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OCCURRENCE IN JAPAN OF *DIADUMENE LUCIAE*, A REMARKABLE ACTINIAN OF RAPID DISPERSAL

BY

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(*With Plate IV, 1 Chart and 4 Text-figures*)

Diadumene Luciae is commonly known in America as "the orange-striped sea-anemone" and in Germany under the name of "Strandrose." The actinian is prominently characterized in its colouration and has frequently been a favourite object of laboratory study on account of its intense hardness. As to the migration of the actinian there has been an interesting problem, since VERRILL (1898) first described the species basing on specimens collected in Long Island Sound. He noted that the actinian at that time was found along the coasts from New Haven to Woods Hole, but no individual was observed there between 1871 and 1887. Taking into consideration his own observations together with VERRILL's note, G. H. PARKER (1902) concluded that the species had made a rapid migration first eastward from New Haven, Conn., and then northward to Salem, Mass., having covered the distance between these two extremes probably within about ten years. He says that five localities on the coasts fall into the following series, when arranged according to the sequence of earliest occurrences; New Haven (1892), Newport (1895), Woods Hole (1898), Nahant (1899) and Salem, Mass. (1901). Since that time the animal has been studied by several American investigators concerning its variation, asexual

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reproduction, regeneration and behaviours. On the other hand, C. L. WALTON (1908) put on record the discovery of the actinian from Plymouth, England, and stated that it had already been found in the Millbay Docks in 1896 and for the first time identified by Davenport in October, 1902. In 1919 D. W. DAVIS who studied the asexual reproduction of the actinian wrote that Prof. H. B. TORREY called his attention to its occurrence in San Francisco Bay as early as 1906 and Prof. C. W. HARGITT (1914) reported its residence at Plymouth in 1908 and at Naples in 1911. In 1921 PAX reported the sudden occurrence of the species on the western German coast and arrived at the conclusion that it had probably been transferred there by ships from another locality. As the postscript of his paper he further stated that the species was already known in Helder, Holland, in 1913. In the same year McMURRICH published a detailed description on the internal anatomy of the species, using many individuals from different localities. In this paper he reported that in the summers of 1909 and 1911 he collected at the Canadian Biological Station at Departure Bay, on the east coast of Vancouver Island, some actinians which were probably identical with the above mentioned species in reference to their agreement in colouration, external and internal structures. He was confident that they had not occurred there in the earlier years, because he had never observed them before. As the result of a comparative study of the anatomy of specimens from Plymouth, England, from the Pacific and from the Atlantic coasts of America, he made clear that they were all referable to the same species. Besides, he pointed out that the species does not belong to the genus *Sagartia,* but is more likely to be eligible for the genus *Chrysoela* proposed by GOSSE (1860) because of the possession of a well-developed fosse, the absence of a mesogloeal sphincter and the presence of only six pairs of perfect mesenteries. As to the distribution of the sea-anemone he put forth his conclusion that the actinians collected by A. AGASSIZ from the Gulf of Georgia in 1859 and figured by him, furnish certain proof that the form had been in existense on the Canadian Pacific coast for over sixty years

at least. He suggested further, that as AGASSIZ's actinians were probably *Diadumene Luciae*, the Pacific might have been the original home of the species. McMURRICH states also (p. 737), "If further observations should reveal its presence on the Asiatic side of the Pacific, the probability of this suggestion would be greatly increased." In 1925 PAX used the name *Chrysoela Luciae* for the actinian following McMURRICH (1921). In this year T. A. STEPHENSON referred the species to the genus *Diadumene* and PAX (1928) afterward agreed with him in adopting the name *Diadumene* for German individuals. In September, 1930, at the 11th Zoological Congress in Padua, PAX told me that he had observed the species near Venice on the Italian coast of the Adriatic Sea.

There has been commonly known in the neighbourhood of the Misaki Marine Biological Station, Japan, an actinian of olive coloured body with vertical orange stripes. It was for the first time described by S. ÔMORI (1895) as *Sagartia* sp. In his descriptions and figures he clearly indicates the presence of the vertical orange stripes on its dark green body wall. From other characters described by him such as the possession of acontia and six pairs of perfect mesenteries, there remains no room to doubt the identity of these actinians with *Diadumene*. In respect to the number and arrangement of the orange stripes on the body wall, Ômori divided individuals occurring in Misaki into the following four groups.

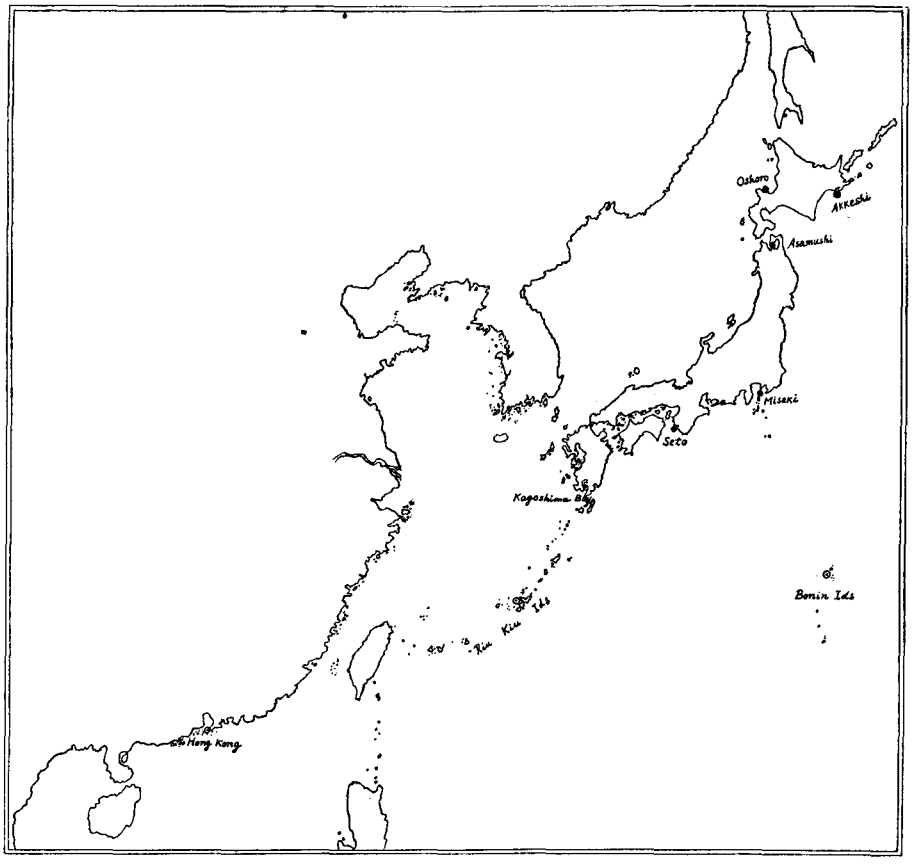
1. Individuals with 12 orange stripes on the brownish dark green wall, each stripe corresponding to the interseptal (endocoelomic) chamber of the first tentacle.
2. Individuals with 48 yellow stripes, making 24 pairs on the deep olive body wall, each stripe corresponding to the interseptal (endocoelomic) chamber of the fourth tentacle.
3. Individuals with 48 yellow stripes on the dark brownish green body wall, each of the stripes corresponding to a mesenterial chamber.
4. Individuals without stripes. Body wall dark greenish and somewhat brownish.

In 1911 H. ASANO published a report on several actinians found in Misaki. In his paper he gave descriptions and figures of an actinian under the name of *Sagartia leucolena* VERRILL. Instead of being similar to *Sagartia leucolena,* the actinian quite agrees with *Diadumene Luciae* in its colouration and structures so far as described by him. According to the number of orange stripes on the body wall, he divided his individuals into three varieties; a. Individuals without orange stripes, b. Individuals with 12 orange stripes, and c. Individuals with 48 orange stripes.

The reason why ASANO identified his specimens with *Sagartia leucolena,* which is so different in form and colouration from *Diadumene Luciae,* is not clear, but *Sagartia leucolena* occurring on the Atlantic coasts of America reaches 63 mm in height, though its diameter is 10 mm. VERRILL (1896) writes about the species as follows, "It is easily distinguished from *S. Luciae* by its very elongated, often flaccid, column, which is transparent flesh-colour or salmon-colour, and by the pale translucent disc and tentacles, without any strong markings." Moreover, ASANO's descriptions agree mainly with my examples of *Diadumene Luciae* both in external and internal characters, so there seems to be no reason to hesitate to refer his *Sagartia leucolena* to *Diadumene Luciae.*

The writer happened to find in the summers of 1927 and 1928 several small individuals in the vicinity of the Asamushi Marine Biological Station and also in September, 1931 and July, 1932 some young ones near the Akkeshi Marine Biological Station. Moreover, through the kind information of Prof. K. OGUMA and Mr. H. YAMAGUCHI I learned that the species occurs about the Oshoro Marine Biological Station. Lately through the kindness of Prof. T. KOMAI of the Kyoto Imperial University and Mr. S. M. SHIINO of the Seto Marine Biological Laboratory it became clear to me that the actinian is commonly found on pebbles near the laboratory.

Therefore, the distribution of the actinian so far as brought to light can be summarized as follows:



Distribution of *Diadumene Luciae* (VERRILL) on Asiatic coasts of the Pacific; ● certain occurrence, ⊙ somewhat uncertain occurrence.

In Europe; Plymouth (England), Helder (Holland), Büsum (Germany), Naples and Venice (Italy).

In America; (in the Atlantic); from New Haven, Conn., to Salem, Mass. (in the Pacific); Departure Bay, the Gulf of Georgia and San Francisco Bay.

In Japan; Akkeshi, Oshoro, Mutsu Bay, Misaki and Seto.

Besides these localities, McMURRICH (1921) suggested that *Sagartia lineata* described by VERRILL (1869) from Hong Kong harbour might be the Asiatic representative of the species. According to his descriptions and figures, out of six species of *Sagartia* reported

by VERRILL (1869) the four, *Sagartia radiata* from Kagoshima Bay, *Sagartia lineata* from Hong Kong harbour, *Sagartia* sp. from the Bonin Islands and *Sagartia* (?) *Napensis* from the Riu Kiu Islands may be reduced to the single species *Diadumene Luciae,* though their descriptions are only limited to the external characters and are insufficient conclusively to determine the specific name.

If the writer's determination is admittable, the distribution of the species will be extended from Seto southward to Hong Kong, having Kagoshima Bay and the Riu Kiu Islands as intermediate localities on the Asiatic coasts, and the Bonin Islands as a junction-point from the Asiatic to the American Continent. Inferring from the intense robustness and the especial power of rapid dispersion, it is not at all impossible to suppose the above mentioned probability.

Before entering upon further discussion on the distribution of the species I want to describe some morphological points of Japanese individuals. As the actinian occurs abundantly in Misaki, observations were mainly based on those found there.

On account of the very great contractibility of the species, the form is extremely variable; when well expanded it becomes cylindrical, but when contracted it is somewhat low-pyramidal. They are in Misaki generally 15–25 mm in height, 10–15 mm wide in oral disc and 15–20 mm wide in pedal disc. Tentacles, when well-expanded, are of about the same length as the height. So far as I have examined, specimens from Asamushi, Akkeshi and Oshoro are much smaller than those from Misaki and barely reach 10 mm high and 15 mm wide. Comparing Misaki specimens with the descriptions based on American and European ones, it is obvious that the former attain a far larger size than any from the latter localities. The body wall is smooth but provided with many cinclides which are distributed on and near the orange stripes. The cinclides are not visible but white acontia are often freely emitted through them from the body wall. In the central portion of the oral disc a mouth opens which is slit-like and provided with elevated and laterally folded lips. Between the base of the outermost tentacles

and the apparent margin of the column there is a deep fosse. The tentacles, tapering, long, slender and very contratile, count 96 in full grown individuals and are arranged in four circlets, with longer ones in the inner portion. The number of them in each circlet, from the inner to the outer, is 12, 12, 24, and 48. The colouration is highly variable in individuals. The tentacles are dark green, brownish green or most commonly greyish brown. The oral disc is generally deeper in colour than the tentacles and greyish with yellow radial lines. The oral lips, brown, light brown or pinkish brown, are often sprinkled with white spots. The body wall is dark olive or brownish olive, with or without yellow or orange vertical stripes. I also found three variations as indicated by the former Japanese investigators:

1. Individuals with homogeneously olive body wall with 12 vertical orange stripes, each corresponding to the endocoelomic chamber of the fourth tentacle (Pl. IV, Fig. 1).
2. Individuals with olive body wall with 24 pairs of yellow stripes. In those specimens the lower half of the body wall is generally somewhat tinged with light brown (Pl. IV, Fig. 2).
3. Individuals with body wall which is destitute of vertical orange stripes. In the actinians the upper half is dark olive, while the lower half is dark brown (Pl. IV, Fig. 3).

The young specimens, less than about 5 mm wide and 7 mm high, are generally more brown than olive. Their vertical stripes are less than 12 and vary in number from 6 to 12; generally the smaller ones have fewer stripes. In well-developed specimens, they are also somewhat variable, though those with 12 and 48 (in 24 pairs) are most common; the stripes are often a few more than 12, or several more or less than 48.

The internal structures generally coincide with the number and arrangement of the orange stripes on the body wall; the young specimens with an irregular number of stripes are subject to a good deal of variation in arrangement of mesenteries (Pl. IV, Figs. 4 and 6),

while well-developed individuals with 12 or 48 stripes are, save a few exceptional cases (Pl. IV, Fig. 5), usually evidently hexamerous in their internal organization. The irregularity of mesenteries in young individuals is probably due to the asexual fission which was often observed in American specimens, though I can not yet observe the actual evidence of the fact in living actinians of Japan.

The well-developed Japanese actinians, in spite of the disparity of the orange stripes (0, 12 or 48), agree with each other in the internal structure and are all hexamerous. The following descriptions are based on these well-developed actinians, about 20 mm high and 15 mm wide. The mesogloea of the fosse is thin and absolutely bare of sphincter. On the surface connected with the endoderm there are often to be seen faintly developed diffused muscles. The tentacles are composed of three layers; the ectoderm

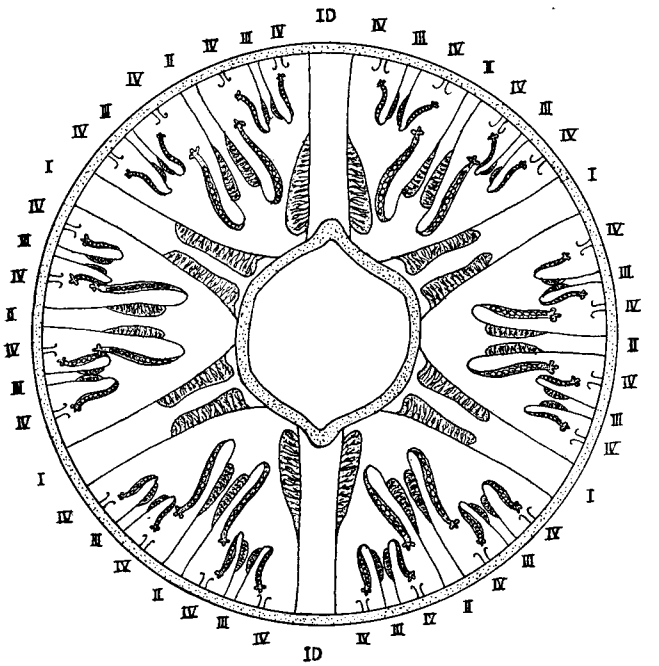


Fig. 1. Diagram of transverse section of a normal individual showing the typical mesenterial arrangement. ID ; directive mesentery pair, I ; perfect mesentery of the first cycle, II ; mesentery of the second cycle, III ; mesentery of the third cycle, IV ; mesentery of the fourth cycle.

thickly armed with elongated spirocysts, the mesogloea with muscle fibers in the outer portion and the endoderm rich in granulated gland cells. The actinopharynx is rather deep and furnished with two siphonoglyphs. The mesenteries are in 48 pairs, divided into four cycles which are, when arranged according to age, 6, 6, 12 and 24 in number. Out of these 48 pairs of mesenteries six are perfect ones, of which two are directives. The perfect mesenteries are always sterile and provided with well-developed muscle pennons which especially develop near the portion adjacent

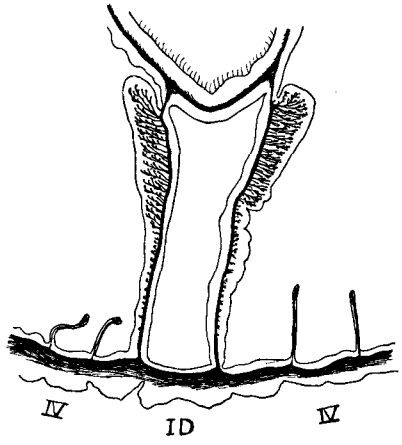


Fig. 2. Transverse section of a pair of directive mesenteries ID ; IV, mesenteries of the fourth cycle. ×30.

to the actinopharynx wall. The mesenteries of the second cycle are generally similar to the former but are in the inner end provided with mesenterial filaments which join with the portion having well-developed muscle pennons by means of a thin narrow filamentous part. In the proximal part of the mesenterial filaments ova and testicular saccules are arranged in a row. The terminal portion of the filaments is three-lobed and provided with many granulated cells. The mesenteries of the third order are smaller than the second but mainly of the same structure. The mesenteries of the fourth circlet

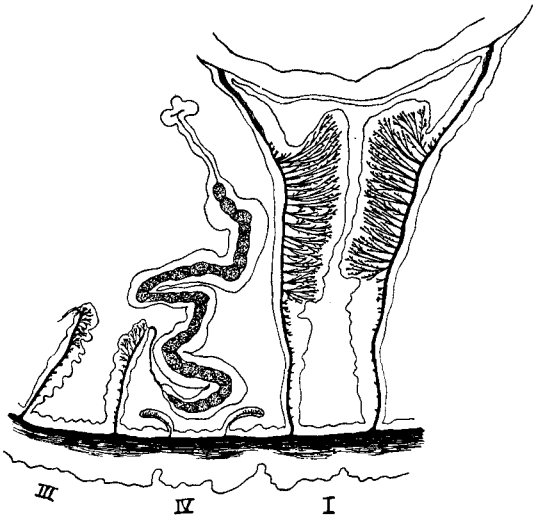


Fig. 3. Transverse section of mesenteries, I, III and IV showing mesenteries of the first (perfect), the third and the fourth cycle respectively. ×30.

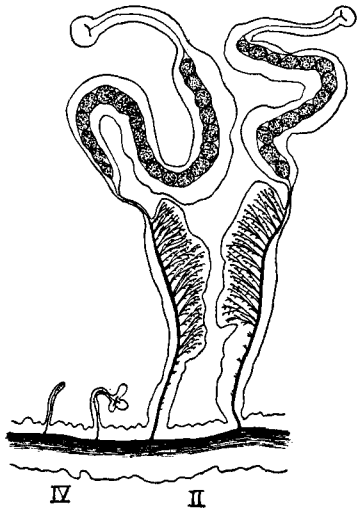


Fig. 4. Transverse section of a pair of mesenteries of the second cycle (II) with a pair of the fourth mesenteries. ×30.

are small, always devoid of gonads and mostly bare of mesenterial filaments, while the retractor develops faintly in its mesogloea. The acontia are present near the basal portion in the stomach, having a T-formed mesogloea in them.

From the description above given, the Japanese actinians seem to be undoubtedly referable to *Diadumene Luciae,* but they have some noticeable differences from American and European specimens.

1) In the first place the average size of the Japanese specimens is found to be considerably larger than that of the American and European. As to the American specimens from the Atlantic, VERRILL (1898, p. 493) states, "Height of column usually about 5 to 8 mm; diameter 4 to 6 mm; length of tentacles 6 to 10 mm." DAVIS (1919, p. 163) who examined many individuals from the Atlantic coasts of America indicates, "Specimens attain rarely a length of 20 mm or a diameter of 15 mm, but in no case are these extreme dimensions approached simultaneously in the same individual.

In the majority of specimens the more extreme measurement does not exceed half the stated maximum." About the actinians from Plymouth, WALTON (1908) describes, "Height of column usually 5 or 6 mm, but I have seen adults when elongated as much as 10 mm in height." According to PAX (1921, p. 162), the individuals from the German coast measure as follows, "Der Durchmesser des lebenden Tieres beträgt in ausgestrecktem Zustand durchschnittlich 5 mm, die Höhe des Scapus 9–10 mm, diejenige des Capitulum 3 mm. Die längsten Tentakel erreichen eine Länge von 7 mm." As to the Japanese specimens, ÔMORI (1895) gives the following measurements, height 20–30 mm and width 15–25 mm. ASANO (1911) says, "20–30 mm high and 15–25 mm wide." My observations on specimens from Misaki coincided with the description of these two investigators. It is also noteworthy that MCMURRICH (1921, p. 735) pointed out the average larger size of specimens from the Pacific coast of America than of those from the Atlantic and from Plymouth. As the result of the internal anatomy, Misaki specimens also exceed in the number and degree of development of mesenteries those from America and Europe. The difference in magnitude and degree of development is often observed in other Coelenterates[1] occurring in different localities but referable to a single species. For example the stalked medusae, *Haliclystus auricula* and *Sasakiella cruciformis*, abundant and larger in size in the northern part of Japan, are comparatively small in number and size toward the southern part of the country.

2) In European and American individuals the fission frequently occurs, but, so far as I am aware, it could almost never be seen in well-developed specimens from Misaki, though the process is also possible from sections made of young ones in the same locality. The mesenteries of well-developed actinians are in typically hexamerous arrangement without any sign of fission. The gonad developed at first in young specimens only in the imperfect

1) T. UCHIDA: Short Notes on Medusae, 2, Relation of Size and Locality. Ann. Zool. Jap., vol. 11, p. 375–376, 1928.

mesenteries of the second cycle and in well-developed ones in the mesenteries of both the second and third cycles.

3) The orange stripes in American and European individuals are extremely variable in number. DAVENPORT (1903) who counted them in about 751 individuals states, "The number varied from 0 to 20." In my young examples from Akkeshi and Asamushi some were found with 0–12 stripes, but in well-developed specimens these stripes numbered generally 0, 12 or 48 as stated before. Those with 20 stripes observed by DAVENPORT were probably to be fissuerd in future. Therefore, the main difference of the Japanese actinian from the American and European lies in the presence of individuals with 48 yellow stripes which are arranged regularly in 24 pairs.

Judging from the facts above given, it seems to me that the species proliferates asexually in the young stage and reproduces sexually in the adult. In this way it develops in Misaki to the full-grown stage, while in Akkeshi, Asamushi, and also in America and Europe it always remains in an incomplete state of development. Among the specimens so far studied in detail, those from Misaki are from the most southern point. Moreover, the presence of 48-striped individuals and the abundant occurrence of the species in Misaki already early in 1895 probably are actual evidences in favour of McMURRICH's suggestion that the actinian had its original home in the Asiatic coast. Furthermore, it seems to be in accord with PARKER's opinion that the species was introduced into the North Atlantic coasts of America from a certain southern coast by some accident. Now that it has become more probable that Asia is the original home of the species, it is very important in respect to its distribution to ascertain if the actinians described by VERRILL from the Bonin Islands, the Riu Kiu Islands and Hong Kong are to be referred to the present species.

As to the intense persistence of the actinian against changes of temperature and salinity, VERRILL (1898), PARKER (1902) and PAX (1921) have already reported.

In closing it must be very interesting to note the influence of the great earthquake on the actinian, which occurred around the Bay of Tokyo on September 1, 1923. As the result of elevation due to the earthquake many animals near the upper tidal line were destroyed. For instance amongst actinians, *Actinia mesembryanthemum* (= *A. equina*?), once so prevalent in the neighbourhood of the Misaki Marine Biological Station, has since then suddenly become all but extinct there; *Cribrina artemisia* and *Anthopleura* spp. have considerably decreased in number, while the present species is still very abundant in slight depressions and crevices on rocks adhering to stone, associated with the rock barnacles (*Balanus* sp.) and is probably increasing year by year.

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Plate IV

Explanation of Plate IV

(*Diadumene Luciae* VERRILL)

Fig. 1. Individual with 12 orange stripes $\times 2$.

Fig. 2. Individual with 48 (in 24 pairs) orange stripes $\times 1$.

Fig. 3. Individual without orange stripes $\times {}^{3}/_{2}$.

Fig. 4. Transverse section of a young specimen with abnormal number of mesenteries $\times 22$.

Fig. 5. Transverse section of an abnormal specimen with 5 pairs of perfect mesenteries $\times 6$.

Fig. 6. Transverse section of a young specimen with abnormal number of mesenteries $\times 22$.

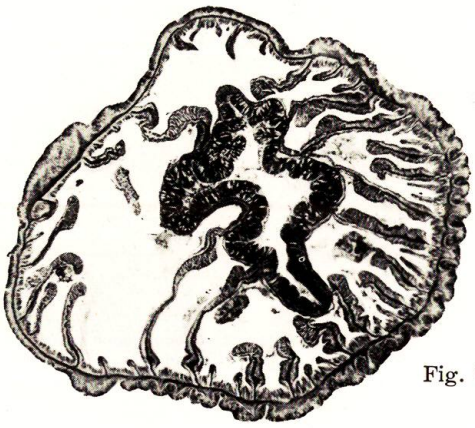


Fig. 6.

Fig. 1.

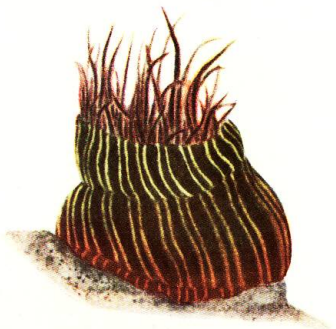
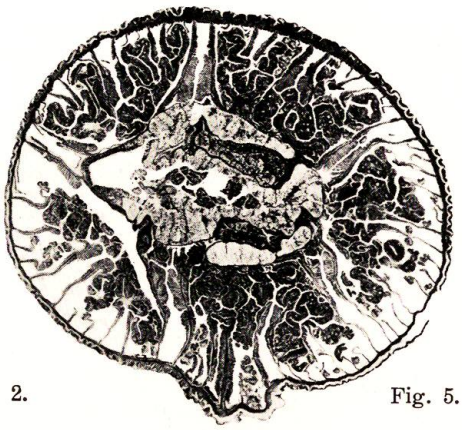


Fig. 2.



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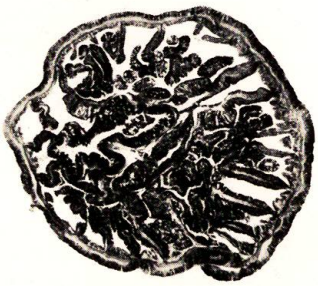

Fig. 4.

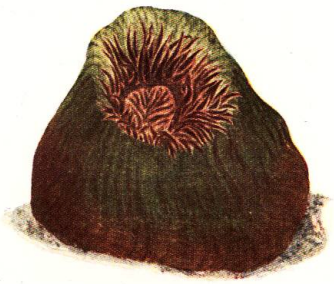

Fig. 3.

T. Uchida: Occurrence in Japan of Diadumene Luciae.

Y. Uchida del. et H. Yamaguchi photo.