries and miliaries.

Key to the Echinoids of the Woods Hole region.

Test nearly hemispherical, with spines of moderate or large size.
  Spines long; color, deep red, purple, or brown to nearly black ..... ARBACIA PUNCTULATA
  Spines short, numerous; color, green or yellowish; spines sometimes reddish or purple-tipped, STRONGYLOCENTROTUS DRÖBACHIENSIS

Test discoidal, flat, with very numerous minute spines.
  Test without lunules ..... ECHINARACHNIUS PARMA
  Test with five lunules ..... MELLITA PENTAPORA



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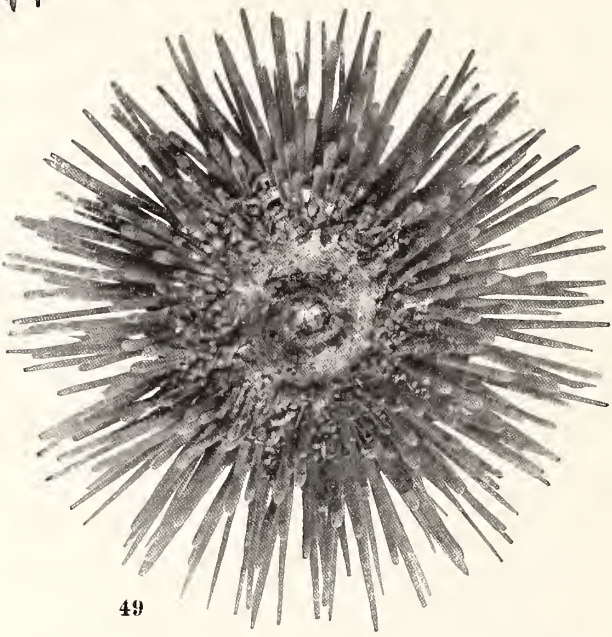

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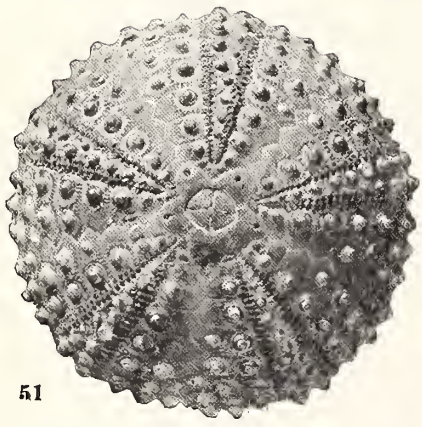

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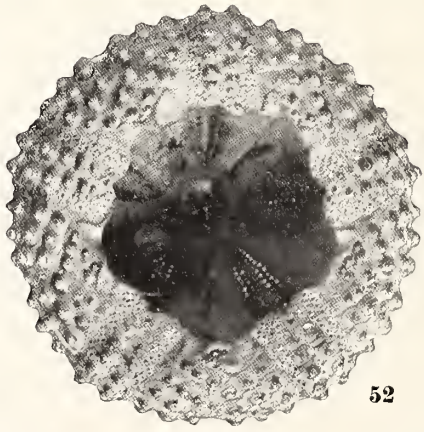

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Figs. 48–52. *Arbacia punctulata* (natural size).—48. Aboral view of test with spines. 49. Oral view of test with spines. 50. Side view of test without spines. 51. Aboral view of test without spines. 52. Oral view of test without spines.

1. Arbacia punctulata (Lamarck). *Common sea-urchin.* (Pl. 7, figs. 48–52.)

Echinus punctulatus, Lamarck, 1816.
Arbacia punctulata, Gray, 1835.
Echinocidaris davisii, Agassiz, 1863; Verrill, 1866.

Description.—Diameter of test 30 to 50 mm.; height 15 to 25 mm. D=2 H. more or less. Length of longest spines 20 to 25 mm.; diameter of anal system 4 to 6 mm.; diameter of whole abactinal system 10 to 15 mm.; diameter of peristome 15 to 25 mm. Test somewhat flattened, sloping markedly toward ambitus, which is nearly circular; actinal surface flat, the peristome only slightly sunken. Branchial incisions deep, with prominent everted edges. Anal plates normally 4, occasionally 3 or 5. Ocular plates (radials) excluded from the circumanal ring in young specimens, but in old ones 1 or 2 sometimes enter it slightly. Genital plates (basals) large, the madrepore plate evidently largest. Ambulacra straight, narrow above the ambitus, but wider below. Poriferous zones narrow, with large pores, in simple pairs dorsally, then in arcs of 3, and on the very edge of the peristome polyserial. Spines few near the abactinal system, the upper half of the median interambulacral space being entirely free from them; secondary and miliary spines altogether wanting; primaries longitudinally striated, longest at ambitus, shortest near abactinal system; those above ambitus pointed or blunt; those at ambitus and below flattened and more or less rounded at tip, and often with a median longitudinal ridge there; those nearest peristome shorter and more or less spatulate. Primary tubercles smooth, imperforate, in a double series on each ambulacrum; in 4 to 8 or more series on each interambulacrum, of which the 2 middle series are smallest, with only 4 or 5 small tubercles each, while the outermost are as long as the ambulacral series. Transverse rows of interambulacral tubercles oblique. All tubercles diminish in size from ambitus upward. A specimen with D=36 mm., H=18 mm., has 13 coronal plates. Buccal plates, 5 pairs, prominent. Color in life, reddish or purplish brown of some shade varying from a light dull reddish to almost black; tube feet, brownish red.

Range.—Nantucket Shoals and Woods Hole to west Florida and Yucatan; low water to 125 fathoms.

Remarks.—This is the common sea-urchin of the Woods Hole region. It is abundant at many places in Vineyard Sound, and is common in Hadley Harbor and, at times, around the Fish Commission wharf. We took one specimen off Sankaty Head, but none at Crab Ledge. In spite of its abundance, we know little of its habits, and its development is only partially known. Garman and Colton ('82) have published some notes on the development, and Fewkes ('81) has also contributed to our knowledge of the early stages.

2. Strongylocentrotus dröbachiensis (O. F. Müller). *Green sea-urchin.* (Pl. 9, figs. 53–57.)

Echinus dröbachiensis O. F. Müller, 1776.
Echinus neglectus Lamarck, 1816.
Echinus granularis Say, 1827.
Strongylocentrotus chlorocentrotus Brandt, 1835.
Echinus granulatus Gould 1841. Desor, 1848.
Toxopneustes dröbachiensis Agassiz, 1846.
Eurychinus granulatus Verrill, 1866.
Eurychinus dröbachiensis Verrill, 1866.
Strongylocentrotus dröbachiensis Al. Agassiz, 1872.

Description.—Diameter of test 60 to 80 mm.; height 25 to 45 mm.; D = 1.75 to 2.25 H. Length of longest spines 10 to 14 mm.; diameter of anal system 6 to 8 mm.; diameter of whole abactinal system 15 to 20 mm.; diameter of peristome 18 to 25 mm., very much larger in proportion in young specimens, sometimes 60 per cent of the diameter. Test more or less flattened, curving at first very slightly then abruptly to the circular ambitus, actinal surface flattened, the peristome sunken 4 to 6 mm. Branchial incisions rather small, and not very deep. Anal plates at first 2 or 3, but increasing in number with age, adults having 35 to 40. Ocular plates (radials) large, two entering circumanal ring to a marked degree. Genital plates (basals) very large, the madrepore much the largest. All the plates of the abactinal system carry miliaries, though they are few on the madrepore. Ambulacra broad at the ambitus, narrower at the peristome, though there they are much wider than interambulacra. Poriferous zones broad, with numerous small pores; pairs of pores in oblique transverse series, abruptly bent at outer end; number of pairs in each series varies somewhat with age, but is usually from 4 to 6; obliquity of series varies much with age, in very small specimens approaching the vertical—in old specimens more nearly horizontal. Spines numerous all over the test; primaries longitudinally striated, pointed but not very sharp, longest at and above ambitus, shortest around

peristome; secondaries similar, but much shorter; miliaries very slender. Primary tubercles smooth and imperforate, a double series on each ambulacrum, and also on each interambulacrum. On the ambulacra the series of primaries are separated by a double series of secondaries, while 2 or 3 series of secondaries on the poriferous zones form transverse lines between the arcs of the pores. On the interambulacra there are about 8 series of secondaries, 4 between and 2 outside of each primary series. Miliary tubercles occur all over the test, on both ambulacra and interambulacra. A specimen with D = 30 mm., H = 17 mm., has 22 coronal plates, while one with D = 60 mm., H = 27 mm., has 35. Buccal plates, 5 pairs, large and bearing miliaries. Pedicellariæ numerous, long stalked. Color in life prevailingly green; the test green or greenish white, purple or purplish white, the poriferous zones markedly lighter than the rest of the test; spines green with yellow, red, or purple cast, especially in young specimens; sometimes the actinal spines are bright violet, while the abactinal may be tipped with red or violet; pedicellaria and miliary spines whitish; tubercles white; tube feet whitish or pale violet.

Range.—Circumpolar; southward in the western Atlantic to New Jersey (not in shallow water south of Cape Cod); in the Eastern Hemisphere to Great Britain and Norway; in the North Pacific from Kamchatka to Puget Sound; low water to 640 fathoms.

Remarks.—In the Woods Hole region this northern urchin is found in abundance off Sankaty Head, Nantucket; it is common at Crab Ledge; it has been taken at several points in Vineyard Sound, and it occurs in 10 to 20 fathoms off Gay Head. At Crab Ledge the specimens we took were all small, but off Sankaty Head a large number of good-sized individuals were secured. In spite of the fact that this is one of the commonest and best known of sea-urchins, no connected account of its development has ever been published, although the egg, segmentation stages, pluteus, and young are all well known.

3. Echinarachnius parma (Lamarck). *Sand Dollar.* (Pl. 10, figs. 58–62.)

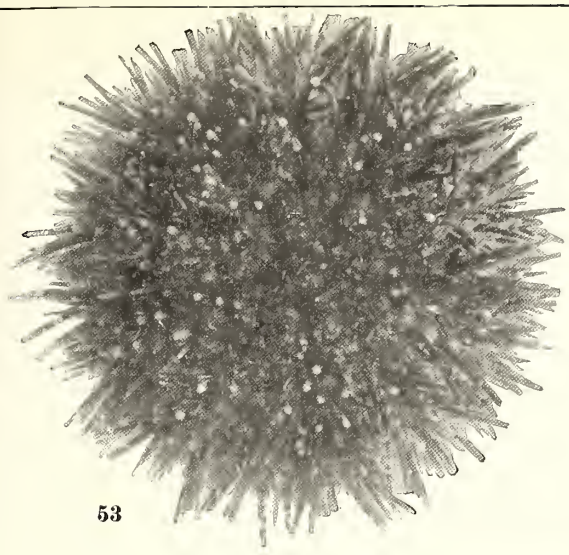
Scutella parma. Lamarck, 1816.
Echinarachnius atlanticus, Gray 1825. Stimpson, 1853.
Echinarachnius parma, Gray 1825.
Scutella triforà Say, 1826.

Description.—Test greatly flattened, closely covered with minute spines, which are shortest and most uniform on the abactinal surface, longer at the margin, and longest in the interradial areas at the peristome. Ambulacra obvious abactinally as widely open, somewhat obtuse "petals," extending more than halfway to margin; actinally the ambulacra appear as furrows, widest at peristome, and when more than halfway to the margin, giving off a prominent branch on each side at an angle of about 45°; all 3 furrows run to the margin, and the main furrow may be continued abactinally. Abactinal system approximately central; genital pores 4. Anal opening abactinal in very young specimens, marginal in adults, actinal in very large or old specimens. One of the latter gives the following measurements: Longitudinal diameter, 78 mm.; transverse diameter, 78 mm.; vertical diameter, 12 mm.; diameter of abactinal system, 8 mm.; length of anterior petal, 26 mm.; length of posterior petal, 24 mm.; length of spine at margin, 1 mm.; length of spine at peristome, 3 mm.

In very young specimens the proportions are somewhat different; thus a specimen 8 mm. long is only 7 mm. broad. The greatest tranverse diameter is not always through the abactinal system, but may be considerably back of it, and the abactinal system may be considerably in front of the center of test. Thus in a specimen 12 mm. in longitudinal diameter the center of the abactinal system is only 5 mm. from the anterior edge of the test, and the greatest tranverse diameter is through a point only 4 mm. from the posterior edge. The relative width of the petals varies greatly; it may be anywhere from 37 to 50 per cent of the length. Color in life, dull brownish-red, varying from flesh-red in very young specimens to a deep reddish-brown in adults; interambulacra distinctly lighter than the ambulacra, which are quite red. When placed in fresh water or alcohol, or even when simply dried, the color changes to a bright, though dark green, which afterwards, in dry specimens, becomes a dull brown. The bare, bleached tests are of course white.

Range.—Labrador to New Jersey; also both sides of the Pacific Ocean, from Vancouver to Japan, and (according to Agassiz) India, Australia, and the Red Sea. Low water to 888 fathoms.

Remarks.—This curious species is very common on sandy bottoms in Vineyard Sound and on the Nantucket Shoals. The finest specimens were taken near the Great Round Shoal Lightship, Nantucket, in 12 fathoms, many of them being 3 inches or more in diameter. The sand dollar is said to be an important article of food for flounders and codfish. It lives more or less buried in the sand, moving about very slowly, chiefly by means of the spines. The development has been studied and partially described by Fewkes ('86).



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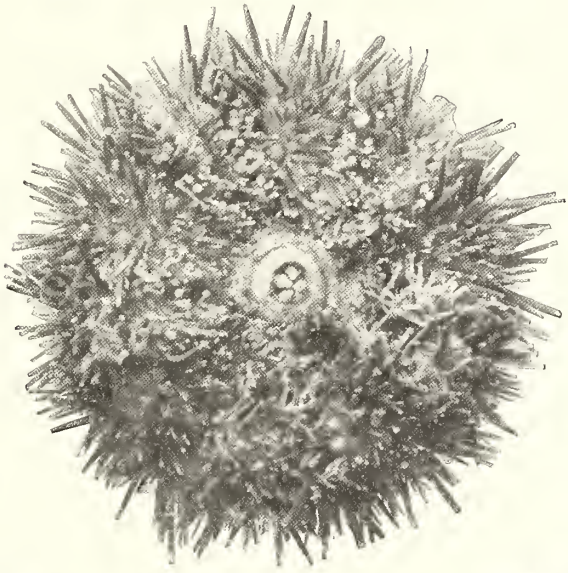

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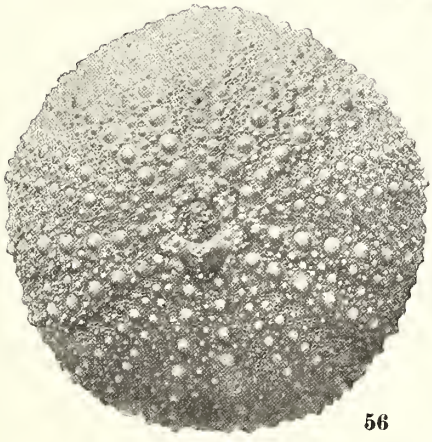

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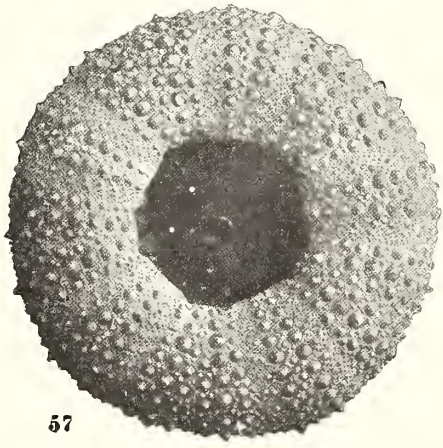

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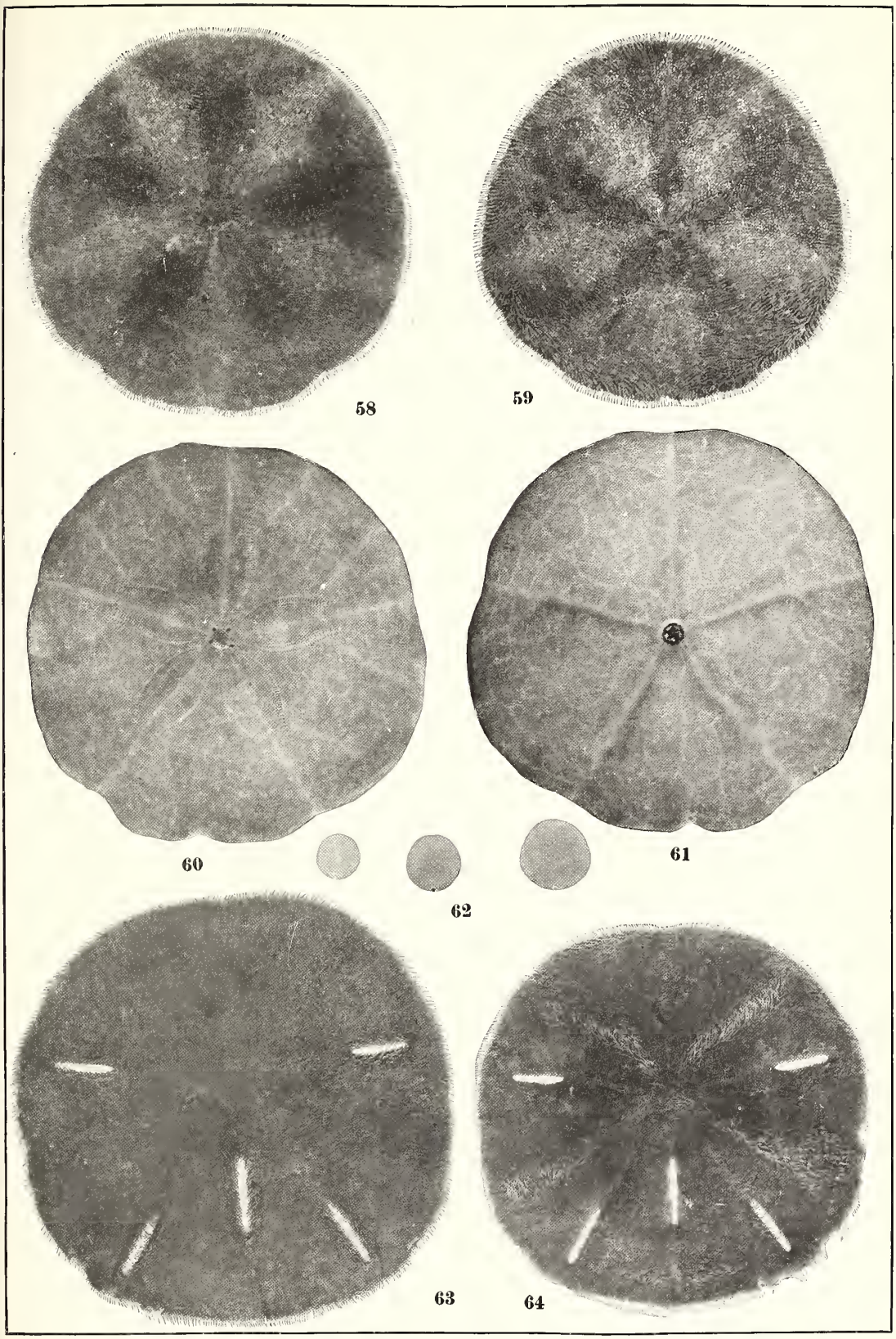
Figs. 53–57. *Strongylocentrotus dröbachiensis* (natural size).—53. Aboral view of test with spines. 54. Oral view of test with spines. 55. Side view of test without spines. 56. Aboral view of test without spines. 57. Oral view of test without spines.



Figs. 58–62. *Echinarachnius parma* (natural size).— 58. Aboral view with spines. 59. Oral view with spines. 60. Aboral view without spines. 61. Oral view without spines. 62. Young specimens without spines, to show form of test and position of anal opening.
Figs. 63, 64. *Mellita pentapora* (natural size).—63. Aboral view with spines. 64. Oral view with spines.

4. Mellita pentapora (Gmelin). *Key-hole Urchin.* (Pl. 10, figs. 63–64.)

Echinus pentaporus Gmelin, 1788
Scutella quinquefora Lamarck, 1816.
Encope pentapora L. Agassiz, 1841.
Mellita quinquefora L. Agassiz, 1847.
Mellita testudinaria Gray, 1857.
Mellita pentapora Lütken, 1864. Verrill, 1873, et seq.
Mellita testudinata Alex. Agassiz, 1872.

Description.—Test very flat, often wider than long when fully grown, truncated posteriorly, covered with very short, delicate spines, which are longest actinally, especially near the margin in the interradii, around the peristome or bordering the lunules. There are 5 of the latter, 1 in the posterior interradius and 1 in each radius, except the anterior one. Ambulacra obvious abactinally as bluntly rounded, nearly closed "petals," not quite reaching the lunules, the posterior pair longer; actinally the ambulacra appear as shallow furrows, the anterior running to the margin, the others ending at the lunules. Abactinal system eccentric, lying anterior to the center while the mouth is directly below; genital pores 4. Anal opening actinal; in adults, at the proximal end of the interradial lunule.

A good-sized specimen gives the following measurements: Longitudinal diameter 110 mm.; transverse diameter 115 mm.; vertical diameter 10 mm.; diameter of abactinal system 9 mm.; length of anterior petal 32 mm.; length of posterior petal 39 mm.; length of interradial lunule 22 mm.; width of interradial lunule 3 mm.; distance from margin 23 mm.; length of postero-radial lunule 24 mm.; width of postero-radial lunule 2 mm.; distance from margin 3 mm.

The difference between the longitudinal and transverse diameters is not always as marked as in the specimen given; moreover, very young specimens have the lunules only partly formed or wanting. In a specimen 3 mm. in diameter there are no lunules, but the position of the interradial one is indicated by a slight actinal depression. A specimen 12 mm. in diameter has the interradial lunule fully formed, the deepening of this actinal depression having continued until the abactinal surface was pierced; the radial lunules are arising as notches in the edges of the test. These marginal notches deepen, and finally the outer sides grow together, thus inclosing the lunule. Color in life, brownish-yellow; in alcohol, rather greenish.

Range.—Nantucket to Brazil, in shallow water; rare and local, north of Cape Hatteras.

Remarks.—This species is admitted to the list of the Woods Hole echinoderms on very scanty evidence. Verrill ('73 *b*) records it from Nantucket on Agassiz's authority, and dead specimens (bare tests) are occasionally taken in Vineyard Sound. Where these come from is a question yet to be answered. Mr. Gray tells me one was taken in the sound in the summer of 1901. Dr. Caswell Grave (1902) has published a brief and partial account of the larva of this species, and I am indebted to him for some of the details of the above description of the adult.

HOLOTHURIOIDEA.

HOLOTHURIANS. SEA-CUCUMBERS.

The holothurians make up more than one-third of the Woods Hole echinoderms, but although the number of species is considerable, in number of individuals the asteroids and echinoids far outrank them. None of the nine species are sufficiently common and generally distributed to be noticed by an inexperienced observer, and it is the exception rather than the rule to find a holothurian in the dredge anywhere in the Woods Hole region. There are, however, three species (*Thyone briareus* and the two *Synaptas*), which one who knows where and how to look can always obtain, and these we may fairly call common. The remaining six are of uncertain occurrence, and while two of them may be expected to occur at the proper locality, the others are distinctly rare and of uncertain occurrence. I have never seen any of these four living. The various species can be distinguished from each other with comparative ease, and few of the terms used in the descriptions will need any explanation to anyone at all familiar with echinoderm anatomy. The names applied

to the calcareous particles in the skin are purely arbitrary, but are quite generally used, and the figures given will prevent any misunderstanding. It must be borne in mind, however, that as holothurians increase in age the calcareous parts undergo considerable change, either becoming larger or smaller, more irregular or less so, and fewer or more abundant. The ambulacral appendages, especially the feet, are frequently much more numerous in adults than in young, and pigment is always more abundant with age. But the following key ought to enable anyone to distinguish even very young individuals of the species given.

Key to the Holothurians of the Woods Hole region.

Ambulacral appendages in the form of feet (pedicels) present, at least on the ambulacra.
- Pedicels chiefly or wholly confined to ambulacra; some scattered ones may be present on the back.
  - Size large, up to 300 mm.; color some shade of brown ..... CUCUMARIA FRONDOSA.
  - Size small, less than 60 mm.; color white or whitish ..... CUCUMARIA PULCHERRIMA.
- Pedicels scattered over the whole body, though the ventral ambulacrum may be distinctly defined.
  - Size large, 75 to 225 mm.; body not noticeably attenuated posteriorly; color very dark ..... THYONE BRIAREUS.
  - Size small, less than 75 mm.; body much attenuated posteriorly; color brown ..... THYONE SCABRA.
  - Size small, less than 60 mm.; body not attenuated posteriorly; color white or whitish ..... THYONE UNISEMITA.

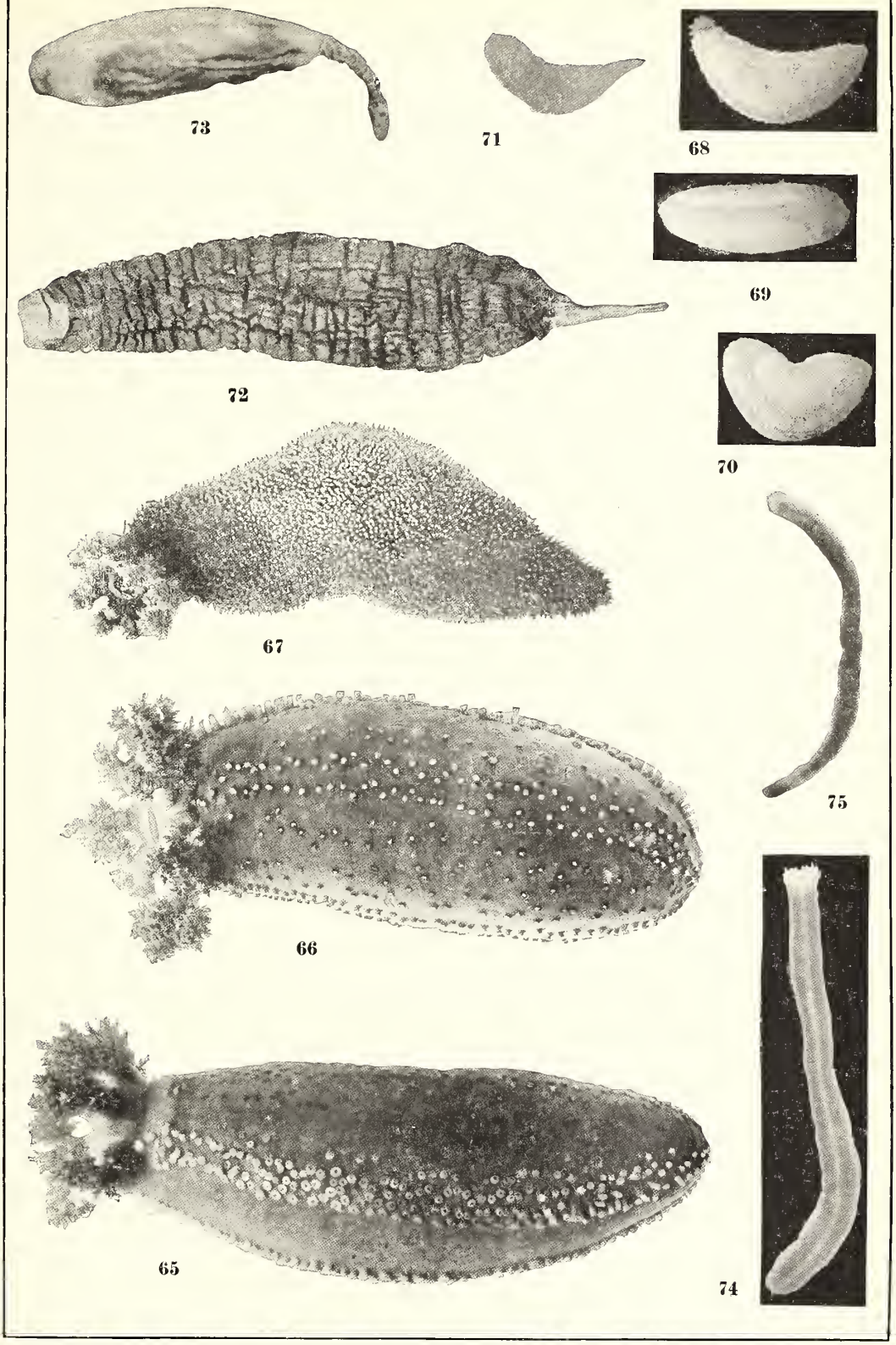
Ambulacral appendages in the form of pedicels wanting.
- Tentacles 15; posterior end of body tail-like.
  - Caudal appendage long; no reddish deposits in the skin ..... CAUDINA ARENATA.
  - Caudal appendage short, abrupt; reddish deposits in the skin ..... TROCHOSTOMA OÖLITICUM.
- Tentacles 12; no tail-like appendage.
  - Color white or yellowish; radial pieces of calcareous ring pierced for passage of nerves ..... SYNAPTA INHÆRENS.
  - Color red or pinkish; radial pieces of calcareous ring simply notched ..... SYNAPTA ROSEOLA

1. Cucumaria frondosa (Gunnerus). *Sea-cucumber.* (Pl. 11, figs. 65, 66; pl. 12, figs. 76–80.)

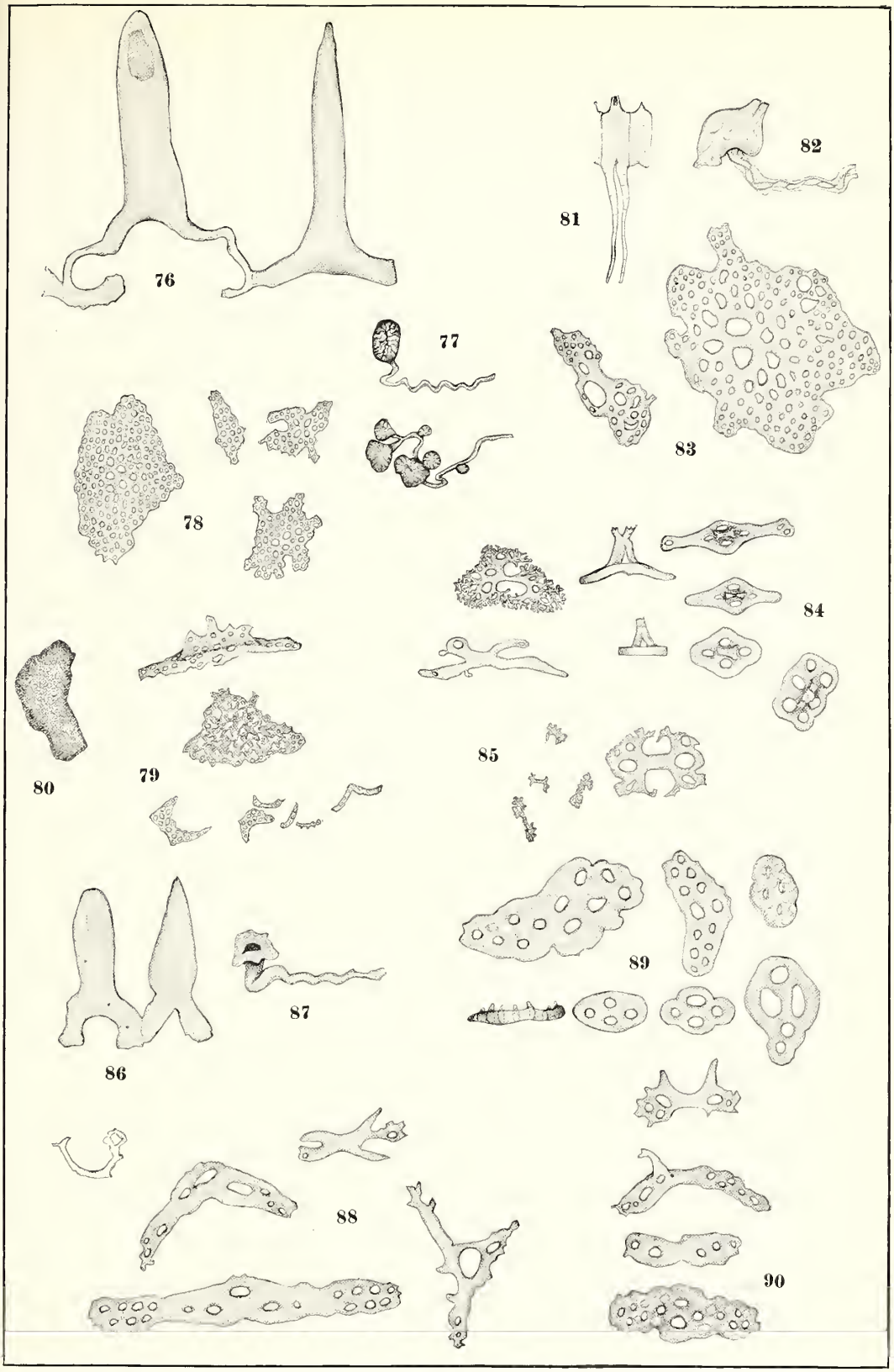
Holothuria frondosa Gunnerus, 1770.
Cladodactyla pentactes Gould, 1841.
Cucumaria frondosa Forbes, 1841.
Botryodactyla grandis Ayres, 1851.
Botryodactyla affinis Ayres, 1851.
Pentacta frondosa Stimpson, 1853.

Description.—Length in life, normally extended, 250 to 300 mm.; may extend to 600 mm. or more; diameter of body 90 to 100 mm., or much less when considerably extended. In life ventral surface much dorsal considerably, flattened, with sides curving upward; anterior end truncated; posterior end bluntly rounded. When disturbed, the body contracts to such an extent that it becomes ovoid or ellipsoidal, or almost spherical, and museum specimens usually show more or less of such contraction. Tentacles 10 (sometimes 9 or 11), of approximately equal size and much branched; rather short and stout. Pedicels rather large, and forming a broad series on each ambulacrum, while slightly smaller and less perfect ones are scattered over the dorsal interambulacra; all lack the usual terminal, perforated calcareous plate. Calcareous deposits consist of irregular, usually smooth, perforated plates (fig. 78), the size, number, and distribution of which vary greatly, though they are apparently most abundant in the young. The largest plates (fig. 80) are near the cloacal opening, though they do not form so-called "anal teeth." At the base of the pedicels and tentacles the plates become more irregular (fig. 79), and often bear minute projections, or more or less prominent ridges. Calcareous ring (fig. 76) very slender for so large an animal, and more or less imperfectly developed, perhaps according to age, being more perfect in smaller specimens; radial pieces somewhat wider than interradial, with a very wide and deep notch in the posterior margin; the interradial pieces not notched posteriorly. Stone canal single, of moderate size, and provided with 1 to 6 madrepore plates (fig. 77). Polian vessel usually single, very long, 100 mm. more or less. Color in life deep reddish- or purplish-brown, darkest on the dorsal side and much lighter below, sometimes nearly white; pedicels often with a strong roseate tinge.

Range.—Greenland to Nantucket; also Iceland and Spitzbergen to Norway and the south coast of England; low water to 200 fathoms. The reported occurrence of this species on the Florida Reef is almost certainly a case of mistaken identification, and the records of its occurrence on the coast of Alaska and in the North Pacific are very probably based on *Cucumaria japonica* Semper, which seems to be quite a distinct species.



Figs. 65, 66. *Cucumaria frondosa* (one-half natural size).—65. Side view. 66. Dorsal view.
Fig. 67. *Thyone briareus*. Dorsal view (natural size).
Figs. 68, 69. *Thyone uniscmita* (natural size).—68. Side view. 69. Ventral view.
Fig. 70. *Cucumaria pulcherrima*. Side view (natural size).
Fig. 71. *Thyone scabra*. Side view of a young specimen (natural size).
Fig. 72. *Trochostoma oöliticum*. Side view of contracted alcoholic specimen (natural size).
Fig. 73. *Caudina arcuata*. Side view of contracted alcoholic specimen (natural size).
Fig. 74. *Synapta inhærens*. Dorsal view (natural size).
Fig. 75. *Synapta roscola*. Dorsal view (natural size).



Figs. 76–80. *Cucumaria frondosa*.—76. Two pieces of calcareous ring (× 5). 77. Madrepore plates (× 10). 78. Perforated plates from skin (× 156). 79. Perforated plates from near base of tentacles (× 156). 80. Perforated plates from near cloacal opening (× 45).

Figs. 81–85. *Cucumaria pulcherrima*.—81. Two pieces of calcareous ring (× 5). 82. Madrepore plate (× 10). 83. Calcareous plates from cloaca (× 156). 84. Tables from body wall (× 156). 85. Particles from tentacles (× 156).

Figs. 86–90. *Thyone unisemita*.—86. Two pieces of calcareous ring (× 5). 87. Madrepore plate (× 10). 88. Supporting rods from tentacles (× 156). 89. Perforated plates from body wall (× 156). 90. Supporting rods from pedicels (× 156).

Remarks.—This large and noticeable, one might even say handsome, holothurian, so abundant on the coast of Maine, just enters the Woods Hole region as a resident of the shoals east of Nantucket. In October, 1894, Mr. Edwards took 6 specimens in 23 to 25 fathoms, some 15 miles east-southeast of Sankaty Head, Nantucket, and in August, 1902, we took 2 good specimens in 12 fathoms, about 8 miles off Sankaty Head. The latter were ready to breed, the reproductive glands being fully ripe. This sea-cucumber feeds upon small particles of organic matter picked up by the tentacles. It seems to prefer generally rocky or shelly bottoms. The larva is red, and passes through a metamorphosis, but the development is not fully known. Dr. William Stimpson reports this species as not only edible, but, when boiled, "as palatable as lobster."

2. Cucumaria pulcherrima (Ayres). (Pl. 11, fig. 70; pl. 12, figs. 81–85.)

Pentamera pulcherrima Ayres, 1854. Verrill, 1873b.
Thyone pulcherrima Semper, 1868.
Cucumaria pulcherrima Lampert, 1885.

Description.—Length 50 mm. or less; diameter 20 mm. or less. Body ovate, the two ends strongly upcurved (at least in preserved specimens), so that the ventral ambulacra are much longer than the dorsal. Tentacles 10, the 2 ventral much smaller than the others. Pedicels numerous, confined entirely to ambulacra. Calcareous deposits chiefly in the form of tables (fig. 84), which are very densely crowded together, so that the skin is quite hard. These tables, when simplest and most symmetrical, have a disk perforated with 4 holes and a small spire, usually made up of 2 rods with few teeth at the apex; but very frequently the disk is irregular in shape, and has 6, 8, 10, or more holes; in the pedicels the disks of the tables are elongated until near the tip of the foot they are simply supporting rods, usually having the ends perforated; terminal plates present; the tentacles contain very few supporting rods (fig. 85), and they are chiefly small and of very irregular shape. Cloacal opening surrounded by 5 tufts of pedicels, 3 or 4 in each, which are almost rigid with their crowded deposits; just within the cloacal opening is a ring of crowded calcareous plates (fig. 83), but so far as one can judge from preserved material there are no true "anal teeth." Close to the cloacal opening the calcareous deposits become very much crowded and increase in size, thus coming to resemble large irregular perforated plates, often with scarcely a trace of the spire left. Calcareous ring (fig. 81) well developed, quite high, the radial pieces with very long and slender posterior prolongations; stone canal single, terminating in a large madrepore plate (fig. 82). Polian vessel single, small. Color white or whitish.

Range.—Vineyard Sound to Fort Johnson, South Carolina; low water to 5 fathoms.

Remarks.—Perhaps no one of our holothurians is less often seen alive than this one, nor is there any of whose habits less is known. The original specimen was taken in shallow water, on the coast of South Carolina, buried 2 inches in the sand. Later the species was found at Fort Macon, North Carolina, and in Vineyard Sound. Prudden and Russell dredged specimens "off Holmes Hole" (Vineyard Haven) in 4 to 5 fathoms, so Verrill ('73*b*) reports, but he gives no date nor any other facts. Large numbers are frequently washed up on the beach near Nobska Light, on the north shore of the Sound, after long-continued or hard easterly storms; but in spite of very thorough dredging and trawling in all depths from the shore outward, across to the Vineyard, Mr. Edwards tells me he knows of no specimens having been found, so that the habitat and habits of this species are still an enigma, and naturally the life history is unknown. During the winter of 1903 there were a number of specimens washed up on the bathing beach at Woods Hole, on the eastern side of Buzzards Bay. Mr. Gray, who very kindly sent me the specimens, says that there had been a long-continued period of heavy westerly winds. In these specimens the reproductive glands were very well developed, of a bright orange yellow, and their condition would seem to indicate that breeding occurs in the late winter or early spring.

3. Thyone briareus (Lesueur). *Common Thyone.* (Pl. 11, fig. 67; pl. 13, figs. 95–102.)

Holothuria briareus Lesueur, 1824.
Sclerodactyla briareus Ayres, 1851.
Anaperus bryareus Pourtalès, 1851.
Thyone briareus Selenka, 1867.

Description.—Length up to 225 mm., according to the state of contraction, a fair-sized specimen in normal condition being 85 to 100 mm. in length and 25 to 30 mm. in diameter. Posterior end of the body rather abruptly tapering and pointed when normally extended, but not at all attenuated; often

more or less blunt and rounded according to amount of contraction. Cloacal opening terminal, surrounded by 5 groups of slender papillæ; just within the cloaca is a well-developed calcareous ring (figs. 101–102) with 5 prominent radial projections, which appear from the outside as teeth, and are usually referred to as "anal teeth." Tentacles 10, the 2 ventral much smaller than the others, which are capable of considerable extension and are much branched. Pedicels rather small, very numerous all over the body, occasionally divided by very narrow lines into 5 broad, apparently radial, bands; many of the pedicels of the dorsal side taper to a point, and are thus more or less papilliform. Calcareous deposits in adults, wanting in most parts of the body wall, but present at each end of the body, and in the pedicels and tentacles; more numerous in young than in old individuals. These deposits are in the form of tables (fig. 97), plates, and rods; tables with a more or less square disk, perforated by about 8 holes, and a spire made up of 4 rather short rods, with one cross bar, ending in single teeth. Such tables are confined almost wholly to the two extremities of the body. In the pedicels, which are provided with a large terminal plate (fig. 98), the disks of the tables are elongated and curved to form supporting rods, and as such they often lack spires (fig. 99). In the tentacles the calcareous supporting rods (fig. 100) are so numerous as to make the trunk and principal branches almost rigid, and occur even to the tips of the smaller branches; around the base of the tentacles are some scattered plates perforated by six or more holes. In very young individuals, specimens an inch long or less, the body wall is often crowded with tables. Calcareous ring (fig. 95) well developed, rather stout, the radial pieces with moderately long, slender prolongations. Stone canal single, with a large madrepore plate (fig. 96). Polian vessels usually 1 or 2. Color in life dull brown or black, the pedicels lighter, often quite reddish, the disks frequently yellow.

Range.—Vineyard Sound to Texas, low water to 10 fathoms.

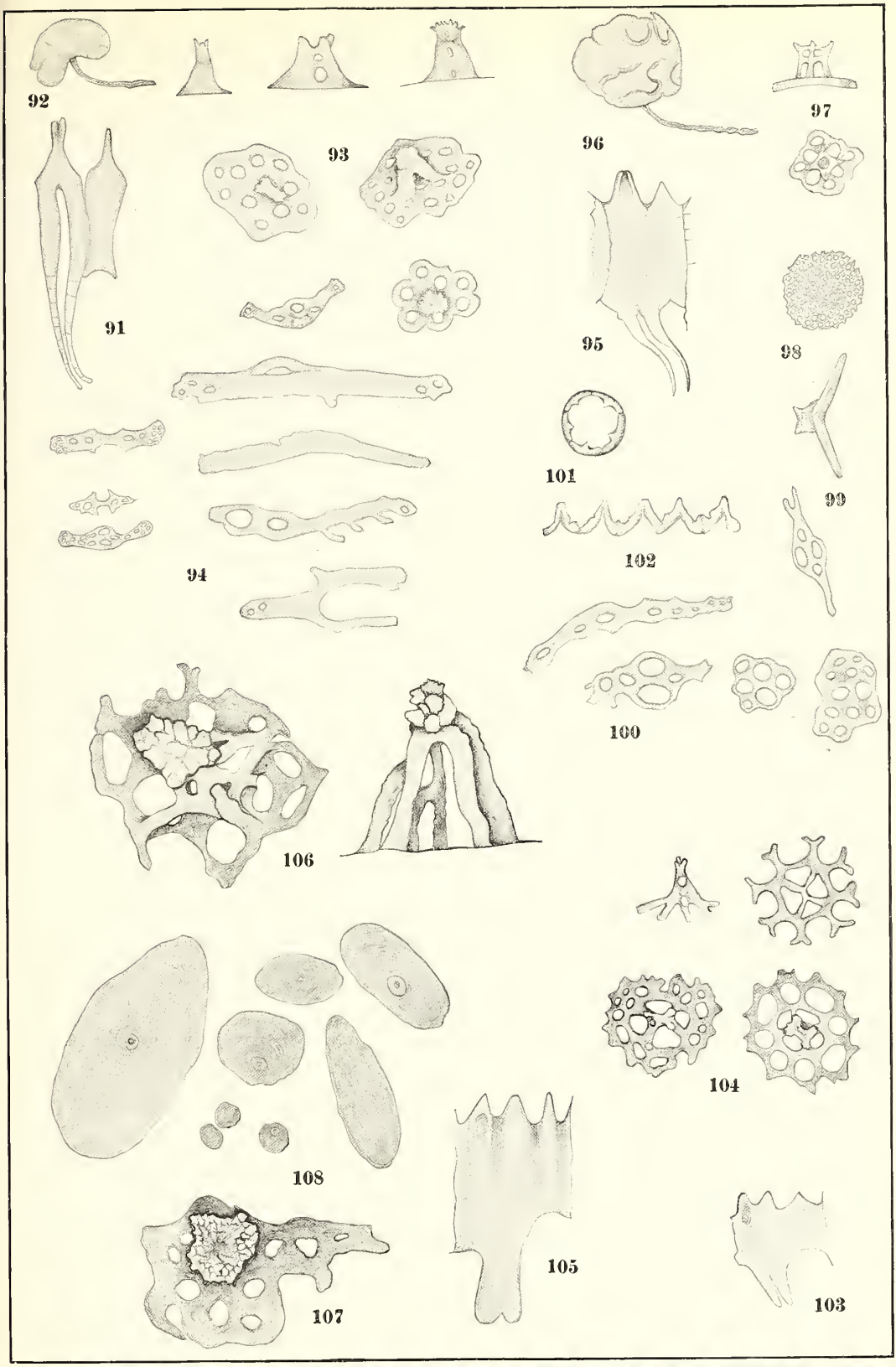
Remarks.—This is undoubtedly the best known, to American students, of the Woods Hole holothurians, as it is the form commonly used for laboratory work. Hadley Harbor furnishes most of this material, *Thyone* being abundant there, but it is also to be found at Waquoit and near Cuttyhunk. Verrill ('73b) reports it from Buzzards Bay and Vineyard Sound. Usually it lies buried in soft mud in shallow water, either the posterior end alone or both ends above the surface. The currents of water repeatedly and continuously driven from the cloacal opening are often quite apparent, especially in very shoal water. The food consists of the fine organic particles gathered by the tentacles. Although this species apparently breeds in the summer, nothing is known of its development. In the winter of 1903 a number of very small specimens were washed up on the Buzzards Bay bathing beach at Woods Hole, after a period of heavy westerly winds, in company with specimens of *Cucumaria pulcherrima*. Mr. Gray kindly sent them to me for examination.

4. Thyone scabra Verrill. (Pl. 11, fig. 71; pl. 13, figs. 91–94.)

Thyone scabra Verrill, 1873*a*.

Description.—Length up to 90 mm. (Théel), usually much less; Verrill says, "Length, in alcohol, about 2 inches." All the specimens which I have seen from the Woods Hole region were less than 50 mm., with a diameter of about 8 mm. Posterior third of the body quite attenuate to a rather sharp point. Cloacal opening terminal, with 5 sets of small papillæ, but, so far as could be determined from preserved material, without the so-called "anal teeth." Tentacles 10, branched from the base, the 2 ventral smaller than the rest, which are not very large. Pedicels rather long and slender, somewhat rigid, quite numerous, and irregularly arranged, provided with terminal plates. Calcareous deposits very abundant, especially in pedicels, and tending to form a rather brittle, thin, and very rough layer over the whole body surface; deposits consist chiefly of tables (fig. 93) with more or less irregular disk, pierced by 6 or more holes (Verrill says 20 to 24), and a more or less prominent and rather solid spire, made up of 2 or 3 stout vertical rods, connected by 1 or 2 crossbars and terminating in a number of teeth; in pedicels, disks of tables elongated, more or less bowed, with 4 holes, and ends expanded and perforated; in tentacles, numerous supporting rods (fig. 94), which are usually more or less perforated, especially at ends. Calcareous ring (fig. 91) well developed, radial pieces with a remarkably deep notch and long, slender prolongations posteriorly. Stone canal single with a large madrepore plate (fig. 92). Polian vessel usually single. Color in life not recorded; alcoholic specimens are brown or yellowish-brown, pedicels lighter.

Range.—Georges Bank and Bay of Fundy to Vineyard Sound, Narragansett Bay, and perhaps even to Delaware (Théel); 10 to 640 fathoms.



Figs. 91–94. *Thyone scabra.*—91. Two pieces of calcareous ring (× 5). 92. Madrepore plate (× 20). 93. Tables from skin; side and external views (× 156). 94. Supporting rods from tentacles (× 156).
Figs. 95–102. *Thyone briareus.*—95. Two pieces of calcareous ring (× 5). 96. Madrepore plate (× 20). 97. Tables: side and external views (× 156). 98. Terminal plate of pedicel (× 50). 99. Supporting rods from pedicels (× 156). 100. Supporting rods from tentacles (× 156). 101. Calcareous ring from cloaca (× 5). 102. Calcareous ring, laid flat and seen from outer side (× 5).
Figs. 103 104. *Caudina arenata.*—103. Part of calcareous ring (× 5). 104. Tables from skin (× 156).
Figs. 105–108. *Trochostoma oölitheum.*—105. Part of calcareous ring (× 5). 106, 107. Tables from skin (× 156). 108. Reddish-brown bodies from skin (× 156).

Remarks.—This is another of those holothurians of which we know altogether too little. It was first dredged on Georges Banks in 1872, and Verrill afterwards found it in the Bay of Fundy. Théel (1886) reports specimens from off the coast of Delaware; they were remarkably large, and he says "the anus possesses five calcareous teeth." Verrill does not mention "anal teeth" nor calcareous ring. The latter, Théel says, resembles that of *Thyone fusus*. I have never seen a living specimen of this species, but in the fall of 1899, Dr. H. C. Bumpus sent me some alcoholic specimens which I understood were dredged in Narragansett Bay, and I have also had 5 specimens dredged by the *Fish Hawk* in Vineyard Sound in 1901. None of these specimens were much over 40 mm. in length. They answer well to Verrill's description, except that the disks of the tables rarely contain 20 holes, while he says 20–24. Théel says that in his specimens the holes were sometimes as many as 20. As for the "anal teeth" which he mentions, they may have been due to the age of his specimen, which was twice the size of any of mine. It is by no means certain that *scabra* is really distinct from the European *fusus*, but the matter cannot be decided without more material. Naturally we know nothing of its habits or development.

5. Thyone unisemita (Stimpson). (Pl. 11, figs. 68, 69; pl. 12, figs. 86–90.)

Cucumaria fusiformis Desor, 1848 (*non* Forbes).
Anaperus unisemita Stimpson, 1851.
Stercoderma unisemita Ayres, 1851; Verrill, 1873b; Théel, 1886.
Thyone unisemita Ludwig, 1892.

Description.—Length 75 mm. (Verrill) or less; diameter, when normally extended, about one-third of the length or less. Body tapering to both ends, which are more or less curved upward. Cloacal opening, terminal, not provided with "teeth," and with no specially prominent papillæ about it. Tentacles 10, 2 ventral smaller than the others, which are rather long and slender, stalked, and not profusely branched at tip. Pedicels short, quite uniformly distributed over the dorsal surface and on the sides; ventrally there is a distinct double row in the midventral radius, and on each side a narrow strip of skin, wholly free from pedicels; it is from this peculiar arrangement that the species has received its name. Calcareous deposits, perforated plates (fig. 89), mostly regular, and with 4 holes, but often larger, irregular, and with more holes; plates usually smooth, frequently with knobs in the pedicels, which lack terminal plates; supporting rods (fig. 90) rather few, broad, flat, with narrow holes, sometimes with knobs, and occasionally projecting spines; in the tentacles, supporting rods (fig. 88) large, perforated, and rather numerous; near the tips of the branches they are much curved. Calcareous ring (fig. 86) well developed, wide, radial and interradial pieces of nearly equal size, but the former with a wider notch in the posterior margin, though there are no posterior prolongations. Stone canal single, with a small and poorly developed madrepore plate (fig. 87). Polian vessel single. Color in life white or yellowish-white, tentacles orange-yellow.

Range.—Grand Bank, Newfoundland, to Narragansett Bay; 17 to 22 fathoms, probably more.

Remarks.—Another uncommon holothurian, of which we collected half a dozen specimens in August, 1902, at Crab Ledge, on sandy and gravelly bottom. All of these were small, from 8 to 25 mm. in length, but several had the ovaries full of apparently mature eggs. Stimpson's specimens from Grand Bank and Massachusetts Bay were about 2 inches in length, while a specimen dredged by Packard, south of Marthas Vineyard, was about 3 inches long. Specimens kept alive at the laboratory were very sluggish, and extended the tentacles very little; the color of the latter is in striking contrast to that of the body. Besides the localities already mentioned, this species has been taken on Nantucket Shoals, off Gay Head, and in Narragansett Bay.

6. Caudina arenata (Gould). (Plate 11, fig. 73; plate 13, figs. 103, 104.)

Chirodota arenata Gould, 1841.
Caudina arenata Stimpson, 1853.

Description.—Length 100 to 175 mm., with a diameter about one-eighth as great; the posterior third of the animal constitutes what we may call the caudal portion, and this has a diameter of only a few millimeters. Integument translucent and smooth, or finely granular. Cloacal opening terminal, surrounded by 5 very small papillæ. Tentacles 15, equal, each with four short, finger-like digits. Calcareous deposits (fig. 104) in the form of tables, with smooth, flat, nearly circular or oval disks, each with a large central hole, and a more or less regular peripheral series of 8 to 12 holes; the central hole appears from above like 4, as the 4 legs of the spire cross it; there are often a few small holes

outside the peripheral circle; the spire is made up of 4 rods, which are united close to their apex, and by a crosspiece near the middle. Calcareous ring (fig. 103) well developed, of moderate width, the radial pieces with not very long, stout posterior prolongations, deeply but narrowly separated. One stone canal, with a single, terminal madrepore plate. Polian vessel single. Color in life, pale to deep flesh-red, pink, or even purplish.

Range.—Pointe du Chene, New Brunswick, to Cuttyhunk; low water to 18½ fathoms.

Remarks.—This and the following species are the rarest of the Woods Hole holothurians. It is admitted to this list on the strength of Verrill's ('73b) statement that Professor Webster took it at Woods Hole, and on the existence of 3 small specimens in the collection of the U. S. National Museum, labeled "Off Cuttyhunk, 18½ fathoms." I have never seen *Caudina* alive, but it is said to be abundant at Revere Beach, Mass., at certain seasons. Strangely enough, however, trawling and dredging offshore in that region failed entirely to bring up specimens. Gerould's ('96) admirable paper on this species leaves nothing to be said as to habits or anatomy. Nothing whatever is known of the development. Théel's variety, *armata*, was taken in 898 fathoms, in latitude 35° 44′ 40″, and in 1,242 fathoms, in latitude 41° 24′ 45″.

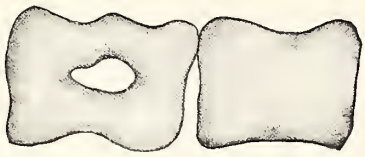
7. Trochostoma oöliticum (Pourtales). (Plate 11, fig. 72; plate 13, figs. 105–108.)

Chirodota oöliticum Pourtalès, 1851.
Molpadia borealis Sars, 1861.
Molpadia oölitica Selenka, 1867. Verrill, 1873b.
Trochostoma oöliticum Danielssen and Koren, 1878.
Trochostoma thomsonii Danielssen and Koren, 1878.
Trochostoma boreale Danielssen and Koren, 1879.

Description.—Length 125 to 150 mm., with a diameter about one-sixth as great; the caudal portion of the body is only about one-eighth of the total length. Integument rather thin and usually quite smooth. Cloacal opening terminal, with minute surrounding papillæ. Tentacles 15, each usually with 2 (sometimes possibly more) digits. Deposits in the skin of 2 very distinct kinds, irregular tables (figs. 106, 107), and reddish or brown discoidal or ellipsoidal bodies (fig. 108). Tables sometimes wanting, apparently most frequent in young specimens and becoming less frequent with age; they are quite irregular in form; disk pierced by holes which vary greatly in number and size, and spire also variable in size and form. "Brown bodies" vary greatly in size and shade of color, for they may be mere grains or nearly as long as the diameter of a table disk, and the shade ranges from brownish-yellow to a very deep reddish-brown; these "brown bodies" may be rather scattered or more or less crowded. As a rule, the fewer the tables the more the "brown bodies," and vice versa. In typical *oöliticum*, there are no tables, and the integument is literally packed with "brown bodies." Calcareous ring (fig. 105) very stout, the radial pieces with very prominent posterior prolongations. Stone canal one, with a single madrepore plate. Polian vessel one. Color of alcoholic specimens very variable, according to the abundance of "brown bodies;" where they are very small and very few the color is dull gray, and the head and tail are always that color or lighter; where the "brown bodies" are more numerous they form brown patches on the surface; if still more abundant, the animal appears yellowish or reddish brown with gray spots of greater or less size; and finally, in typical *oöliticum*, the color appears uniformly deep brown or even almost black. Verrill (73b) says of a living specimen, "uniform flesh color."

Range.—Banks of Newfoundland to south of Marthas Vineyard, and in the Arctic Ocean north of Norway and Siberia; reported from Florida Reef also; 18 to 600 fathoms, but usually over 50.

Remarks.—This distinctly northern form is admitted to the list of Woods Hole echinoderms solely on the record of one small specimen taken by Professor Packard and reported by Verrill ('73b). Even the locality of this specimen is in doubt, for on page 715 Verrill says, "Off Block Island, 29 fathoms, sandy mud," while on page 510 he says "15 miles east of No Mans Land," and Block Island is 30 miles west of No Mans Land. The genus *Trochostoma* is probably more imperfectly known and its legitimate species less well defined than any other genus of holothurians. After the examination of a fairly large series from the collection of the U. S. National Museum, I am convinced that the differences which were supposed to separate *oöliticum* and *boreale* are unimportant and that Sars's name is really a synonym of Pourtales's. I can not agree with Ludwig (1900), however, that *arcticum* v. Marenzeller is identical with *boreale*, for specimens of the former are easily separable from the latter by several good characteristics. As to Verrill's *turgidum*, if the characters given are constant, it is also a good species.



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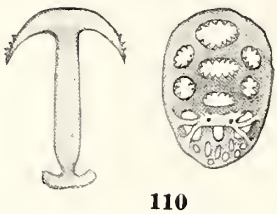

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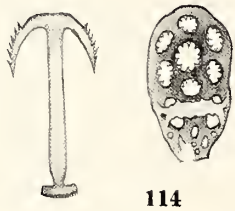

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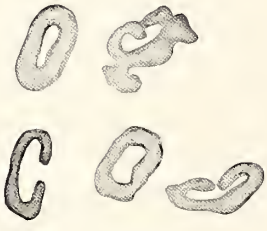

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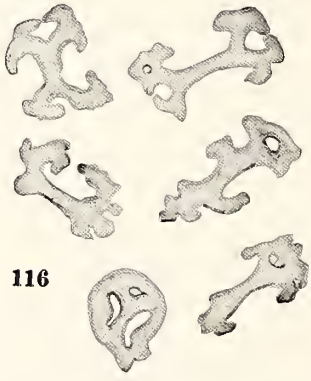

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Figs. 109–112. *Synapta inhærens.*—109. Two pieces of calcareous ring (× 45). 110. Anchor and plate (× 156). 111. Particles from longitudinal muscles (× 450). 112. Particles from tentacles (× 450).

Figs. 113–116. *Synapta roscola.*—113. Two pieces of calcareous ring (× 45). 114. Anchor and plate (× 156). 115. Particles from longitudinal muscles (× 450). 116. Particles from tentacles (× 450).

8. Synapta inhærens (O. F. Müller). *Common Synapta.* (Pl. 11, fig. 74; pl. 14, figs. 109–112.)

Holothuria inhærens O. F. Müller, 1788.
Synapta inhærens Duben and Koren, 1846.
Synapta tenuis Ayres, 1851.
Synapta girardii Pourtalès, 1851.
Synapta pellucida Ayres, 1852.
Synapta ayresii Selenka, 1867.
Synapta gracilis Selenka, 1867.
Leptosynapta tenuis Verrill, 1867.
Leptosynapta girardii Verrill, 1873b.

Description.—Length 100 to 180 mm., more or less; diameter 5 to 10 mm. Body slender, very extensile, cylindrical. Integument thin, more or less translucent, sometimes minutely rough. Cloacal opening terminal. Tentacles 12, with 3 to 7 pairs of digits pinnately arranged, and 10 to 20 or more very small, sensory cups on the inner surface near the base. Calcareous deposits minute discoidal or irregularly rounded bodies (fig. 111) in the external layers of the longitudinal muscles; similar but more irregular bodies (fig. 112) at the base of the tentacles, besides curved knobbed rods in the digits; and anchors and plates (fig. 110) everywhere in the body wall, smallest anteriorly and largest posteriorly; anchors with minute teeth on the outer side of flukes; plates with 7 principal holes, with toothed margins, and 3 large and several small holes with smooth margins at posterior end. Calcareous ring (fig. 109) well developed, with no projections either anteriorly or posteriorly; the radial pieces pierced for passage of radial nerves. Stone canal and Polian vessel single. Color in life white, with or without a more or less pronounced yellow tinge; particles of red pigment frequently lie scattered in the skin, sometimes in sufficient quantity to give a pink cast to the whole animal.

Range.—Massachusetts Bay to South Carolina; also from the Arctic Ocean to the Mediterranean Sea in the Old World; and from Sitka, Alaska, to Pacific Grove, Cal.; probably circumpolar; above low water to 116 fathoms.

Remarks.—This is the most uniformly distributed, and perhaps the most common, Woods Hole holothurian, occurring in abundance along the shores of Buzzards Bay, and also about the islands of Uncatena, Nonamesset, and Naushon. It is less common along the Sound shore, but is found near the entrance to the Eel Pond. Although usually preferring a clean sand bottom, it often occurs in soft mud, even though very black, and is common in some very gravelly spots. It is often found above low-water mark. An account of this species and the next has already been published (Clark '99), so no record of the habits need be given here. Very little is known of the development, beyond the fact that segmentation is total and equal.

9. Synapta roseola (Verrill). (Pl. 11, fig. 75; pl. 14, figs. 113–116.)

Leptosynapta roseola Verrill, 1873b.
Synapta roseola Théel, 1886.

Description.—Length 100 mm., rarely more, usually much less. Body very slender. Integument translucent, very thin, soft, and delicate. Cloacal opening terminal. Tentacles 12, with 2 or 3 (rarely 4) pairs of digits pinnately arranged, and 7 to 15 sensory cups on the inner surface near base. Calcareous deposits, C or doughnut-shaped bodies (fig. 115) in the longitudinal muscles; branched, curved, and perforated rods and plates (fig. 116) in the tentacles; and everywhere in the body wall anchors and plates (f.g. 114) similar to those of the preceding species, sometimes more slender and delicate, but not always. Calcareous ring (fig. 113) rather narrow, radial pieces merely notched for passage of radial nerves. Stone canal and Polian vessel single. Color in life, rosy red, varying from very pale to quite deep, rarely reddish-yellow; due to numerous pigment granules in the thin integument.

Range.—Provincetown, Mass., to New Haven Conn ; also very abundant at the Bermuda Islands, where it is the commonest holothurian; near low-water mark, above and below.

Remarks.—At Woods Hole I found this species only on the southeastern side of Buzzards Bay, from the breakwater southwestward, but Verrill ('73b) records it from Naushon. It seems to prefer gravelly and stony beaches, and often occurs under stones above low-water mark. Its anatomical characters and habits, so far as known, have already been recorded (Clark '99). Nothing is known of its development, though Dr. Wesley R. Coe, of Yale University, assures me that artificial fertilization is easily accomplished, and segmentation is total and equal.

Olivet College, Michigan, *October, 1903.*

LIST OF PUBLICATIONS REFERRING TO THE ECHINODERMS OF THE WOODS HOLE REGION, OR TO WHICH REFERENCE IS MADE IN THE PRECEDING PAGES.

'63. Agassiz, A. On the Embryology of Echinoderms. Proc. Amer. Academy.

'64. ——— On the Embryology of Echinoderms. Memoirs Amer. Academy, vol. IX.

'72–'74. ——— Revision of the Echini. Ill. Cat. Mus. Comp. Zool., No. 7.

The classical work on the Echini, and absolutely indispensable to every student of the group.

'77. ——— North American Starfishes. Mem. Mus. Comp. Zool., vol. V., No. 1.

Discusses and figures the hard parts of several Woods Hole species in addition to a number from other regions.

'65. Agassiz, A. and E. C. Seaside Studies in Natural History. Marine Animals of Massachusetts Bay. Boston.

An interesting popular account of many echinoderms.

'41. Agassiz, L. Monographe de Scutellidæ.

'46. ——— Catalogue raissoné * * * des Echinoderms. Ann. des Sci. Nat., III ser., tome VI.

'47. ——— Ditto. Tome VII.

1901. Arnold, Augusta Foote. The Sea Beach at Ebb Tide. Century Co., New York City.

An admirable attempt to provide a popular guide to marine botany and invertebrate zoology. Most of the illustrations are excellent, but the nomenclature of the echinoderms is antiquated and misleading in some respects.

'51–'54. Ayres, W. O.—Notices of Holothuriæ and other Echinoderms. Proc. Bost. Soc. Nat. Hist., vol. IV.

Some of the earliest but most interesting accounts of many of the Woods Hole species.

'35. Brandt, J. F.—Prodromus Descriptionis Animalium ab H. Mertensio observatorum. Petropoli.

'99. Clark, H. L.—The Synaptas of the New England coast. Bull. U. S. Fish Commission.

Deals with the synonymy, anatomy, and physiology.

1901. ——— Synopses of North American Invertebrates. The Holothurioidea. American Naturalist, vol. XXV, No. 414.

'78. Danielssen and Koren.—Echinodermer fra den Norske Nordhavs Expedition. Nyt Mag. for Naturvid., vol. XXIV.

'79. ——— Ditto, vol. XXV.

'28. Delle Chiaje, S.—Memorie * * * degli Animali senza Vertebre, etc. Naples.

'48. Desor, E.—Echinoderms of Nantucket Shoals. Proc. Bost. Soc. Nat. Hist., vol. III.

'46. Duben and Koren.—Öfversigt af Skandinaviens Echinodermer. K. Vet. Akad. Handl. Stockholm.

1780. Fabricius, O.—Fauna Groenlandica. Hafniæ et Lipsiæ.

'28. Fleming, John.—A History of British Animals. Edinburg.

'81. Fewkes, J. W.—On the Development of the Pluteus of Arbacia. Mem. Peabody Acad. of Sci. No. 6.

'86. ———. Preliminary Observations on the Development of Ophiopholis and Echinarachnius. Bull. Mus. Comp. Zool., vol XII, No. 4.

'87. ———. On the Development of the Calcareous Plates of Amphiura. Bull. Mus. Comp. Zool., vol. XIII, No. 4.

'88. ———. On the Development of the Calcareous Plates of Asterias. Bull. Mus. Comp. Zool., vol. XVII, No. 1.

'92. Field, G. W.—The Larva of Asterias vulgaris. Quar. Jour. of Mic. Sci., Nov., 1892.

'39. Forbes, Ed.—On the Asteriadæ of the Irish Sea. Mem. Wernerian Soc. Edinburgh, T. VIII, p 1.

'41. ———. A History of British Starfishes, etc., London.

A classic work most interestingly written; treats of several species which occur at Woods Hole.

'52. ——— Monograph of the Echinodermata of the British Tertiaries. Palæontological Society. London.

'88. Ganong, W. F.—The Echinodermata of New Brunswick. Bull. Nat. Hist. Soc., New Brunswick, No. VII.

A most interesting and useful list of 28 species, though the illustrations are poor.

'82. Garman and Colton.—Some notes on the Development of Arbacia punctulata. Studies Biol. Lab. Johns Hopkins Univ., vol. II.

'96. Gerould, J. H.—The Anatomy and Histology of Caudina arenata Gould. Proc. Bost. Soc. Nat. Hist., vol. XXVII.

The most important paper yet published dealing with the anatomy of one of our echinoderms.

1788. Gmelin, J. F.—Linnæi Systema Naturæ. Editio XIII. Lipsiæ.

'98. Goto, S.—The Metamorphosis of Asterias pallida, etc. Jour. Coll. Sci., Imp. Univ. Tokio, vol. X, pt. 3.

'41. Gould, A. A.—Report on the Invertebrata of Massachusetts. Cambridge, Mass.

1900. Grave, C.—Ophiura brevispina. Mem. Nat. Acad. Sci., Baltimore.

An important contribution to the life history of one of the Woods Hole brittle-stars.

1902. ——— Some points in the Structure and Development of Mellita testudinata. Johns Hopkins Univ. Circulars, No. 157.

'25. Gray, J. E.—On Echinarachnius parma. Ann. Phil., p. 6.

'35. ——— On Arbacia punctulata. Proc. Zool. Soc., London, p. 58.

'48. ——— List of British Animals, etc. Part I, Centroniae. London.

'51. ——— On Mellita testudinaria. Proc. Zool. Soc., London, p. 36.

1770. Gunnerus, J. E.—Beschreibung dreier norwegischer Seewürmer. Abh. d. Kgl. Schwed. Akad. d. Wiss. Deutsche Ausgabe. Leipzig.

'35. Johnston, G.—Illustrations in British Zoology. London's Magazine Nat. Hist., vol. VIII.

'81. Kingsley, J. S.—Contributions to the Anatomy of the Holothurians. Mem. Peabody Acad. Sci., vol. I, No. 5.

1901. ——— Preliminary Catalogue of Marine Invertebrata of Casco Bay. Proc. Portland Soc. Nat. Hist. vol. II.

Gives 29 species of echinoderms, of which 24 have been taken in less than 50 fathoms, and 13 occur in the Woods Hole region.

'16. Lamarck, J. B. P. A. de.—Histoire Naturelle des Animaux sans Vertèbres. T. III. Paris.

'85. Lampert, K.—Die Seewalzen. Wiesbaden.

An important monograph, but not nearly so useful as Théel's Challenger Report, 1886.

'24. Lesueur, C. A.—Description of several new species of Holothuria. Jour. Acad. Nat. Sci. Phila. vol. IV, pt. 1.

1767. Linnæus, C.—Systema Naturæ. Editio duodecima. Holmiæ.

'66. Ljungman, A. V.—Ophiuroidea viventia huc usque cognita. Öfvers. Kongl. Vet.-Akad. Förh.

'71. ——— Same journal.

'92. Ludwig, H.—Die Seewalzen. In Bronn's Thierreich, Band II, Abt. 3, Buch 1.

The best monograph on holothurians ever published, but not dealing with the systematic identification of forms below genera.

1900. ——— Arktische und subarktische Holothurien. In Fauna Arctica, Band I, Lieferung 1.

'54. Lütken, C. F.—Oversigt over Grönlandshavets Ophiurer. Vidensk. Medd. November.

'56. ——— Oversigt over Vestindiske Ophiurer. Nat. For. Videns. Med. January and February.

'59. ——— Additamenta ad Historiam Ophiuridarum, pt. III.

'64. ——— Kritiske Bemærkninger over forskjellige Söstjerner, etc. Vidensk. Medd. Kjöbenhavn.

'71. ——— Same journal.

'60. Lyman, T.—New Ophiurans, etc. Proc. Bost. Soc. Nat. Hist., vol. VII.

'65. ——— Ophiuridæ and Astrophytidæ. Ill. Cat. Mus. Comp. Zool., No. 1.

One of the classic works, indispensable to all systematic students.

'82. ——— Report on the Ophiuroidea. Challenger Reports, vol. V., pt. 14.

Another invaluable work, bringing the systematic history of ophiurans down to date and containing much valuable anatomical matter also.

'99. Mead, A. D.—The Natural History of the Starfish. Bull. U. S. Fish Commission, vol. XIX.

An unusually important and very interesting paper.

1776. Müller, O. F.—Zoologicae Danicae Prodromus. Hafniäe.

'42. Müller and Troschel.—System der Asteriden. Braunschweig.

'65. Norman, A. M.—On the Genera and Species of British Echinodermata. Ann. Mag. Nat. Hist. (3) vol. XV.

'63. Packard, A. S., jr.—A list of animals dredged near Caribou Island. Canadian Naturalist, vol. VIII.

1777. Pennant, T.—The British Zoology, vol. IV. London.
'51. Pourtalés, L. F.—On the Holothuriæ of the Atlantic Coast of the United States. Proc. Amer. Ass. Adv. Sci. Washington.
1783. Retzius, A. J.—Asteriæ Genus. Vetensk. Acad. Nya Handlingar, IV.
'61. Sars, M.—Oversigt of Norges Echinodermer. Christiania.
'25. Say, T.—On the Species of the Linnæan Genus Asterias, etc. Jour. Acad. Nat. Sci. Phila., vol. V., pt. 1.
'26. ——— Same journal.
'27. ——— Same journal.
'67. Selenka, E.—Beiträge zur Anatomie und Systematik der Holothurien. Zeit. f. wiss. Zool., Bd. XVII.
'68. Semper, C.—Reisen im Archipel der Philippinen. Bd. I. Holothurien. Leipzig.

A standard work, specially remarkable for the unusually good illustrations, the colored plates being particularly attractive.

'89. Sladen, W. P.—Report on the Asteroidea. Challenger Reports, vols. XXX and XXXI.

A most important monograph, the only serious defect of which is the absence of a bibliography.

'51. Stimpson, W.—Descriptions of new Holothurians. Proc. Bost. Soc. Nat. Hist., vol. IV.
'52. ——— New Ophiurans. Proc. Bost. Soc. Nat. Hist., vol. IV.
'53. ——— Marine Invertebrata of Grand Manan. Smithsonian Contributions, VI.
'62. ——— On New Genera and Species of Starfishes, etc. Proc. Bost. Soc. Nat. Hist., vol. VIII.
'86*a*. Théel, H.—Report on the Holothurioidea, pt. II. Challenger Reports, vol. XIV.

The one absolutely indispensable work to every worker on holothurians; can not be praised too highly.

'86*b*. ——— Report on the Holothurioidea * * * of the "Blake." Bull. Mus. Comp. Zool., Cambridge, vol. XIII, No. 1.
1901. Tower, W. L.—An abnormal Clypeastroid Echinoid. Zool. Anzeiger. No. 640.
'66. Verrill, A. E.—On the Polyps and Echinoderms of New England. Proc. Bost. Soc. Nat. Hist., vol. X.

An interesting and important paper.

'67–'71. ——— Notes on Radiata. Trans. Conn. Acad., vol. I, pt. 2.
'73*a*. ——— Results of Recent Dredging Expeditions on the Coast of New England. Am. Jour. Sci., 3d ser., vol. X, No. 26.
'73*b*. ——— Report on the Invertebrate Animals of Vineyard Sound. U. S. Fish Commission Report. Washington.
'74. ——— Explorations of Casco Bay * * * in 1873. Proc. Am. Ass. Adv. Sci., Portland meeting.
'76. ——— Note on some of the Starfishes of the New England Coast. Am. Jour. Sci., 3d ser., vol. XI.
'95. ——— Distribution of the Echinoderms of Northeastern America. Am. Jour. Sci., 3d ser., vol. XLIX, No. 290.
'99. ——— North American Ophiuroidea. Trans. Conn. Acad., vol. X, pt. 2.

Although these 8 titles are far from completing the list of Verrill's valuable papers on the echinoderms of northeastern America, they comprise those reports which bear most directly on the Woods Hole fauna. Those dated '66, '73b, '76, '95, and '99 are the most useful, '73b being extremely helpful to all students of marine zoology at Woods Hole.

1670. Winthrop, J.—Concerning * * * a very curiously contrived Fish. Philosophical Transactions. IV. London.

A most interesting account of *Gorgonocephalus*. (See Lyman, '65.)

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