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XXVIII.—The classificatory position of *Hemiaster elongatus*, Duncan & Sladen: a reply to a criticism by Prof. Sven Lovén

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XXVIII.—*The Classificatory Position of Hemiaster elongatus, Duncan & Sladen: a Reply to a Criticism by Prof. Sven Lovén.* By Prof. P. MARTIN DUNCAN, F.R.S., and W. PERCY SLADEN, F.L.S.

WE have quite lately received from Professor Sven Lovén his most interesting and valuable work entitled ‘On *Pourtalesia*, a Genus of Echinoidea.’ This beautifully illustrated work was read before the Swedish Academy of Sciences in June 1882, and was published in 1883.

On studying this most masterly communication, we were impressed that Prof. Lovén had hardly done himself justice in a criticism upon the zoological position which we have given to a very interesting species of *Hemiaster*. The criticisms are short and sufficiently decided; but we felt that as they came from the most exact student of the Echinoidea of the age, they demanded our most respectful and candid attention. We both studied the form of *Hemiaster* to which Prof. Lovén has given an altogether different generic position; we both agreed to the description of the species which appeared in our work on the Echinoidea of the Ranikot group of the Tertiaries of Western Sind; and we are both responsible for the correctness of the drawings on our plate xix. *Fortu-*
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nately the specimens of *Hemiaster elongatus*, nobis, are still in our hands, and we have again gone very carefully over them. It is only just to ourselves to state that in describing the species the more or less exact resemblance of the apical system to that of *Palæostoma* was not lost sight of; but the construction of the whole actinal area differed so decidedly from that of the genus just named, that we could not entertain the possibility of our form belonging to it.

Moreover, since the publication of the 'Echinoidea of the Ranikot Group,' we have completed and published a description of the fossil Echinoidea of the true Nummulitic rocks of the Khirthar strata of the same region, and amongst them are some forms of another *Hemiaster* (*H. digonus*, d'Archiac) with two large generative pores only, and which should equally be the subject of Prof. Lovén's criticism.

The first passage in which Prof. Lovén refers to our species is on page 73, in a footnote:—"Another stranger is *Hemiaster elongatus* of Indian Tertiaries. It is a *Palæostoma*." The second notice is on page 79, in a footnote:—"A fossil species of this genus from the Nummulitic strata of Western Sind has been described as *Hemiaster elongatus* by Duncan and Sladen, Mem. Geol. Survey India, Tert. Ser. xiv. vol. iii. p. 78, pl. xix. figs. 7-15, 1882."

We propose in this communication to reply to Prof. Lovén's statements by arranging our answer as systematically as possible:—

I. The classification of the Leskiadæ, Gray, and the details of those parts of the structures of *Palæostoma* which have a special bearing upon its generic diagnosis, with a notice of the descriptions of Gray, A. Agassiz, and Lovén.

II. A notice of Lovén's comparison of the genera *Palæostoma* and *Palæotropus*, and of its bearing upon the method of distinguishing other genera.

III. A description of *Hemiaster elongatus*, nobis, so far as the structures bear upon its generic position.

IV. A description of *Hemiaster digonus*, d'Archiac.

V. A comparison of the essential structures of *Palæostoma mirabile*, *Hemiaster elongatus*, and *H. digonus*.

VI. A brief notice of the reasons why we still place the two species from Sind in the genus *Hemiaster*.

I.

In the 'Revision of the Echini,' by A. Agassiz, p. 582, the subfamily of the Leskiadæ of Gray is introduced, in order to

include the genus *Leskia*, which was afterwards named *Palæostoma* by Lovén, and it belongs to the family Spatangidæ.

Leskiadæ.—No distinct subanal or actinal plastron; a peripetalous fasciole, enclosing slightly sunken ambulacra, which are petaloid. Anal system covered by a small number of plates; actinostome *pentagonal*, covered by five converging plates, flush with the actinal surface.

Dr. Gray gave a very full diagnosis of his family (not subfamily) *Leskiadæ* in the Cat. Recent Echinida in the Coll. of the Brit. Mus. pt. i. p. 63, and in consequence reduced the length of the generic diagnosis in the same work. The date of the genus of Gray is 1851, and it was first published in the Ann. & Mag. Nat. Hist. 1851 (vol. vii.). The family is diagnosed as follows:—

Shell ovate, subglobose, thin; vertex central; lateral ambulacra broad, petaloid, rather sunken, and separate from each other; the hinder lateral pair rather the shortest; the odd anterior ambulacrum is in a rather broad sunken groove, rudimentary, with a single series of pores on each side, all surrounded by a broad, rather sinuous, peripetalous fasciole; lateral and subanal fasciole none; mouth anterior, *round*, on a level with the rounded under surface, and covered with five triangular converging valves; plastron and subanal plate not distinctly defined; anus round, in the upper part of the rounded posterior end, and covered with five triangular converging valves, forming a cone, with small spicula in the centre; ovarian pores two, very large; spines and tubercles subequal, subulate, those of the back being rather the largest.

As the genus *Leskia* (subsequently *Palæostoma*) was the only one of the family, Dr. Gray did not give a special generic diagnosis, but contented himself with stating that the genus has the characters of the family.

He remarks, "This genus agrees with *Brissus* in the form of the peripetalous fasciole, but differs from it and all other Spatangidæ in the form of the mouth and vent." He mentions the species *Leskia mirabilis*, and states that the test is ovate and subglobose. Dr. Gray gave two drawings of the species (Cat. Echin. Brit. Mus. &c., pl. iv. fig. 4), and the delineations carry out the idea given in the descriptions; the absence of a definite plastron, and the generally rounded form of the under part are evident; but the drawing conveys the impression that the peristome is not round, but pentagonal. The upper surface of the test presents posteriorly a shallow groove, in which is the anal opening with its plates. By way of contrast Dr. Gray placed a figure of the under surface of *Kleinia luzonica* below that of his *Leskia*, and the well-

developed plastron and crescentic-shaped peristome of the *Kleinia* show how greatly the forms differ.

Gray termed his species *Leskia mirabilis*, and this has very properly become *Palæostoma mirabile*, Gray, sp.

There are several excellent drawings of the apical system of *Palæostoma mirabile*, Gray, sp., and the last given by Lovén is of course most worthy of study ('On *Pourtalesia*,' &c., plate xvi. fig. 190). Other plates equally exact are in Lovén's 'Études,' plate xii. figs. 103 and 104. In the drawing on the first-mentioned plate, fig. 190, the remarkable appearance of the two large generative pores situated on prominent mamilliform projections is very distinctly rendered. No madreporic plate is to be seen, and the right and left anterior generative plates are not perforated by pores for the ovaries. The drawing shows one perforation on the flank of the right posterior plate and another in the median line, but in the right anterior plate; it is probable that these pores are the feebly developed water-pores. Behind the mamilliform projections there is a space without any signs of sutures, and which is broad posteriorly, where it separates the posterior ocular plates.

In front of the mamilliform projections the right anterior generative plate extends as a narrow and somewhat pointed plate between the ambulacra, and the left anterior plate is of the same general shape, but is smaller and not so pointed in front.

The drawing does not leave the impression that the mamilliform projections are situated upon keel-shaped elevations of the posterior lateral interradia, Nos. 1 and 4. In the outline figure, plate xii. fig. 103, of the 'Études,' the deficiency of sutures in the apical disk is almost as evident as in the finished drawing just noticed.

The only sutural line is that which separates the small left anterior generative plate from the combined plates. There is no plate penetrated by water-pores, and the amount of plate behind the two mamilliform eminences is considerable.

The figure 104 of the same plate of the 'Études' is a view from within of the apical system. It shows the two large generative pores, the small left anterior generative plate, and the united right anterior and right and left posterior plates. But the right anterior plate has no pore or perforations, and it passes backwards, pushing the large pores apart, and reaches behind them and separates the posterior ocular plates somewhat widely. This figure is taken from a young individual whose plates Lovén notices are not distinct.

The meaning of the view from within can be readily

understood on reading Lovén's summary of the apical structures (*op. cit.* p. 79)—“*Palæostoma* offers a calicinal system, . . . with the five radials [ocular plates] distinct, the I. and V. widely separated [that is, the postero-lateral ocular plates], and out of the costals [generatives, or the basals of one of us], the 3 alone defined by a suture [the left anterior], all the rest being coalesced into one piece; with the madreporic filter represented, in the young specimens examined, by a few punctures placed before the middle, and with the two huge sexual outlets, mammiform and prominent, occupying a considerable portion of the system and placed transversely against the interradians 1 and 4, so as to prevent the retrograde passage of the madreporite.” In other words, the madreporite does not pass backwards between the postero-lateral generative plates Nos. 1 and 4.

The peristome of *Palæostoma* is very excentric in front, is small, flush with the test, and of course is five-sided, with the five angles well pronounced. The sides of the pentagon are nearly equal in length, and nearly the whole of each is formed by the margin of a corresponding interradian plate. One cannot but notice the width of the inner (peristomial) part of the interradian plates which bound the mouth, and that whilst these plates occupy so much of the peristomial region, the inner or peristomial plates of the ambulacra are at the angles of the mouth, and hardly enter into the construction of the orifice at all. Broad as the ambulacral plates certainly are, they only touch the peristome with their tops, so that whilst the ambulacra I. and V. form points at the angles of the base of the pentagon, the ambulacra II., III., IV. only form blunter points at their corresponding angles. At the lowest computation the interradian plate No. 1 of each interradium occupies two thirds of that side of the mouth, and the ambulacral plates “a” 1 and “b” 1 only the remaining third.

The peristome is angular in front and has a straight broad margin posteriorly, the postero-lateral sides of the mouth are of the same breadth as the posterior margin, and the remaining edges of the mouth are equal in dimensions to the others already noticed. It is very important to realize this preponderance of size of the interradian plates No. 1 over those of Nos. “a” 1 and “b” 1 of the ambulacra. This arrangement is invariable in *Palæostoma*.

There is no downward projecting lip to the plate 1 of the odd interradium, there is no arched margin in front of the mouth, joining the sides of the lip with a narrow curve, and the lower edges of the peristomial marginal plates are not rounded off or otherwise ornamented; they are sunken.

With regard to the critical plates of interradium No. 1, it may be observed, in Lovén's exquisite drawings (pl. xvi. figs. 185 and 187, 'On *Pourtalesia* &c.'), that the broad first plate of interradium No. 1 enlarges in width slightly, and then contracts, being nipped in between the ambulacral plates on either side; it is narrower at that suture which is remote from the mouth than at the peristomial margin.

With regard to the ambulacra of *Palæostoma*. On examining Lovén's plate ('Études,' xxxii. fig. 197) of the spread-out diagram of the test of *Palæostoma mirabile*, and studying the ambulacra I. and V., one is struck with the difference between them; the ambulacrum V. presents nothing unusual except that the plates 2, 3, 4 of both rows, "a" and "b," are broader than is usual—in *Hemiasiter*, for instance. The plates are large in relation to those of the corresponding interradium, and the No. 4 of row "b" fits in with the posterior lateral suture of the large sternal plate No. 2 of the odd interradium, row "a," and the edge of the plate No. 3. With regard to the ambulacrum No. I., the plate 4 of row "a" is moderate in size, and comes in contact with the antero-lateral suture of the interradiial (5) plate No. 3, row "b."

The next ambulacral plate, No. 5, row "a," is very large, much larger than the corresponding plate of the row "b" of ambulacrum V.; it is broad, and indeed broader than long, and it projects towards the median line. It occupies a part of the space which is left, in consequence of the peculiar arrangement of the plates of the odd interradium, at the posterior part of the sternum, so that its inner part appears to form a portion of the odd interradium (5). The postero-lateral suture of this large ambulacral plate touches the side of plate 4 of interradium 5, and much of it fills up the space between plates 3 and 4 "b" of interradium 5.

On looking at Lovén's drawing of the peristomial surface of *Palæostoma* ('Öfversigt af K. Vetensk.-Akad. Förhandlingar,' 1867, p. 434) the remarkable breadth of the ambulacra Nos. I. and V. contrasts with the breadth of the plates of the interradia 1 and 4 &c. An ambulacral plate is as broad as the first or peristomial plate of any interradium.

In plate xxxii. of the 'Études,' fig. 197, the following details can be observed:—The odd or posterior interradium (No. 5 of Lovén) is exceptionally formed, and it does not constitute a plastron; moreover, the arrangement of the plates does not resemble that of other Spatangoids. The plate 1 is broad, but not broader at the peristomial margin than the other first plates of the interradia, but it is long. Behind are plates 2, but that of row "a" is longer than that of row "b,"

and its posterior end reaches backwards almost quite behind plate 3 of row "b," to reach and touch the plate "a" 3 which is almost in the median line, having both its lateral sutures in contact with ambulacral plates (that is, with the row "b" of amb. V. and row "a" amb. I.). Plate 2 of row "b" is much shorter than the corresponding plate of row "a," and it only extends as far back as the posterior edge of the third ambulacral plate of row "a,"—ambulacrum No. I., or the right postero-lateral. The anterior suture of plate No. 2, row "b" of interradius 5, is rather wide, and is in contact with nearly the whole of the posterior suture of the first plate of that interradius, and thus the anterior suture of plate 2, row "a," is pushed so far to the true left that a very small portion of the plate comes in contact with plate No. 1.

The posterior suture of the short plate 2, row "b," is broad and almost forms a right angle with the median suture of the interradius; it is in complete union with the anterior suture of plate 3, row "b." The outer margin of this short plate is in contact with plates 2 and 3 of row "a" of ambulacrum No. I. only.

Plate 3 of row "b" of the odd interradius is irregularly pentagonal in shape; it is about three fourths the size of the plate in front of it, is larger than the corresponding plate 3 of row "a," and is placed altogether anteriorly to this last. Moreover it extends from right to left, over the direction of the median line, and is in contact with no less than five plates. The anterior suture is entirely attached to the interradial plate 2, row "b;" the left-hand suture is in contact with the posterior right suture of plate 2, row "a;" the right-hand suture comes against the fourth and fifth plates of the ambulacrum No. I., row "a;" the left posterior suture joins entirely with the right antero-lateral suture of plate 3, row "a;" and the remaining suture, the right posterior, unites with the fifth ambulacral plate of I., row "a." The plate now under consideration seems, as it were, to compensate for the shortness of the plate 2 of row "b," interradius 5. In Lovén's last work on *Pourtalesia* &c. pl. xvi. fig. 185, there is a most beautiful drawing of *Palaeostoma mirabile*. It is of the actinal part of a half-grown individual, and the sutures of the plates are very visible. It shows the great size of the ambulacral plates in relation to the interradials, and it indicates all that has been stated above about the different plates and sutures. Nothing can be more clear than the pentagonal shape of the mouth and the extremely small part played by the ambulacra in forming the margin. In fact, hardly any part of the margin that relates to the interradia Nos. 4 and 1 is produced

by the ambulacra; on the other hand, the margins are formed by the very broad ends of the first plates of the interradia 4 and 1. The most conspicuous feature of this part of the test is this preponderance in size of the marginal interradiial plates over the marginal ends of the ambulacral plates.

Continuing the description of the interradium No. 5, it is only necessary to remark that the plates 4 of both rows are placed side by side, are united to plate 3 of row "a" in front, and not at all to plate 3 of row "b;" but there appears to be a slight junction of the interradiial (5) plate "b" 4 with the large fifth ambulacral of row "a," ambulacrum I. Behind these plates (4 of the odd interradium) are two (5) which contribute to the anal opening, and this is completed by the plates 6 and 7 of both rows.

Lovén, in dealing with the Spatangoids without an anal fasciole, and which have a peripetalous one only, states that these Prynadetes present a certain irregularity in the arrangement of the plates of the bivium. There is an evident tendency towards a constant disposition in the plates called No. 2, in the lateral interradia 1 and 4; but this tendency is shown in a variable and inconstant manner.

It is the *Palæostoma mirabile*, Gray, a form which is exceptional in many respects, that presents the most singular deviation. Whilst all the other Spatangoids that are still existing, excepting *Urechinus Naresianus*, A. Ag., have in the regular interradia the interradiial plate 1, at the peristome, followed by a pair of plates, the 2 of row "a" and the 2 of row "b," this genus has this second plate of both rows *confounded in one plate*, and this is seen in all the interradia except the odd posterior one (5). Moreover the interradium No. 1, that is the right posterior lateral, has the consolidated plates 2 row "a" and 2 row "b" united to the plate "b" 3. This is the only example of this fusion of three plates that is known, and it does not occur in the other interradia of this species. Inasmuch as this fusion does not take place in the interradium No. 4 of *Palæostoma*, abnormal heteronomia of the interradium No. 1 occurs. Lovén terms the union of the plates 2 and 3 of row "a" in the interradium No. 1 a normal heteronomia, and remarks that it occurs in the genera *Hemister*, *Abatus*, *Agassizia*, *Schizaster*, and *Moiria*.

There is a specimen of *Palæostoma mirabile* in the British Museum, and it most unfortunately is adherent by the actinal surface. The shape of the form and the nature of the apical structures can be seen very well. As in the specimens described by Lovén, there are no sutures visible between the apical plates, and the madreporite is not seen between the two

perforated generative plates. But there is a little more porosity of the space between the perforated plates than is drawn by Lovén.

II.

In considering the distinctions between *Palæostoma* and *Palæotropus* it is necessary to quote from Prof. Lovén's work on *Pourtalesia*, p. 79. He writes: "*Palæostoma mirabile*, Gray, deviates in a strange manner from nearly all the rest of the Spatangidæ by the fusion into one single plate of the second plates of the interradia 2, 3, 4, the heteronomy of 1 being effected through the union of the plates *a* 2, *b* 2, and *b* 3; by the very irregular interradium 5, and by the pentagonal peristome with its five valves, and from *Palæotropus* in particular, by its distinct petals and by the absence of a subanal, the presence of a peripetalous fasciola. But with all this, *Palæostoma* offers a calycinal system evidently constructed upon the same plan as in that genus," *i. e.* *Palæotropus* &c. Then follows a summary of the calycinal features, which have been given already. But that part of the description which relates to the madreporite is given so definitely by Lovén that it may well be given again, especially as the statement affects this reply in a very decided manner. Lovén notices that the two mammiform and prominent sexual outlets are placed transversely against the interradians 1 and 4, so as to prevent the retrograde passage of the madreporite.

The point in the argument that we wish to make after this comparison of the two genera is exceedingly simple, and it is that Prof. Lovén admits certain structural differences in *Palæostoma* to be of sufficient importance to override the similarity of the calycinal structures which the genera have in common.

It is clear that, like any other naturalist, Lovén admits that although two forms possessing some similar and important structures are closely allied, yet if there are some other and very decided structural differences between the forms they cannot belong to the same genus. *Palæostoma* is not the same genus as *Palæotropus*, because, although there are some points in common about the apical disk, there are others, elsewhere, which are not so. The same elementary reasoning will apply to any other genera which may have some, but which may not have all, of the principal characters of *Palæostoma*. In concluding this part of our reply, we can state that *Hemiaster elongatus*, nobis, having some structures in common with *Palæostoma*, possesses many more which do not characterize the genus in which Prof. Lovén would place it. The

same remark holds good for the species *Hemiaster digonus*, d'Archiac.

III.

The following description of *Hemiaster elongatus*, nobis, is taken from the work quoted by Prof. Lovén, named 'A Monograph of the Fossil Echinoidea of Sind, collected by the Geological Survey of India, from the Palæontologia Indica, series xiv. Fasc. 2. The Ranikot series.' We only refer to those points which bear especially upon the diagnosis.

On page 79 it is stated as follows :—"The apical system is compact and small, the madreporic body is small, and separates the posterior ocular plates, but does not extend into the posterior interrarial area; there are only two generative pores, and they are situated on the tops of truncated cones, separated at their bases by the granular surface of the madreporic. The cones are at the extremities of a narrow transverse ridge. The right and left antero-lateral generative plates (2 and 3) are very small, and they are not perforated by generative pores; and the postero-lateral plates are the largest and are perforated. There is no posterior generative plate. The ocular plates are well developed, and are placed in hollows, and intrude on the generative plates. The apical system is slightly behind the centre of the test, is small, and is situated on a narrow transverse keel of the lateral interradia."

The madreporic body is continuous with plate 2, the right anterior, and is perforated by numerous pores; but as the extension of the pores on to the plates on either side is only tolerably visible in one specimen, we have a doubt upon this matter. The separation of the posterior oculars Nos. I. and V. by the madreporic body is most decided, and our fig. 9 on plate xix. is quite correct. This body is most certainly not prevented from passing backwards by the costals 1 and 4 of Lovén: on the contrary, it passes between these plates, separating them widely, in a manner perfectly foreign and opposite to what is seen in *Palæostoma* and *Palæotropus*.

The peristome is, as stated in our Monograph, placed very excentrically in front, is small, much the longer transversely, has a rim, and is round at the sides. It is also mentioned that the lip on the anterior end of the plastron is slightly prolonged downwards. The drawing in pl. xix. fig. 8 shows the projecting posterior lip, and fig. 10 indicates that the posterior lip is on a lower level than the front of the actinal part of the test. As we considered the species to be a *Hemiaster*, there was no necessity to enlarge upon the very characteristic peristome in the specific description; but in order to place the

form in a proper antagonism to *Palæostoma*, which was so named in consequence of its supposed ancient and therefore pentagonal shape, we now give the details in full.

The peristome is *rudely crescent-shaped* and is broader than long. The anterior margin is *broad and curved*, with the convexity forwards, whilst the posterior margin is rather narrow from side to side, and *is curved*, but less so than the anterior edge, the convexity being forwards. The anterior margin is prolonged *backwards, on either side*, behind the line of the projection of the posterior lip, and ends in a rather narrow rounded angle on either side. The edges of the plates forming the margin are turned forwards and backwards, according to their position, and this is particularly observable on the posterior lip. This lip projects downwards in the median line and is at its edge lower than that of the front lip and the sides of the mouth. *In specimens which are less than one half the size of the type figured, the peristome is of the same shape as in the adults; all the difference is that in the smaller forms the aperture is a little more open than in the others. There is not the slightest approach to an equal- or unequal-sided pentagon in the shape.*

In the remarks we made on the species, at the close of the descriptions of the Ranikot Echinoid fauna (p. 96), it is stated that "The shape of *Hemiaster elongatus*, which is a very common fossil, is remarkable; and its structural details separate it from others. The presence of only two generative pores situated on mamelons, and the fact that the madreporic body passes backwards and separates the ocular plates, make the form to look much more modern than the Nummulitic."

On reconsidering this description we do not find that there is anything material to alter. But to place our species more definitely we may state that the madreporic body is continuous with the small right antero-lateral generative plate (No. 2), and that it is distinctly separated from the generative plates on either side of it (Nos. 1 and 4) *by sutures*. The small left antero-lateral plate (3 of Lovén) is separated from the madreporic and from the left posterior lateral plate (4 of Lovén) by sutures. *In other words, there are sutures limiting all the generative plates*. Nothing can be more decided than the pushing aside of the plates perforated by the ovarian pores, by the sutureally defined and limited madreporic body.

The margin of the peristome is composed of ambulacral plates mainly; the interradia enter in very slightly, except in the instance of the posterior or odd one (No. 5 of Lovén). This interradium *has a plastron*, and the ambulacra are sunken

on either side of it, and the plastron is on a lower level than the rest of the actinal surface. The first plate (No. 1) of this interradium (No. 5) is much the broadest of all the corresponding plates around the mouth, and it is "cheese-knife" in shape—that is, convex at one end and broad, but narrowing behind to an almost straight handle. The convex part nearly forms the whole of the posterior lip of the peristome, but parts of it are made up of ambulacral plates, and these indent the sides of this first interrarial plate and produce the peculiar shape of its sides. Plates *a 2* and *b 2* of interradium 5 are very long; they unite along the median line by a straight suture, and are in contact with plate 1 by means of a narrow forwardly curving suture, the breadth of the suture of "*a*" and "*b*" being equal. The plate *a 2* is longer than plate *b 2*; both are narrow, widest in the middle and becoming narrower backwards. The smaller plate *b 2* unites posteriorly with plate *b 3*, and the long plate *a 2* is in contact posteriorly with plate *a 3*, and also by its proper right posterior suture with plate *b 3*. The plates *a 3* and *b 3* are in contact by the left posterior suture of *b 3*, and both of these plates are sutured to plates *a 4* and *b 4* respectively. The plates *a 4* and *b 4* are larger than plates 3.

The following is the arrangement of the ambulacral plates in relation to the several interrarial plates of interradium 5. The narrow part of plate 1 is in contact with the large ambulacral plate amb. I. *a 1*, and the following ambulacral plate *a 2* and one half of plate *a 3* are also boundaries of the large interrarial plate 1. The remaining half of ambulacral plate *a 3* and all of *a 4* and part of *a 5* limit the interrarial plate *b 2*. *Now it is important to observe that the posterior half of the ambulacral plate *a 5* is in contact by suture with the interrarial plate *b 3*, but not with *a 3*, for that is on the further side of *b 3*; moreover the ambulacral plate *a 5* does not encroach towards the median line.*

This description refers to the usual condition of the interradium, but there are occasional departures from the normal, which, however, do not affect the argument. Thus in one instance the interrarial plate *a 2* is crossed by a suture on a level with the posterior suture of the ambulacral plate *b 2* of zone V., but the arrangements of the interrarial plates further back is the same as in the type.

With regard to the width of the ambulacral plates it is evident that as a whole they are narrow; the plates *a 1*, *b 1*, and *a 2*, *b 2* of ambulacrum I. are broader than the following plates 3 and 4 of *a* and *b*. Plates *a 5* and *b 5* are broader than those just noticed, are placed side by side as is usual in

Hemiaster, and are followed by two smaller plates. *There is no resemblance between this arrangement and that of Palæostoma.*

Interradium 1 has its plates visible on the actinal surface in some specimens, and its plate 1 has a very small edge at the peristome, where it forms the margin of the narrow blunt angle. The space occupied by this and indeed all the interradia at the margin of the peristome, except the interradium 5, is much less than that presented there by the ambulacral plates. Although the peristomial part of plate 1 is narrow, the rest of it gradually increases in width, so that at the level of the third ambulacral plate of ambulacrum I. it is very broad, stretching across the interradium 1, and having a slightly curved posterior suture, which can be traced from plate *b* 3 of ambulacrum I. to *a* 3 of amb. II.

The plate 1 is followed by two plates: one is *b* 2 and the other is the combined *a* 2 and *a* 3, these last forming the larger plate of the series. The plate *a* 2 is in contact with the ambulacral plates 3 and *a* 4, of amb. II. (one half of each), and on the opposite side it is sutured to plates 2 and 3 of interradium 1. This combined plate comes in contact with the ambulacral plates 4, 5, and 6 *b* of amb. I.

There is no union of the plates so as to form an unusual heteronomia; on the contrary the arrangement of the plates is exactly as it is in the species of the genus *Hemiaster*—*H. expergitus*, Lovén, for instance.

In interradium 4 there is the usual double row of plates *a* 2 and *b* 2 following plate 1, and there is no union of any others as in *Palæostoma*.

So far as *Hemiaster elongatus*, nobis, is concerned, it has not the characteristic heteronomia of *Palæostoma mirabile*, Gray.

IV.

Hemiaster digonus, d'Archiac, was first fully described by MM. d'Archiac and Haime in their great work 'Sur les Animaux fossiles de l'Inde,' p. 220. Subsequently we examined a large collection of very indifferent specimens from the Khirthar series of Sind, and we published the results in our monograph 'On the Fossil Echinoidea of Western Sind' (Pal. Indica, ser. xiv. fasc. iii. p. 200). We gave careful drawings of as much of the tests as we could on plate xxxv. figs. 4-9.

The species is characterized by the short, broad, posteriorly elevated test, the great width of the odd ambulacrum and of its groove, and the position of the apical system rather far back. But the principal character which it has in common

with *Hemiaster elongatus* is the presence of two large generative pores, each placed upon a conical process; the apical system is, moreover, small.

The madreporic plate is *continuous with the generative No. 2*, and is placed *between the two large pored plates Nos. 1 and 4, which it separates widely, and from which it is partitioned off by distinct sutures*. The madreporic also extends *behind* those generative plates, and *separates the posterior oculars I. and V.* nearly as much as it does the generative plates 1 and 4. It extends backwards behind the line of the ocular pores and ends in a peak-like process, which slightly separates the long pair of interradiial plates of the odd interradium.

The generative plate 3 is very small and broader than it is long; it is separated from the madreporic and from the generative plate No. 4 by sutures. There is no fifth plate. Both of the conical and perforated plates 1 and 4 are limited by sutures, and the water-pores are upon the madreporic plate only. The ocular plates are rather large.

On the actinal surface the peristome is seen far in front and to be *crescent-shaped*; it is broader than long, has a curved front lip and a downward-projecting curved posterior lip. The plate 1 of interradium 5 is broad at the margin of the mouth; but the corresponding plates of the other interradia are very narrow there. As is invariable in more or less adult *Hemiasters*, the ambulacral plates contribute to the peristomial margin more than the interradials. Unfortunately the peculiar saccharine-looking fossilization prevents the sutures of the plates of interradium 1 being seen; but in one specimen it is clear that the first plate is large and of the same shape as in *H. elongatus*; moreover, what can be seen of the following plates indicates that there are two, and not only one behind the first. There is no unusual heteronomia.

There is a distinct plastron.

V.

It is evident from what has been stated regarding the essential and characteristic structures of the three forms, *Hemiaster elongatus*, *H. digonus*, and *Palæostoma mirabile*, that the first two are closely allied, there being only some specific distinctions between them, such as the shape of the test, the breadth of the odd ambulacrum, and the greater length of the generative plate 3 in the first-named *Hemiaster*. It is also evident that these two species can be separated in almost every essential structural detail from the species of *Palæostoma*.

Having put forward the several points which characterize

the genera under consideration, it is only necessary to compare the forms one with another.

We may admit that the two species of *Hemiaster* differ equally from *Palæostoma*.

In all the forms the apical system is small, and two of the generative plates, 1 and 4, have conical eminences, on which are the large ovarian pores.

In all three forms the generative or basal plates 2 and 3 are small and without perforations for ovarian ducts, and here the structural similarity ceases. The genus *Palæostoma* has no madreporite passing back between the two perforated plates 1 and 4; the other two forms have this, and, moreover, the madreporite reaches back between the posterior oculars I. and V. There are no sutures in *Palæostoma*, but they are present between all the plates in the forms we have called *Hemiaster*.

The peristome of *Palæostoma* is pentagonal at all ages; that of our *Hemiasters* is never pentagonal, and is of the crescentic shape of the genus, the front edge being curved widely and the back lip being also curved and projecting downwards as a prominent structure. In *Palæostoma* the interradial plates 1 at the margin of the mouth are large, nearly equal in their considerable space, and the ambulacral plates contribute but slightly to the margin. In the other forms only the plate 1 of interradius 5 is large, and, as in all *Hemiasters*, the other first plates barely contribute to the peristome, whilst the greater part of the margin is made up of the ambulacral plates. The first interradial plates of 1, 2, 3, and 4, not very wide posteriorly in *Palæostoma*, are decidedly wide in the *Hemiasters*.

There is a most remarkable heteronomia of the interradius 1 in *Palæostoma mirabile*, but there is nothing of the kind in the two other forms. They present the normal heteronomia of the interradia, actually, which is usual to such Spatangoids. There is no plastron in *Palæostoma*, but there is in the other forms.

The very broad ambulacra on either side of the odd interradius in *Palæostoma*, are not characteristic of the *Hemiasters*; on the contrary, their ambulacra are narrow. In *Palæostoma* there is a remarkable enlargement of the fifth ambulacral plate of amb. I. row *a*, and it is pushed to the left because plate *b* 3 of interradius 5 is placed so much to the front of *a* 3 of the same interradius that there is a vacant space. This is not the case in the two species which we have named *Hemiaster*, and plates *a* 3 and *b* 3 of the odd interradius are as is usual in the Spatangoids.

We consider that we have proved that the generic characters

of *Palæostoma* are not present in the form we named *Hemiaster elongatus*, nor are they in the closely allied species *H. digonus*.

VI.

Prof. Lovén remarks in his work on *Paurtalesia*, p. 75 :—“ In the adult of *Hemiaster* and of all the other Spatangoids of early Mesozoic origin the calyx in the adult presents a structure essentially different from that of the calyx in the adult of a *Spatangus* or of any other form of later or recent appearance, and very rarely a link is found between the two.” On page 73 of the same admirable work there is the following statement in reference to *Hemiaster* :—“ Now these three species of the existing seas are true *Hemiasters*, fully sharing the well-known characteristics of that highly natural genus, the subglobose form, elevated in its posterior region, a calyx of four costals [generative plates], the madreporite confined to costal 2, the 4 and 1 and the radials I. and V. closing from either side, in strict accordance with the mode of conformation universally prevalent within the calycinal system during the older Mesozoic period.”

Lovén then compares this calicular or apical arrangement of the *Hemiasters* with that seen in the genus *Abatus*. This he shows has five generative plates, “ the 5 being reproduced between the radials I. and V., and bearing the madreporic filter, thus set free, on its unimpeded retrograde movement.” He asserts that if a form like this is allowed to remain in the genus *Hemiaster* its integrity is vitiated.

Under any circumstances the two forms we have described as *Hemiasters* are closely allied to *Abatus*, but they have no basal (“ costal ”) plate 5, and the madreporite is clearly on the plate 2 ; moreover, the Sindian forms never have three generative pores. *Abatus* has the same arrangement of the inter-radial plates on the actinal surface in areas 1 and 4 as the two *Hemiasters* from Sind ; the plates of the ambulacrum No. I. are more numerous in *Abatus* than in our *Hemiasters* ; but the shape of plate 1 of interradium 5 of both forms is the same. Comparing the Sindian *Hemiasters* with the recent *H. expergitus*, it will be noticed that the details of the actinal surface correspond ; but on the apical disk the madreporite of the recent form does not pass between the plates 1 and 4. The correspondence is not very close, however, in dimensions, for the ambulacra on either side of interradium 5 are broader in the recent form, and the front part of the peristome is not with a prominent rim. Considering the two species to belong

to the same genus, one would say that the specific difference is in the position of the madreporic plate.

With regard to *Hemiaster zonatus*, A. Ag., the notice in the 'Challenger' Echini gives no structural details.

Hemiaster gibbosus, A. Ag., agrees with the Sindian forms in every generic detail, except in the structure of the apical disk.

Of course the whole question of the value of such generic forms as *Abatus*, *Tripylus*, &c., depends upon the greater or less importance of the presumed fixity of the position of the generative plates. We cannot agree to the hard-and-fast lines regarding *Hemiaster* laid down by Lovén, because we believe that the position, as well as the number and perforation of the costals of Lovén (the basals of one of us) are variable, and more so than the details of the actinal structures. With some other naturalists we consider all these forms to be simple groups of *Hemiaster*, some being possibly of subgeneric value.

It is somewhat singular—and we believe it shows our appreciation of Lovén's generalization, that the madreporite tends to pass backwards in Tertiary and recent species of Mesozoic genera—that we should have been impressed with the position of the madreporite in the Sindian forms as indicating a variation that should be found in Tertiary *Hemiasters*.

The researches of M. P. de Loriol in our opinion confirm the propriety of separating *Palæostoma* and the *Hemiasters* with only two generative pore-openings and an encroaching madreporite. M. de Loriol published in the 'Palæontographica' (xxx.) a work entitled "Eocene Echinoideen aus Aegypten und der Libyschen Wüste" (1881), and in it are two most interesting forms which bear considerably on the subject before us. In the Libysche Stufe there is a *Palæostoma*, and in the same deposit there is a *Hemiaster Schweinfurthi*, both species of de Loriol's. *Palæostoma Zitteli* (p. 33, pl. viii. figs. 1-1 d) is closely allied to *P. mirabile*; the shape of the test and that of the peristome are the same, but the pores of the ovarian plates "sind nicht deutlich zu erkennen." The peristome has all the characters of *Palæostoma*, but none of *Hemiaster elongatus*—"Peristom nahe am vorderen Rande in gleicher Ebene mit der Schale, genau fünfeckig, mit beinahe gleichen Seiten. Der Umriss ist durch eine deutliche Leiste eingesäumt."

This interesting fossil form in no way resembles our *Hemiasters*. *Hemiaster Schweinfurthi* is described on page 34 and figured on the plate viii. figs. 3, 4, 5.

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This *Hemiaster* has but two generative pores, "Nur die Genitalporen der beiden hintern paarigen Interambulacrafelder entwickelt, Madreporenplatte klein, in der Mitte gelegen." The plates represent a true *Hemiaster* so far as shape, fasciole, peristome, and ambulacra are concerned. The two generative pores are not upon cones, but they are wide apart, and it is stated in the description of the plate that the indistinct madreporite has not been rendered by the artist. Its place is evident enough between the posterior costals 1 and 4 of Lovén. De Loriol remarks that the form belongs to a group of the genus *Hemiaster* in which there are only two, and rarely three, genital pores (instead of four) in the apical disk. He notices that *H. cavernosus* sometimes has only two, seldom three pores, and he evidently takes the view that this diminution of the number of generative pores is not to remove the forms from the genus *Hemiaster*, all other generic characters being the same. Amongst these characters the presence of a madreporic between the posterior ovarian plates does not, in the eyes of this very exact and careful zoologist, militate against the species thus endowed being a *Hemiaster*. De Loriol's work shows that the number of the pore-bearing plates is a variable quantity, and that too much must not be made of the occurrence in classification.

In concluding this reply to the criticisms of Prof. Sven Lovén, we restore the form which he has removed into the genus *Palæostoma* to its original position in the genus *Hemiaster*, and its fellow species from the higher Tertiary horizon must also be associated with it. The Ranikot and Khirthar Sindian Nummulitic *Hemiaster elongatus*, Duncan and Sladen, and *Hemiaster digonus*, d'Arch., retain those classificatory terms. We trust that the distinguished naturalist, from whom we have both learned so much, and for whom we entertain a sincere admiration, will receive this reply in the same spirit which prompted him to notice our work in his great essay on *Pourtalesia*.

Note.—We have used the term "interradium" throughout this paper because it is customary; but it should certainly be interradius.

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