On Some Plymouth Holothurians.

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With 13 Figures in the Text.

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PART I.

ON THE SPECIFIC CHARACTERS OF *CUCUMARIA NORMANI* PACE, AND *CUCUMARIA SAXICOLA* BRADY AND ROBERTSON, WITH AN ACCOUNT OF SOME UNDESCRIBED DIFFERENTIAL CHARACTERS AND AN INVESTIGATION OF THE VARIATION OF THE GONAD IN *C. SAXICOLA*.

COMPARISON OF THE CHARACTERS OF *C. NORMANI* AND *C. SAXICOLA*.

Some of the specific and differential characters of these two species have already been enumerated by Pace (1). Subsequently Norman (2)

denied that these two forms were different, so that the literature on them was left in an unsatisfactory state. On investigating these two forms, however, I have obtained sufficient evidence—from the characters of the gonadial tubes, the calcareous collars, and the young of both forms—to verify the observations of Pace and to meet satisfactorily the objections put forward by Norman against them. The differential characters of these two species as given by Pace (loc. cit.) have been verified in an unpublished investigation by Mr. W. De Morgan and by the present writer. These characters, most of which were observed by Pace, are now given revised * in the following table in a comparative manner, so that the differences between these two species can be readily shown :—

TABLE 1.—A comparison and a contrast of the characters of *C. saxicola* Brady and Robertson and *C. normani* Pace.

Cucumaria saxicola B. and R.	*Cucumaria normani* Pace.
† Common on the shore, also taken in depths of a few fathoms.	† Fairly common on the shore, also taken in depths of a few fathoms.
General colour of body a pure milk white, becoming black when exposed to light.	General colour of body dirty brownish white, becoming black when exposed to light.
Surface of body smooth.	Surface of body much wrinkled.
Body wall delicate, relatively thin, marked only with transverse striæ due to encircling fibres of the superficial muscle layer, with relatively few spicules.	Body wall tough, coriaceous, crowded with spicules.
General body spicules devoid of nodulation, lozenge-shaped in one stage of growth, but subsequently developing 2 or even 3 additional foramina on the ends of the spicule and thus losing their lozenge shape. (See 4, Plate LXXII, Fig. 3.)	General body spicules typically lozenge-shaped, perforated with four large foramina, and always bearing on each side about 12 very prominent nodules. (See 3, Plate XI, Fig. 1.)

* Owing to the fact that both species develop black pigment when and where exposed to light, it follows that the differential characters depending upon the degree of pigmentation of the tentacles and anal aperture noted by Pace cannot be relied upon, and have consequently been abandoned.

† As an example for illustrating the occurrence of these two forms, in one day's collecting on the shore (3rd April, 1911, Wembury Bay) about 80 *C. saxicola* were obtained and only about 6 *C. normani*, including specimens of various sizes. Another day (1st May, 1911) about 40 *C. saxicola* were obtained and only 2 *C. normani*. This disproportion is usual in this district.

Cucumaria saxicola B. and R.	*Cucumaria normani* Pace.
Surface spicules of body irregular in shape, consisting of rods radiating from a central portion, scattered in the skin. (See l.c. above and also Fig. 6, p. 221.)	Surface spicules campanulate, forming a continuous covering in the skin of the body. (See Figs. 8 and 7, pp. 225 and 222.)
Podial spicules have foramina typically in a single series. (See Fig. 6, p. 221.)	Podial spicules have foramina in two or more parallel rows or with a group of 3 or 4 small foramina at each end of the spicule. (See Fig. 7, p. 222.)
Gonadial tubes relatively few, varying in number between 10 and about 60, large, and club-shaped. (See Fig. 1, p. 214.)	Gonadial tubes very numerous, frequently more than 500, relatively small, and of even cylindrical calibre. (See Fig. 2, p. 214.)
Calcareous collar relatively delicate. Interradial calcareous pieces deeply bifurcated posteriorly. (See Fig. 4, p. 218.)	Calcareous collar relatively strong. Interradial calcareous pieces only slightly bifurcated posteriorly. (See Fig. 5, p. 219.)
Dorsal ambulacra with modified tube-feet. (See Fig. 9, p. 228.)	Dorsal ambulacra with ordinary ambulatory tube-feet.
Spawning period about May.	Spawning period about March.

The differential characters of most importance in the foregoing table are (1) those of the main body spicules, (2) the spicules near the surface of the body, (3) the shape and number of the gonadial tubes, and (4) the shape and relative stoutness of the pieces of the calcareous collar. Pace has already emphasized the first and second of these characters. These have, however, gained additional importance from the recent observation of their correlation with differences in the gonad and calcareous collar. In *C. saxicola* the gonadial tubes are large, club-shaped, and few in number (see Fig. 1, p. 214), while those in *C. normani* are relatively small, of even, cylindrical calibre, and very numerous. (See Fig. 2, for the faithful drawing of which I am indebted to Mrs. Orton, as well as for all the figures by which this paper is illustrated.) The gonad in the male and female in each of these forms is alike in its structure. The eggs of both species are about the same size, i.e. about ·4 mm. in diameter, but the sperm has not been examined closely.

VARIATION OF THE GONAD OF *CUCUMARIA SAXICOLA*.

The variation in the gonad of *Cucumaria saxicola* has been investigated in 50 adult specimens varying in size* from about 6 cm. to about 10 cm. in length. The gonad in adult *C. saxicola* consists of from about 10 to 60 club-shaped tubes (see Fig. 1, p. 214). These tubes vary in length

Fig. 1.

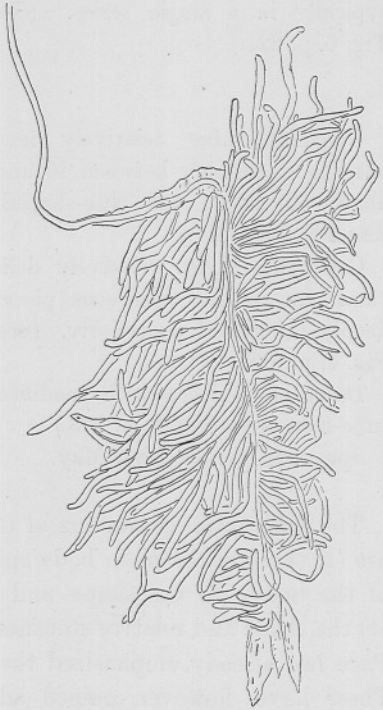

Fig. 2.

FIG. 1.—The gonad and gonoduct of *C. saxicola* B. and R. (Drawn *in situ*, × ⅔.)
The single tube in the lower part of the figure on the right shows the shape of the tubes in this species better than those in the upper figure. This tube was taken from a male gonad, those in the upper figure constitute the whole gonad of a female.

FIG. 2.—The gonad and gonoduct of *C. normani* Pace. (Drawn *in situ* from a female specimen, × ⅔.)

from about 1 mm. to about 3·4 cm.: they are narrowest at the attached end, and vary somewhat in the degree to which the distal end is swollen (see Fig. 1), but at this part they are commonly 3 mm. in diameter. In any particular individual the tubes may vary greatly in size. The

* These specimens were all measured when preserved, but as they were mostly well expanded the measurements may be regarded as roughly comparable.

tubes are arranged to the right and left of the mesentery supporting the alimentary canal in a position which is just behind the middle of the length of the animal. In this species the tubes join up at their attached ends to form a very short duct which unites almost immediately with its fellow on the opposite side to form the main gonoduct. The number of tubes on each side of the mesentery was noticed in all the specimens and recorded in columns 4 and 5 in Table 2 (see p. 215). It was found that the same number of tubes occurs only rarely on each side of the mesentery, but that there is generally about the same number: on the whole, however, more were found on the left than on the right side.

TABLE 2.—Illustrating the variation in the distribution and number of gonadial tubes in *Cucumaria saxicola* of different sizes.

Ref. No.	Approximate Length of Specimen.	Sex.		No. of Gonadial Tubes. On Left Side.	Right Side.	Total.
1.	6·0 cm.	♀*		9	6+1 R.†	16
2.	6·0 ,,	♂	tubes full of sperm.	6	11	17
3.	6·3 ,,	♂		7	8	15
4.	6·4 ,,	♂		6+1 R.	12+3 R.	22
5.	6·6 ,,	♀		5+1 R.	3+1 R.	10
6.	6·6 ,,	♂	tubes full of sperm.	12+1 R.	8+2 R.	23
7.	7.0 ,,	♀	tubes up to 2·6 cm. long.	2+1 R.	12+1 R.	16
8.	7·0 ,,	♂		14	16	30
9.	7·0 ,,	♂		16	15+2	33
10.	7·0 ,,	♂		12	9	21
11.	7·0 ,,	♂	tubes full of sperm.	22	17	39
12.	7·0 ,,	♂		16	7	23
13.	7·0 ,,	♂		17+3 sm.	13+3 sm.†	36
14.	7·0 ,,	♀		8	10	18
15.	7·1 ,,	♂		14	8	22
16.	7·3 ,,	♀		4+2 R.	3+1 R.	10
17.	7·3 ,,	♂		12+4 R.	10+3 R.	29
18.	7·3 ,,	♀		9	9+1 R.	19
19.	7·4 ,,	♀		10	7	17
20.	7·4 ,,	♀		10+2 R.	7+1 R.	20
21.	7·4 ,,	♀		12	12	24
22.	7·5 ,,	♂		30+1 sm.	30	61
23.	7·5 ,,	♂		18	11	29
24.	7·5 ,,	♀		6	4	10
25.	7·8 ,,	♂		12	8	20

* Eggs in various stages of development were observed in the tubes of all the females.

† *R.* means a rudimentary; *sm.* a rather small tube.

Ref. No.	Approximate Length of Specimen.	Sex.		No. of Gonadial Tubes. On Left Side.	Right Side.	Total.
26.	7·9 cm.	♀	very large tubes.	6+1 R.	6	13
27.	8·0 ,,	♀		8	10	18
28.	8·0 ,,	♂		8	9	17
29.	8·0 ,,	♂		13	16	29
30.	8·3 ,,	♀		13+1 sm.	12+1 sm.	27
31.	8·5 ,,	♂		6	7	13
32.	8·5 ,,	♀		13	15	28
33.	8·5 ,,	♀		13	13	26
34.	8·5 ,,	♂		21	28	49
35.	8·5 ,,	♀		15	18	33
36.	8·5 ,,	♂		29	23	52
37.	8·7 ,,	♀		7+1 sm.	7+1 sm.	16
38.	8·8 ,,	♀	tubes up to 3·0 cm. long.	13	14	27
39.	8·8 ,,	♂		14	15	29
40.	8·8 ,,	♀		10	13	23
41.	9·0 ,,	♂		11+3 sm.	11	25
42.	9·0 ,,	♂		12+12 sm.	14+12 sm.	50
43.	9·0 ,,	♀		12	10	22
44.	9·0 ,,	♂		11+1 sm.	11	23
45.	9·5 ,,	♀	tubes up to 3·4 cm. long.	16+1 R.	15+1 R.	33
46.	10·0 ,,	♂		16	21	37
47.	10·0 ,,	♀		7	12	19
48.	10·0 ,,	♀		8	4	12
49.	10·0 ,,	♀		12	8	20
50.	10·0 ,,	♂		14	12	26

A glance at the last column of Table 2 shows at once that the variation in number of the gonadial tubes in this species is distributed sporadically among individuals, and that the number does not necessarily increase with the size of the adult animal. Since the number of gonadial tubes is variable, it is of interest to examine the relative frequencies of the occurrence of any particular number. The frequencies of particular numbers, as, for example, of numbers between 10 and 15, and 16 and 20, and so on, have been plotted to give the curve in Fig. 3, p. 217. As, however, the number of individuals examined is small, the curve is less symmetrical than it would probably have been if a thousand specimens could have been examined. The ideal curve indicated by that in Fig. 3 would doubtless have one maximum in the region of 24 and 25, as indicated by the dotted line. Whether, however, the smaller crest of the curve (between 40 and 50) would become more important can only be found

out by further investigation. The usual number of gonadial tubes in *C. saxicola* may therefore be fairly stated as 24 or 25. Curiously enough, about 25 is also the average number of tubes given for the whole of the 50 specimens examined. There is variation, however, in the number of gonadial tubes in this species between 10 and 61, as has already been observed.

It is an interesting fact that the males appear to be more variable in this respect than the females, although the small number of individuals examined necessitates caution in making this suggestion. Of the 50 specimens examined 24 were females and 26 males. The number of gonadial tubes in individual females varied between 10 and 33, whilst in the males the variation lay between 15 and 61. The total number of gonadial tubes in all the females was 477, giving an average of less than 20, while all the males gave a total of 769, giving an average of about 29·5.

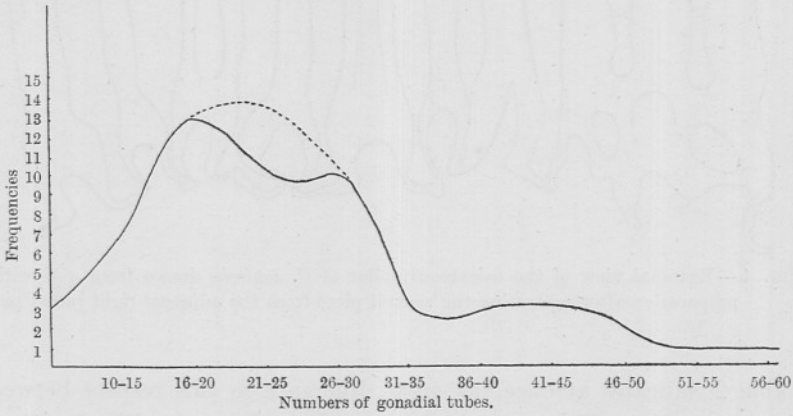

FIG. 3.—Curve showing the frequencies of different numbers of the gonadial tubes in 50 specimens of *Cucumaria saxicola* B. and R.

Ordinates=frequencies; abscissæ=number of gonadial tubes between 10 and 15, 16 and 20, and so on. The continuous line denotes the actual curve obtained, the dotted one an approximation to the form of the curve if a larger number of individuals were examined.

THE GONAD OF *CUCUMARIA NORMANI*.

The gonad of *C. normani* consists of a very large number of small cylindrical tubes of almost even bore. These tubes are arranged as in *C. saxicola*, on each side of the mesentery supporting the alimentary canal. The tubes on both sides open into one longitudinal collecting duct which extends in the mesentery some distance behind and in front of a point about the middle of the length of the body. This duct is

continued anteriorly as the main gonoduct (see Fig. 2, p. 214). The largest individual tubes in a very fine specimen were found to be about 3·0 cm. long, and less than 1 mm. wide.

The number of tubes was counted for the purpose of comparison with those in *C. saxicola* in 6 individuals, of which 3 were males and 3 females. In these specimens, whose lengths were (1) 5·3, (2) 7·2, (3) 8·2, (4) 8·6, (5) 9·0, and (6) 12·5 cms., there were respectively 528, 582, 473, 513, 839,* and 250 tubes. A similar large number of tubes was, however, observed in all the specimens obtainable, namely, 30, of sizes similar to those given in Table 1. A comparison with similar specimens of *C. saxicola* from

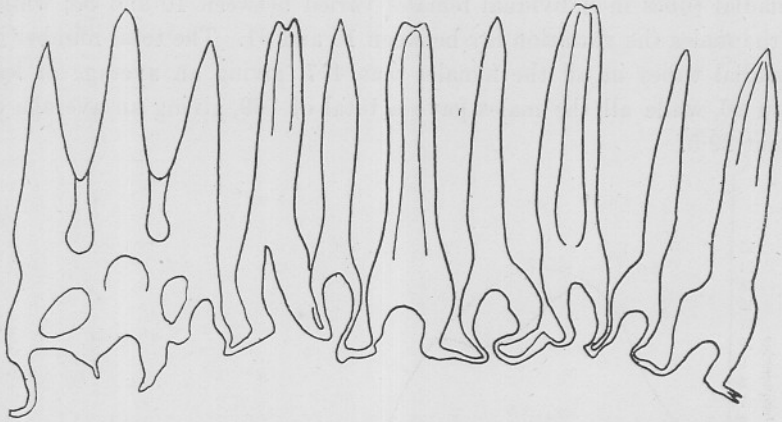

FIG. 4.—External view of the calcareous collar of *C. saxicola* drawn from a glycerine preparation after separating the ventral piece from the adjacent right radial piece ($\times \frac{20}{3}$).

Table 2 indicates at once the great difference in this respect between the two species. The number in the specimen drawn for Fig. 2 was not counted. In this figure it may be mentioned that the tubes shown are chiefly those constituting the upper of several similar layers.

It is an interesting fact that the examination of the gonad of even these few specimens of *C. normani* indicates a similar range of variation to that observed in *C. saxicola*, namely, that the males (numbers 1, 2, and 5) possess more gonadial tubes than the females (numbers 3, 4, and 6), that the number of these tubes is not necessarily larger in the larger individuals, and that within the species there is a wide range of variation in the number of the gonadial tubes, which may vary from about 250 to more than 800.

* At least this number were present. Thirty-nine tubes which might have been broken were not added to the total.

The number of gonadial tubes was also counted in a few small specimens of *C. saxicola* and in one small immature specimen of *C. normani*. In specimens of the former of 3·8, 3·1, and 2·8 cms. in length, there were respectively 8, 4, and 6 small tubes, while in the specimens of *C. normani* of 3·3 cms. in length there were 199 tiny tubes.

It is thus evident that there is a marked difference between *C. saxicola* and *C. normani* in the characters of the shape and number of the gonadial tubes.

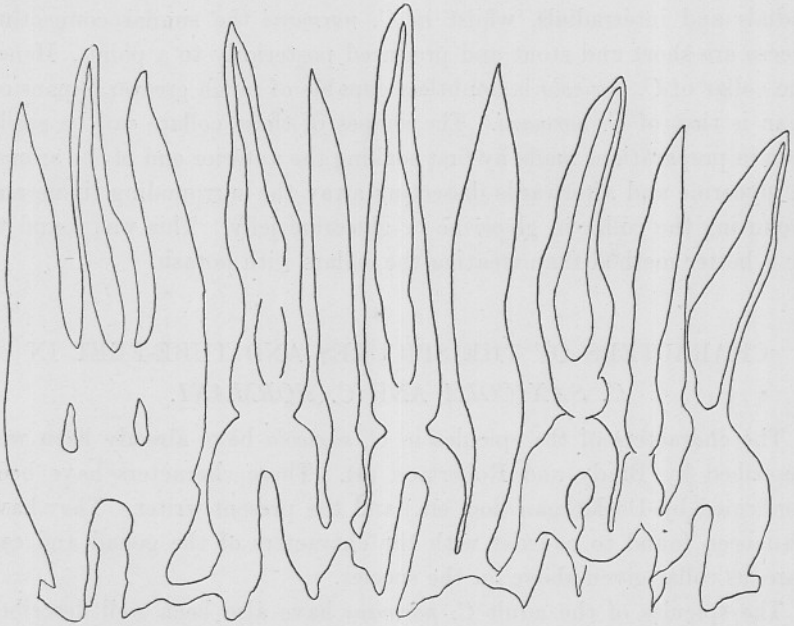

FIG. 5.—External view of the calcareous collar of *C. normani*, drawn from a glycerine preparation after separating the ventral piece from the adjacent right radial piece ($\times \frac{20}{3}$).

CHARACTERS OF THE CALCAREOUS COLLAR OF *C. SAXICOLA* AND *C. NORMANI*.

The calcareous collars of both *C. saxicola* and *C. normani* consist alike of 5 radial alternating with 5 interradial pieces, and in both forms three of the ventral pieces, one radial and two interradials, are partially fused together. (See Figs. 4 and 5.) There is, however, a general difference in the relative stoutness of the collars in the two species, and some differences in the shapes and mode of connexion of the parts.

The collar of *C. saxicola* is relatively delicate, that of *C. normani* relatively stout. In specimens of the two species of about the same size, both the radials and interradials in *C. normani* are stronger, wider, and longer than in *C. saxicola*. (See Figs. 4 and 5.) In the latter species the interradials are deeply bifurcated at the posterior end (see Fig. 4), whereas in *C. normani* these plates are only slightly bifurcated (see Fig. 5), and the radials of *C. normani* differ from those of *C. saxicola* in being deeply constricted at the sides near the posterior end. Further, in *C. saxicola* there is a long narrow calcareous connecting loop between the radials and interradials, whilst in *C. normani* the similar connecting pieces are short and stout and produced posteriorly to a point. Hence the collar of *C. saxicola* is doubtless capable of much greater expansion than is that of *C. normani*. The shapes of these collars can be easily seen in preparations made by first soaking the anterior end of the animal in glycerine and afterwards dissecting away the surrounding tissue and mounting the collar in glycerine or glycerine jelly. This was found to be a better method than treating the collars with potash.

CHARACTERS OF THE SPICULES AND TUBE-FEET IN *C. SAXICOLA* AND *C. NORMANI*.

The characters of the spicules in *C. saxicola* have already been well described by Brady and Robertson (4). These characters have been confirmed by De Morgan (loc. cit.) and the present writer. They have also been found to co-exist with the characters of the gonad and calcareous collar given above for the species.

The spicules of the adult *C. normani* have also been well described and figured by Norman (2 and 3, Plate XI, Figs. 1, 2, 3, and 4) from his specimen labelled *A*. Spicules identical with these have been found to be correlated with a gonad consisting of a large number of small tubes and a calcareous collar as described above.

It is therefore only necessary here to point out the main features of difference between the chief kinds of spicules occurring in these two forms. The chief body spicule in *C. saxicola* is plate-like and rhomboidal in outline, having the opposite ends of one axis more or less produced. The central portion of the spicule is perforated by four holes, placed along the long axes and around the centre of the spicule. On the produced axis of the spicule one, two, or even three additional holes may be developed. In some individuals the holes on the shorter of the long axes are usually circular, while those near the centre on the long axis

are more or less ellipsoidal in outline and larger than the former: in other individuals, however, the relative sizes of these foramina are reversed (see Brady and Robertson, 4, Plate LXXII, Fig. 3).

The chief body spicule in *C. normani* is also plate-like but ellipsoidal in outline; it has rarely more than four foramina, and bears on each surface usually 12 rounded bosses or nodules. The foramina are arranged diamond-wise along the long axes of the spicule. There are a great many more spicules in a given area of the body wall in *C. normani* than in *C. saxicola*, as may be easily seen in preparations of the skin: it is difficult to obtain exactly comparable specimens, but at a rough computation one would doubtless be well below the actual proportion in stating that they are twenty times more numerous in *C. normani* than in *C. saxicola*.

The surface body spicules in *C. saxicola* are well shown in Brady and Robertson's figure (4, Plate LXXII, Fig. 2). They are microscopic, stellate, of varying shape and size, but rarely more than 30 μ. wide, and scattered

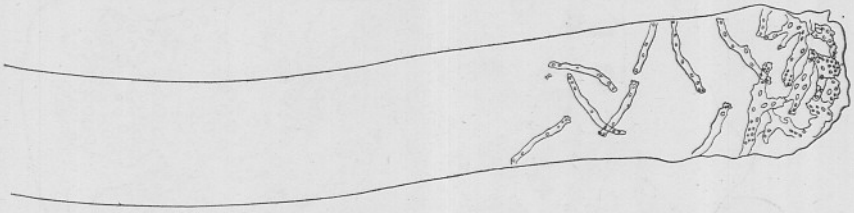

FIG. 6.—A single tube-foot of *C. saxicola*, showing the kind and number of the podial spicules (× about 30).

sparsely over the body. Usually they consist of a thin central plate from which radiate tiny cylindrical rods about 12 μ. long. On the other hand, the corresponding spicule in *C. normani* is bell-shaped, being slightly rectangular across the mouth of the bell, where on the average they measure about 40 μ. by 36 μ. These spicules are almost uniform in size, forming a continuous covering over the whole of the body and passing on to the bases of the tube-feet. Their compactness may be gathered from Fig. 8, which is a view through a low power of a microscope of a portion of the body wall of a small specimen in which, however, only one of the bell-shaped spicules is fully developed.

The podial spicules in *C. saxicola* are, as Pace has shown (loc. cit.), usually perforated with a single series of holes. These are well shown in Fig. 4, which is a drawing of a whole tube-foot well expanded (taken from specimen 45, Table 1). One of the microscopic surface spicules only is present. In *C. normani*, on the other hand, these spicules are mostly larger, and with two or more series of foramina (see Fig. 5, p. 219).

This figure is a drawing of a tube-foot of a specimen of *C. normani* 5·3 cm. long, taken from the right ventral ambulacral row—as was that of *C. saxicola*, shown in Fig. 6, p. 221. A comparison of these two figures, which may be regarded as typical, indicates the differences which occur in the podial spicules of these two forms. Those in *C. saxicola* are relatively few, mostly straight, with foramina in a single series, although there may be spicules with more than one series. Those in *C. normani*, on the other hand, are mostly broadly V-shaped, with foramina in two or more series: some spicules, however, are straight, with foramina in single series, as in *C. saxicola*. There are also a few bell-shaped surface spicules around the base of the tube-foot.

The difference in the relative number of spicules in these two forms

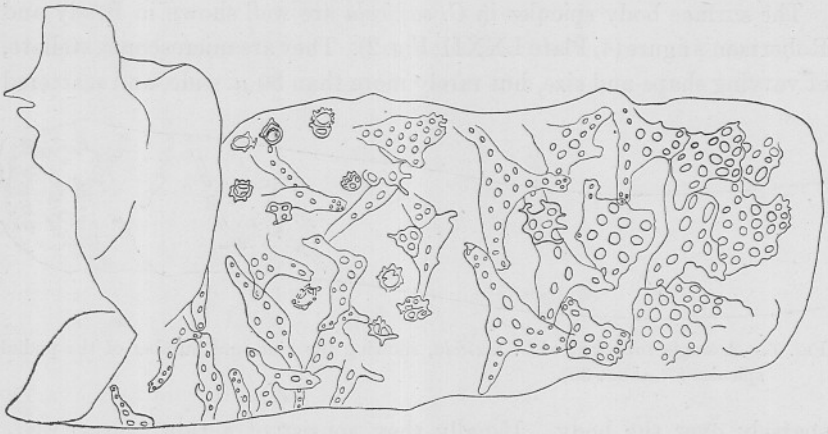

FIG. 7.—A single tube-foot of *C. normani*, showing the kind and number of the podial spicules (× about 65).[1]

is also well shown in these figures, and this difference is emphasized still more by the fact that not all the spicules in the tube-foot of *C. normani* could be drawn.

DISCUSSION OF SOME FORMER OBSERVATIONS ON *C. SAXICOLA* AND *C. NORMANI*.

The establishment of undoubted specific and differential characters—given in the preceding pages—for these two species enables a partial clearing up to be made of the literature referring to these forms. Norman (3) in 1893 described three specimens, A, B, and C, of *Cucumaria* obtained at Polperro in 1865 as *C. montagui*. Subsequently Pace (1) in 1904 showed that one of Norman's specimens, A, was undoubtedly the same

as the Plymouth species known at that time at Plymouth as *C. planci*, while the other two, B and C, were similar to the species known at that time at Plymouth as *C. pentactes*. After discussing the synonymy of Norman's *C. montagui*, Pace showed (1) that this name is a complex one, whose original form could not be traced, (2) that *C. planci* Brandt "cannot be applied to the very different species from Plymouth," and (3) that *C. pentactes* (Linnæus) "is now generally regarded as an indeterminate species." He therefore proposed to abolish all these names, substituting *C. normani* for the Plymouth *C. planci* and specimen A of Norman's *C. montagui;* and *C. saxicola* Brady and Robertson for the Plymouth *C. pentactes*, and B and C of Norman's *C. montagui*, which were shown to be identical with a species described in 1871 by Brady and Robertson as *C. saxicola*.

The researches here described support Pace's contention that Norman's *C. montagui* consisted of two species, subsequently named by Pace as *C. normani* Pace, and *C. saxicola* Brady and Robertson.

In 1905 Norman (2) wrote a paper maintaining his former views, which at this stage can be stated to be as follows: That he considered the Plymouth *C. saxicola* as the young of the Plymouth *C. normani* Pace, and that both were really equivalent to *C. montagui* Fleming. Norman's main contention in this paper is that the Plymouth *C. saxicola* are the young of the Plymouth *C. normani*. He, however, freely states that "When young specimens of *C. montagui*, say 14 mm. long, should be found having spicules agreeing with those of the adult, my view that B and C are young forms of that species would require to be reconsidered." In further support of his view Norman cited the known facts that spicules found in the young of some forms (for example, *C. frondosa*) disappear in the adult, and that spicules which in the young of some forms are smooth (for example, *C. hyndmanni*) become nodulous or thickened in older specimens.

The correlation of differences in the gonad and calcareous collar with the differences in the spicules described above is doubtless sufficient to establish the distinctness of these two species. Fortunately, however, tiny young ones of both species have been obtained, and so enable a comparison of both forms to be made throughout all stages of growth.

Besides these, however, De Morgan also obtained tiny *C. normani*. In his unpublished MS. he states: "I have examined specimens of both species from about one centimetre to three inches in length, both fresh and preserved in spirit, and find the plates that distinguish *C. normani* confined to *C. normani*; and those of *C. saxicola* to *C. saxicola*."

Tiny specimens of *C. normani* were obtained by the writer from a floating raft moored in Cawsand Bay, just outside Plymouth Sound. These specimens measured about 13 and 14 mm.; in fact, just the size Norman wished for. These specimens were examined while living, and sketches made *from the living animal* of all stages of growth of the bell-shaped spicules.

Subsequently a preparation was made of the skin of these animals and a drawing of the spicules made *in situ* for Fig. 8, p. 225. This figure shows the different stages of growth of the bell-shaped spicules and also the degree in which these spicules are crowded in the surface of the skin. The young of *C. saxicola* have been reared by the writer from the egg to a size of about 5 mm., i.e. somewhat smaller than the tiny *C. normani* mentioned above. In these no bell-shaped spicules developed, although the body spicules were well formed. Specimens of all sizes of both species have been obtained from dredgings, forming a parallel series from the tiny ones mentioned above to the adults of sizes whose gonadial tubes and other correlated characters have been described. The evidence for the distinctness of these two forms is thus complete, whatever their ultimate names may be decided to be.

THE GROWTH-STAGES OF THE BELL-SHAPED SPICULES OF *C. NORMANI*.

The tiny specimens of *C. normani* mentioned above presented an opportunity of following the development of the bell-shaped surface spicules of this species. These spicules develop in four well-defined stages. In the earliest stage they consist of a microscopic plate forked at both ends (see Fig. 8 for this, as well as for the following stages). At a later period of development each of the forked ends divides dichotomously twice to give two succeeding well-marked stages. At the same time the central portion of the spicule becomes wider and thicker, and the growing arms arch outwards to form a hemisphere. At this stage one branch of each of the last-formed bifurcations grows towards a similar branch derived from the subdivision of the adjacent primitive prong. These branches grow together, but frequently become slightly forked again before fusing to form the rim of the spicule. The whole spicule at this stage becomes thickened, and generally two branches of the third order of division persist as projections at each of the four corners and one in the middle of each side of the rim when the spicule is fully formed. There are, however, sometimes variations from the general course. Occasionally three or five original prongs may develop and a

three- or a five-rayed spicule is produced, at other times further subdivision of the branches of the third order occurs, giving rise to bell-shaped spicules slightly different from the usual form ; the normal form is, however, the one described above.

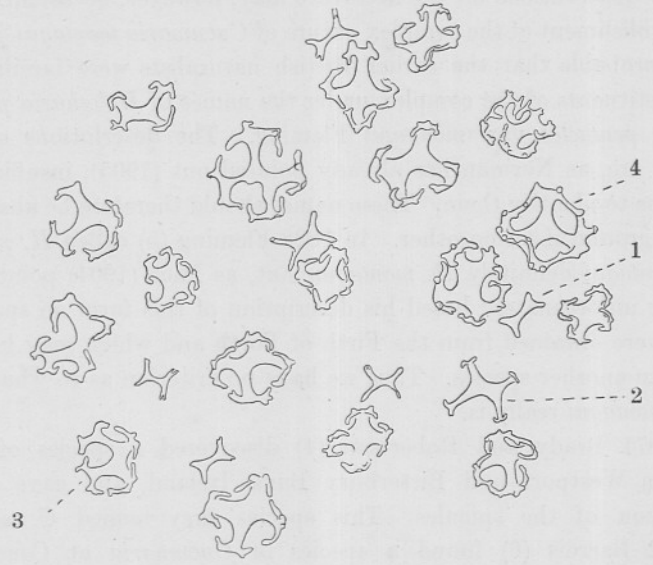

FIG. 8.—The campanulate surface spicules of *C. normani*. Drawn from a piece of the skin (mounted whole) of a specimen 13 mm. long to show a series of stages in the development of these spicules and their compact arrangement.* One fully developed spicule is depicted (× about 300).

THE SYNONYMY OF *C. SAXICOLA* BRADY AND ROBERTSON AND OF *C. NORMANI* PACE.

It will be evident from the foregoing accounts that the synonymy of the two species mentioned above may be expected to be and actually is in a highly confused state. This confusion has been rendered still worse by the fact that continental zoologists have regarded *C. montagui* as a good species, whereas it has been shown to be a complex one. Thus according as the one or the other constituent of *C. montagui* has fallen into the hands of these zoologists, the other constituent—on the Continent —has been given another name. There can be little doubt that the two species discussed in this paper do occur on the Continent, but at present

* Drawings were made of some of these stages of development from the fresh living animal as a safeguard against their possible subsequent alteration in preservation. It was found, however, that the spicules in the mounted specimen agreed with the drawings from the living animal.

pass under other names. It is therefore improbable that the literature on these Holothurians will be properly purged until some specialist can take the whole group into consideration and obtain and compare type specimens from the various authors and stations.

A few observations on the literature may, however, be useful. From the establishment of the complex nature of *Cucumaria montagui*, it seems highly probable that the earlier British naturalists were familiar with the constituents of the complex under the names of *Holothuria pentactes* and *H. pentactes* var. *montagui* Fleming. The descriptions of these animals are, as Norman has already pointed out (1905), insufficient to enable us to identify them. These names should therefore be abandoned on this ground if on no other. In 1828 Fleming (5) called *H. pentactes* var. *montagui* definitely *H. montagui*, but, as Pace (1904) pointed out, Fleming unfortunately based his description of this form on specimens which were obtained from the Firth of Forth and which may have belonged to another species. Thus we have no criterion as to what *Cucumaria montagui* really is.

In 1871 Brady and Robertson (4) discovered a species of *Cucumaria* in Westport and Birterbury Bays, Ireland, and gave a good description of the spicules. This species they named *C. saxicola*. In 1882 Barrois (6) found a species of *Cucumaria* at Concarneau on the shore which he called *C. lefevrei*. This species resembles that described by Pace (1904) as *C. normani* closely in the characters of its spicules (as described) and its calcareous collar. It is, indeed, highly probable that these are the same species, but it would be necessary to compare actual specimens of these forms to be certain of their identity. If, however, such were established Pace's name would have to give way to that of Barrois'. It should be pointed out that Barrois' figures do not agree with his description.

In 1889 Hérouard (7), having apparently never seen Brady and Robertson's description of *C. saxicola*, described a form apparently identical with the latter as *Colochirus lacazei* n.sp. It is a somewhat amusing fact that this writer was roundly accused shortly afterwards by Marenzeller (8, 1893) of wilfully renaming what he well knew was *C. montagui*. It is also of interest that Marenzeller—like Pace—states confidently in the same paper that *C. montagui* is quite and obviously different from *C. lefevrei* Barrois. Now Marenzeller's *C. montagui* were sent to him by Norman (2, p. 389), who definitely states they were like his specimens B and C, which have been shown above to be *C. saxicola*.

About the same time Ludwig and Hamann (9, 1892) state, but with-

out giving a discussion, that *C. lacazei* Hér. =*C. lefevrei* Barrois. It is thus a curious fact that two pairs of men, one in England and one on the Continent, should hold independently similar conflicting views on what appears to be the same pair of species.

A little later Koehler (10, 1893), discussing the synonymy of *C. montagui* Fleming, gives as synonyms among others *C. lacazei* Hér., *Holothuria montagui* Fleming, and *Cucumaria pentactes* Bell, pointing out, however, at the same time that *C. montagui* differs from *C. lefevrei* in the shape and number of its genital tubes. He also figures spicules of *C. montagui* which are identical with those of *C. saxicola*. Now Koehler also received his specimens of *C. montagui* from Norman, who admits, as we have seen, that those sent were identical with his specimens B and C, i.e. with *C. saxicola*.

About this time Bell (11) added his quota to the confusion by giving as synonyms *Holothuria montagui* Fleming, *Cucumaria pentactes* Forbes, *C. elongata* Düb. and Kören. In 1902 Perrier (12) obtained *C. elongata* from the Gulf of Cadiz, and stated that this species is fundamentally different from *C. montagui:* he did not indicate, however, what were the characters of his *C. montagui*. Kemp (13) in 1905 described *C. elongata* Düb. and Kör. from Ireland and figured its spicules. Subsequently I obtained specimens of this species from various localities in this neighbourhood (see description on p. 229) from which there can be no doubt of the distinctness of this species.

From the foregoing historical account it appears that the complex, *Holothuria montagui*, of the older naturalists has subsequently been renamed as *Cucumaria saxicola* Brady and Robertson, *C. lefevrei* Barrois, *Colochirus lacazei* Hér., and *C. normani* Pace, as well as other names. Of these four names one pair, *C. saxicola* and *Colochirus lacazei*, seem to be undoubtedly synonymous; from the apparent identity in the characters of the spicules and genital tubes it is highly probable also that the other pair are synonymous. It is important, however, that these latter forms should be compared in actual specimens before making further alterations of names; hence until the whole of the European Cucumarians are revised by a specialist, the name *C. normani* Pace may be said to stand for that constituent of the old *C. montagui* whose characters are summed up in the foregoing pages.

CORRELATION IN THE CHARACTERS OF THE GONAD AND AMBULACRA IN THE GENUS *CUCUMARIA*.

The difference in the character of the gonad in *C. saxicola* and *C. normani* described in the foregoing pages suggested that similar differences might occur in other Cucumarians. On investigating the other

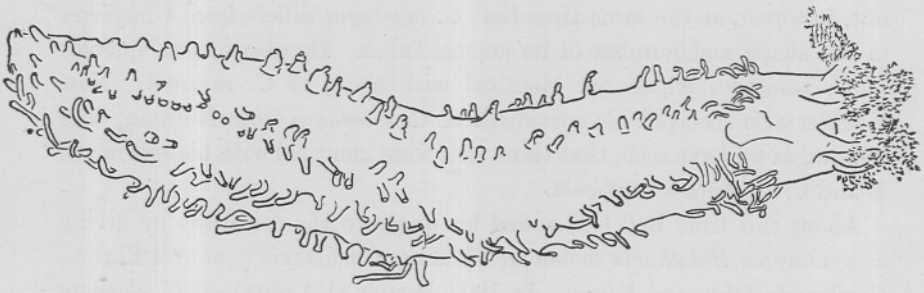

FIG. 9.—View of *Cucumaria saxicola*, showing the five ambulacral rows (× $\frac{3}{4}$).
The view is mainly lateral from the right side, but the posterior end of the animal is turned somewhat dorsalwards to show in this region the three ventral ambulacral rows. These rows are seen to consist of suctorial tube-feet. On the upper right side of the figure are seen the two dorsal ambulacra, the right one of which is continued in profile to the posterior end of the body; both rows are seen to consist merely of ambulatory papillæ, except at the anterior end, where there are a few suctorial tube-feet.

species of this genus occurring in this district, it was found that they fall into two groups, having the following characters :—

GROUP A. Species whose gonad consists of numerous short cylindrical tubes, and whose dorsal as well as ventral ambulacra have well-developed tube-feet.
In this group fall the species *normani*, *hyndmanni*, *elongata*. (Compare Fig. 10, p. 230.)

GROUP B. Species whose gonad consists of relatively few, large, club-shaped tubes and whose dorsal ambulacra contain mostly ambulatory papillæ, which are less numerous than the tube-feet in the ventral rows, but with a few definite tube-feet at the anterior ends. (See Fig. 9, p. 228.)
In this group fall the species *saxicola* and *brunnea*.

Now the genus *Colochirus* differs in the literature (9, p. 343) from the genus *Cucumaria* mainly in having ambulatory papillæ in the dorsal ambulacra. It is possible, however, that when the gonad in species of

Colochirus is examined it may be found to be similar to that in *C. saxicola* and *C. brunnea*.

With regard to the Group B given above, it is an interesting fact that Norman himself (2, p. 382) states that some of his specimens (which have been shown to belong to *C. saxicola*) would be placed by some naturalists in the sub-genus *Colochirus* merely on account of the characters of the dorsal ambulacra, and also that Hérouard placed what is almost certainly *C. saxicola* in that very genus as *Colochirus lacazei*. It is not improbable, therefore, that when the European *Cucumarians* are revised the whole of the genus *Cucumaria* may be divisible into two groups similar to those given above, and that those specimens having the characters of Group B may have to be designated as species of the genus *Colochirus*.

PART II.

ON THE OCCURRENCE OF *CUCUMARIA ELONGATA* DÜB. AND KÖR. AND *THYONE RAPHANUS* DÜB. AND KÖR. IN THE PLYMOUTH DISTRICT.

During the period from March, 1911, to Sept., 1912, numerous specimens of *Cucumaria elongata* Düb. and Kör. were obtained at various stations in the Plymouth district. These specimens were nearly all taken in a dredge with a fine-meshed net, worked from the Laboratory steamer *Oithona*. The depths from which these *Cucumarians* were dredged varied from about 5 to about 30 fathoms, and the nature of the bottom in which they were living was almost invariably muddy, but varying from fine mud in Plymouth Sound and off Rame Head, to muddy gravel in the region about 2 miles south of Wembury Bay, and to fine muddy sand on the Rame-Eddystone Trawling Ground. (See 16 and 17.*) There can be little doubt that *C. elongata* is fairly common in this district on all the muddy grounds, and is probably not uncommon on the fine sand of the outer grounds.

The captures of this species have been made at 15 stations within a small area, so that the distribution can be described with reference to the various grounds already defined in earlier volumes of this Journal (16* and 17) as follows :—

Plymouth Sound. On one occasion (18th May, 1911) 4 specimens

* See these references for a description of the grounds in the Plymouth district. Since those accounts were written in 1899 and 1904 there has been a good deal of mud deposited on the various grounds just outside the Sound from dredgings in the harbour.

were taken in one haul of the dredge in the middle of Plymouth Sound, while on the date 23rd March, 1911, one specimen was obtained similarly in the same locality. Many unsuccessful hauls have, however, also been made.

Off Rame Head 6 specimens were taken in the dredge in mud about 1 mile south of the headland. Five of these specimens were taken in one haul of about five minutes' duration.

From the region of the Mewstone "Amphioxus" Ground, between and about the points 1½ to 2 miles south of the Mewstone and Yealm Point, captures of *C. elongata* were made in the dredge on seven different occasions. On the 3rd June, 1912, 12 specimens were obtained in about half a day's work with the fine-meshed dredge. In all, about 20 specimens have been obtained from this ground.

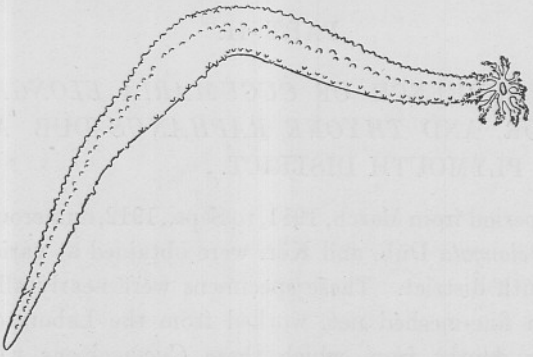

FIG. 10.—*Cucumaria elongata* well expanded, showing the tentacles and dorsal ambulacra (× 3/2).

Two specimens have been taken on different occasions on the Rame-Eddystone trawling grounds, both from a position about 5 to 5½ miles S. ½ E. of Rame Head.

The total number of specimens obtained from all the grounds is about 35. They varied in size from about 1·4 cm. long and 2·5 mm. broad to 6·6 cm. long and 9 mm. broad at the broadest part. The specimens when caught were U-shaped, or more or less S-shaped, with a tapering posterior end, and varied in colour from a purplish brown to a browny grey.

NOTES ON *CUCUMARIA ELONGATA*.

The discovery of this species in the Plymouth district is of some interest with regard to the unravelling of the synonymy of British *Cucumarians*. Bell in 1892 (11, p. 38) gives *C. elongata* Düb. and Kör.

as a synonym of *C. pentactes*, most of the specimens of which he records from Plymouth.

It has been shown in the foregoing pages that the Plymouth species called *C. pentactes* in 1892 is undoubtedly the same as Brady and Robertson's *C. saxicola*. This species is, however, totally different from *C. elongata* Düb. and Kör., as may indeed be gathered from the description of this animal given by Düben and Kören (14). Kemp (13) has recently given a good description of the external characters and spiculation of *C. elongata* Düb. and Kör. from Ireland. The Plymouth specimens agree well with Kemp's description and with that given by Düben and Kören themselves. There is thus no doubt that *C. elongata* is a good species and quite different from other Plymouth *Cucumarians*.

Some of the specimens obtained have been kept under observation alive for as long as nine months embedded in fine sand. In life the posterior end of the body, "the tail," protrudes above the surface of the

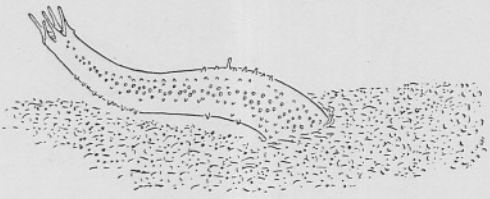

FIG. 11.—Drawing from life of the "tail" of *Thyone raphanus* protruding from the sand (× 4).

sand presumably for the purpose of respiration. (Comp. Fig. 11.) The body is bent in a U- or S-shaped fashion as was observed in the freshly caught animal. During the whole of the period these animals were kept the tentacles have rarely been seen above the surface of the sand. It is possible, therefore, that the animal feeds mainly by ingesting mud or sand, as it is apparently much too sluggish to search actively for food. The tentacles in this species are very short, as may be gathered from Fig. 10, which is a drawing of a specimen narcotized by menthol. In this figure is well shown the double rows of tube-feet near the middle of the body and the gradual passage into single rows towards both the tapering ends of the body.

It has already been noted that the gonadial tubes of this species are numerous and cylindrical, resembling those of *C. normani* both in shape and approximately in numbers. The retractors of the buccal mass are extremely short and altogether poorly developed.

The gonads of female specimens taken in June and July were found to contain nearly ripe eggs; in July, 1912, a specimen was obtained

with active sperm and an unsuccessful artificial fertilization tried. It is highly probable, however, that the species breeds a little later than this time of the year, as specimens taken in early May and September had only immature ova in the gonad.

ON *THYONE RAPHANUS* DÜB. AND KÖR.

Nine specimens of *Thyone raphanus* Düb. and Kör. were taken at various times between July, 1911, and July, 1912. These specimens were captured, except in one case, in the fine-meshed dredge in muddy sand or in muddy gravel in depths from about 12 to 30 fathoms. Four specimens were taken on one occasion 1½ to 2 miles S. of the Mewstone, and on another one specimen 1½ miles off Yealm Point. Two were obtained in July, 1911, about 3 miles S. of Rame Head, and two in May,

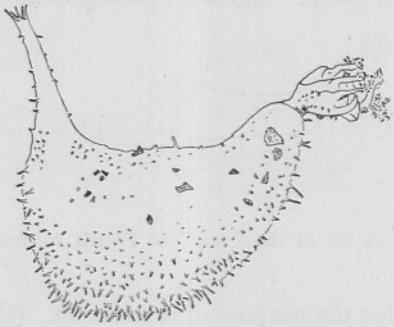

FIG. 12.—*Thyone raphanus*. The body portion was drawn from the living animal and the tentacles afterwards added from a preserved specimen (× ⅔).

1912, in a position 5 to 5½ miles S. ½ E. of Rame Head. In the same month one specimen was taken in the trawl on the inner portion of the Rame-Eddystone trawling grounds.

The specimens varied in size from 2·5 cms. long by 7 mms. wide at the widest part to 6·2 cms. long by 1·1 cms. wide, the measurements being taken from the preserved animals. Their general colour was of a creamy white, and when obtained from the dredge they were bent in the form of a U. In none of the specimens examined were ripe sexual products found, hence it is likely that breeding occurs during the winter months. The spicules from the skin, tube-feet, and tentacles agree closely with those given by Düben and Kören (14, Plate V, Figs. 49 to 55). There are, however, some spicules with bosses arranged concentrically around the foramina, but probably the Figures 50, 51, and 54 in the aforementioned plate are an attempt to represent these bosses. The calcareous

collar is shown in Fig. 13, from which it will be seen that it is very similar to the portion figured by Marenzeller (18): the connecting pieces are not calcified in the smaller forms. The polian vesicle is single and very

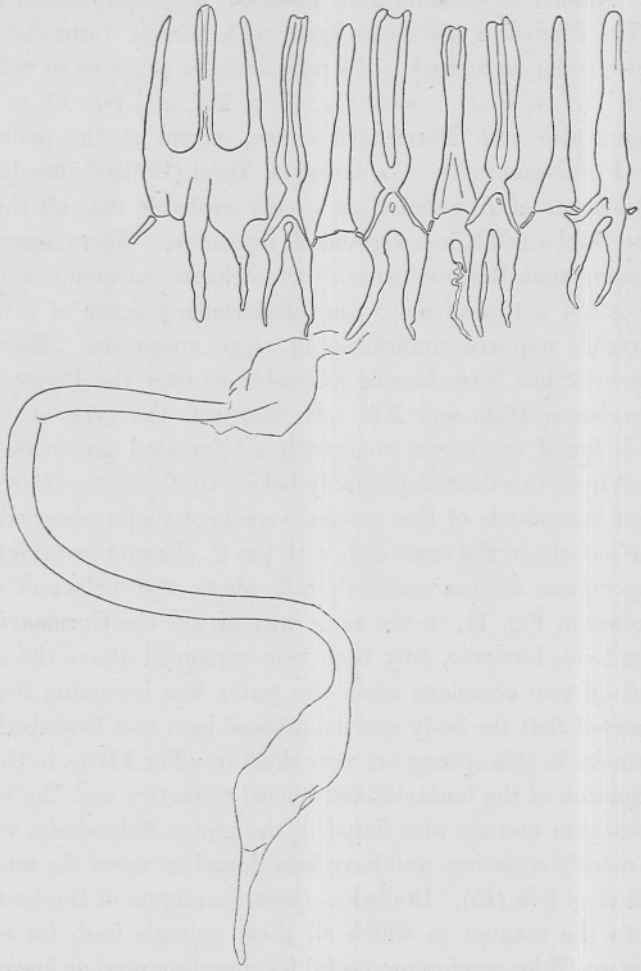

FIG. 13.—External view of the calcareous collar of *Thyone raphanus* Düb. and Kor. drawn from a glycerine-jelly preparation after separating the ventral piece from the adjacent right radial piece: the polian vesicle and the stone canal are shown attached to the collar* (× 9).

long, and longer in the larger than in the smaller specimens; in preserved specimens it may be dilated at the proximal or the distal end, or at both ends.

* The constituent pieces of the collar are somewhat delicate, so that drawings from potash preparations are liable to be inaccurate, inasmuch as the middle portion of the radials is very thin and might easily be abraded to give such a figure as is drawn by Barrois for *T. poucheti* (loc. cit.).

It is unfortunate that Düben and Kören did not figure the calcareous collar and polian vesicle of the type specimens, for Barrois has described a form which only differs from *T. raphanus* in having a bifurcated polian vesicle. Neither of these authors, however, found more than one specimen. The Plymouth specimens agree with Barrois' form except in the calcareous collar as figured by Barrois and the presence of tube-feet on the "tail" (cf. 6, Plate I, with Fig. 11, p. 231, and Fig. 13, p. 233), and they agree also with Marenzeller's form except in the polian vesicle as figured by Marenzeller. As, however, Théel (19) had already doubted the distinctness of *T. poucheti*, it is very probable that all these forms belong to Düben and Kören's species *T. raphanus*. There is some ground for believing that Barrois' figure of the delicate calcareous collar of his Thyone is not a typical one; and Marenzeller's figure of a bifurcated polian vesicle requires confirming in more specimens. Therefore for the present it has been deemed advisable to refer the Plymouth forms to *T. raphanus* Düb. and Kör. If, however, the type of the latter species is found to possess constantly a bifurcated polian vesicle, then the forms from this district probably belong to *T. poucheti* Barrois.

Several individuals of this species were kept under observation alive for some months in the same dish with the *C. elongata* mentioned above. These specimens maintained their tails above the surface of the sand, as is shown in Fig. 11, in the same way as did the *Cucumarian*. The tentacles have, however, only been seen expanded above the surface of the sand on two occasions when the water was becoming foul, and it was observed that the body was maintained bent in a U-shaped manner. The tentacles in this species are very short (see Fig. 12), as in *C. elongata*. This reduction of the tentacles and buccal retractors and the correlated tailed posterior end are also found in the group Malpodiida, which also inhabit muddy situations and have been found to ingest the muddy sand in which they live (15). Doubtless these characters of the tentacles are related to the manner in which all these animals feed, for short stiff tentacles would be much more useful for ingesting mud or fine sand than the long dendritic tentacles such as are found, for example, in some other species of *Cucumaria* and *Thyone*. Thus these mud-dwelling *Holothurians* form one more example of that interesting phenomenon in nature, namely, the occurrence of similar adaptations in different animals for performing the similar functions necessitated by a similar mode of life.

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