ASEXUAL REPRODUCTION IN THE STARFISH, *SCLERASTERIAS*.

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In sea stars, self-division involving the disk occurs much more rarely than autotomy of rays only. The first condition, termed fissiparity, is a form of asexual propagation and in the Asteriidæ is characteristic of three genera, namely, *Coscinasterias* (both the *calamaria* type and the *tenuispina* type), *Sclerasterias*, and *Stephanasterias*. In the last genus asexual reproduction appears to be fully as important as gametic. In *Linckia*, belonging to a different order, an entire animal may be regenerated from a cast-off ray. The curious comet forms originate in this manner.[2]

In *Coscinasterias* and *Stephanasterias* fissiparity persists in adult life, but in *Sclerasterias* [3] it is strictly confined to a very immature stage, in which the number of rays is predominantly *six*, whereas in the adult it is five. Furthermore these young differ so

[1] From the Hopkins Marine Station of Stanford University.

[2] For figures see Fisher, "Asteroidea of the North Pacific," Bull. 76, U. S. Nat. Mus., 1911, plate 48, Figs. 1 and 2.

[3] *Sclerasterias euplecta* is figured in Fisher, "The Starfishes of the Hawaiian Islands," U. S. Fish. Comm. Bull. for 1903, part 3, plate 42, Figs. 1 to 4. Figure 3 is in the intermediate stage. The closely related *S. hypacantha* is figured in Fisher, "Starfishes of the Philippine Seas," Bull. 100, U. S. Nat. Mus., 1919, pl. 141, Figs. 2, 3.

The species of *Sclerasterias* resemble *Marthasterias glacialis*, the well-known European sea star. The genus is a fairly homogeneous group of thirteen known species, related to *Coscinasterias*. Its type, *S. guernei*, was supposed to be a highly peculiar small species but proves on examination to be immature and congeneric with *Eustolasterias* Fisher, a name of later application. From among the thirteen species may be mentioned: *S. alexandri* (Ludwig), Bay of Panama; *S. contorta* (Perrier), Florida to Barbados; *S. euplecta* (Fisher), Hawaiian Islands; *S. eustyla* (Sladen), Tristan da Cunha; *S. guernei* Perrier, genotype, Bay of Biscay; *S. mollis* (Hutton), New Zealand; *S. tanneri* (Verrill), Atlantic coast of United States; *S. heteropæs* Fisher, new species, Monterey Bay, California.

Perrier states that his genus *Lytaster* is fissiparous. I can confirm this from an examination of the types, at Paris. But the types are only very immature specimens of *Coscinasterias tenuispina*.

For a synopsis of the family Asteriidæ, see Fisher, *Annals and Mag. of Nat. Hist.* (9), Vol. 12, 1923, pp. 247, 595.

markedly from the adult [4] that they have been described as of a different genus. I have found this condition in three species: *Sclerasterias euplecta* (Fisher), *S. heteropæs*, new species, and *S. alexandri* (Ludwig). The young of the last was described by Ludwig as *Hydrasterias diomedeæ*, while *Hydrasterias richardi* (Perrier) is the fissiparous phase of an unknown adult.

In this stage the sea stars actively divide by splitting into equal halves. The number of these divisions is not known. In one instance, in *S. euplecta*, a division has taken place nearly at right angles to the plane of the prior fission. Since adult *Sclerasterias* are almost invariably five-rayed and the majority of the young are six-rayed, an arm is lost somewhere in the process—probably at the last division. These dividing young range in size from R 8 mm.[5] to R 20 mm., the latter being unusually large. R 15 mm. is nearer the normal maximum size of fissiparous individuals.

The species of *Sclerasterias* live in deep water, usually among rocks. All the specimens of fissiparous young which I have seen were taken by means of hempen tangles. The data for the following notes are admittedly incomplete. There is every reason to believe, however, that many years will pass before more material is forthcoming.

Of the thirty-six young of *S. euplecta* examined, nine, or one fourth, have five rays. None of these show signs of fissiparity although two have lost individual rays. All of the twenty-six fissiparous specimens have six rays. Of these six rays, three are usually smaller and represent the regenerating half.

In *S. heteropæs*, fourteen of the young have six rays and only one has five rays. Twelve out of these fourteen six-rayed specimens have four madreporites symmetrically placed, with two on either side of the plane of fission (the two opposite interradii through which the disk splits being without them). Thus each half, after fission, has 2 madreporites—one on either side of the

[4] It is not essential to introduce data to prove that these specimens are really young *Sclerasterias*, although there is ample evidence. In the fissiparous stage the crossed pedicellariae (which are like those of the adult) are not concentrated in circumspinal wreaths as in the adult, but are scattered between the spinelets. The latter are short, uniform, and two to four on each median radial plate and two or three on each superomarginal plate. In the adult only each alternate plate of the two series mentioned carries a single spine. The extra spines are absorbed.

[5] *R* is the distance between the center of disk and tip of ray—the major radius.

central ray of the triad (Figs. 1–3). The exceptions are a tiny symmetrical specimen with R 7.5 mm., on which I can find only one madreporite; and a specimen with 2 pores on the regenerating

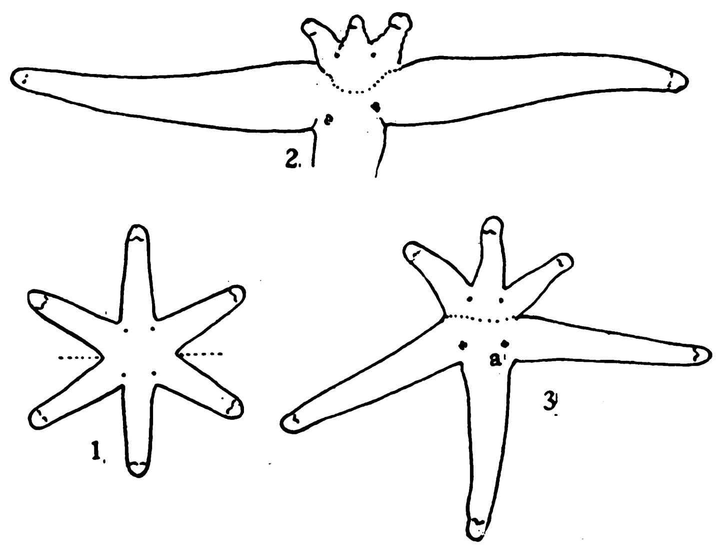

FIG. 1. *Sclerasterias euplecta.* The smallest symmetrical six-rayed specimen *R* 5.5 mm. The dotted lines indicate plane of cleavage. The four madreporites are indicated by dots; × 3.

FIG. 2. *Sclerasterias heteropæs.* Individual regenerating three new rays and two new madreporites; × 3.

FIG. 3. Same; a more advanced stage. In one specimen similar to this the madreporite *a* is lacking; × 3.

half and only one on the original half (Fig. 3). *S. euplecta* has three or four madreporites in regenerating material where the new rays are large enough to have developed pores.

The only five-rayed specimen of *S. heteropæs* has two madreporites in nearly opposite interradii. Of the nine five-rayed examples of *S. euplecta*, eight have one madreporite and one has three madreporites (which are smaller than the single madreporite of the other five-rayed specimens).

It is clear that active fissiparity is correlated with six rays and with usually four symmetrically placed madreporites; for none of the five-rayed examples shows evidence of having split through the disk. In these only separate rays have been shed as in ordinary autotomy, the disk remaining entire with the five oral angles uninjured. In fissiparity two opposite oral angles are split neatly in twain.

The location of the madreporites with reference to the plane of splitting would provide two directly opposed "physiologically anterior" points (Cole) and would thus automatically favor an equal splitting of the disk. Crozier (20) regards the multiplication of madreporites at separated points on the disk of *Coscinasterias tenuispina* as furnishing an assurance that portions of the body separated by autotomy will each be provided with a madreporic canal. This seems reasonable. However, a large, non-fissiparous species, *Acanthaster planci*, with upward of sixteen rays has four to eight madreporites.

The utility of several madreporites in fissiparous species would appear to be clear. But as to origin, it is not evident in *Sclerasterias* that the extra madreporites are solely post-larval developments as a preparation for fission. Furthermore we have a transitory post-larval hexamerous symmetry to account for in a characteristically pentamerous genus. The six-rayed young with four madreporites may have descended from larvæ with four hydropores. If so it is likely that we have in nature the sort of hydropore duplication reported by Newman in laboratory cultures of *Patiria miniata* (Newman 21, 21*a*). This physiological twinning in the larva may be here a normal precursor to a subsequent post-larval "untwinning," by which the six-rayed, four-pored, fissiparous young becomes a five-rayed, non-fissiparous adult with one madreporite. [I have specimens showing this last stage, *before* the spines and pedicellariæ have assumed the fully adult reduction and concentration.] In other words some of the incentive to splitting may be due to a sort of physiological duality locked up in the young with six rays. The five-rayed young with one madreporite would naturally be derived from larvæ with one hydropore. Possibly the five-rayed young with two and three madreporites are descended from incompletely twinned larvæ; or again, they may already have accomplished the reduction division without showing outward signs.

Although the mechanics behind this curious condition are as yet material for speculation, the phenomenon itself seems to produce a fairly definite asexual generation following close on the heels of the larval stage. This asexual mode of reproduction is associated with an abnormal symmetry for the genus.

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