

An Arm-Stump Specimen of Archaster angulatus Müller & Troschel, **1842 (Echinodermata Aseroidea)**

Summary

- We report a specimen of Archaster angulatus Müller & Troschel that has an arm stump that definitively healed in left-right fashion and did not regenerate the arm tip.
- Recurrence (N = 3) of this distinctive stump condition in taxonomically distant Archaster, Linckia, and Asterias indicates that pattern regulation is involved.
- This stump condition and its failure to regenerate indicates that positional information in the starfish arm is left-right symmetrical and that distal outgrowth of the starfish arm is by intercalation between a distal signaling center and the last-formed section of arm.



(1) Archasteridae, (2) Ophidiasteridae, and (3) Asteriidae (cladogram of asteroid families from Gale 2011)

Methods and materials

- USNM 1139740, dry; healed (non-regenerating) arm-stump specimen of Archaster angulatus, det. and coll. John Keesing; 31° 47' 37" S, 115° 43' 1.4" E, Indian Ocean, near Fremantle, West Australia; 8m depth; 11 Jan 2009.
- Control specimens: *A. angulatus* with regenerating arm tips were observed and photographed in the field. See also Lawrence et al. 2010.
- Terminology/Abbreviations: IM, IMM = inferomarginal, inferomarginals; SM, SMM = superomarginal, superomarginals. Ray



designations A,B,C,D,E assigned based on table of ray homologies proposed by Hotchkiss (1998). Arm left-right (L/R) based on furrow as ventral, and distal as posterior.

Description

Frederick H. C. Hotchkiss¹ and John K. Keesing² ¹MPRI, Box 1016, Vineyard Haven, MA 02568 USA • ² CSIRO, Marine and Atmospheric Research, Private Bag 5, Wembley, WA, 6913 Australia

> • The specimen has an arm stump that healed and did not regenerate the arm tip. The stump is well-formed, with no sign of recent injury or recent healing or regeneration: so not a recent event. The affected arm is ray B.

Intradiscally and on the uninjured arms the skeletal plating is typical. The intact rays are of uniform length; the arm radius (R) is 65mm; the disk interradius (r) is 12mm.

The arm stump is 26mm long. The stump furrow is 19mm long and has 14 tube feet in good health on each side of the furrow. The radial nerve cord is visible in the ambulacral furrow. The arm stump is wider (14mm) than the intact arms (13mm).

The tube feet have suckers; there is no evidence of an un-suckered terminal tentacle; there is no evidence of a terminal plate.

• The distal adambulacral plates of the two sides of the furrow arc and join smoothly together near the midline, arranged like a hairpin turn. The distal IMM and SMM of the two sides of the arm arc and join smoothly and form the rounded terminus of the stump.







- adambulacral plate.
- of each side.

• There are seven IMM on each side before the hairpin turn; six IMM form the hairpin turn. Although slightly unequally developed, the six IMM are explainable as three from each side of the arm. So the stump has ten (7+3 = 10) IMM on each side. The 10th IM of the left side is smaller than the rest and is occluded such that it is doubtfully or just barely in contact with an

• There is one less SM than there are IMM; the first 8 IMM of each side are aligned with the first 8 SMM. The distal four IMM of the hairpin turn correspond with only three SMM. The well-formed 9th SM of the left side is enlarged and imprecisely overlies the 9th and 10th IMM. The SM at the tip of the arm stump overlies imprecisely/ partially the most distal IM (10th)

Control specimens: It is usual for *A. angulatus* to regenerate an amputated arm. The arcing and joining of left-right ossicles to form a hairpin turn is not seen in regenerating arms.

Findings

- The cause of injury is probably trauma, but obs.)
- Archaster, Linckia, and Asterias belong to involved.
- arm is L/R symmetrical, and that the bestfit model for starfish arm regeneration is the distalization followed by intercalation model (Agata et al. 2003, 2007).
- This finding postulates that distal outgrowth of arm.
- The hypothesis of universal spatial patterning include echinoderm rays, amphibian limbs, cockroach legs, and transected planarians is this arm stump.

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This type of arm-stump organization, together with its failure to regenerate, was described in a Linckia laevagata and an Asterias rubens, and the previous analysis still holds (Hotchkiss 2009).

there is no indication of the type of trauma. A. angulatus is not prone to autotomy (Keesing pers.

separate families. Recurrence of this organized stump condition in taxonomically distant species indicates that principles of pattern regulation are

Analysis based on positional information theory and regeneration models indicated (Hotchkiss 2009) that positional information in the starfish

the starfish arm in both intact and regenerating specimens is by intercalation between a distal signaling center and the last-formed section of

mechanisms across regenerating systems that supported by its explanatory value in analyzing

Literature cited Agata, K., Y. Saito, & E. Nakajima. 2007. Unifying principles of regeneration I: Epimorphhosis versus morphallaxis. Development, Growth and Differentiation 49:73-78. Agata, K., T. Tanaka, C. Kobayashi, K. Kato, & Y. Saitoh. 2003. Intercalary regeneration in planarians. Developmental Dynamics 226:308-316. Gale, A.S. 2011. The phylogeny of post-Palaeozoic Asteroidea (Neoasteroidea, Echinodermata). Special Papers in Palaeontology No. 85, 112 pp. Hotchkiss, F.H.C. 1998. A "rays-as-appendages" model for the origin of pentamerism in echinoderms. Paleobiology 24:200-214. --- 2009. Arm stumps and regeneration models in Asteroidea (Echinodermata). Proceedings of the Biological Society of Washington 122:342-354. Lawrence, J.M., J.K. Keesing, and T.R. Irvine. 2010. Population characteristics and biology of two populations of Archaster angulatus (Echinodermata: Asteroidea) in different habitats off the central-western Australian coast. Journal of the Marine Biological Association of the United

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