NOTES ON ASTEROIDS IN THE BRITISH MUSEUM (NATURAL HISTORY) V. *NARDOA* AND SOME OTHER OPHIDIASTERIDS

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NOTES ON ASTEROIDS IN THE BRITISH MUSEUM (NATURAL HISTORY) V. *NARDOA* AND SOME OTHER OPHIDIASTERIDS

By AILSA McGOWN CLARK

THE present study includes notes on the provenance of *Nardoa variolata* (Lamarck) the type-species of *Nardoa*, details of the true holotype of *N. gomophia* (Perrier), description of a new species from northern Australia and a discussion of the remaining species of the genus coupled with notes on the validity of the monotypic *Gomophia*, a new subspecies of which is described.

In the course of this, the following conclusions are reached :—

Ophidiaster watsoni Livingstone (1936) is referred to *Gomophia* and is probably conspecific with *G. egyptiaca*

Nardoa mamillifera Livingstone (1930) and *N. tumulosa* Fisher (1917) are probably synonyms of *N. frianti* Koehler

Nardoa obtusa (Perrier) is conspecific with *N. tuberculata* Gray

Nardoa lemonnieri Koehler is revived from the synonymy of *N. mollis* de Loriol and

Nardoa faouzii Macan is designated as type-species of a new subgenus.

A key to the species of *Nardoa* is included.

Other Ophidiasterids dealt with include :—

Fromia indica (Perrier), with *F. tumida* Bell newly referred to synonymy but *F. elegans* H. L. Clark revived as a valid species

A new species of *Fromia* from the Indian Ocean.

Ferdina Gray, re-diagnosed and restricted to a monotypic genus by removal of *F. heffernani* Livingstone to a new genus ; *Ferdina flavescens* Gray partially redescribed

Tamaria tumescens (Koehler), with *T. ajax* Livingstone, 1932*a*, newly referred to synonymy and

Ophidiaster helicostichus Sladen now referred back to *Ophidiaster* from *Hacelia* with possible synonym *O. astridae* Engel, 1938.

Gomophia egyptiaca egeriae[1] subsp. nov.

(Pl. 1, figs. 1–5)

Nardoa tuberculata (pt.) Bell, 1894 : 396.

? *Nardoa aegyptiaca :* Koehler, 1910 : 157 [Non *Gomophia egyptiaca* Gray].

MATERIAL. Macclesfield Bank, South China Sea ; Admiralty :—23 metres, 2 specimens—the holotype and paratype, B.M. reg. no. 92.8.22.52 and 53 ; 66–76 metres, 3 specimens, nos. 92.8.22.74, 259 and 260 ; 58 metres, 1 specimen, no. 92.8.22.29 ; 76–84 metres, 1 specimen, no. 93.8.25.203.

[1] Named after H.M.S. " Egeria " which surveyed Macclesfield Bank.

Description of holotype. R/r = 70 mm./11·5 mm. = 6·1/1. The arms taper fairly evenly to attenuated tips ; br at the base = 10·5 mm., at half R = 9·0 mm. and at 10 mm. from the tip = 4·0 mm.

The aboral skeleton is reticulate but the oblong secondary plates linking the five- or six-lobed primary abactinal ones are relatively inconspicuous and the reticulum is more compact than in the holotype of *G. egyptiaca egyptiaca*, the pore-areas being relatively small, mostly with only 3–6 pores in each. Three plates around the centre of the disc and fifteen to twenty other primary ones scattered along the upper side of each arm are abruptly elevated, the larger ones 2·4–2·6 mm. in basal diameter and 2·0–2·4 mm. in height. Their shape is conical but some have the apex blunted.

The supero-marginal series of plates similarly includes both flat and markedly convex plates, the former being mostly equal in size to the largest of the flat abactinal plates. The convex plates arise at intervals of one to four flat ones, and are more widely-spaced on the distal half of the arm.

The entire surface is coated with fine granules concealing the underlying plates. On the flatter parts of the aboral skeleton these number c. 60/sq. mm. but on the convexities they become distinctly coarser, especially towards the tips of the plates. Most of these tips have been rubbed but on those that remain intact the apex is crowned by several enlarged granules among which a single central one may reach twice the diameter of the granules encircling it. Though slightly higher than the other granules, this single one is throughout too small to evoke comparison with a nipple. It is more often developed on the supero-marginal plates than the abactinal ones.

The infero-marginal plates form a much more regular series than the supero-marginals, all being similar and gradually reducing in size distally ; the proximal ones are conspicuous by their size and measure almost 3 mm. in diameter. The number in one series partially denuded is c. 30.

Between the two main marginal series proximally is a row of intermarginal plates. Beyond the basal third of the arm length these are concealed by the granulation but spaced ones are revealed on the denuded arm to c. half R. Small pore-areas are present both above and below the intermarginal plates continuing distally beyond them but there are none on the lower surface of the body below the infero-marginals.

The actinal series of plates is poorly developed, the one cleared consisting of 18 plates, about three corresponding to each infero-marginal where they lie adjacent ; the distalmost actinal plate lies interstitially between the seventh and eighth infero-marginals and the adjoining adambulacrals, i.e. at just over one-third R from the mouth.

The adambulacral plates for much of the arm each bear four, rarely five, prismatic furrow spines c. 1 mm. long, the fans of which are slightly oblique so that consecutive ones tend to overlap. Behind these are series of usually three shorter subambulacral spines, the middle one becoming progressively stouter and relatively longer on the distal part of the arm, while the proximal one disappears or becomes granuliform. The outer part of the plate bears polygonal granules indistinguishable from those of the adjacent actinal and infero-marginal plates so that the two rows of spines project

abruptly. In comparison with the species of *Nardoa*, the adambulacral spines are more slender and spaced farther apart.

PARATYPES. [Treated in the same order as in table 1 on p. 177]. As indicated in the table, the raised abactinal and supero-marginal plates are more or less rounded at the tips and may lack the single enlarged granule altogether. In the specimen from the same depth as the holotype (R 65 mm., Pl. 1, fig. 4) the enlargement of the supero-marginal plates is more frequent, there being a marked tendency for every second one to be convex. In this specimen the furrow spines number five on most of the plates of the proximal half of the arm ; also the granules adjacent to the subambulacral spines are slightly elongated.

No. 93.8.25.203 (R 70 mm.) has alternate proximal supero-marginal plates tubercular but distally the frequency of these is less. Again there are five furrow spines on most of the proximal plates.

No. 92.8.22.29 (R 60 mm.) has very regular alternation of convex and flat supero-marginals for almost the entire length of all the arms. There are four, occasionally five, furrow spines.

In no. 92.8.22.74 (R 52 mm.) the single apical granule of some of the supero-marginal plates at least (most of the aboral ones being rubbed) approaches nipple-like proportions. The furrow spines usually number four.

Finally, nos. 92.8.22.259 and 260 are smaller, R 34 and 32 mm. (The latter has only two arms intact and is not included in the Table). The former (Pl. 1, fig. 5) has markedly conical tubercular plates, of which the two midradial ones near the base of each arm are so large as almost to meet the supero-marginal plates each side, only one small flat plate intervening. This is in marked contrast to the specimens of *G. egyptiaca egyptiaca* of similar size from Christmas Island, where the abactinal plates are relatively smaller and more numerous (Pl. 1, fig. 6). Another difference is that the intermarginal plates are very narrow in the Macclesfield Bank specimen and indeed are only visible when the granulation is removed, being sandwiched closely between the two main marginal series. The Christmas Island specimens have conspicuous broad series of intermarginal plates extending for about half R. However, the two from Macclesfield Bank cannot be referred to *Nardoa frianti* since they both have unusually well-developed, almost nipple-sized and sharp apical tubercles on the conical abactinal and supero-marginal plates. It may be noted that a few of the supero-marginals are crowned by two or even three tubercles, which may also occur in *G. egyptiaca egyptiaca*, as shown by a specimen from Samoa (poorly preserved and not included in Table 1) though here the tubercular plates tend to have a double apex like a cow-bell and the tubercles are separated at the ends of the ridge.

Comparative remarks between *egeriae* and *egyptiaca* as well as with *Nardoa* are included in the general discussion of *Nardoa* and *Gomophia*.

Nardoa variolata (Retzius)

Tetractis cruciata variolata Linck, 1733 : 19, pl. i, no. 1.
Pentadactylosaster variolatus Linck, 1733 : 34, pl. viii, no. 10.
Hexactis variolata Linck, 1733 : 37, pl. xiv, no. 24.

[Un-named] Encyclopedie Méthodique, 1792 : pl. cxix, figs. 4, 5 [" *Asterias variolata :* Lamarck " in captions, 1827].
Asterias variolata Retzius, 1805 : 19 ; Lamarck, 1816 : 565.
Linkia variolosa (sic) : Nardo, 1834 : 717.
Nardoa variolata : Gray, 1840 : 286 ; 1866 : 15 ; Fisher, 1919 : 379, pl. cviii, fig. 4 ; H. L. Clark, 1921 : 51, pl. xxviii, figs. 3, 4. [Non Domantay & Roxas, 1938 : 224–225, probably = *N. novaecaledoniae*].
Nardoa Agassizii Gray, 1840 : 287 ; 1866 : 15.
Scytaster variolatus : Müller & Troschel, 1842 : 34–35 ; Michelin, 1845 : 21 ; Peters, 1852 : 178 ; Lütken, 1865 : 41 ; Perrier, 1875 : 159–162 (423–426) ; Smith, 1879 : 566 ; Möbius, 1880 : 50 ; de Loriol, 1885 : 43–44. [Non Bell, 1882 : 220 ; 1887 : 647 ; ?1902 : 226 ; ?1909 : 19].

This species was formally designated as type-species of *Nardoa* by H. L. Clark (1921). Unfortunately, although there has long been agreement that the common *Nardoa* of Mauritius should be called *variolata*, the basis for this is not perfectly secure since no holotype is extant. One solution would be for a neotype to be chosen. Alternatively a lectotype could be selected from among Linck's figures (1733) which were cited by Retzius, the first post-Linnean author to use and thereby validate the name. As Linck's specimens are not preserved at the present museum in Trier the figures alone will have to suffice. Those of the normal five-armed specimen (Linck, pl. viii, no. 10) reproduced in the "Encyclopedie Méthodique", are to be preferred; they certainly have a strong resemblance to the common *Nardoa* of Mauritius. Linck, Retzius and Nardo all failed to give a locality for the species but Lamarck put " mers d'Europe " from which Gray appears to have derived " Mediterranean Sea " at the same time as he gave " Isle of France " (Mauritius) for *Nardoa Agassizii*, subsequently referred to the synonymy of *variolata* by Müller and Troschel, who also record specimens from Mauritius.

Some remarks about the geographical and morphological limits of the species are included in the general discussion of *Nardoa*.

Nardoa gomophia (Perrier)

(Pl. 2, figs. 1–4)

Scytaster gomophia Perrier, 1875 : 167–169 (431–433). [Non *Nardoa " gamophia " :* Fisher, 1919 : 380, which is based on a specimen of *N. novaecaledoniae*].

Material. New Caledonia ; Cuming ; the holotype, B.M. reg. no. 59.4.25.3.

As Fisher noted in 1919, the specimen (Pl. 5, fig. 2) in the British Museum collections hitherto labelled as the holotype of Perrier's *Scytaster gomophia* does not particularly resemble *Gomophia egyptiaca* with which Perrier allied and compared his new species but is close to *Nardoa novaecaledoniae*. Its number is 59.4.25.4 and a search through the dry collections yielded a second specimen not conspecific with the first but also labelled as from New Caledonia and having the consecutive number 59.4.25.3 (Pl. 2, figs. 1–4). This specimen bears a label " *Scytaster* n. sp. ", though not in Perrier's handwriting. A later printed label names it *Nardoa perrieri*, which I think must be an MS name given it by Bell prior to placing it on exhibition. This second specimen does have a considerable resemblance to *Gomophia egyptiaca*

owing to the presence of some spaced, abruptly projecting, tubercular plates on the upper side. As in Perrier's description, these are hemispherical rather than conical, unlike *G. egyptiaca*, and tend to form three alternating series along each arm. No such projections are present in the first specimen, 59.4.25.4, but this does agree in diameter with Perrier's measurement of 135 mm., the mean of its five possible diameters being 131 mm., whereas the same mean in no. 59.4.25.3 is 167 mm. However, the R/r ratio of 7·7/1 in the latter compared with 5·5/1 in no. 4 agrees so closely with Perrier's estimate of " nearly 8/1 " that I am convinced the wrong specimen has been labelled as the holotype of *N. gomophia*. Accordingly the assessment of the species must be reviewed since H. L. Clark referred *gomophia* to the synonymy of *N. novaecaledoniae* following Fisher's comments. On the one hand it is clearly related to those species of *Nardoa* which have some of the abactinal plates distinctly tubercular and on the other to *Gomophia egyptiaca*, as Perrier stated. To avoid repetition, the comparison is included in the general discussion of *Nardoa* and *Gomophia*.

Nardoa sphenisci[1] sp. nov.

(Pl. 3, figs. 1–3)

Material. Holothuria Bank, N.W. Australia, 27 metres ; H.M.S. " Penguin ". 1 specimen, the holotype, B.M. reg. no. 92.1.14.27.

Parry Shoal (N.W. of Darwin), 22 metres ; H.M.S. " Penguin ". 2 specimens, no. 92.4.4.6 and 7.

Description of the holotype. R 115–120 mm. ; r c. 13 mm. ; R/r = 9·0/1. The arms are slender and attenuated, br at the base = 13–14 mm., at half R = c. 10 mm., at 10 mm. from the tip = 4·5–5·0 mm. and at the very tip = c. 2 mm. One arm has been broken near the base and is regenerating.

Most of the abactinal plates are more or less convex, especially the midradial ones near the bases of the arms, which are 2·5–3·5 mm. in transverse diameter (slightly less longitudinally) and up to 1·5 mm. in height ; their tops are rounded. Beyond the bases of the arms the more convex plates are scattered over the whole upper side. Across the base of each arm between the two supero-marginal series the abactinal plates number five to seven ; when there are seven the two outermost plates are small, for most of the proximal part of the arm there are about five plates across the width though the arrangement is irregular. Distally the plates gradually decrease in size and become elongated, the more convex ones measuring 2·0–2·5 mm. in length and 1·0–1·5 mm. in breadth. Only on the regenerating arm is there an abrupt reduction in the size of the plates at the point of cleavage.

The entire aboral surface is coated with polygonal granules which gradually increase in size on the convexities of the skeleton. The smaller granules between and towards the edges of the plates number 25–30 per square mm. ; they are flat-topped and each granule bears a small boss in the centre except for the coarser ones near the apices of the more conical plates, which tend to have their whole free surface

[1] Of the " Penguin ".

convex and smooth. The smaller distal convex plates particularly have the few enlarged central granules distinctly projecting and on some of these plates there is one central granule which is markedly larger than the seven or eight immediately encircling it. This gives a rough texture to the distal parts of the arms although the central granules are barely visible with the naked eye and never so abruptly different from the other granules as to recall the nipple-like tubercles found on the swollen plates of most specimens of *Gomophia egyptiaca*.

The supero-marginal plates also are more or less convex in form though never to the same extent as the proximal mid-radial plates. There is a strong tendency for alternate supero-marginals beyond the basal five to ten to be larger and more convex than the rest so that the outline of the arms in perpendicular view is distinctly and fairly regularly scalloped. The larger plates of the basal half of the arm are 2·0–2·5 mm. in diameter, the alternate plates being only c. 1·0 mm. long though still c. 2 mm. wide. In two supero-marginal series counted the total number of plates is 58.

In contrast the infero-marginal plates are fairly equal in size, gradually diminishing distally. They number c. 54.

Both series of marginal plates are covered with granulation similar to that on the abactinal plates ; this again becomes increasingly coarse on the more convex surfaces. On some of the distalmost plates of both series when only a single granule is enlarged the height of this may exceed its basal breadth though the tip is rounded.

In each interradius the two marginal series are separated by a progressively narrowing series of irregularly-placed and irregularly-shaped intermarginal plates. On one area cleared these number about 40 and extend for c. 40 mm. along the arm, although when the granule-covering was intact the plates of the distal half of the series were concealed.

On the lower side, the main series of actinal plates is visible through the covering granulation for about half the arm length, (i.e. to about the twenty-fifth infero-marginal) ; further plates extend interstitially concealed by the granulation to about the thirty-fifth infero-marginal or two-thirds of the arm length. The actinal plates are twice as numerous as the adjoining infero-marginals. On the disc there is a second series consisting of only two or three plates. The granulation is again coarser on the centres of the plates than around their edges.

The adambulacral plates correspond in number to the actinal plates. Each bears four or five blunt angular furrow spines, the distal plates more often four, though the number may be only three on the terminal fifth of the arm. When there are five furrow spines, usually the proximalmost one is slightly smaller than the rest and inset from the furrow so that the series is curved and adjacent ones tend to overlap. The subambulacral row consists usually of three spines, shorter but somewhat stouter than the furrow spines and often with a smaller fourth proximal spine almost in series with them. The outer part of the plate bears polygonal granules some of which, close behind the subambulacral spines are slightly elongated so that there is no abrupt transition from spines to granules.

The pore-areas are small in comparison to the size of the plates. The number of pores in each area is difficult to estimate, perhaps owing to the dried condition ;

on the upper side it is probably 4–8 in most areas. Smaller pore-areas are also present intermarginally and below the infero-marginals on the proximal half of the arm.

PARATYPES. Both have R/r 75–85 mm./10 mm., approximately 8/1. The arms are slender and attenuated as in the holotype, which they closely resemble. Both have the intermarginal series of plates well-developed on most arms and only lacking on those arms which appear to have regenerated from the base. This can be assumed from the abrupt break in all three marginal series close to the interradius and to coincidence in the occurrence of intermarginal series on both sides of a single arm rather than on the two continuous series of adjacent arms across an interradius. The actinal plates are more extensive than in the holotype, being visible for about five-eighths R with further plates extending to three-quarters R concealed to the naked eye beneath the granulation. The furrow spines number four on most plates of the proximal half of the arm, then three.

REMARKS. All three specimens were identified as *Nardoa tuberculata* by Bell. In 1953 I re-named them *Gomophia egyptiaca* on account of the intermarginal series of plates and the attenuated arms, disregarding the rounded rather than conical tubercular abactinal plates lacking in central conical nipples. However, a recent study of material of these two genera convinces me that the three specimens are referable to neither species. Their relationships are dealt with below in the general discussion of *Nardoa* and *Gomophia*.

NARDOA Gray

Gray, 1840 : 268 ; 1866 : 15 ; Fisher, 1919 : 378–382 ; H. L. Clark, 1921 : 49–50.

The species of *Nardoa* are usually divided into two groups, those in which some of the abactinal plates are distinctly more convex than the rest and those with similar low plates. The relationship between the first group and the monotypic genus *Gomophia* should be reviewed, the latter having been referred to the synonymy of *Nardoa* by several specialists including Sladen (1889), Koehler (1910) and Fisher (1919) but restored to generic rank by H. L. Clark (1921) and following workers.

Unfortunately, most of the species involved seem to be solitary and the available samples are very inadequate, rarely more than one or two specimens being taken at a time so that the range of variation is poorly known. Following the restoration here of *N. gomophia* as a valid species and the addition of *N. sphenisci* as a new one, the nominal species to be included in such a survey are :—

Gomophia egyptiaca Gray, 1840
" *Ophidiaster* " *watsoni* Livingstone, 1936
Nardoa frianti Koehler, 1910
Nardoa tumulosa Fisher, 1917
Nardoa mamillifera Livingstone, 1930
Nardoa gomophia (Perrier), 1875
Nardoa sphenisci sp. nov.

Nardoa tuberculata Gray, 1840
Nardoa obtusa (Perrier), 1875 and possibly also
Nardoa rosea H. L. Clark, 1921.

Some of the distinguishing characters between these are brought out by the following table. In this the skeletal structure is indicated as either open, when the papular areas are sufficiently large to give a reticular appearance, as opposed to compact, with the spaces small and irregular in arrangement. A comparison of Pl. 1 figs. 1 and 3 with 6 and 8 may serve to illustrate this point). Negative entries for the abactinal tubercles signify that they are conical. The degree of fineness of the covering granulation is shown by an assessment of the number per square mm. taken on the flatter parts of the aboral skeleton where the granulation is at its finest. The other columns should be self evident. Intermediate conditions are indicated by " +/— " and a tendency one way or infrequent occurrence by brackets.

H. L. Clark distinguished *Gomophia* from *Nardoa* by the unspecialized supero-marginal plates resembling the abactinal ones (this being enhanced by the series of intermarginal plates separating the supero-marginals from the markedly enlarged infero-marginals proximally) and by the absence of actinal papulae below the infero-marginals (this character implicit in his key) coupled with the conical form and apical " nipples " of the tubercular abactinal plates ; an additional distinction is provided by the rather open, apparently reticulate, aboral skeleton.

However, although in the holotype of **Gomophia egyptiaca** and in a few other specimens closely resembling it, notably the one from Samoa shown in Pl. 1, figs. 7 and 8, none of the supero-marginal plates are enlarged or projecting, this is not always the case ; for instance the fine large specimen from the Gulf of Aqaba (see A. M. Clark, 1952), the second one in the table, has a conspicuous conical tubercular plate in the position of every third or fourth supero-marginal. Similarly some much smaller specimens from Christmas Island in the Indian Ocean have some elevated supero-marginals; in this case alternate plates are so modified, as in the holotype of Livingstone's **Ophidiaster watsoni** to which the Christmas Island specimens bear great resemblance. In fact, despite the extent of some of the actinal series of plates beyond half the arm length and the slight enlargement of the granules adjoining the subambulacral spines, I have no hesitation in declaring *O. watsoni* to be congeneric, possibly even conspecific, with *Gomophia egyptiaca.* It is significant that Endean (1965) has recorded *G. egyptiaca* from Queensland.

Seven specimens from Macclesfield Bank, South China Sea, which I have referred to *Gomophia*, also have some of the supero-marginals, often alternate ones, tubercular ; such a frequency of the tubercular plates coupled with their linear arrangement gives a greater appearance of specialization to the supero-marginals than is evident in the holotype of *G. egyptiaca.* Bell included these China Sea specimens, together with three others which I believe are *Nardoa frianti*, in *N. tuberculata.* However, the presence of intermarginal series of plates, the much more prominent tubercular plates of the aboral side often crowned with enlarged granules or even a single small tubercle, the absence of actinal papulae, the reduction of the actinal series of plates and the abrupt transition from the granulation of the lower side to

TABLE I.

Species	Locality	R (mm.)	Skeleton open	Tubercles rounded	Nipples present	Arms blunt-tipped	Some s.m. plates tubercular	Inter-marginal plates present	Actinal plates extent /R	Actinal papulae present	Interstitial granulation no./sq. mm. (approx.)	Adambulacral armament graduated
Gomophia egyptiaca T	Red Sea	65	+	−	+	−	−	+	c. ½	−	110	−
,, ,,	,, ,,	90	+	−	+	−	(+)	+	<½	−	90	−
,, ,,	Samoa	50	+	−	+	(−)	−	+	<½	−	90	−
,, ,,	Mauritius	35	+	−	+	(−)	−	+	<½	−	85	−
,, ,,	Loyalty Is.	43	−	−	+	+/−	+	+	<½	−	100	+/−
,, ,,	Christmas I.	32	+	−	+	(+)	+	+	c. ½	−	100	−
" *Ophid. watsoni* " T	Queensland	50	+	−	+	(+)	+	+	½–⅔†	−	" minute "	+
G. e. egeriae T	Macc. Bank	70	−	+/−	(+)	−	+	+	<½	−	60	−
,, ,, ,,	,, ,,	65	−	+	−	−	+	+	<½	−	70	+/−
,, ,, ,,	,, ,,	70	−	+	−	−	+	+	<½	−	70	−
,, ,, ,,	,, ,,	60	−	+/(−)	(+)	−	+	+	<½	−	75	+/−
,, ,, ,,	,, ,,	52	−	+/−	(+)	−	+	+	<½	−	66	−
,, ,, ,,	,, ,,	34	−	−	+	−	+	+	<½	−	75	+/−
Nardoa frianti T	Andaman Is.	95	−	+	−	−	+?	(+)/−	c. ½	−	−	−
,, ,, : Fisher	Sulu Arch.	126	−	+	−	−	?	?	?	+	−	?
,, ,,	Macc. Bank	72	−	+/−	−	−	(+)	−	⅔–¾	+	48	+
,, ,,	,, ,,	85	(−)	+/−	(+)/−	−	+	−	½–⅔	+	60	+
,, ,,	,, ,,	90	(−)	+	−	−	+	−	⅔–¾	(+)	55	+
,, ,,	Loyalty Is.	65	(−)	+	−	+	+	−	c. ⅞	+	36	+
,, ,, *C	,, ,,	55	(−)	+	−	+	+	−	c. ¾	+	50	+/(−)
N. mamillifera T	Queensland	63	−?	+	−	+	+?	?	c. ¾†	+?	−	+
N. rosea : Liv.	,,	88‡	−	+	−	−	+	−	½–⅔	+	33	+
N. tumulosa : Hay.	Ryu Kyu Is.	65	−?	+	−	−	+?	−	?	?	−	?
,, ,, T	Sulu Arch.	90	(−)	+	−	−	−	(+)	c. ⅓	−	−	+
,, ,, : Hay.	Carolines	54	?	+	−	−	?	−	c. ⅞	+	−	?
N. gomophia T	New Caledonia	92	(−)	+	−	−	+	−	c. ¾	+	35	+
N. tuberculata T	Philippines	82	−	+	−	+	−	−	⅞+	+	25	+
N. sphenisci T	N. Australia	118	−	+	−	−	+	+	⅔	+	28	+

* C signifies a specimen from the Cambridge Museum collection.

† These estimates are derived from Livingstone's photographs as his descriptions of the actinal (or actino-lateral) plates are confused.

‡ Livingstone gives R as only 72 mm. but the " string-along-furrow " method of measurement gives c. 88 mm. on all four intact arms.

the two rows of adambulacral spines all agree with *G. egyptiaca*. Nevertheless, when the fine coat of granules is removed from the upper side, the underlying skeleton appears to be much more compact in these specimens from Macclesfield Bank than in the others included in the table from the Red Sea, Mauritius, Samoa and Christmas Island. Possibly this can be attributed in some degree to contraction in preservation since an unnaturally flattened specimen from Eilat in the Red Sea similarly shows compaction of the abactinal skeleton. The more or less rounded form of the swollen abactinal and supero-marginal plates in most of the specimens from Macclesfield Bank, coupled with the poor development of the apical nipples (these often being confined to the supero-marginals) provides another distinction and three of the specimens have a slight transition from the granulation of the lower side to the subambulacral spines. Also the granulation of the abactinal plates seems to be slightly coarser than in those specimens of *G. egyptiaca* which most resemble the holotype. I do not consider that these differences carry sufficient weight to merit more than a subspecific distinction for the Macclesfield Bank specimens which are accordingly described here as *Gomophia egyptiaca egeriae*.

The relative specialization of their supero-marginal plates weakens the generic distinction of *Gomophia* on the basis of this character. Of the other supposedly diagnostic characters, the absence of actinal papulae is certainly constant in *G. egyptiaca* but unfortunately is matched by individuals of several species of *Nardoa*, for instance the types of both **Nardoa frianti** and **Nardoa tumulosa,** also the specimen from the Ogasawara (Bonin) Islands referred to *frianti* by Hayashi (1938*b*) ; certainly the actinal papulae are few and inconspicuous in the specimens from Macclesfield Bank which I have attributed to *frianti*.

As for the occurrence of intermarginal plates, these are not restricted to *G. egyptiaca*. Fisher notes that there are a few intermarginal plates at the base of each arm of the holotype of *N. tumulosa*, while Koehler writes to the effect that in the two syntypes of *N. frianti* " sometimes the two marginal series are fully contiguous but sometimes there are small plates intercalated between them, though these rarely form a regular and distinct series but rather are inserted in the intervals between the larger plates ". No such intercalary intermarginals are developed in the Macclesfield Bank specimens of *Nardoa*, while Hayashi (1938 and 1938*a*) mentions only intermarginal papulae, not plates, in the specimens from the Caroline and Ryu Kyu Islands which he referred to *N. tumulosa*. However, the specimen from the Ogasawara Islands (Hayashi, 1938*b*), figured under the name of *N. frianti*, not only has well-developed series of intermarginal plates but also has the tubercular abactinal plates restricted to the proximal parts of the arms (like Hayasaka's specimen from Taiwan [Formosa], 1949, Pl. ii, fig. 4, named *tumulosa*), combining to give it a strong resemblance to the holotype of *N. tumulosa*. Hayashi gave no reasons for naming his specimen *frianti* rather than *tumulosa*. Intermarginal series of plates are also developed in the type material of *N. sphenisci*.

It should be noted that *Nardoa frianti* and *Gomophia egyptiaca* are sympatric for at least part of their ranges ; both have been taken in the Andaman Islands (Koehler), on Macclesfield Bank and in the Loyalty Islands. Koehler gave insufficient information about his material of *Gomophia* from the Andamans for me to be

certain whether it should be left in *egyptiaca* or referred to subspecies *egeriae*, though his photograph suggests that the aboral skeleton is fairly open giving a reticulate appearance and thus linking it with *egyptiaca* sensu stricto. Following from the variation in shape of the abactinal tubercular plates in *G. egyptiaca egeriae*, I cannot help suspecting that Koehler's unfigured syntype (or paratype) of *N. frianti* should have been referred to *Gomophia*. This would account for the discrepancies between his description and the Macclesfield Bank specimens which I have referred to *frianti* with regard to the occasional presence of intermarginal plates and the absence of actinal papulae (though the latter could well evade detection if they are few in number).

The generic status of *Gomophia* is therefore in some doubt but, since the range of variation and specific limits of most of the species involved in the comparison have yet to be properly determined, I hesitate at present to refer it yet again to the synonymy of *Nardoa*. [In this it must be confessed that I am influenced to some extent by respect for Gray's eye for a genus, so often vindicated].

Included in the table is a column dealing with the shape of the arm tips, whether blunt or attenuated. However, since several of the species of *Nardoa* appear to be particularly susceptible to loss of parts of the arms, the subsequent regeneration, when incomplete, may give a false impression of the true shape. However, the mutilated holotype of **Nardoa mamillifera** Livingstone has all three of there maining arms ending abruptly, R/r being 5·7/1. Similarly abbreviated arms are found throughout in the two specimens I have seen from the Loyalty Islands (R/r 5·7/1 and 5·5/1), which otherwise agree closely with the three of *N. frianti* from Macclesfield Bank. The latter all have markedly attenuated arms with R/r 7·75–8·2/1. In the syntypes of *N. frianti* the ratio is 7·3 and 7·1/1, while Domantay and Roxas (1938) recorded a specimen from the Philippines with a value as high as 8/1. Döderlein (1926) recorded as *N. frianti* one from the Caroline Islands with R/r 6·4/1 but Hayashi (1938) identified as *N. tumulosa* his tuberculated Carolinian specimen; this has relatively short though tapering arms, R/r being only 5/1. A specimen from the Ryu Kyu Islands which Hayashi (1938*a*) similarly named *tumulosa* has R/r 5·3/1. In Fisher's holotype of *N. tumulosa* the ratio is 6·4/1. There is considerable resemblance between the Ryu Kyu specimen and the individual taken by the Barrier Reef Expedition which Livingstone (1932) referred to **Nardoa rosea**. Despite Livingstone's assurance that the latter agrees perfectly with the original description of *rosea* and shows no variation, a direct comparison with a paratype of *N. rosea* (Pl. 5, figs. 3 and 4) reveals a marked disparity in the size and convexity of the larger abactinal plates, many of which in the Barrier Reef specimen are c. 3 mm. in transverse diameter and c. 1·5 mm. in height (compared with c. 2 mm. and <1 mm. in *rosea*) so that it is far more reminiscent of the holotype of *N. mamillifera*, described by Livingstone in 1930, though the height of the convex plates is less. In addition it has some resemblance to the holotype of *N. gomophia*, not only in the dimensions of the plates but also in the spaced granulation and fairly attenuated arms, R/r being c. 7·5/1. The character of the alternating enlarged supero-marginals which H. L. Clark thought to be characteristic of *N. rosea* is shared by several other nominal species, notably by *N. frianti, gomophia, sphenisci* and possibly by the

holotype of *N. mamillifera*, judging from what can be seen in the photographs of the last-named. However, Fisher mentions no alternation in the holotype of *N. tumulosa*. I doubt whether the number and shape of the abactinal tubercles are much use for the specific distinction of *tumulosa* as these seem rather variable in the material from Macclesfield Bank ; possibly both *mamillifera* and *tumulosa* will prove to be conspecific with *N. frianti*, though if a consistently blunt-armed species exists at the Loyalty Islands and off Queensland this could be distinguished as *mamillifera*.

As for **Nardoa gomophia,** the distinct though isolated abactinal tubercles are intermediate in size and shape between those of **Nardoa tuberculata** and *N. frianti*. Whereas *tuberculata* (Pl. 4, figs. 1–3) has relatively low and infrequent tubercular plates, often restricted to the sides of the distal parts of the arms and rarely exceeding 2·5 mm. in diameter or over 1 mm. in height, *N. gomophia* has tubercles on the disc, arm bases and midradial as well as lateral parts of the arms throughout their length, in size up to almost 3 mm. diameter and with height often exceeding 2 mm. The modification of the supero-marginal plates is also intermediate in *gomophia*, the first five to ten plates in each series and then every second plate, with almost complete regularity, being distinctly convex and projecting c. 0·5 mm. so as to give a slightly scalloped outline to the body. The alternate supero-marginals are markedly reduced in size and convexity, as in *N. rosea*. In *N. tuberculata* the supero-marginals are all similar and barely convex but in *N. frianti* a number of them are more convex, well over 1 mm. high and there is a tendency for alternate plates to be so modified.

The slender attenuated form of the arms of *N. gomophia* (R/r being 7·7/1) also distinguish it from *N. tuberculata*, nine specimens of which (including the holotype) have an R/r range of 5·2–6·8/1 with a mean of 6·0/1, the arms of all of them having blunt tips. Concurrently with the blunt-tipped arms, the main series of actinal plates in *N. tuberculata* runs for almost the entire arm length, whereas in specimens with attenuated arms, such as the holotype of *N. gomophia* and the Macclesfield Bank specimens of *N. frianti*, the adambulacrals and infero-marginals are in direct contact for at least the last quarter of the arm length. At least one of the two blunt-tipped specimens of *frianti* from the Loyalty Islands has the series of actinal plates extending for more than three-quarters of the arm length.

The structure of the aboral skeleton in *N. gomophia* is very similar to that of the holotype of *N. tumulosa*. However, the much greater extent of the actinal plates, the alternating form of the supero-marginals, the complete absence of intermarginal plates and the presence of actinal papulae, though only about two per area, in *N. gomophia* seem to distinguish them.

Much closer to *N. tuberculata* comes the holotype of **Nardoa obtusa** (Pl. 4, figs. 2 and 3) which Fisher examined in 1914, concluding (1919 : 379) that " its relationship is with the strongly tuberculate forms, such as *frianti* and *tumulosa* " also (p. 385) he suggested that *obtusa* is a young *tuberculata* with " the tubercles a little more prominent than usual ". Like Hayashi (1938*a*) I fully agree with the latter conclusion. There is some resemblance to the holotype of *N. gomophia*, but the fact that the supero-marginals show no tendency for alternation in size, the actinal plates already extend for well over half the arm length and the arm tips are blunt

(possibly correlated with the relatively small size of the specimen, R/r being 35/7·5 mm. = 4·7/1) all point towards synonymy with *N. tuberculata*. Hayashi treated *obtusa* as a forma of *tuberculata* with relatively shorter arms and some colour difference in life from *tuberculata* sensu stricto.

There is in the collections a specimen from Batjan, Moluccas (Pl. 4, fig. 4) which I can only designate " *Nardoa* sp. aff. *tuberculata* ". Although registered in 1949, it is much older, carrying labels first as *Linckia tuberculata*, then *Ophidiaster tuberculata* (possibly in Bell's hand) and finally *Nardoa tuberculata* (printed for exhibition). The arms are much more slender than is usual in *tuberculata* and the tubercles more prominent and numerous but the compact aboral skeleton, the un-modified supero-marginal plates and the extension of the actinal plates right to the arm tips all agree with *N. tuberculata*. Von Martens (1866) commented on similar slender-armed specimens from Batjan.

Turning to **Nardoa sphenisci** nov., this species certainly approaches *Gomophia egyptiaca*. Two of the seven specimens from Macclesfield Bank which I am describing as subspecies *egeriae* of *G. egyptiaca* have most of the elevated abactinal and supero-marginal plates unusually rounded at the apex, though a few are more conical in shape, and there are several enlarged granules rather than a conical tubercle at the apex. Consequently the individual tubercular plates of these particular specimens are very reminiscent of those found in *N. sphenisci*. However, not only do these plates reach a much greater height in *Gomophia*, many of them being c. 2·5 mm. high, (when R is 60–65 mm.) but also they contrast markedly with the almost flat surrounding plates from which they arise in isolation. The granulation of the low plates is almost uniformly fine and, in general, even near the apices of the convex plates, the granulation is much finer in *G. egyptiaca* than in *N. sphenisci*, the granules on the flatter parts of the plates numbering 60–110/sq. mm. where counted in the former and only c. 30/sq. mm. in *sphenisci*. The development of intermarginal plates is another point of resemblance between the two species but the absence of pore areas on the lower surface below the infero-marginals and the lesser extent of the actinal plates (rarely to half R) in *G. egyptiaca* are in marked contrast. Also the armament of the adambulacral plates is rather different ; in *Gomophia* the two rows of spines usually project abruptly from the fine granulation of the lower side with no transitional enlarged granules forming a third series, whereas in most species of *Nardoa*, including *sphenisci*, the transition is more gradual. *G. egyptiaca* too may have five slender furrow spines, even at R c. 65 mm., though the number is more often four.

Finally there is some resemblance, geographically as well as morphologically, between *N. sphenisci* and *N. rosea*, both being known from northern Australia. In his key, H. L. Clark included *rosea* among the species of *Nardoa* lacking abruptly enlarged and projecting abactinal plates but his photograph of the holotype shows that some of the plates, especially the proximal midradial ones, are distinctly convex, approximating to the form of the corresponding plates of *N. sphenisci*. The rugose texture produced by the coarse granulation is another point of similarity and I was inclined to refer the " Penguin " specimens to *N. rosea*. Thanks to Dr. H. B. Fell and Mr. James F. Clark I have been able to study type material of *N. rosea*

from the Museum of Comparative Zoology for comparison. This does have a considerable resemblance in the aboral skeleton to *N. sphenisci* though the size and convexity of the larger plates is rather less, their diameter not exceeding 2·0 mm. while few of them reach a height of 1·0 mm. The denuded skeleton is similarly compact though there is not so much size discrepancy between large and small plates. The resemblance in granulation, however, proved to be more superficial, since all the granules in *N. rosea* are more or less widely spaced from each other, as in the holotype of *N. gomophia,* not forming the almost continuous coating found in *N. sphenisci.* Also the granules are simply rounded, not flat-topped, although some of the larger ones on the convexities of the plates are slightly polygonal in outline. The number of fine granules interstitially is similarly c. 25–30/sq. mm. and of coarse ones 10–12/sq. mm. in *N. rosea* but, being spaced, the size of the individual granules is less than in *sphenisci.* Another difference lies in the adambulacral spines, the two rows of which in *N. rosea* stand out abruptly, whereas in *sphenisci* there is a transitional third row of elongated granules.

More obvious differences lie in the blunt-tipped rather than attenuated arms of *N. rosea* and the complete absence of intermarginal plates despite the strong tendency in both for alternation in size of the supero-marginals. Mr. Clark found no intermarginals in the rest of the type material in the Museum of Comparative Zoology, which he kindly examined for me. He gives the R/r ratios as 6·9/1 (in the holotype), 7·5/1, 7·3/1 and 6·8/1. In the paratype lent to me R is c. 78 mm. and the arm breadth at the very tip is as much as 4·5 mm., compared with c. 2 mm. in the holotype of *N. sphenisci.*

There is a specimen in the British Museum collections from Bassett-Smith Bank (also off northern Australia) which I had identified as *N. rosea* some years ago. It is in spirit, which may partly account for the smoother appearance in comparison with the type material of *rosea,* but the granules are almost continuous, not spaced from each other, though they are similar in number. However, alternate supero-marginals, especially distally, are regularly reduced in size. R/r is 7·0/1. The proximal midradial abactinal plates are only slightly convex and are relatively larger than in the type material of *N. rosea* with five plates rather than about seven across the base of the arm. There is no sign of intermarginal plates. This specimen is certainly not conspecific with Livingstone's one from the Barrier Reef and possibly not with the type material of *N. rosea* either. Obviously much still remains to be ascertained about the specific limits of these species.

In view of the intermediate condition of the aboral skeleton shown by *N. rosea* and the close affinity between *N. tuberculata* and *pauciforis* discussed further below, the division of the species of *Nardoa* into two groups according to the occurrence of distinctly convex plates is not a sharp one. Nevertheless it is a convenient distinction for most of the species.

The remaining species of *Nardoa*—those with all the abactinal plates of similar low or flat contour—include the following :

Nardoa variolata (Retzius), 1805—the type-species
Nardoa lemonnieri Koehler, 1910

Nardoa mollis de Loriol, 1891
Nardoa novaecaledoniae (Perrier), 1875
Nardoa galatheae (Lütken), 1865
Nardoa pauciforis (von Martens), 1866
Nardoa faouzii Macan, 1938 and
Nardoa rosea H. L. Clark, 1921—if that is not included in the first group.

The limits of **N. variolata** need re-examination. Bell has recorded the species from Stanley Gardiner's collections at various islands in the western Indian Ocean (1909) and from the Maldives (1902) as well as from Dr. Ondaatje's collections in Ceylon (1887). The last record was based on three small specimens (R up to 28 mm.) and I believe that these are conspecific with the much larger specimens from Ceylon which Bell referred to *N. novaecaledoniae* (Perrier) and which I am currently relabelling as *N. lemonnieri* Koehler, being unconvinced by H. L. Clark's proposal to synonymize the latter with *N. mollis* de Loriol. Nearly all the Gardiner specimens are in the Cambridge Museum. I have studied one of these from S. Nilandu, Maldives. This is not a *Nardoa* at all but is conspecific with another Gardiner specimen from the Amirantes, which is in the British Museum collections. I consider that both of them represent a new species of *Fromia* described below. I cannot say whether the specimens from the second Maldive locality of Gardiner's are really referable to *N. variolata*. H. L. Clark has already commented that the specimens from at least Minikoi recorded as *N. novaecaledoniae* by Bell must surely have been in reality *Linckia laevigata*, judging from their blue colour—the species of *Nardoa* being various shades of brown. However, in 1957, Major W. W. A. Phillips presented the British Museum with two specimens from Male in the Maldives which were referred to *N. variolata* (Clark & Davies, 1966) on the basis of H. L. Clark's key to the species of *Nardoa* (1921), since the largest abactinal plates exceed 3·0 mm. in transverse diameter, even 3·5 mm. in one specimen, and there is no abrupt reduction in size of the plates distally. One of the two has only four arms and R is 85 mm. The second, five-armed, specimen has R 95–105 mm. *N. variolata* at Mauritius and East Africa rarely exceeds R 70 mm., though the single specimen taken by the Transit of Venus Expedition at Rodriguez and named by Smith does have R 100–110 mm. The large size and the proportions of the abactinal plates of the Maldive specimens approximate to the figured syntype of **N. lemonnieri** from the Andaman Islands, though the arms are probably somewhat broader terminally. Unfortunately Koehler cut off all the arm tips from his photographs of *lemonnieri* in making up the plate ; as far as can be seen the arms are fairly slender distally ; he describes them as narrow and sharp at the tip. In his three larger specimens, R 95+ mm., R/r is 6·6, 7·0 and 8·0/1.

The British Museum collections include three large individuals of *N. lemonnieri* from the Andaman Islands, one with four arms being excluded from table 2, and eleven from Ceylon, three of them very small. As can be seen from the table, these all have relatively more attenuated arms than the two from the Maldives and their distal aboral plates are consistently smaller, though the diminution in size distally is similarly fairly gradual. The Maldive specimens therefore seem to

be intermediate both morphologically and geographically between *Nardoa variolata* from the Mascarene Islands and East Africa and *N. lemonnieri* from Ceylon and the Andaman Islands but their true status must await the study of further material to show the extent of variation.

Some details of all these specimens together with data from available material of **N. mollis** and **novaecaledoniae** is given in table 2. Apart from the quoted types, all the specimens are in the British Museum collections except for five of *novaecaledoniae* from the type-locality, which are on loan from the Oslo Museum.

Were it not that Perrier gives R/r of the holotype of *N. novaecaledoniae* as 6·7/1, I would have thought from the present material that the species can be differentiated from *N. lemonnieri* and *mollis* by the moderate length of the arms and their lack of attenuated tips, as Koehler (1910) also remarked. However, H. L. Clark (1921) distinguished *novaecaledoniae* by the relatively larger proximal aboral plates, as well as by a colour difference of little use for the determination of preserved specimens. Unfortunately only two specimens of *N. mollis* are available to me. These do tend to substantiate the distinction from *novaecaledoniae* by the smaller size of the proximal aboral plates and the more attenuate arm tips.

Apart from the specimens shown in Table 2, there is one from Timor the identity of which with *N. lemonnieri* or *N. mollis* I am uncertain. It has R 115–125 mm., R/r 7·5/1, br 10 mm. from arm tip 5·0 mm., the arms being very attenuated, maximum aboral plate diameter just over 3 mm., distal plate diameter c. 0·8 mm. and seven to nine plates across the arm width basally. The distal plates are extremely elongated and the enlarged polygonal granules which they bear tend to be arranged in two rows of about five granules each. The interstitial areas between the groups of large granules are occupied by only about two rows of much finer ones. This contrasts on the one hand with the irregular-shaped groups each of about four large granules shown by de Loriol (1891, pl. 3, fig. 4*c*) on the distal plates of the holotype of *N. mollis* and on the other hand with the broader, though still somewhat elongated, groups of 12–18 granules found in the specimens of *N. lemonnieri* from the Andaman Islands, while the individuals from Ceylon have even larger distal plates.

Domantay and Roxas (1938) have recorded *N. variolata, mollis, novaecaledoniae* and *lemonnieri* all from the Philippines. Judging from their photographs the first-named is certainly not conspecific with the species found at Mauritius but is probably based on a specimen of *N. novaecaledoniae*; their other identifications may be correct. The individual named *N. lemonnieri* (Pl. 10, figs. 55, 56) has extremely attenuated arms and some resemblance to the British Museum specimen from Timor except that the proximal aboral plates are smaller. Fisher too (1919) has recorded as *N. lemonnieri* a specimen from the vicinity of the Philippines (the Sulu Archipelago) ; this has R/r 7/1 so that the arms are elongated if not attenuated.

The position of **Nardoa galatheae** (Lütken) also remains to be determined. The unique type was from the Nicobar Islands and the arms were described as narrow and acute, though R/r is only c. 6/1, so that there is a strong probability that its affinities lie with *N. lemonnieri*, which may also have four furrow spines.

In addition to the characters already discussed, Fisher has used the occurrence of an abrupt reduction in magnitude of the aboral granulation at the edges of the

TABLE 2.

Species	Locality	R (mm.)	R/r −/1	br 10 mm. from tip (mm.)	Diameter of aboral plates: Max. (mm.)	Diameter of aboral plates: distal (mm.)	No. pls. across arm base
N. variolata	Rodriguez	105	5·8	8·0	4·0	2·5	c. 9
	Mozambique	68	5·7	6·0	4·0	2·0	c. 7
	,,	67	5·6	7·5	3·5	2·0	c. 7
	Mauritius	67	5·3	8·5	4·5	2·5	5
	,,	66	5·6	7·5	4·5	2·5	5
	,,	63	4·8	7·5	3·5	2·0	4, 5
	,,	62	5·2	6·5	4·0	2·0	c. 7
	,,	62	5·6	5·5	2·5	1·5	c. 7
	,,	60	5·0	5·0	3·5	2·0	c. 5
	,,	58	5·7	6·0	4·0	2·0	5–7
	Zanzibar	58	4·8	7·0	4·0	2·0	c. 5
	Mauritius	57	4·7	6·0	3·5	2·0	c. 7
	,,	55	5·0	7·0	3·0	2·0	6, 7
R/r range of 12 with R 55–68 mm. = 4·7–5·7/1, mean 5·2/1							
Nardoa sp.	Maldive Is.	100	6·6	8·5	3·7	2·0	5, 6
	,,	85	6·5	7·0	3·3	2·0	c. 8
N. lemonnieri T*	Andaman Is.	98	7·0	?	3·5	1·5	c. 7
	,,	118	6·9	5·5	2·5	1·2	c. 9
	,,	115	6·6	5·0	2·5	1·0	7–9
	Ceylon	114	6·6	7·0	3·2	1·5	7, 8
	,,	110	7·4	6·0	3·2	1·7	c. 7
	,,	88	5·6	6·0	2·5	1·2	c. 7
	,,	85	6·0	5·5	2·5	1·5	c. 7
	,,	76	5·9	6·0	2·5	1·2	c. 7
	,,	72	6·2	5·5	1·7	1·2	c. 7
	,,	65	5·4	5·5	2·0	1·2	6, 7
	,,	57	5·7	6·0	2·0	1·2	c. 7
R/r range of 11 with R 57–118 mm. = 5·4–7·4/1, mean 6·4/1							
N. mollis T*	New Britain	111	7·0	5·5	2·5	c. 0·5	?
	Monte Bello Is.	90	6·4	5·0	2·0	0·7	c. 7
	,, ,, ,,	65	6·0	5·0	1·5	0·7	c. 7
N. novaecaledoniae T*	New Caledonia	94	6·7	—	3	—	c. 10
	,, ,,	95	5·6	7·0	3·0	1·0	7, 8
	,, ,,	92	5·4	7·5	3·0	0·7	c. 9
	,, ,,	85	5·8	7·5	3·0	0·7	7–9
	Barrier Reef	92	7·1	7·0	3·0	1·0	c. 9
	Fiji	84	5·3	8·0	2·5	0·8	7–9
	New Caledonia	75	5·8	7·5	3·0	1·0	c. 7
	,, ,,	75	5·5	6·5	2·5	0·8	c. 7
	,, ,,	72	5·2	5·5	2·5	1·0	7–9
	Port Essington	74	5·7	6·0	2·0	0·5	6, 7
	,, ,,	74	5·2	5·5	2·5	0·8	6, 7
	,, ,,	72	5·2	6·0	2·0	0·5	c. 7
	,, ,,	72	5·5	5·5	2·0	0·5	c. 7
	,, ,,	55	5·0	6·0	2·5	0·5	6, 7
	Duke of York I.	63	5·2	6·0	2·0	0·5	c. 7
R/r range of 13 with R 55–95 mm. = 5·0–5·8/1, mean 5·4/1							

TABLE 2. Data from specimens of four species of *Nardoa* for comparison with two from the Maldive Islands. The distal br measurements are given to illustrate the degree of attenuation of the arms. The diameters of the plates are approximate measurements made without denuding the plates. The entries for the relevant types (marked T*) are derived from the literature and the approximately life-sized figures given by Koehler and de Loriol.

plates and a lobate form of the denuded plates to try and distinguish between the species of *Nardoa*. H. L. Clark discounts the latter and I too have found lobate plates to be more widespread among the species of *Nardoa* than Fisher supposed. As for the granulation, this seems to be variable ; it can give a very distinctive appearance when the change to fine interstitial granulation is abrupt but this may be exaggerated to some extent by the state of preservation. Contrary to Fisher's statement, an abrupt change in size of the granules does occur in *N. novaecaledoniae* as well as in *N. variolata*, *lemonnieri* and *mollis*. However, it may be less marked in **Nardoa pauciforis,** which differs too from the other four species by regularly possessing pedicellariae of the split-granule kind among the interstitial granules but distinctly coarser than these. The abactinal plates are also particularly small in *N. pauciforis*, not even the proximal mid-radial ones approaching the marginal plates in size so that there are usually about 13 plates across the width of the arm basally when R is c. 100 mm.

Hayashi (1938) considers *Nardoa pauciforis* to be a forma of *N. tuberculata*, noting that it differs only in lacking the scattered tubercular aboral plates. The colouration of the two he says is similar as well as the other morphological characters. Certainly *N. tuberculata* has arms of similar shape, extensive actinal plates, granulation little finer interstitially than on the abactinal plates and interstitial pedicellariae usually present. However, the holotype of *N. tuberculata* with R 82 mm. has only nine or ten aboral plates across the width of the arm basally and other specimens in the British Museum collections with R c. 100 mm. rarely have more than eleven plates. Without larger samples for study I cannot comment further on this problem.

Finally **Nardoa faouzii** Macan differs from all the other species in the conspicuously regular arrangement both longitudinally and transversely of the abactinal plates of the proximal third or nearly half of each arm. This is comparable to the arrangement in *Scytaster semiregularis* Müller and Troschel, which was for long included in *Nardoa* but split off by H. L. Clark as type-species of the genus *Certonardoa*, though Tortonese (1955) does not approve this action. *Certonardoa* is distinguished from *Nardoa* not only by the skeletal arrangement but also by the complete absence of papulae below the infero-marginal plates, whereas *N. faouzii* does have well-developed actinal series of pore-areas, numbering 14 or 15 on each side of each arm. H. L. Clark also referred to *Certonardoa* two species described by Koehler (1910), *Nardoa carinata* from the Andaman Islands and *N. squamulosa* from Burma. I am uncertain about the affinities of the latter. However, there is a specimen with R 42 mm. from south of Galle, Ceylon, collected by Dr. Herdman, in the British Museum. It is similar to the holotype of *C. carinata* not only in size but also in the semi-regular arrangement of the aboral skeleton, the tapering arms almost flat below (though rounded rather than slightly carinate above) and the absence of inter-marginal or actinal papulae. However, the Sinhalese specimen has a number of well-developed alveolar pedicellariae on the larger plates. Probably on this account, coupled with the partially regular abactinal plates, it was formerly labelled as an *Ophidiaster* or *Tamaria* but the more Goniasterid-like adambulacral armament serves to distinguish it from these genera. In comparison with this specimen, *N. faouzii* has blunt arms, no pedicellariae and pore-areas present

not only inter-marginally but also below the infero-marginals in an extensive series.

The partially regular arrangement of the skeleton is I believe a character of some weight, distinguishing *faouzii* easily from *N. variolata* and all the other species discussed above. However, since it is not supported by a difference in the extent of the pore-areas, I consider that the distinction should be only at the subgeneric level. Accordingly I propose to establish the following :—

NARDOA subgen. ***ANDORA**** nov.

TYPE SPECIES. *Nardoa faouzii* Macan, 1938.

DIAGNOSIS. A subgenus of *Nardoa* with the aboral plates of the proximal third of the arms arranged in regular longitudinal and transverse rows.

KEY TO THE SPECIES OF *NARDOA*

1	A number of isolated abactinal plates abruptly more convex and projecting than the rest, often hemispherical	2
1′	Abactinal plates mostly similar in contour, though often variable in size, none markedly projecting	6
2	Some of the supero-marginal plates hemispherical as well as some abactinal plates, the height of these often equal to the basal diameter[1] . ***frianti*** Koehler, 1910 ***mamillifera*** Livingstone, 1930	
2′	No supero-marginal plates conspicuously tubercular, though in some species the alternate ones may be more or less convex ; tubercular abactinal plates distinctly wider than high, though sometimes no broader than the unspecialized flatter plates	3
3	Tubercular abactinal plates low, broad and cushion-like, absent from the distal parts of the arms, often transversely elliptical, measuring 3–4 mm. in diameter at R > 50 mm. . . . . ***tumulosa*** Fisher, 1917	
3′	Tubercular plates relatively small, rarely much exceeding 2 mm. in diameter, even at R > 70 mm., often present distally as well as (or rather than) proximally	4
4	Arms not attenuated but more or less blunt at the tip, R/r 5·0–7·0/1 ; the main actinal row of plates extending the whole length of the arm ; tubercular abactinal plates inconspicuous, tending to be fewer proximally and restricted to the lateral areas of the distal parts of the arms ; supero-marginal plates all similar in size, not alternating . . . . . ***tuberculata*** Gray, 1840	
4′	Arms very attenuated distally, R/r 7·5–9·2/1 (in the only four specimens known) ; the main actinal row of plates terminating at half to two-thirds R from the base of the arm ; tubercular abactinal plates well-developed, proximally as well as distally ; some of the supero-marginals, often alternate ones, reduced in size	5
5	Intermarginal plates present in the arm angles ; the majority of abactinal plates markedly convex, particularly the midradial ones . . . ***sphenisci*** sp. nov.	
5′	No intermarginal plates ; tubercular abactinal plates widely separated, as well-developed laterally as mid-radially . . . ***gomophia*** (Perrier), 1875	
6	Supero-marginal plates tending to alternate large and small, especially distally ***rosea*** H. L. Clark, 1921	

* An anagram of Nardoa.

[1] If the abruptly terminating arms of the mutilated holotype of *N. mamillifera* are shared by other specimens from the type-locality this might provide a valid distinction from *N. frianti*, in which case specimens from the Loyalty Islands could also be referred to *mamillifera*.

6′ No regular alternation in size of the supero-marginals 7
7 Abactinal plates of the proximal third to half of the arm forming distinct regular longitudinal and transverse series, though this breaks down distally
Nardoa (Andora) fouazii Macan, 1938
7′ Abactinal plates irregular in arrangement throughout 8
8 Adambulacral plates each bearing only four furrow spines and four subambulacral ones (though in my interpretation of Lütken's danish the granulation backing on to these spines is transitional) . . . . . ***galatheae*** (Lütken), 1865
8′ Granulation of the outer part of each adambulacral plate usually modified to form a third row of spines, numbering three like the two inner rows, though the furrow series may consist of four spines 9
9 Many of the abactinal plates more or less conspicuously broadened and alternating to form an almost continuous pavement, the interstitial pore-areas being small ; the larger plates markedly bigger than the supero-marginals, exceeding 3 mm. in diameter, even at R only c. 40 mm., numbering only about five across the width of the arm basally at R < 50 mm., seven at R 50–70 mm. or up to nine in the rare specimens that exceed 70 mm. ; the distal abactinal plates similar to the proximal ones though gradually becoming smaller . . ***variolata*** (Retzius), 1805
9′ Few if any of the abactinal plates conspicuously larger than the supero-marginals and rarely broadened transversely to exceed 2·5 mm. in diameter ; if some large plates are present proximally then the distal plates are relatively much smaller, often with an abrupt change in magnitude at about two-thirds R 10
10 All the abactinal plates, both proximally and distally, small in comparison with the marginal plates, numbering about 13 across the arm width basally, at least at R>90 mm. ; granuliform pedicellariae often present between the aboral plates and distinctly coarser than the granules ; ventral papulae few and inconspicuous
pauciforis (von Martens), 1866
10′ The proximal abactinal plates, especially midradially, distinctly larger than the distal plates and sometimes equalling or even slightly exceeding the supero-marginals in diameter, rarely more than eleven plates across the width, more often seven or nine ; pedicellariae not recorded ; usually a number of pore-areas developed between infero-marginal and actinal plates 11
11 R/r usually 5·0–6·0/1 (see Table 2) . . ***novaecaledoniae*** (Perrier), 1875
11′ Arms more attenuated, R/r usually 5·5–8·5/1 12
12 Distal abactinal plates conspicuously smaller than the proximal ones, not exceeding 1 mm. in transverse diameter, their positions shown by rounded groups of coarse granules among the fine interstitial granulation . . ***mollis*** de Loriol, 1891
12′ Distal abactinal plates becoming gradually somewhat smaller than the proximal ones and usually 1·2–1·5 mm. in diameter but markedly elongated in form with ovate groups of coarse granules . . . . . ***lemonnieri*** Koehler, 1910

Fromia indica (Perrier)

Scytaster indicus Perrier, 1869 : 255 (?63).
Fromia indica : Perrier, 1875 : 177–178 (441–442) ; Koehler, 1910 : 140, pl. xvii, figs. 7, 8 ; H. L. Clark, 1921 : 42 ; Hayashi, 1938*a* : 207 ; 1938*b* : 59–62, figs. 1, 2, pl. iv, figs. 1–4 ; 1938*c* : 279–280.
Fromia tumida Bell, 1882*a* : 124, pl. vi, fig. 4 ; H. L. Clark, 1921 : 41.
Fromia andamanensis Koehler, 1909 : 105–108, pl. vii, figs. 5, 6 ; H. L. Clark, 1921 : 41.
Fromia elegans : Engel, 1938 : 11, fig. 1, pl. iii, fig. 1 [Non *F. elegans* H. L. Clark, 1921].
Fromia indica forma *andamanensis :* Hayashi, 1938 : 428–430, pl. ii, figs. 7, 8.

MATERIAL. Ceylon ; Mr. Kelaart ; two syntypes of *Fromia tumida* Bell, B.M. reg. no. 52.5.15.62 and 63.

Ceylon ; Dr. Ondaatje ; 1 specimen, no. 88.4.13.3.

Andaman Islands ; Dr. Anderson ; 5 specimens, no. 86.6.26.20–22 and 79.

Fiji Islands ; Admiralty ; 1 specimen, no. 56.9.24.26.

SYNONYMY. I agree with Hayashi (1938 and 1938*b*) that *Fromia andamanensis* Koehler is better ranked as no more than a forma of *F. indica* distinguished by the similar dimensions of the abactinal plates as opposed to forma *indica* with two series of enlarged plates along each arm. The material in the British Museum collections from the type-locality of *andamanensis* supports this synonymy. However, I do not agree that *F. elegans* is also a synonym, since Mr. James F. Clark has re-examined the holotype in the Museum of Comparative Zoology at my request and found that the granules of the actinal plates number seven to nine on a plate and are no higher than wide, differing from the very characteristic elongated granules or short blunt spines, usually in groups of about five, found in *F. indica*. My thanks are due to Mr. Clark for his observations. Both Domantay and Roxas (1938) and A. H. Clark (1949) have extended the geographical range of *F. elegans* from Torres Strait to the Philippines. Judging from the photographs given by the former, their specimens could well be *elegans* but the specimen from Banda Neira referred to *elegans* by Engel (1938) has the distinctive elongated armament of the actinal plates characteristic of *F. indica*.

To the synonymy of *F. indica* must also be added *Fromia tumida* Bell. The syntypes are dried and have suffered some distortion so that the lower surface has become concave and the arms are probably unnaturally wide. The hollowed under side probably evoked Bell's erroneous statement that the adambulacral spines are smaller than the spines of the actinal plates. In fact the armament is just like that of *F. indica* with short spines on the actinal plates and slightly longer ones on the adambulacrals.

Fromia nodosa sp. nov.

(Pl. 6, figs. 1–3)

Ferdina Offreti (pt.) Koehler, 1910 : 143, 147, pl. xvi, figs. 4, 5 only.

MATERIAL. Amirante Islands, W. Indian Ocean ; Gardiner collection ; the holotype and one paratype. B.M. reg. no. 1907.7.1.95 and 96.

South Nilandu, Maldive Islands ; Gardiner collection ; 1 specimen. Cambridge Museum.

DIAGNOSIS. A species of *Fromia* with very conspicuous alternation in size and shape of the supero-marginal plates, the larger ones being abruptly convex and separated by less than their own width from the series of similarly enlarged and convex spaced carinal plates ; no crystal-bodies embedded in the surface of the plates.

DESCRIPTION OF THE HOLOTYPE. R/r = 32 mm./7·5 mm. = 4·3/1 ; br at base 7·5 mm. and at arm tip 3·5 mm. The body is flattened above and the arms taper evenly to blunt tips.

The abactinal plates are of two distinct kinds, the majority being flat and polygonal while nine to eleven spaced carinal plates on each arm, starting with the primary radial plates, are enlarged, up to 2·75 mm. in transverse diameter (slightly less longitudinally), rounded in outline and markedly convex, standing out sharply from the surface though not exceeding 1 mm. in height. When denuded, the plates between the convex carinal ones are revealed as not part of the series, some being adradial in position though others may be midradial. All the plates are slightly notched at intervals peripherally to accommodate the single interstitial papular pores. There are four to six pores around each of the flatter plates but seven to nine round most of the enlarged ones. The surface of the denuded plates is almost smooth, there being no embedded crystal-bodies.

The supero-marginals are similarly of two forms with almost perfect alternation, the larger ones equal to or even slightly exceeding the diameter of the enlarged carinal plates. The swollen supero-marginals alternate in position obliquely with the swollen carinals, the three series on each arm being separated by only single small flat plates for most of the arm length while from the tenth supero-marginal all three rows of swollen plates are partially in contact laterally or obliquely. There are fifteen supero-marginal plates in one series denuded, the first, second, fourth, sixth, eighth, tenth, twelfth, fourteenth and fifteenth being convex and dwarfing the intervening plates.

The infero-marginals number sixteen and are all similar in form though gradually decreasing in size from a proximal breadth of c. 2 mm.

There are two series of actinal plates, the outer consisting of ten plates and extending to the fifth infero-marginal, two actinal plates corresponding almost exactly to one marginal. The inner row consists of 24 plates (in the series denuded) extending to the middle of the eleventh infero-marginal or 25 mm. distance from the mouth.

All these plates are covered with a continuous coat of polygonal granules which are slightly larger on the swollen abactinal and supero-marginal plates, numbering c. 35/sq. mm. as opposed to c. 55/sq. mm. on the flatter plates. Adjoining many of the papular pores one or sometimes several of the granules are distinctly enlarged.

There are about 46 adambulacral plates in each series. Four or five of the basal ones bear four furrow spines, the adoral one of these usually smaller and inset on the plate, like a thumb. The remaining plates, except at the very tip of the arm, each have three furrow spines. These are flattened and spatulate, measuring up to 0·75 mm. in length. Separated from the furrow spines by a distinct gap come two subambulacral spines, which are about two-thirds as long as the furrow spines but slightly stouter. Between the twenty-fifth and thirtieth adambulacral plates the number of subambulacral spines falls to one. The outer part of each plate is covered with small low polygonal granules similar to those on the actinal plates and abruptly contrasting with the projecting subambulacral spines.

There are two series of single actinal papulae corresponding in extent to the actinal plates.

Paratypes. The second specimen from the Amirantes has R/r = 19 mm./5 mm. = 3·8/1 and closely resembles the holotype except that the arms maintain the

same width for about two-thirds of their length. Also the enlarged supero-marginal plates are distinctly bigger than the enlarged carinals. The second series of actinal plates consists of only one or two plates. There are only about five actinal papulae between the proximal infero-marginals and the main series of actinal plates.

The Maldive specimen (Pl. 6, fig. 3) has R/r 34 mm./8·5 mm. = 4·0/1 ; br is 9·5 mm. basally but only 2·5 mm. at the tip, the arms tapering markedly. The swollen carinal and supero-marginal plates, particularly the latter, are even larger than in the holotype, producing a very mosaic-like effect, the low interstitial plates occupying little area. The largest supero-marginals are as much as 4·0 mm. in breadth and 4·5 mm. in length. Again there is a distinct enlargement of one or more granules near many of the papular pores and there are two rows of actinal papulae ; in one infero-marginal series there are 17 plates.

Remarks. The specimen with R 13·5 mm. from Ceylon thought by Koehler (1910) to be the immature fully granule-covered form of his *Ferdina offreti* is probably referable to *Fromia nodosa*. The holotype of *Ferdina offreti* (R 37–38 mm.) from the Andaman Islands likewise has enlarged swollen supero-marginal and carinal plates but these are completely bare and contrast conspicuously in colour with the granular areas. Livingstone (1931) has since referred *offreti* to *Neoferdina*, which he characterized by the presence of some bare enlarged aboral and marginal plates, as opposed to *Ferdina* sensu stricto with complete granulation even though some of the plates may be convex. *Ferdina heffernani* Livingstone (referred below to a new genus) has a superficial resemblance to *Fromia nodosa* but differs in the single row of adambulacral spines and the absence of papulae from the under side. Since these two features also apply to *Ferdina* I have no doubt that *nodosa* is most appropriately placed in *Fromia*. Nevertheless it does provide an interesting link between these genera.

Only two other species of *Fromia* agree with *F. nodosa* in having a tendency for alternation in size and more or less marked convexity of the supero-marginal plates, namely *Fromia monilis* Perrier and *F. ghardaqana* Mortensen. The latter particularly may also have some slightly convex carinal plates but nowhere does the size and degree of projection of these enlarged plates approach the condition found in *F. nodosa* where these plates are separated laterally from each other by less than their own width, while in the distal third of the arm they are partially in contact with each other.

In *Fromia nodosa* too the surface of the denuded plates is almost smooth, whereas in the other two species there are numerous glassy knobs or crystal-bodies embedded in them. Among the other species of *Fromia*, crystal-bodies are present in *F. milleporella, armata* and *balansae* but absent in *indica* and *elegans* ; their occurrence in *F. hemiopla, hadracantha* and *pacifica* is unknown.

FERDINA Gray

Ferdina Gray, 1840 : 282 ; 1866 : 12–13 ; Fisher, 1919 : 370 ; H. L. Clark, 1921 : 58 ; Livingstone, 1931 : 305.

Type species. *Ferdina flavescens* Gray, 1840 ; designated by Fisher, 1919.

Remarks. In 1931 Livingstone restricted *Ferdina* by splitting off *F. cumingi* Gray and several other species with some conspicuously naked plates as a new genus *Neoferdina*. At the same time he re-diagnosed *Ferdina* itself and added a new species, *Ferdina heffernani*. Unfortunately his generic diagnosis appears to have been based more on the latter than on the type-species, which he knew only from photographs of the holotype and the very inadequate published descriptions. Re-examination of the holotype of *F. flavescens* (Pl. 6, fig. 6) and the removal of the aboral granulation of one arm reveals that the skeleton is of similar form to that of *Gomophia* and some species of *Nardoa*, with larger abactinal plates placed at irregular intervals and superimposed on a reticulum of smaller plates leaving meshes of sufficient size to accommodate small groups of slightly spaced papulae. Probably because the specimen has R only 26–28 mm. the number of pores in each area is small, mostly two to four, which may form linear series around the larger plates so that the grouping is not obvious. Nevertheless, some grouping can be seen even with the granulation intact, this showing up both in the photographs of the holotype published by Livingstone and in de Loriol's drawings of a specimen from Mauritius, the type-locality. This is nothing like the condition in *F. heffernani*, which resembles *Fromia* in its polygonal close-fitting pavement of abactinal plates with isolated papulae at the angles.

In addition, in *flavescens* the supero-marginals are indistinguishable from the abactinal plates on the one arm cleared, only a few large ones near the arm tip being arranged in a linear series. This may also be the case in some larger specimens of *Gomophia egyptiaca* where the degree of specialization of the supero-marginals is variable.

Another unusual feature of *Ferdina flavescens* is that the actinal and adambulacral plates are embedded in tissue so that the uniform granulation covering them is almost completely smooth and conceals the limits of the underlying plates. In *F. heffernani* these plates are much more easily dislodged when the skin is dissolved by bleach and their presence is evident without denuding due to their contours and to the coarsening of the granulation in the middle of each one.

Finally, the armament of the adambulacral plates differs from that of *F. heffernani* in that the even granulation of the lower surface runs up the outer side of the single row of furrow spines, having shrunk in drying, leaving only the tips of the spines projecting. This produces somewhat the same effect as found in *Linckia* where the furrow spines appear to be sunk into the furrow. However, in *Linckia* the tips of the furrow spines hardly project at all from the surface. Possibly the same will prove to be true of live and spirit specimens of *Ferdina flavescens*, as opposed to dried ones.

Thus, although *F. flavescens* appears to agree with *heffernani* in having complete granulation, no actinal papulae and only a single series of adambulacral spines, in fact the two species are not at all closely related and are certainly not congeneric. It remains then to re-diagnose *Ferdina* and to establish a new genus to accommodate *F. heffernani*.

Diagnosis. A genus of Ophidiasteridae with the aboral skeleton consisting of

irregularly-placed larger plates superimposed on a reticulum of smaller ones leaving space between for small papular areas with poorly-integrated groups of usually two to four pores in each ; the limits of the underlying plates concealed by continuous even granulation ; supero-marginal plates irregular and only distinguishable from the abactinal plates near the tips of the arms ; actinal and adambulacral plates embedded in soft tissue so that their limits are concealed by the uniform granulation covering them ; no actinal papulae ; adambulacral plates armed with only a single row of short blunt furrow spines, only the outer halves of which project from the continuous granulation of the under side.

Affinities. *Ferdina* thus becomes a monotypic genus. It seems to occupy an isolated position within the family but may have some affinity with *Gomophia.*

CELERINA gen. nov.

Type-species. *Ferdina heffernanii* Livingstone, 1931.

Diagnosis. A genus of Ophidiasteridae with polygonal aboral plates, irregular in size, convexity and arrangement, having isolated papulae at the angles between ; supero-marginal plates tending to alternate large and convex with small and flat ; actinal plates not embedded in tissue ; granulation continuous all over, coarser on the centres of the actinal plates ; no actinal papulae ; a single row of short but projecting furrow spines.

Celerina heffernani (Livingstone)

(Pl. 6, figs. 4 and 5)

Ferdina heffernanii Livingstone, 1931 : 306–307, pl. xxiv, figs. 1–5.

Material. Macclesfield Bank, South China Sea ; 40–55 metres ; Admiralty ; 1 specimen, B.M. reg. no. 93.8.25.90.

This specimen was named *Fromia milleporella* by Bell.

Description. R/r = 29 mm./6 mm. = 4·8/1 ; br basally = 6·5 mm. The abactinal plates are mostly about 1·0 mm. in diameter and are irregular in arrangement, even the carinal series being indistinct proximally, though four to seven spaced carinal plates in the distal half of each arm are enlarged up to c. 1·5 mm. diameter and are slightly convex. At the base of the arm there are three or four plates across the width. The supero-marginal plates number about 17 in each series and exhibit a fairly regular alternation of large convex plates, up to 2·0 mm. in breadth and 2·4 mm. in length, with small flat plates in between. Consequently, the upper side superficially has considerable resemblance to that of *Fromia monilis.* The whole aboral surface is covered with a close coat of very fine granules, c. 150/sq. mm. These are very slightly coarser on the convexities of the skeleton but much less so than in the holotype of *F. heffernani.* However, on the distal marginal plates, especially the infero-marginal ones, the granulation is distinctly coarser centrally. There are about 19 similar infero-marginals in each series, decreasing gradually

in size distally. In each arm angle there are about six narrow intermarginal plates, three each side of the inter-radius. The main series of actinal plates numbers about 20 with an odd inter-radial plate adjoining each pair of oral plates. The granulation of these is distinctly coarser than the aboral granulation and in the centre of each actinal plate one to four granules are both broader and higher than the rest. Similarly the adambulacral plates, after the basal three or four, have one or more enlarged granules in the centre, a single one on the distal plates becoming increasingly prominent though without reaching the eminence of a spine. Along the furrow margin runs a single series of small sharply-pointed spines up to 0·6 mm. long. On the first 15–18 plates these usually number three ; the following plates normally bear two furrow spines. There are single papular pores between the angles of the abactinal plates and intermarginally but none on the lower surface.

Remarks. The holotype of *Ferdina heffernani* from the Santa Cruz Islands (east of the Solomons) has R 40 mm., which may account for its more numerous enlarged abactinal plates and the coarser granules on the centres of these ; however, Livingstone counted only two furrow spines, despite the larger size. He made no mention of intermarginal plates but these could easily be overlooked if they are as inconspicuous as in the British Museum specimen.

Tamaria tumescens (Koehler)

Linckia megaloplax (pt.) Bell, 1894 : 395.
Ophidiaster tumescens Koehler, 1910*a* : 281–283, pl. xvi, figs. 3, 4.
Tamaria tumescens : H. L. Clark, 1921 : 94 ; 1938 : 141 ; 1946 : 123–124.
Tamaria propetumescens Livingstone, 1932*a* : 369–371, fig. 1, pl. xlii, figs. 1–5.
Tamaria ajax Livingstone, 1932*a* : 371–372, fig. 2, pl. xli, figs. 1–5.

Material. Parry Shoal, Arafura Sea ; 22 metres ; Admiralty ; 4 specimens including the holotype of *T. propetumescens* Livingstone, B.M. reg. no. 92.4.4.2–5. 1 specimen, no. 92.4.4.27.

Holothuria Bank, northern Australia ; 27 metres ; Admiralty ; 1 specimen, no. 91.8.26.83. 2 specimens, no. 92.1.14.326–327.

Broome, N.W. Australia ; presented by Museum of Comparative Zoology, Harvard ; 1 specimen, no. 1939.6.15.65.

Dammer I., Banda Sea ; 16–27 metres ; Admiralty ; the holotype of *T. ajax* Livingstone, no. 92.4.4.24.

Synonymy. Unfortunately Livingstone had only photographs upon which to base his two nominal species, *Tamaria propetumescens* and *ajax*, and was unable to handle personally these and the other relevant specimens in the British Museum collections. The five individuals from Parry Shoal, including the holotype of *T. propetumescens*, show a range of variation in the armament of the central parts of the convex abactinal plates from almost as fine as the peripheral granules (as in the type of *T. propetumescens*) through somewhat coarser granulation (as in the type of *tumescens*) to markedly coarser with often a single enlarged flattened or conical tubercle (as in the type of *ajax* from the Banda Sea). H. L. Clark (1938) has already referred *T. propetumescens* to the synonymy of *T. tumescens* and I

consider that the holotype of *T. ajax* also comes within the range of variation of the species.

Livingstone distinguished *T. propetumescens* from the holotype of *tumescens* by the more obvious demarcation of the marginal plates, the greater extent proximally of the subambulacral spines, their separation from the furrow spines by granulation and by the development of stout infero-marginal tubercles in the type of *propetumescens*. H. L. Clark found the infero-marginal armament to be very variable, while the marked separation of the marginal plates is due to shrinkage in the drying of Livingstone's type. Also I suspect that Koehler's artist omitted to draw the granules between the furrow and subambulacral spines since these are present in the other specimens in the British Museum collections but may be inconspicuous owing to contraction of the adambulacral plates. The extent and regularity of the subambulacral spines proximally are variable in other species of *Tamaria*.

As for *Tamaria ajax*, Livingstone believed this to be related to *T. triseriata* (Fisher) from the Hawaiian Islands and did not compare it with *T. tumescens*. However, it shares the distinctive broadened carinal row of plates so characteristic of *tumescens* with which the armament is much more closely comparable than is that of *triseriata*. The holotype of *ajax* is in spirit, which accounts for its smoother appearance in photographs than the type of *propetumescens*. The apparent difference in the pedicellariae of the two shown by C. C. A. Monro's drawings in Livingstone's paper is not constant, the valves being equally short and with inconspicuous teeth all round the expanded end in some pedicellariae of the type of *propetumescens* as in the one shown for *ajax*.

Ophidiaster helicostichus Sladen

Linckia nodosa : Bell, 1884 : 124 [Non *L. nodosa* Perrier, 1875, which is a synonym of *L. bouvieri*.]
Ophidiaster helicostichus Sladen, 1889 : 405–407, pl. lxix, figs. 5–7.
Hacelia helicostichus : H. L. Clark, 1909 : 111 ; 1921 : 86 ; 1938 : 139 ; 1946 ; 122–123.
Tamaria sp. Livingstone, 1932 : 261–262 (at least the specimen in pl. xi, figs. 5, 6).
?*Ophidiaster astridae* Engel, 1938 : 12–14, figs. 2–4, pl. iii, fig. 3.

Material. " Challenger " station 187, Booby I., Torres Strait ; 11 metres ; the holotype, B.M. reg. no. 90.5.7.618.

Cape York, N. Queensland ; Mr. Damel ; 1 specimen, no. 67.5.27.1.

Prince of Wales Channel, Torres Strait ; 13 metres ; Admiralty (H.M.S." Alert "); 2 specimens, no. 82.2.22.22 and 23.

N.W. Australia ; Admiralty ; 1 specimen, no. 92.1.14.76.

Holothuria Bank, northern Australia ; Admiralty (H.M.S. " Penguin ") ; 1 specimen, no. 92.1.14.69. Holothuria Bank ; 40 metres ; 1 specimen, no. 92.1.14.238.

Port Molle, Queensland ; 26 metres ; Admiralty (H.M.S." Alert ") ; 1 specimen, no. 81.10.26.125–127. Port Molle ; presented by Sydney Museum ; 1 specimen, no. 83.12.9.88.

Affinities. In 1909, following receipt of a British Museum specimen from Prince of Wales Channel (" Alert "), H. L. Clark commented " There can be no

question, I think, that this species is congeneric with *Hacelia attenuata* Gray from the Mediterranean ". In his key to the genera of Ophidiasteridae (1921) he distinguished *Hacelia* as having ten series of pore-areas on each arm, the lowest one each side situated between the adjacent rows of actinal plates and so more numerous than the others. This is true enough of *H. attenuata* and evidently also of Koehler's variety *inarmatus* of *helicostichus* (1885) from the Sunda Islands, which was raised to specific rank by H. L. Clark (1921). However, in 1938 Dr. Clark referred another Australian specimen to *helicostichus* and noted that " the actinal papulae are poorly developed and only here and there at isolated spots can one count ten (or even nine!) longitudinal series of papulae". There are nine specimens of *helicostichus* in the British Museum collections, six of them with R > 100 mm., including two from the same station as the one sent to H. L. Clark in 1909. In none of these can I find more than eight series of papular areas, the lowest of which are between the infero-marginal plates and the outermost series of actinals. Similarly in 1946, D. D. John of this museum could find no interactinal papulae in the six larger specimens when he examined them at the request of Dr. Engel. Nothing appears to have been published by Engel concerning this but in 1938 he had described a large sea-star (R up to 220 mm.) from the East Indies as *Ophidiaster astridae*. This is clearly closely related to, if not conspecific with, *helicostichus* ; his description and figures bring out no way in which the two can be distinguished.

In view of this, I consider that there are insufficient grounds for treating *helicostichus* as congeneric with *Hacelia attenuata* and accordingly refer it back to *Ophidiaster*. It differs from the Mediterranean and Atlantic type-species, *O. ophidianus*, in having more numerous series of actinal plates, about four proximally when R = 100–150 mm., rather than two, and the area covered by these plates is correspondingly more extensive. However, several of the Indo-Pacific species of *Ophidiaster*, such as *O. hemprichi*, approximate to *helicostichus* in the number and extent of the actinal plates, though they do not reach nearly such a large size.

Immature specimens of *O. helicostichus* (R < c. 70 mm.) with the lowest series of pore-areas below the infero-marginals barely developed or even lacking, may be confused with *Tamaria* but can be distinguished from the Australian species of that genus by the more attenuated arms. The specimen with R 103·5 mm. from Port Curtis, Queensland, shown in Livingstone's pl. xi, figs. 5 and 6 (1932) under the caption of " *Tamaria* sp. " is almost certainly conspecific with *helicostichus*, resembling closely the two specimens from Port Molle, Queensland (R 50–57 mm.) and a smaller one (R 36 mm.) from Holothuria Bank, which I have referred to this species. The incipient pore-areas below the infero-marginals (which prompted Livingstone's doubts about the validity of *Tamaria* as a genus distinct from *Ophidiaster*), the faint grooving of the furrow spines and their alternation in size (though this is admittedly a general tendency in *Tamaria*) as well as the form of the skeleton with its even armament of granules, are all as would be expected in *helicostichus* at this size.

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PLATE 1

FIGS. 1–3. *Gomophia egyptiaca egeriae* subsp. nov., holotype, B.M. reg. no. 92.8.22.52, aboral (1) and oral (2) views, with detail of denuded arm (3).

FIGS. 4, 5. The same, paratypes, no. 92.8.22.53 and 259, aboral views; all from Macclesfield Bank.

FIG. 6. *Gomophia egyptiaca egyptiaca* Gray, no. 98.10.17.12, Christmas I., Indian Ocean, aboral view.

FIGS. 7, 8. The same, no. 67.1.7.42, Samoa, side view of denuded arm (7) and aboral view (8), in (7) the lowest series of plates is the infero-marginal one.

FIG. 9. *Nardoa frianti* Koehler, no. 92.8.22.264, Macclesfield Bank, aboral view.

FIG. 10. The same, no. 98.8.8.53, Loyalty Is., aboral view.

All approximately $\times \frac{2}{3}$ except (2) $\times 2\frac{1}{3}$ and (7) $\times 1\frac{1}{3}$.

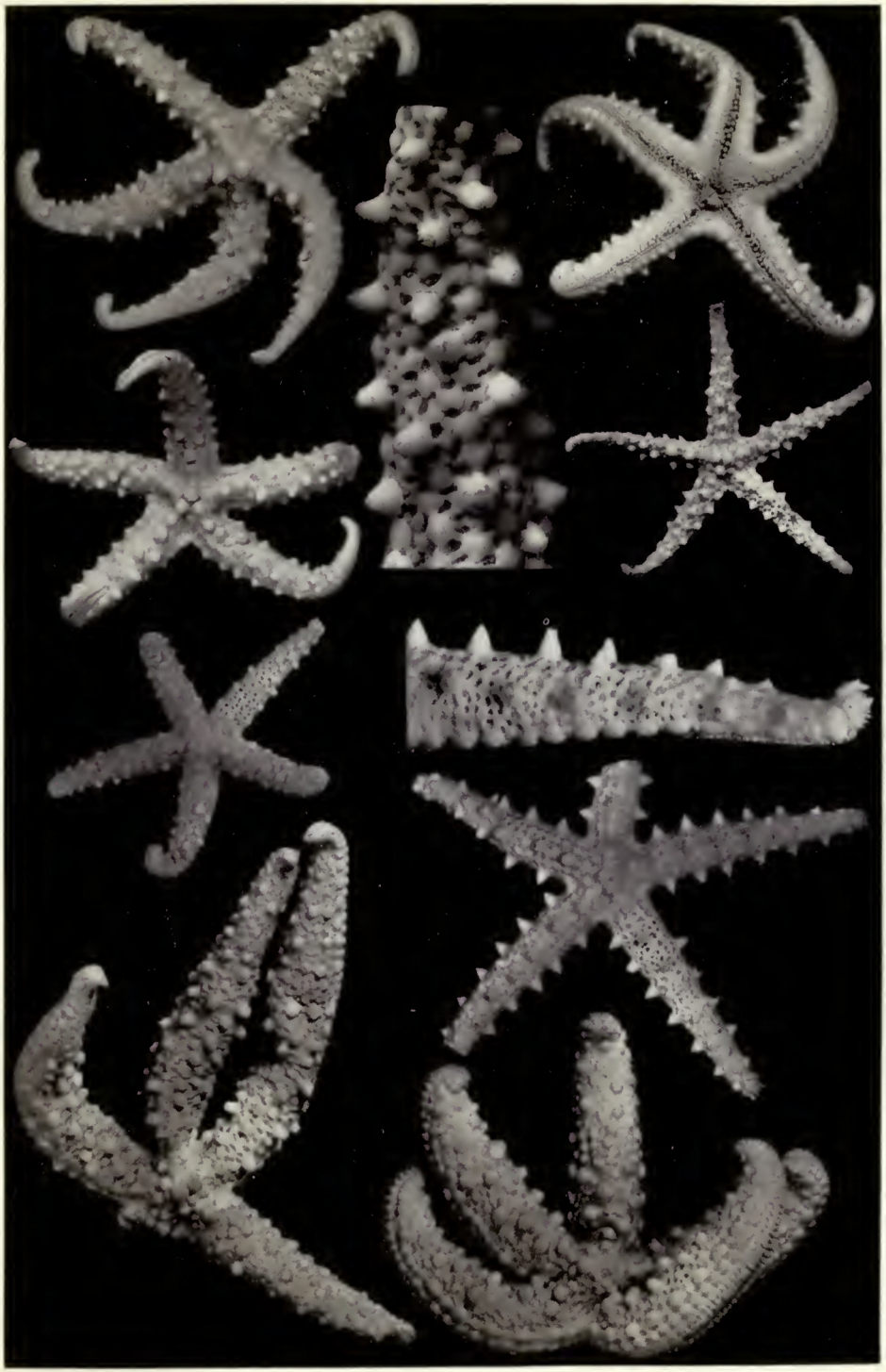
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PLATE 2

FIGS. 1–4. *Nardoa gomophia* (Perrier), holotype, B.M. reg. no. 59.4.25.3, New Caledonia, aboral (1) and oral (2) views, both $\times \frac{2}{3}$, detail of denuded arm (3), $\times 2\frac{1}{3}$ and side view of arm (4), $\times 1\frac{1}{3}$.

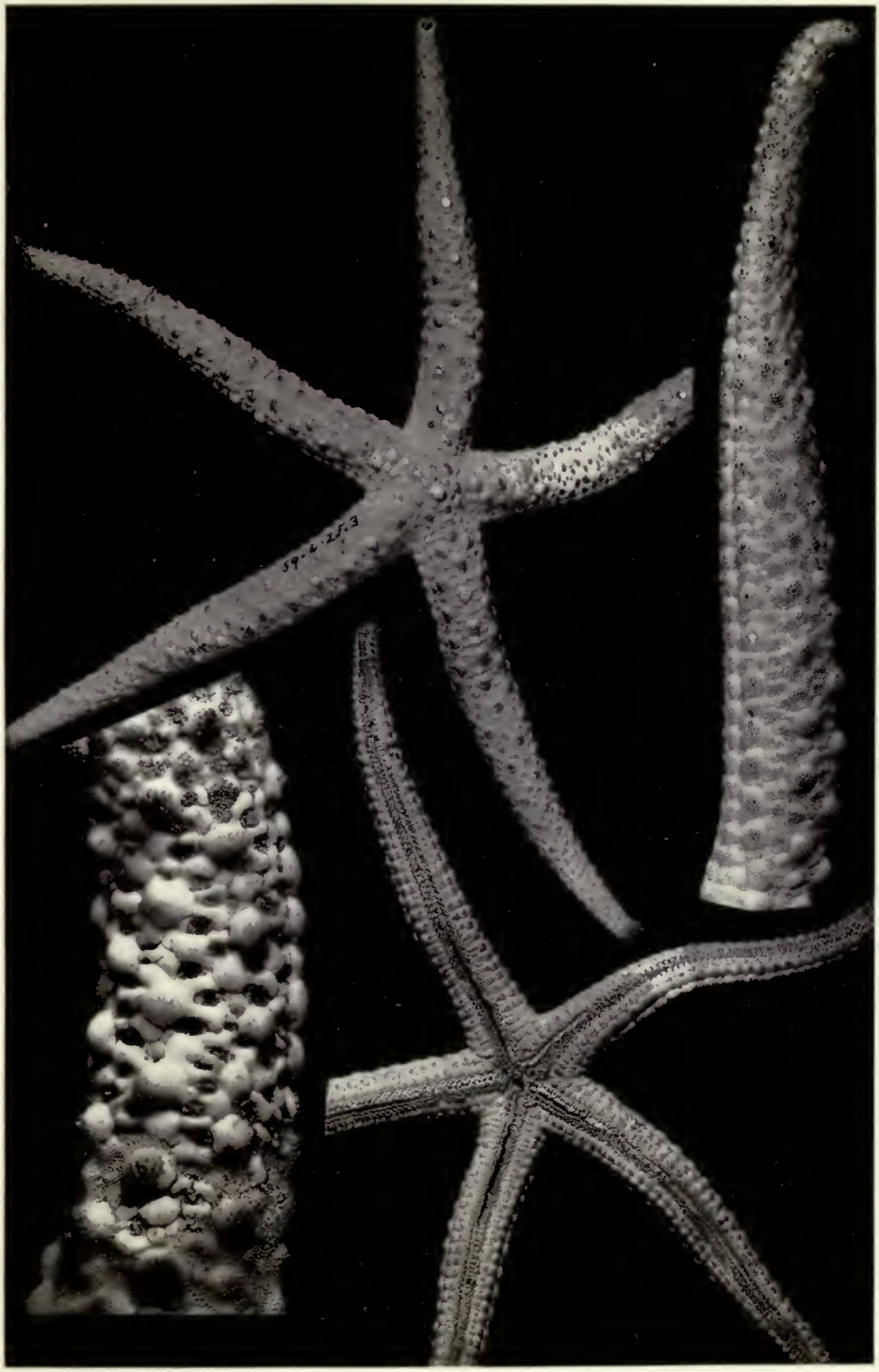
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PLATE 3

FIGS. 1–3. *Nardoa sphenisci* sp. nov., holotype, B.M. reg. no. 92.1.14.27, Holothuria Bank, N.W. Australia, aboral (1) and oral (2) views, both × ⅔ and side view of partly denuded arm (3), × 2.


1
3
2

PLATE 4

FIG. 1. *Nardoa tuberculata* Gray, holotype, B.M. reg. no. 1938.6.23.4, Sual, Philippine Is., aboral view, × ⅔.

FIGS. 2, 3. The same, holotype of *Scytaster obtusus* Perrier, no. 43.3.29.6, Siguijor, Philippine Is., aboral view (2), × ⅔ and side view of arm (3), × 1⅓.

FIG. 4. *Nardoa* sp. aff. *tuberculata*, no. 1949.2.14.16, Batjan, Molucca Is., aboral view, × ⅔.

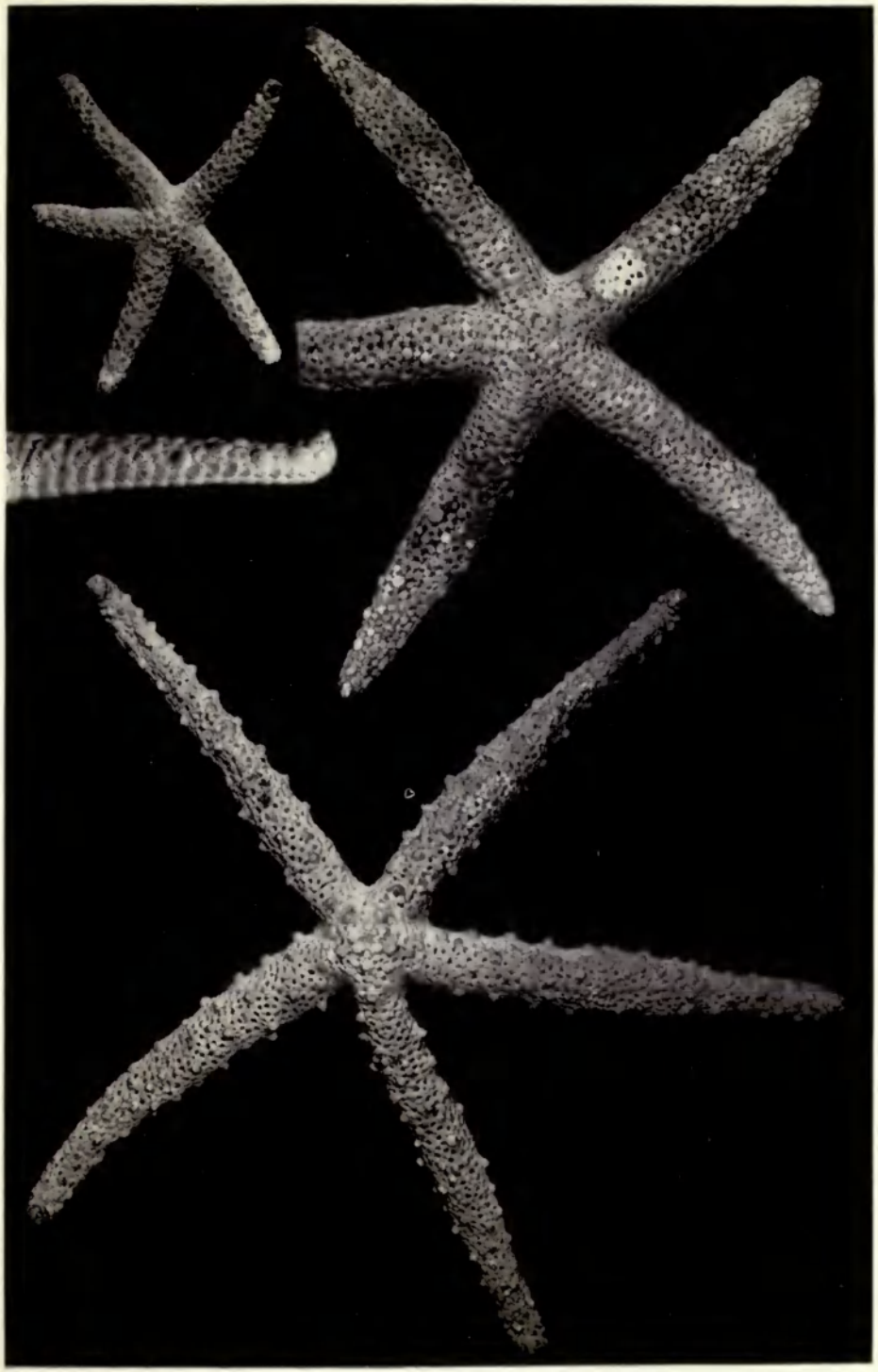
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PLATE 5

FIG. 1. *Nardoa novaecaledoniae* (Perrier), Oslo Museum collection, New Caledonia, aboral view, × $\frac{2}{3}$.

FIG. 2. The same, B.M. reg. no. 59.4.25.4, New Caledonia, previously labelled as holotype of *N. gomophia*, aboral view, × $\frac{2}{3}$.

FIG. 3. *Nardoa rosea* H. L. Clark, paratype, no. 1966.7.14.1, Mer, Torres Strait, side view of the single arm, × $1\frac{1}{3}$.

FIG. 4. The same, paratype, Museum of Comparative Zoology, Harvard collection, no. 2326, Mer, detail of partly denuded arm, × $1\frac{1}{3}$.

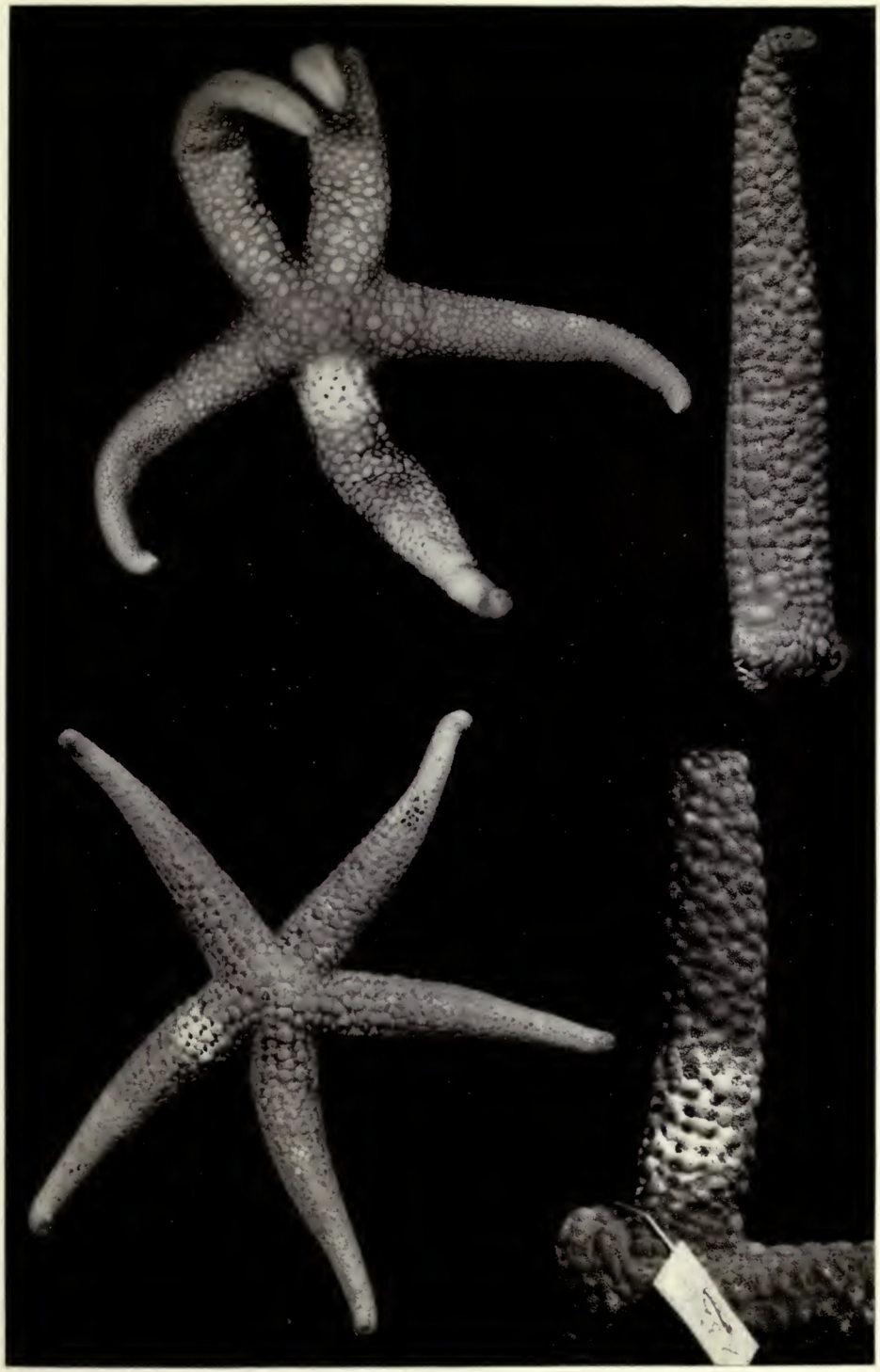
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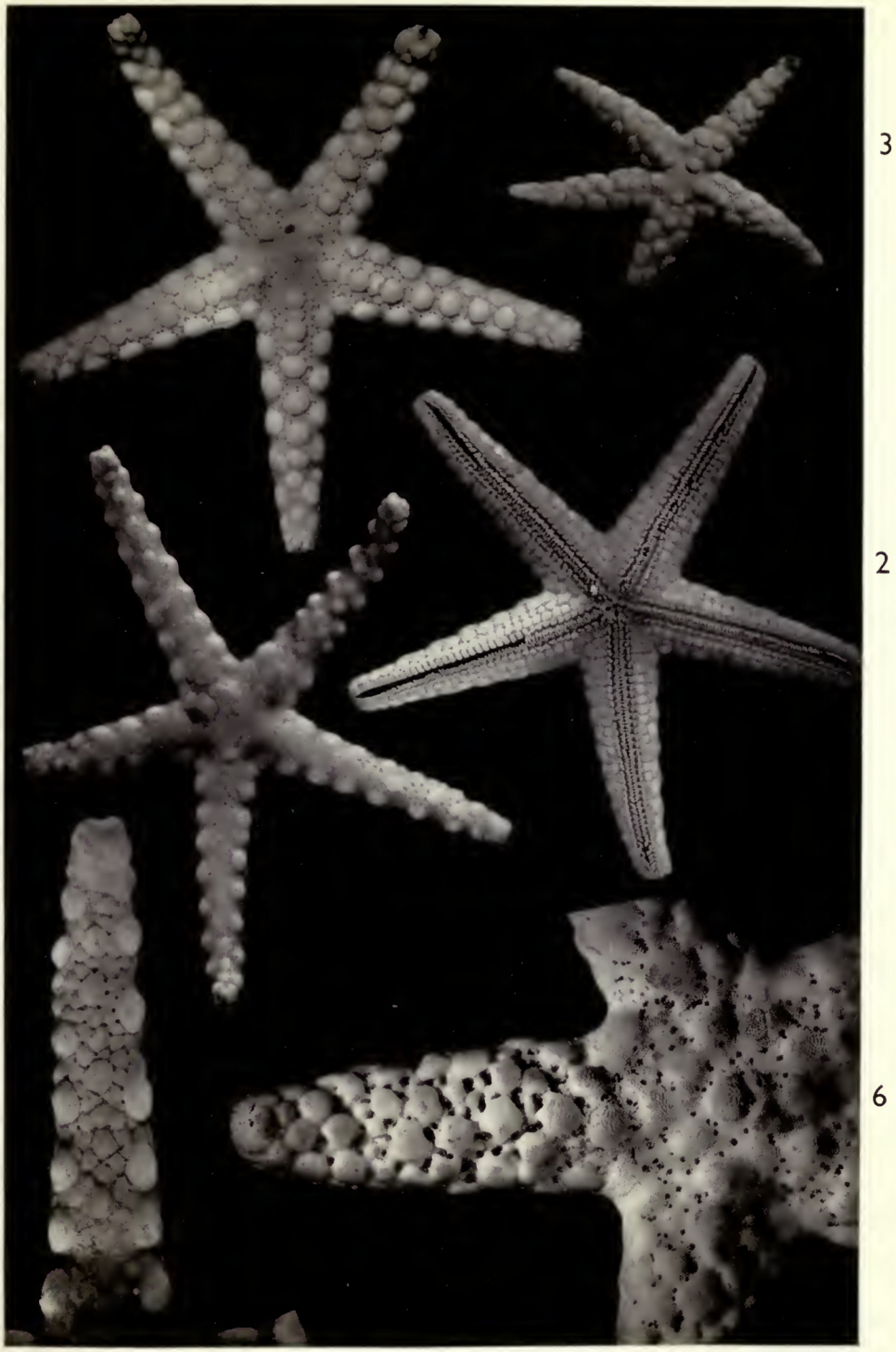
PLATE 6

FIGS. 1, 2. *Fromia nodosa* sp. nov., holotype, B.M. reg. no. 1907.7.1.95, Amirante Is., aboral (1) and oral (2) views, both × $1\frac{1}{3}$.

FIG. 3. The same, Cambridge Museum collection, S. Nilandu, Maldive Is., aboral view, × $\frac{2}{3}$.

FIGS. 4, 5. *Celerina heffernani* (Livingstone), no. 93.8.25.90, Macclesfield Bank, S. China Sea, aboral view (4), × $1\frac{1}{3}$ and detail of denuded arm (5), × $2\frac{2}{3}$.

FIG. 6. *Ferdina flavescens* Gray, holotype, no. 1938.6.23.7, Mauritius, detail of denuded arm and part of disc, × $2\frac{1}{2}$.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