

RESTORATIVE REGENERATION IN NATURE OF THE STARFISH *LINCKIA DIPLAX* (MULLER AND TROSCHEL).

BY VERNON L. KELLOGG, STANFORD UNIVERSITY, CALIF.

On the surface of the coral reefs guarding the harbor of Apia (Samoa) the five-rayed starfish, *Linckia pacifica*, with its long, slender, smooth, sky-blue arms, is the most conspicuous and abundant echinoderm in a place where echinoderms abound. Associated with it, and similarly blue and conspicuous, although smaller,

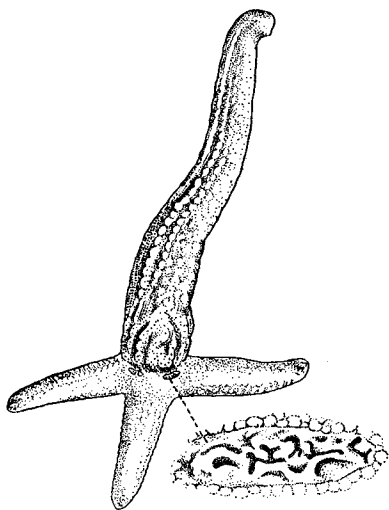


FIG. 1. *Linckia diplax*, regenerating from a single arm; note these new arms and new disc with madreporites.

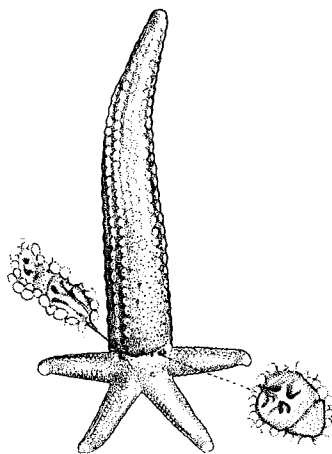


FIG. 2. *Linckia diplax*, regenerating from a single arm; note four new arms and new disc with madreporites.

is the species *L. diplax*. Both for number of species and wealth of individuals, the Apia reefs are distinguished by their starfish, sea-urchin and holothurian fauna. In collecting on these reefs during several weeks in the summer of 1902, as a member of

the U. S. Bureau of Fisheries' Samoan Explorations party, my attention was particularly attracted by the many examples of starfishes with regenerating arms, and I gave some special care to picking up such specimens. From this material the figures here presented have been drawn and in themselves tell how effectively this capacity for restorative regeneration obtains in this species.

Morgan calls attention in his "Regeneration" (1901, p. 102 and elsewhere) to the assertions of some authors that starfishes

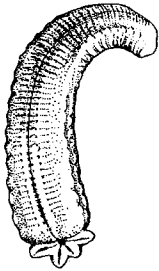


FIG. 3. *Linckia diplax*, regenerating from a single arm.

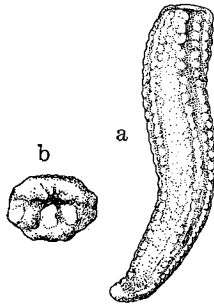


FIG. 4. (a) *Linckia diplax*, a single arm broken at both ends regenerating. (b) Aspect of proximal end of arm.

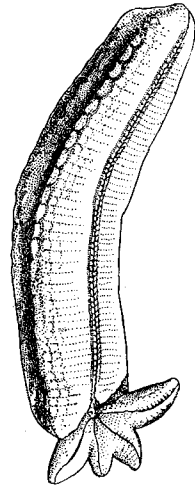


FIG. 5. *Linckia pacifica*, regenerating from a single arm, broken off obliquely from the original disc; note four new arms and disc, the outer arms larger than the two inner ones.

can regenerate a new disc and other arms from an arm torn off without any part of the disc attached, and to the denials by other authors that such radical restoration can take place. In the case of *Linckia diplax* there seems to be no doubt of the capacity of an arm torn off at some distance from the disc to regenerate a complete new animal from its proximal surface. The possibility that these arm pieces were thrown off by autotomy instead of being torn off by enemies may be noted, but such a condition makes the

regenerative phenomena none the less interesting. I have seen no example of the regeneration of several new arms (or a new disc and arms) from the distal end of a mutilated arm, as observed by the Sarasins in *Linckia multifera* (Ergeb. Naturforsch. auf Ceylon, 1884-85, I, Wiesbaden, 1888). In all cases of regeneration from the distal end of an arm noted among the Apia reef starfishes, simply a continuation, in straight line, of the tapering tip occurred. Among the figures will be noted the illustrations of three specimens in which the regenerating arm has had its distal end

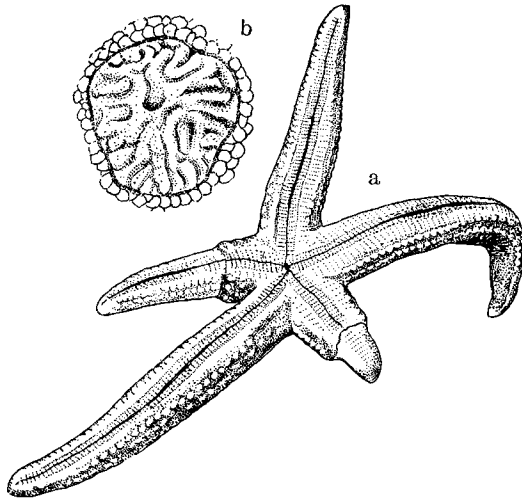


FIG. 6. *Linckia diplax*, (a) a specimen regenerating parts of two arms: (b) the aspect of a normal madreporite (compare with the regenerated madreporite shown in figures 1 and 2).

torn off (or thrown off) as well as having been itself broken off from its basal extremity, and thus freed from the rest of the body to which it originally belonged. In all of these cases of mere segments of a single arm regeneration is proceeding at both mutilated ends.

In Figures 1 and 2 a new mouth and both¹ madreporites are in the regenerated part. In Figure 3 a new mouth has been already regenerated, but no madreporite as yet. In Figure 4 is shown an

¹*Linckia diplax* is characterized by the possession of two madreporites.

arm torn off at some distance from the disc, just beginning to regenerate. The cut end has "calloused" over, apparently by the inbending of the edges of the body wall, but in the center is left a small opening (serving as mouth?). No protuberance indicating new disc or arms has yet appeared. The arm segment, which is regenerating at both ends, shown in Figure 5, is of another species of *Linckia*, probably *pacifica*, and had an obliquely cut surface at the proximal end, and the two outer arms of the four regenerating ones, that is, those nearest the parent arm, are about twice as well developed (as far as size goes) as the other two. No madreporite is yet developed on the new discal portion. The specimen illustrated in Figure 1 is regenerating but three new arms instead of the normally missing four. In all the specimens illustrated by Figures 1, 2, 3, 4 and 5 the arms were undoubtedly broken off without any part of the disc attached.