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A NEW FAMILY OF ASTEROIDEA (ECHINODERMATA), WITH THE DESCRIPTION OF FIVE NEW SPECIES AND ONE NEW SUBSPECIES OF *ASTERODISCIDES*.

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SUMMARY

The genera *Asterodiscides* A. M. Clark, *Paulia* Gray and *Amphiaster* Verrill are compared and assigned to a new family. The relationship between *Paulia* and *Pauliella* is discussed. Five new species and one new subspecies are described for the genus *Asterodiscides* with the holotype of the type-species, *Asterodiscus elegans* Gray, being fully described for the first time. *Asterodiscus hiroi* Hayashi is considered to be conspecific with *A. helenotus* (Fisher) and two juvenile specimens of the species are described. Examination of many juvenile specimens has allowed an assessment to be made of the relative constancy of form of the various structural elements used in determining specific limits within the family. A key is given to the genera and species of the family.

INTRODUCTION

Gray (1840) established a monotypic genus, *Paulia,* in the family Pentacerotidae, for the species *P. horrida,* which was collected from Punta Santa Elena, Ecuador. Later (1847) he described another monotypic genus, *Asterodiscus,* for the species *A. elegans,* from an unknown locality (probably the Philippines, see Clark and Rowe, 1971 p. 40). Gray (1866) considered both of his genera related at family level, placing them together in the family Pentacerotidae.

Müller and Troschel (1842) grouped several of Gray's genera, including *Paulia,* in their embracing genus *Goniodiscus.*

Verrill (1868) described the monotypic genus *Amphiaster* with *A. insignis* from La Paz, Lower California, comparing it with the genera *Oreaster* and *Nidorellia* in the family Pentacerotidae.

Perrier (1875) restricted Müller and Troschel's genus *Goniodiscus.* He recognised Gray's *Asterodiscus,* but considered *Paulia* a synonym of *Nidorellia.* Perrier included *Asterodiscus elegans* and *Paulia horrida* (as *Nidorellia horrida*) in the family Goniasteridae. He re-described Gray's type specimen of *P. horrida.*

Records of The Australian Museum, 1977, **Vol. 31 No. 5**, 187-233, Figures 1-5

Viguier (1878), classifying the Asteroidea (Stellérides) on skeletal features, placed *Asterodiscus,* with *Goniaster, Goniodiscus, Anthenea, Nectria, Culcita, Choriaster, Nidorellia, Pentaceros* and *Gymnasteria,* in the family Goniasteridae, tribe Goniasterinae. He separated a second tribe, Pentagonasterinae (including *Pentagonaster, Hippasteria, Ferdina, Fromia* and *Metrodira*) on the lack of 'systèmes interbrachiaux; pas de spicules dans les ambulacres'. He clearly did not dissect the only specimen of *Asterodiscus* available to him (Paris Museum) but considered it closely related to *Culcita* because of its shape. He did not deal with *Amphiaster* and treated *Paulia* as a synonym of *Nidorellia.*

Perrier (1884), classifying the Asteroidea according to the form of the pedicellariae, recognised four orders and placed *Asterodiscus* in the order Valvatae (Valvulatae), family Pentacerotidae (together with *Pentaceros, Nidorellia, Culcita* and *Choriaster* — a restriction of Viguier's Goniasterinae). He, like Viguier, did not mention *Amphiaster.*

Sladen (1889) dismissed Viguier's and Perrier's classifications in favour of reliance on the distribution of papulae and the characters of the ambulacral and marginal plates. He recognised two orders, Phanerozonia and Cryptozonia, placing *Asterodiscus, Paulia* and *Amphiaster* in the Phanerozone family Pentacerotidae. He considered this to be a discrete group having unequally developed marginal plates, superomarginals often hidden under a membrane, a reticulate skeleton, plates with large, isolated tubercles or spinelets, granulose or covered with a membrane and actinal interradial areas with large pavement-like plates bearing unequal-sized granules. He recognised Perrier's Pentagonasteridae, Antheneiidae and Gymnasteriidae as distinct from the Pentacerotidae, using his own system.

Ludwig (1889) following Perrier and Sladen, merely recorded *Asterodiscus, Amphiaster* and *Paulia* in the family Pentacerotidae. In 1905 Ludwig described the monotypic genus *Pauliella* in the same family. The species *P. aenigma* was based on two small specimens with R = 13.5 and 16.5 mm from Cocos Islands (Pacific). He gave an exhaustive description of both *Paulia horrida* var. *galapagensis* (a new variety) and *Pauliella aenigma.* He clearly showed the spaced marginals in *Paulia* as well as other diagnostic features, but thought that *P. aenigma* might prove to represent the juvenile form of *Paulia. P. aenigma* has not been recorded since it was first described.

Fisher (1906) described a new species, *Asterodiscus tuberculosus,* from Hawaii, classifying it in the family Pentacerotidae. In 1911 he described the family Oreasteridae in a key. In the same publication he included *Amphiaster* in the sub-family Goniasterinae of the family Goniasteridae. He did not classify *Paulia* or *Asterodiscus* at that time. Fisher (1911) had, in fact, merged Perrier's Valvata and Paxillosa into Sladen's Phanerozonia, but dropped Cryptozonia in favour of Perrier's Spinulosa and Forcipulata. He did this by combining the characters used by Sladen and Perrier and, in fact, Viguier, though he did not credit Viguier.

In 1914 Verrill included *Amphiaster* in his sub-family Goniasterinae (Verrill, 1899), though this name had been used previously by Viguier (1878). At no time does it appear that Verrill was aware of (or at least did not take into account) Viguier's work.

Fisher (1919) indicated that the name Oreasteridae replaced the untenable name Pentacerotidae and included *Asterodiscus* in that family when he described another new species, *A. helenotus.*

Boone (1928) clearly follows Fisher's classification of *Amphiaster.*

Döderlein (1935) reviewed the families Pentagonasteridae (= Goniasteridae (Goniasterinae), see Fisher, 1911) and Oreasteridae when he examined the 'Siboga' material. He concluded that *Asterodiscus* should be removed from the Oreasteridae and placed in the Pentagonasteridae. He justified this move mainly on the absence of a calcareous interbrachial partition and lack of spicules in the disc of the tube-feet. Both of these features, he considered were very important in distinguishing the two families. He did not mention Viguier's work but seemed to be following a similar line of reasoning.

Döderlein did not deal with *Amphiaster* but retained *Paulia* in the Oreasteridae. He could not have examined any specimens of either of those two genera. In 1936 he listed *Pauliella aenigma* as a synonym of *Paulia horrida* in the family Oreasteridae.

H. L. Clark (1946) merely considered that *Asterodiscus* was more probably an oreasterid and was prepared to believe Fisher rather than Döderlein.

Spencer and Wright (1966) adopted a combination of Perrier's and Viguier's classification of asteroids, but in a modified form, this being based, they considered, 'on recent palaeontological evidence'. It is obvious, however, that the features stressed by Sladen also played a large part in their classification. They listed *Paulia* (with *Pauliella* as a synonym) and *Asterodiscus* in the family Oreasteridae, but included *Amphiaster* in a list of genera belonging to an unknown subfamily of the Goniasteridae.

Clark and Rowe (1971) include *Asterodiscus* in the family Oreasteridae.

A. M. Clark (1974) replaced the preoccupied name *Asterodiscus* Gray (non *Asterodiscus* Ehrenberg, 1939 = Protozoa) with *Asterodiscides;* including it in the family Oreasteridae.

I think that the affinities between *Asterodiscides, Paulia, Pauliella* and *Amphiaster* have not been fully recognised, though Sladen had included the three known to him, from the literature, in one family. The uniqueness of this group of genera, in respect to recognised families, has obviously never been recognised.

The recognition of a new family was prompted by the examination of over a hundred specimens from widely separated Indo-Pacific localities. From these collections it became apparent that five species and one sub-species were also new to science. It seemed no longer possible to retain the genus *Asterodiscides* within either the Oreasteridae or Goniasteridae. Further investigation revealed the close relationships between this genus and *Paulia, Pauliella* and *Amphiaster.*

A large number of juvenile specimens, particularly from Western Australia, has allowed an assessment to be made of changes which occur with growth within certain members of the new family.

In this report, a standardised method of measurement has been adopted. The R and r measurements are taken from the centre of the disc to the distalmost vertical plane of each radius and interradius respectively. This seems to be more reliable, in determining shape, than attempting to measure to the terminal plate, either abactinally or actinally, especially since in some instances the ambulacral groove extends on to the abactinal surface.

The distalmost superomarginals are measured along their greatest horizontal (h.d.) and vertical (v.d.) diameters when viewed from the *side* of the arm.

The following abbreviations are used for Institutions which have loaned material for examination:

A.M. = The Australian Museum, Sydney, Australia.
B.M. = The British Museum (Natural History), London, England.
B.P.B.M. = Bernice P. Bishop Museum, Hawaii.
M.C.Z. = Museum of Comparative Zoology, Harvard, U.S.A.
N.M.W. = National Museum, Wellington, New Zealand.
U.S.N.M. = United States National Museum (Smithsonian Institution), Washington, D.C., U.S.A.
W.A.M. = Western Australian Museum, Perth, Australia.

Full locality data on the specimens examined during the course of this investigation is given in the list at the end of this paper.

SYSTEMATIC ACCOUNT

Family **Asterodiscididae** nov.

DIAGNOSIS: Pentagonal to stellate forms with a large disc. Juvenile form goniasterid-like. Abactinal skeleton reticulate, invested in a thick integument. Abactinal plates linked by internal radiating ossicles, which may develop into a complex supporting meshwork. Plates flat or slightly raised, each bearing an enlarged tubercle or a spine and a peripheral ring or rings of granules, or granules only. Granules and small tubercles occur on small plates which are supported in the investing integument which covers the open meshes. The skeletal meshes contain discrete groups of papulae, but this is not evident superficially. Superomarginal plates few, 3-5 on each side of the arm, with the distalmost sometimes enlarged. The superomarginals become separated from each other by intercalated intermarginal and abactinal plates as the animal increases in size. Inferomarginal plates, 8-18, likewise separated from each other by intermarginal and actinal plates. The two marginal series are separated from each other by the development of intermarginal plates. Papular areas may extend as far as the inferomarginal line but do not occur actinally. Adambulacral plates with a furrow series of spines (3-7) backed across the plate (at 90° to the furrow) by 1 (or 2) + 0 or 1 (rarely 2) + 0 or 1 well-developed, truncate spines. Pedicellariae foraminate, vertically elongate (forceps-shaped), sometimes absent. Interbrachial septum membranous. Tube-feet lacking spicules.

TYPE-GENUS: *Asterodiscides* A. M. Clark, 1974.

OTHER GENERA INCLUDED: *Paulia* Gray, 1840; *Amphiaster* Verrill, 1868.

REMARKS: This family has some characters in common with the families Oreasteridae and Goniasteridae: the reticulate skeleton invested in a thick integument, the groups of papulae (though not evident externally) (features of the Oreasteridae); the membranous interbrachial septum, the lack of spicules in the tube-feet (features of the Goniasteridae); the foraminate pedicellariae (feature of Goniasteridae but only few Oreasteridae); the absence of actinal papulae and the juvenile form (features shared with the Goniasteridae and Oreasteridae). This family is defined most clearly on the low number, form and arrangement of the marginal plates, the armament of the skeletal plates, the characteristic adambulacral armament and the distribution of the papulae.

KEY TO THE GENERA AND SPECIES OF THE FAMILY *Asterodiscididae*

1. Stellate or pentagonal forms; abactinal armament comprises tubercles <4 mm high; papulae extend to inferomarginal line; 3-4 superomarginal plates, distalmost larger than 2-3 proximal plates (except in *A. culcitulus* n. sp.); Indo-west Pacific: south-east Africa — Hawaii ..... *Asterodiscides* A. M. Clark, 1974 2
— Stellate forms; abactinal armament of large spines up to 6 mm high and 3 mm diameter at base; papulae restricted to abactinal surface above superomarginal line or few papulae extending to inferomarginal line; 4-5 superomarginal plates of similar size, distalmost *not* larger than proximal plates; Eastern-tropical Pacific: Galapagos — Lower California — Peru ..... *Paulia* Gray 1841 and *Amphiaster* Verrill, 1868 11
2. Pentagonal forms, R/r = 1.1-1.3 (rarely to 1.5, if so only 3 superomarginal plates present); 3-4 superomarginal plates; distalmost superomarginal either larger than proximal plates or of similar dimensions 3
— Stellate forms, R/r = 1.5-2.0; 4 superomarginal plates, (sometimes only enlarged distalmost superomarginal plate obvious); distalmost supero-marginal always larger than proximal superomarginal plates 5

3. — Four superomarginal plates of similar size, distalmost *not* larger than 3 proximal plates, in specimens with R = 50 mm distalmost is separated from terminal plate by 1-2 small plates. West coast of Western Australia. ..... *A. culcitulus* sp. nov. (p.193).

— Three superomarginal plates, distalmost always adjacent to terminal plate and always much larger than 2 proximal superomarginal plates, in larger specimens only distalmost may be obvious but the animal is more or less pentagonal. .....*A. elegans* (Gray, 1847) (p.197). 4

4. Abactinal pedicellariae slender in vertical profile (forceps-like); actinal plates with up to seven subequal tubercles, one may be slightly more prominent than others; 4-5 furrow spines; R/r = 1.3-1.5; N. E. Australia — Philippines .....*A. elegans elegans* (Gray, 1847) (p.197).

— Abactinal pedicellariae flask-shaped in vertical profile (with bulbous base and tapering neck); actinal plates with one (rarely 2) large tubercles dominating plate; 3-4 furrow spines; R/r = 1.1-1.3; Southeast Africa, islands of western Indian Ocean, India, Ceylon. .... *A. elegans belli* subsp. nov. (p.199).

5. Distalmost superomarginal plates usually very large, flat or strongly convex, h.d. = v.d. or h.d. > v.d., when plate viewed from side of arm; two distalmost superomarginal plates at arm tip broadly contiguous abactinally above terminal plate; abactinal tubercles inverted cone-shaped or more or less cylindrical; furrow spines few in number (3-4); subambulacral spines in one or two series 6

— Distalmost superomarginal plates flat or only slightly convex, oval, h.d. < v.d. when plate viewed from side of arm; two distalmost superomarginals just in contact abactinally above terminal plate or just separated by it; abactinal tubercles rounded or apically pointed; furrow spines 5-7; subambulacral spines in two (very rarely in 3) series 8

6. Distalmost superomarginal plates strongly convex; 4-5 prominent inferomarginals under each distal superomarginal; abactinal tubercles more or less cylindrical; actinal tubercles subspherical; 3-4 furrow spines; one series of subambulacral spines; Southern and south-eastern Australia — New Zealand — Kermadec Islands. .... *A. truncatus* (Coleman, 1911) (p.200).

— Distalmost superomarginal plates flat, squarish; > 5 small inferomarginals under each superomarginal; abactinal tubercles inverted cone-shaped; actinal tubercles spatulate; 3 furrow spines; 2 series of subambulacral spines; Western Indian Ocean, Philippines — Japan. 7

7. Distalmost superomarginals with not more than h.d. = 1/5 R; abactinal tubercles rounded in cross-section, not forming mosaic-like pattern; Philippines — Japan. .....*A. helenotus* (Fisher, 1913) (p.202).

— Distalmost superomarginals with h.d. = 1/3 R; abactinal tubercles angular in cross-section, forming mosaic-like pattern when viewed from above; Western Indian Ocean. .....*A. tessellatus* sp. nov. (p.203).

8. Large forms with obese arms; abactinal tubercles very small, crowded, two sizes, larger tubercles (1.75 mm high) in three spaced, longitudinal rows along arm; only distalmost flat superomarginal plate distinguishable; actinal plates with one large conical tubercle (2.75 mm high) and peripheral ring of small, variously sized granules; actinal tubercles markedly larger than abactinal tubercles; R/r = 1.6; Western Australia (Shark Bay — Exmouth Gulf). .....*A. pinguiculus* sp. nov. (p.204).

— Arms not obese, narrowing to fairly acute tip; abactinal tubercles in 3 sizes, larger tubercles > 1.75 mm high; infero and superomarginal plates

all distinguishable; actinal plates with 4-10 subequal granules or tubercles; largest actinal tubercles not markedly larger than abactinal tubercles 9

9. Actinal plates with 1-2 central granules surrounded by 6-8 similar sized granules, *none* prominent; furrow spines usually 5; distalmost superomarginal more or less flat; proximal marginal plates with a cone-shaped process; no regular longitudinally alternating order of different sized tubercles; Western Indian Ocean (off Socotra) .... *A. lacrimulus* sp. nov. (p.206).

— Actinal plates with 4-10 unequal granules and tubercles, 1-3 more prominent; furrow spines 6-7; distalmost superomarginals slightly convex; other marginal plates without the cone-shaped processes; three sizes of abactinal tubercles in alternating, longitudinal rows along arms; N. E. Australia, Kermadec Islands, Hawaii 10

10. R/r = 1.5; inferomarginal plates predominantly bare; Hawaii. .... *A. tuberculosus* (Fisher, 1906) (p.207).

— R/r = 2.0; inferomarginal plates obscured beneath variously sized granules and tubercles; N. E. Australia, Kermadec Islands .... *A. grayi* sp. nov. (p.208).

11. Four superomarginal plates, all widely separated (3 in juvenile?); distalmost superomarginal plates on each side at arm tip spaced from terminal plate by large spiniferous plate and not contiguous abactinally above it; papulae restricted abactinally above superomarginal line; subambulacral spines in two series; Galapagos — Cocos Islands — Peru — Lower California..... *Paulia horrida* (Gray, 1840) (p.210).

— Four-five superomarginal plates, some plates in contact, others separated; distalmost superomarginals on each side at arm tip adjacent to and contiguous abactinally above the terminal plate; papulae extend to inferomarginal line, at least in specimens with R = > 38 mm; subambulacral spines in single series; Lower California .... *Amphiaster insignis* (Verrill, 1868) (p.212).

Genus **Asterodiscides** A. M. Clark, 1974

Asterodiscus Gray, 1847, p. 75; 1866, p. 5, pl. 12 figs 1-2; Perrier, 1875, p. 256; Viguier, 1878, p. 188, Sladen, 1889, pp. 343, 353; Ludwig 1899, p. 689; Fisher, 1906, pp. 1072, 1074; 1919, p. 354; H. L. Clark, 1946, p. 108; Spencer and Wright, 1966, p. U63; Clark and Rowe, 1971, p. 53. (non *Asterodiscus* Ehrenberg, 1839 = Protozoa)

Asterodiscides A. M. Clark, 1974, p. 435.

DIAGNOSIS: Body form pentagonal to stellate, R/r = 1.1-2.0; 3-4 superomarginal plates of which the distalmost is larger than the 2-3 proximal plates, bare and prominent (except in one species in which the distalmost superomarginal is as small as the 3 proximal plates); abactinal tubercles variously shaped, no higher than 4 mm; actinal graulation and tuberculation varied; intermarginal papulae abundant; furrow spines 3-7; subambulacral spines in 1 or 2, rarely 3, series.

TYPE-SPECIES: *Asterodiscus elegans* Gray, 1847.

OTHER SPECIES INCLUDED: *Asterodiscus tuberculosus* Fisher, 1906; *Asterodiscus truncatus* Coleman, 1911; *Asterodiscus helenotus* Fisher, 1913; *Asterodiscides culcitulus* sp. nov.; *A. elegans belli* subsp. nov.; *A. tessellatus* sp. nov.; *A. pinguiculus* sp. nov.; *A. lacrimulus* sp. nov.; *A. grayi* sp. nov.

REMARKS: Although the species now included in *Asterodiscides* exhibit a wide range of form, there does not appear to be sufficient justification for the establishment of named supraspecific groups.

The genus is separated from *Paulia* and *Amphiaster,* not only geographically but on the form and distribution of the marginal plates, the distribution of the papulae and the form of the abactinal armament.

Asterodiscides culcitulus n. sp.
Fig. 1 a-c

Asterodiscus sp. Marsh, 1972, p. 67-8

DIAGNOSIS: Pentagonal form at all stages of growth, R/r = 1.1-1.3, R up to 97 mm; 4 superomarginal plates of similar size, distalmost *not* larger than proximal plates, superomarginal plates become difficult to distinguish amongst the tuberculation with growth of the sea-star; up to 12 inferomarginal plates; abactinal tubercles subspherical, 3-4 sizes; actinal plates each with up to 7 subequal tubercles; furrow spines 5-7, subambulacral spines in 2 series, first series 2 spines per plate, second series 1 spine per plate; pedicellariae, when present, slender, forceps-like.

DESCRIPTION: Holotype W.A.M. No. 1063-74; Stn 104, 29° 29'S, 114° 12'E, W.S.W. Dongara, Western Australia, 108 m, 8.xii.70, H.M.A.S. 'Diamantina'.

The body is pentagonal, somewhat flattened, with R= 54 mm, r = 49 mm, R/r = 1.1 (fig. 1 a-c). There is a slight marginal indentation interradially, also, the abactinal interradial areas are sunken. Abactinal tubercles are of four sizes and are subspherical. The tubercles are largest (h.d. = 2.5 mm × v.d. = 2 mm) near the centre of the disc and are not arranged regularly along the arms. A ring of small granules is present around the base of the larger tubercles. Scattered between the largest tubercles are the tubercles of the other three sizes. The second and third sized tubercles also have granules at their bases, but the smallest tubercles, which are little larger than granules, do not. Interstitial granules are present but not dense. The madreporite is rounded, cushion-like and about 1/3r from the centre of the disc. Pedicellariae are very numerous, one usually associated with each of the tubercles. The bare marginal plates are obvious amongst the tuberculation. There are four superomarginal plates but the distalmost superomarginal is only slightly larger than the proximal three superomarginal plates (2.0 mm h.d. × 3.5 mm v.d.). The distalmost superomarginals are each surrounded by a ring of unequal granules, are not contiguous abactinally above the terminal plates and a pedicellaria is associated with each. The three other superomarginals (h.d. × v.d.: 2 mm × 2.5 mm; 2 mm × 2.2 mm; 2 mm × 2.7 mm) are spaced along the arm (fig. 1b). The second is 6 mm from the first, the third is 8.5 mm from the second and 8.5 mm from the distalmost. Each superomarginal is surrounded by a ring of small granules. There is a tubercle on the actinal edge of each proximal superomarginal, a pedicellaria on the abactinal edge and a second tubercle placed between; the rest of the plate is bare. There are nine inferomarginal plates, separated from the superomarginals proximally by five intermarginal plates. Only 2-3 inferomarginals underlie the distalmost superomarginal. The nine inferomarginals can be easily recognised from amongst the tuberculation. Each plate (the first five measure: h.d. × v.d. = mm; 2 × 3; 2 × 3; 2 × 3; 2 × 2.75; 2 × 2.5) comprises an actinally directed protuberance and has 1-2 tubercles on its abactinal edge. The plate is ringed by subequal granules and each plate has an associated pedicellaria (occasionally two). There is a sharp delimitation between the abactinal and actinal tuberculation at the level of the inferomarginal line.

The actinal plates bear up to seven subequal tubercles, of which one is usually very prominent and almost reaches the same size as the largest abactinal tubercles (fig. 1c). Unequal, sub-prismatic granules are present around the periphery of each plate. The plates are rather diamond-shaped. The tubercles are largest on the actinal plates adjacent to the adambulacral plates, where one tubercle becomes especially prominent on the distal plates. A pedicellaria is associated with most of the actinal plates.

The adambulacral plates (50) bear 6-7 furrow spines for the first 28-30 plates, 5 spines for the next five plates, thereafter 4 then 3 to the tip of the arm. The distalmost furrow spine is largest, proximalmost smallest, the second about 2/3 the size of the distal 3-6 spines. The subambulacral spines are in two series along the arm. The first series comprises two subequal spines on each plate. These are truncate, more or less aligned along the furrow though occasionally obliquely aligned, and extend for 15 plates after which the proximal spine becomes prismatic and granule-like and insignificant. The second series comprises a single, wide, flattened spine on each plate. This spine is small (almost insignificant) on each of the first seven plates, as often as not in the form of two subequal, pointed granules. After the seventh plate the spine is more prominent, but never attains the height of the larger first row spine. By the 25th plate the second series of subambulacral spines is again reduced, insignificant and granule-like. Each adambulacral plate also bears small angular granules around its periphery. No pedicellariae are present on the adambulacral plates.

The oral plates bear 9 furrow spines, 3-4 large actinal spines and 4 prismatic granules.

There are 11 Paratypes (Pl-II); W.A.M. No. 1116-74; Stn 107, 30° 29'S, 114° 40'E, S. W. of Jurien Bay, Western Australia, 114 m, 9.xii.70, H.M.A.S. 'Diamantina'. These range in size from R = 57 mm (Pl) - R = 34 mm (PII). They differ from the holotype in only very minor ways, including the presence of pedicellariae on the adambulacral plates and in the number of inferomarginal plates.

COLOUR: In life the smaller granules and integument are yellow brown abactinally, slightly darker in the centre of the disc and radially than interradially. The larger tubercles are cream to light yellow-brown. The very small specimens have the central tubercles, the radial areas and some superomarginal plates yellow-brown, the rest is cream (photograph and comments provided by Mrs L. M. Marsh, Western Australian Museum); preserved specimens are straw-coloured, with little indication of life colour.

OTHER MATERIAL EXAMINED: Besides the type-specimens, there are a further fifty-nine specimens collected from between Shark Bay and Mandurah off the west coast of Australia.

The smallest specimen measures R=6.5 mm, r=4.5 mm, R/r=1.3, and resembles a small *Tosia*. The largest specimen measures R = 97 mm, r = 75 mm, R/r = 1.3. The R/r ratio varies between 1.1-1.3, but is usually 1.2. The ratio is relatively constant with the difference between the minimum and maximum being only 18%. Considering the total number of specimens (71) examined, and the range of sizes (R = 6-97 mm), it would appear that the R/r ratio is a good species character.

With the exception of Fisher's (1906) description of two juvenile specimens of *Asterodiscus tuberculosus* from Hawaii, there has never been a large enough series of specimens on which to observe any growth changes. This collection, therefore, provides a unique opportunity to describe the changes which occur during the growth of an asterodiscidid. A representative series of specimens is discussed, from the smallest to the largest.

At R=6.5 mm (W.A.M. No. 1086-74) (fig. 1d), the central abactinal plate and ring of five primary radial plates and the five somewhat larger interradial plates are obvious. Between the radials and the abactinal central plate are 1 or 2 intercalary plates, and these preclude

contact between the central and the primary interradial plates. The madreporite is formed on the outer edge of one of the interradial plates. A row of four plates, smaller than the radial plate, extends as a carinal row to the comparatively large terminal plate of the arm. There are two rows of abactinal-lateral plates and 3-5 small plates in the remaining interradial triangle between two adjacent arms. The abactinal plates are circular, each with a peripheral ring of small granules and, centrally, 1-5 small, spherical tubercles. The largest abactinal plate has a diameter of 0.75 mm. The tip of the arm is turned up so that the triangular terminal plate is vertical. The marginal plates form a continuous border with four superomarginals and five inferomarginals. The distalmost superomarginal is small and wedged between the third superomarginal and the terminal plate. The superomarginals are bare, slightly convex and with a peripheral ring of small granules. The inferomarginals are similar. Between the superomarginal and inferomarginal series are 3-4 intermarginal tubercles. Actinal plates bear 3-12 granules, 1-3 of which are larger than the rest. There are 18 adambulacral plates, 5 or 6 furrow spines, reducing to 4-3 about half way along the furrow. The subambulacral spines are in a single row of two spines on each plate. Distal plates carry only one subambulacral spine. There are three granules on the outer edge of each adambulacral plate. The oral plate bears 6 furrow spines, 3 actinal spines and 3-5 granules.

At R = 10 mm (W.A.M. No. 1082-74) (fig. 1e), the rings of primary abactinal plates are not as obvious amongst the increased number of plates. Each has a central tubercle. Small tubercles are developed on small plates between the larger plates (but the diameter of the plates is still larger than the diameter of the tubercles). There is a carinal row and two lateral rows of plates and about ten plates are present in the interradial angle between two adjacent arms. Pedicellariae are present on one or two carinal plates. Successive marginal plates are spaced, with a channel between adjacent plates, except between the distalmost superomarginal and the terminal plate on the arm. The superomarginals are bare, with a peripheral ring of granules. There are six inferomarginal plates, each with 1 or 2 prominent tubercles on their abactinal edge. Intermarginal plates extend to between the 2-3 more or less vertically aligned pairs of marginals. The adambulacral plates bear 5-6 furrow spines, the proximalmost often the size of a granule. The subambulacral spines are in two series. The first series comprises two subequal spines on each plate, and the second series comprises a single spine, which develops from the middle of three granules, particularly on the distal half of the arm. The oral plate bears seven furrow spines.

In a specimen with R =12.0 mm(W.A.M. No. 1083-74), seven inferomarginal plates have developed and the intermarginal plates developed as far as the 3-4 vertical pair of marginal plates.

Surprisingly, a specimen with R = 12.5 mm (W.A.M. No. 1088-74) (fig. 1f), has only six inferomarginals. The distalmost superomarginal is as large as the third superomarginal and each superomarginal has an associated pedicellaria. There are a few actinal pedicellariae.

In a specimen with R = 14.5 mm (W.A.M. No. 1075-74) (fig. 1g), the diameter of the abactinal tubercles equals that of the abactinal plates. The regularity of the carinal and two abactinal-lateral rows of tubercles is just obvious. The distalmost superomarginal is larger than the other superomarginals. There are seven inferomarginals, some of which bear a pedicellaria. Intermarginal plates extend to between the 3-4 vertically aligned pair of marginals. There are 5-6 furrow spines, 4 distally, and the subambulacral spines are as in the holotype. There are no actinal pedicellariae on this specimen.

At R = 18 mm (W.A.M. No. 1070-74) intermarginal plates extend in a single line to the 3-4 supero- and inferomarginals but in the angles between vertically adjacent marginal plates two tubercled plates are present. The distalmost superomarginals are convex but the proximal superomarginals have a conical projection. There are 5-6 furrow spines for about half the length of the arm, thereafter only 4. The oral plates bear 9 furrow spines.

With increase to R= 23 mm (W.A.M. No. 1070-74) the abactinal regularity of tubercles is now less obvious. The distalmost superomarginal measures 2.5 mm v.d. × 1.5 mm h.d. and the proximal superomarginals are not very obvious amongst the general tuberculation. There are eight inferomarginals, with small plates occurring between adjacent inferomarginal plates. The intermarginal plates have increased to a definite double row, and, proximally, a triple row. Adambulacral armament as in the holotype.

At R = 30 mm (W.A.M. No. 1068-74) the distalmost superomarginal almost reaches its maximum size (3 mm v.d. × 2 mm h.d.). There are eight inferomarginal plates, each with a conical protruberance, a pedicellaria and some enlarged granules. The adambulacral plates bear 5-6 furrow spines for most of the length of the furrow and actinal pedicellariae are numerous.

At R = 38 mm (W.A.M. No. 1073-74) (fig. 1h), there is no observable order to the arrangement of the abactinal tubercles. There are nine inferomarginals with 1 or 2 plates between adjacent inferomarginal plates. The adambulacral plates bear 6-7 furrow spines for about half the length of the furrow. There are only a few actinal pedicellariae.

There is little, if any, variation occurring between R = 38 mm – R = 54 mm (holotype), except that the distalmost superomarginal becomes more obscured, especially in more bun-shaped (R/r = 1) specimens. There are, however, three specimens which greatly exceed the holotype in size.

In a specimen with R = 83 mm (W.A.M. No. 1069-74) the abactinal tubercles are closely packed and no order is apparent. The distalmost superomarginals are sub-terminal, being separated from the terminal plate by a small intercalary plate. The proximal superomarginals are only distinguishable after denuding. There are 10-12 inferomarginal plates, which are difficult to distinguish. There are 5-6 small plates separating adjacent inferomarginal plates. The two marginal series are separated by about 8 small plates proximally. The adambulacral plates bear 6 furrow spines along the greatest length of the furrow. The subambulacral armature is not unusual. The furrow recurves abactinally at the tip. The oral plates bear 10 furrow spines.

In a specimen with R = 93 mm (W.A.M. No. 1077-74) (fig. 1i-k), the abactinal tubercles are not as crowded. The distalmost superomarginals are not distinguishable at all and the proximal three superomarginals are difficult to distinguish even after denuding. There are 10-12 inferomarginals. The distal ones are difficult to find but the proximal six can be distinguished by the clusters of granules and tubercles on the plates. The adambulacral plates bear 7 furrow spines for the greatest part of the furrow, the first spine is often very small. Subambulacral spines not unusual, except the second series spine remains equal in length to the first series spine for the greatest part of the arm. The furrow tip is visible abactinally.

The largest specimen measures R = 97 mm (W.A.M. No. 1078-74). The abactinal tubercles are very crowded and no order is discernable. The superomarginals can only be distinguished after denuding. The distalmost superomarginal is separated from the terminal plate by two small plates. There are ten to twelve inferomarginal plates and the inferomarginal series is separated from the superomarginal series, at least proximally, by about twelve small plates. There are six furrow spines for most of the length of the arm and the furrow recurves abactinally at the tip. Pedicellariae are not common abactinally or actinally.

DISTRIBUTION: Between Shark Bay and Mandurah, on the west coast of Australia (25°-33°S Lat., 113°-115°E Long.), 90-180 m. (For details see Appendix 1.)

ETYMOLOGY: *culcitulus* (Lat.) = little cushion.

REMARKS: The characters that are exhibited by this species, particularly in respect to the form of the superomarginal plates, separate it easily from the other species considered in this paper.

Little is known of predation on starfish around the coasts of Australia so it is of interest to note that a large deep-water volutid (*Cottonia nodiplicata* (Cox)), collected off Mandurah, W.A., was seen to discharge asteroid plates, including tubercles of an 'undescribed *Asterodiscus*' in its faeces (Marsh, 1972), the asteroid being *Asterodiscides culcitulus*.

Asterodiscides elegans (Gray)

DIAGNOSIS: Pentagonal form, stellate in juvenile stage (subsp. *elegans*), R/r = 1.3-1.5, R up to 90 mm; only large distalmost, pear-shaped, flat — slightly convex superomarginal obvious in adults (R = > 50 mm), in juveniles 2 proximal, predominantly bare superomarginal plates are obvious (at least for subsp. *elegans*); up to 12 inferomarginal plates; abactinal tubercles subspherical — bluntly pointed, 3 sizes; actinal plates each with up to 7 tubercles (subsp. *elegans*) or with prominent single tubercle (subsp. *belli*); furrow spines 4-5 (subsp. *elegans*), 3-4 (subsp. *belli*), subambulacral spines in 2 series, first series 2 spines per plate, second series 1 spine per plate, occasionally in large specimens a third subambulacral spine is developed from a granule on the outer edge of the adambulacral plate; pedicellariae, when present, slender, forceps-like (subsp. *elegans*) or bulbous, flask-shaped (subsp. *belli*).

Asterodiscides elegans elegans (Gray)
Fig. 2 a-j

Asterodiscus elegans Gray, 1847, p. 75; 1866, p. 5, pl. 12, figs 1-2; Perrier, 1875, p. 256; Viguier, 1878, p. 188; Sladen, 1889, p. 353; Ludwig, 1899, p. 690; Fisher, 1919, p. 355, pl. 97, fig 2, pl. 101, fig 2; Spencer and Wright, 1966, U63; Clark and Rowe, 1971, pp. 34, 40, 53 (part).

non *Asterodiscus elegans*, Bell, 1907, p. 19 (part); Macnae and Kalk, 1969, p. 129; James, 1969, p. 52; Clark and Rowe, 1971, pp. 34, 40, 53, pl. 6 fig 4 (part).

non *Asterodiscides elegans*, A. M. Clark, 1974, p. 435.

DESCRIPTION: Holotype B.M. No. 45.3.5.353; no locality data, purchased Argent.

Body flattened abactinally, slightly concave actinally, with R = 36 mm, r = 24 mm, R/r = 1.5 (fig 2a-c). The arms are triangular from the base. Abactinal tubercles, of three sizes, are subspherical or bluntly pointed. The largest tubercles (h.d. = 1.25 mm × v.d. = 1.3 mm) are conical, surrounded at the base by a ring of small granules, and more or less form longitudinal lines along each arm. The two smaller-sized tubercles are rounded, scattered between the largest tubercles and do not possess a basal ring of small granules. The madreporite is rounded, cushion-shaped and is close to the centre of the disc and stands out white against the 'museum' colour of the abactinal surface. There are no abactinal pedicellariae.

The marginal plates are not very conspicuous, except the slightly convex distalmost superomarginals (h.d. = 3.5 mm × v.d. = 5.5 mm) (fig 2b). Each of these latter superomarginals is surrounded by a ring of small, rounded granules. There are two proximal superomarginal plates (h.d. × v.d. = mm: 1.75 × 2.2; 1.75 × 2.0) besides the distalmost one on each side of the arms. These are barely distinguishable amongst the tuberculation, but can be picked out because of the close grouping of 3-5 tubercles (of similar size to the smallest abactinal tubercles), these being surrounded by a ring of various sized, subquadrate granules. The second proximal superomarginal is 12 mm from the first and 10 mm from the distalmost superomarginal.

There are nine inferomarginal plates, each bearing a conical tubercle (of similar size to the largest abactinal tubercles). The remainder of the plate is covered with subquadrate granules of different sizes, up to fifty on the largest inferomarginal plate (fig 2b-c). The proximal inferomarginals are larger than the proximal superomarginals (the first five measure: h.d. × v.d. = mm; 2 × 3; 1.8 × 2.2; 1.8 × 1.9; 1.8 × 1.8). The inferomarginal series is separated from the superomarginal series, at least proximally, by about three rows of plates. There are no pedicellariae associated with the marginal plates. The actinal plates bear up to seven tubercles, of which one is more prominent and may reach the same size as the largest abactinal tubercles. No distinct arrangement of the actinal plates can be discerned because of the tubercle cover on the plates, except that the tubercles of the first actinal row adjacent to the adambulacral plates appear in a parallel line with the subambulacral spines (fig 2c). There are no actinal pedicellariae.

The adambulacral plates (c. 39) bear 5 furrow spines for at least the first 14 plates, 4, occasionally 5, to the 30th plate, diminishing to 3 then 2 thereafter to the 39th plate. The 3rd or 4th spine is largest, the proximalmost on each plate often very small, can easily be overlooked. Subambulacral spines are in two series. The first series is small, slender and overshadowed by the larger, blunt, distal spine of each pair. The proximal spine becomes smaller towards the arm tip and insignificant from about half way along the arm (c. 16th adambulacral plate). The second subambulacral series is similar to the first (fig 2c).

The oral plates bear 12 furrow spines and 3 actinal spines. Two of the actinal spines are equal in size and very prominent, the one in the apex of the plate is small and more slender.

OTHER MATERIAL EXAMINED: A specimen of similar size to that of the holotype was collected by the 'Albatross' in the Philippines (U.S.N.M. No. 40544) and fully described by Fisher (1919) (fig. 2d-e). The only minor differences that I can detect are that the largest abactinal tubercles are slightly larger than in the holotype; the regular number of 4 furrow spines; the very reduced proximal subambulacral spine in each pair; abundant abactinal and actinal pedicellariae.

The smallest specimen of *elegans* so far recorded is from 'N. China' (B.M. No. 47.6.18.4) (fig 2f-h). This specimen measures R = 24 mm, r = 16 mm, R/r = 1.5, and is figured by Gray (1866, pl. 12 fig. 2). The two proximal superomarginal plates are obvious because each is mainly bare but bears a tubercle of similar size to the largest abactinal tubercles on the upper part of the plate. The superomarginals are ringed by small granules. There is evidence of a few abactinal pedicellariae (the position of three was detected from the foramina in the plates) but there are no actinal pedicellariae. There are only eight inferomarginal plates and the inferomarginal series is separated from the superomarginal series (proximally at least) by two rows of plates.

In larger specimens of *elegans* the ratio R/r becomes lowered as the animal becomes larger. The specimen figured by Gray (1866, pl. 12 fig. 1) is larger than the holotype, measuring R = 43 mm, r = 32 mm, R/r = 1.35 (B.M. No. 43.3.10.9). The two proximal superomarginals are only distinct when denuded. There are 10 inferomarginal plates. Pedicellariae are numerous. (A.M. Clark, pers. comm.).

In two other specimens from 'China' (B.M. No. 49.1.31.4) and 'N. China' (B.M. No. 49.1.31.3) (fig. 2i), the proximal superomarginal plates are *not* distinguishable at all, even after denuding the arm. These specimens measure R = 62 mm, r = 47 mm, R/r = 1.3 and R = 64 mm, r = 49 mm, R/r = 1.3 respectively. There are ten to eleven inferomarginal plates, which can be distinguished by their size and tuberculation and without denuding the plates. The distalmost superomarginals measure h.d. = 5 mm × v.d. = 8 mm. A few abactinal and actinal pedicellariae are present.

The largest specimen that I have examined is from the Philippines and was collected by the 'Challenger' and identified by Sladen. It measures R = 90 mm, r = 67 mm, R/r = 1.3 (B.M. No. 1890.5.7.501) (fig. 2j). The abactinal tubercles are of three sizes and widely scattered. The distalmost superomarginals measure h.d. = 5.2 mm × v.d. = 9.25 mm. The proximal superomarginals are not distinguishable even after denuding the side of the arm. There are 12 inferomarginal plates which bear 1 or 2 large tubercles and from 8-10 subequal, wedge-shaped granules. Pedicellariae are present abactinally. The actinal plates bear 1-4 subequal tubercles, usually a slender pedicellaria and a peripheral ring of subequal, prismatic granules. The adambulacral plates bear 4, occasionally 5, furrow spines along most of the length of the arm. The subambulacral spines are large, truncate and in 2 or 3 series. The first and second series are of single spines, but occasionally the middle granule of three on the outer edge of each adambulacral plate is greatly enlarged, being almost equal in size to that of the inner spines and forming an irregular third series. Occasionally two of these granules are enlarged to spine-sized proportions. Distally this third series of spines is absent. A large lanceolate pedicellaria stands between the two first subambulacral spines on the adoral edge of each adambulacral plate. Unequal, small, prismatic granules occur along the ad- and abradial edges of the plates. There are eight furrow spines and five actinal spines on each oral plate.

Asterodiscides elegans belli subsp. nov.
Fig. 3a-d

Asterodiscus elegans, Bell, 1909, p. 19 (part); Macnae and Kalk, 1969, p. 129; James, 1969, p. 52; Clark and Rowe, 1971, p. 34, 40, 53, pl. 6, fig. 4, (part).

Asterodiscides elegans, A. M. Clark, 1974, p. 435.

DESCRIPTION: Five specimens from the Indian Ocean agree in almost all respects with the larger specimens of *elegans* described above. There are, however, three conspicuous differences. Firstly, the tuberculation of the actinal plates can be seen to be markedly different when the Indian Ocean forms and the China/Philippine forms are directly compared. In the Indian Ocean specimens each actinal plate is dominated by a single, large tubercle, rarely are 2 or 3 tubercles present, and when they are it is near the interradial margin of the animal (fig. 3d). The periphery of each plate bears prismatic granules. From examination of over seventy specimens of *A. culcitulus* sp. nov. (R = 6.5 mm to 97 mm) the actinal tuberculation appears to be constant throughout the size range, suggesting that the differences discussed here are real. Secondly, the furrow spine number is lower, 3-4 usually, rarely 5. Thirdly, the abactinal pedicellariae, when present, are distinctly flask-shaped, with a broad shoulder basally and a narrow neck. This is of course an unreliable character due to the lack of consistency in the occurrence of the pedicellariae. Nonetheless, the distinctive actinal tuberculation and the lower number of furrow spines seem sufficiently constant to recognise these features as important enough to warrant recognition of a subspecies *belli* subsp. nov. I nominate two specimens from the Amirante Islands as holotype (B.M. No. 1907.7.1.46) (fig. 3a-b) and paratype (B.M. No 1907.7.1.44) respectively. Three other specimens examined are from Madras, India (B.M. no. 1890.1.13.11-12(1); A.M.J9735 (1) two specimens) (fig. 3c-d) and Saya da Malha Bank, western Indian Ocean (B.M. No. 1907.7.1.45 (part); one specimen). Other specimens of *A. elegans* have been reported from East Africa (Macnae and Kalk, 1969; Clark, 1974) and Ceylon (James, 1969). I believe that these should be referred to *A. elegans belli.*

DISTRIBUTION: China (exact locality unknown, possibly South China Sea) — Philippines — North-east Australia (A. Birtles, pers. comm.) for *A. elegans elegans* (Gray). Indian Ocean, South Africa to Ceylon for *A. elegans belli* subsp. nov., 18-120m.

ETYMOLOGY: *belli* (subspecies) = named after F. J. Bell, who originally identified the material examined here.

REMARKS: *A. elegans elegans* and *A. elegans belli* appear to be most similar in form to *A. culcitulus,* differing in the number of superomarginal plates, in the relative size of the distalmost superomarginals to the proximal superomarginals and in the lower number of furrow spines. In larger specimens of each, when the proximal superomarginals are not easily distinguishable, the smaller size of the distalmost superomarginal, or its apparent absence, in *A. culcitulus* is sufficient to distinguish between the species. In juvenile specimens of each species the R/r ratio of *elegans elegans,* at least, is as high as 1.5, whereas that of *culcitulus* remains no more than 1.3, this latter species being more pentagonal at all stages of growth. However, the juvenile *elegans elegans* has only two proximal superomarginals and this will distinguish it from all other species in the family. The low R/r ratio alone will separate the two subspecies from all the other species described in this paper.

Asterodiscides truncatus (Coleman)
Fig. 3 e-g

Nectria ocellifera, H. L. Clark, 1909, p. 529 (non *Nectria ocellifera* Perrier, 1875)

Asterodiscus truncatus Coleman, 1911, p. 699, figs 123-125, pl. LXXXIII; H. L. Clark, 1916, p. 50; 1938, p. 101; 1946, p. 108; Powell, 1937, p. 78; Serventy, 1937, p. 81; Cotton and Godfrey, 1942, p. 199; Pope, 1951, p. 146, pl. frontispiece; Fell, 1958, p. 13; Shepherd, 1968, p. 737; Dartnall, 1968, p. 23.

DIAGNOSIS: Stellate form, R/r = 1.5-2.0, R up to 166 mm; 4 superomarginal plates, proximal 3 small, bare distalmost large, strongly convex, adjacent superomarginals at arm tip broadly contiguous abactinally above the terminal plate; 9-12 inferomarginal plates, the distal 4-5 underlying the distalmost superomarginal are unusually prominent; abactinal tubercles more or less cylindrical, 2 sizes; actinal plates each with a prominent tubercle surrounded by unequal granules; furrow spines 3-4 (rarely 5), subambulacral spines in a single series; pedicellariae slender, forceps-like.

DESCRIPTION: The description of the two syntypes given by Coleman is very detailed and little needs to be added here. The smallest specimen I have examined is from Tollgate Ids., N.S.W., Australia (A.M. No. J6910) and measures R = 44 mm. The large tubercles dominate, forming a carinal and two abactinal lateral rows. Scattered between are very small tubercles and granules. The three proximal superomarginal plates are obvious, each being convex and surrounded by a ring of small granules, these granules are notably absent from the base of the large tubercles. The distalmost superomarginals measure 5 mm h.d. × 4 mm v.d., are widely contiguous abactinally above the terminal plate and are strongly convex. There are nine inferomarginal plates, the first four bear a tubercle on the abactinal edge, the last four on the actinal edge. The latter four plates lie under the distalmost superomarginal. Each inferomarginal is surrounded by a ring of small granules. There are four rows of actinal plates, each plate with a prominent tubercle which is no more than ¼ the size of the largest abactinal tubercle. There are 5-6 very small tubercles in the distal interradial area between adjacent arms. The adambulacral plates bear three furrow spines and a single, large subambulacral spine, the outer three sides of the plate bearing small, subequal, prismatic granules. Small pedicellariae are present on the marginal plates, each of the plates of the first actinal row and on several of the remaining actinal plates.

The regularity of the arrangement of the abactinal tubercles becomes less as the animal increases in size. There can be, however, alternating rows of tubercles of two distinct sizes, but the concentration of scattered granules between the tubercles is variable. The position of the proximal superomarginals is less obvious in the larger specimens, but they can usually be detected because of the peripheral ring of small granules. The distalmost superomarginal can reach a size of h.d. = 10 mm.

The number of inferomarginal plates increases to 11 or 12 in specimens up to R = 166 mm. A feature which seems to stand out, but which has received little attention, is the large size of the 4 or 5 distal inferomarginals which lie under the distalmost superomarginal plate. This is a distinctive feature since in all other species known these inferomarginal plates are much smaller than the proximal ones.

The actinal armament is relatively constant, with one large, prominent tubercle on each plate, but the granulation covering the rest of the plate varies a little. The adambulacral armament is also relatively constant with 3 (rarely 4) furrow spines and a single subambulacral spine on each plate.

A specimen from Kermadec Islands (N.M.W. No. 1281), measuring R = 64 mm, r = 32 mm, R/r = 2.0, shows one or two interesting features. The proximal superomarginals are very difficult to distinguish but where they can be seen three can be counted. The distalmost superomarginals measure h.d. = 5.5 mm × v.d. = 4.5 mm and are *not* markedly convex. There are five furrow spines on the first 2-3 adambulacral plates, thereafter constantly four. All other features are in keeping with the species.

COLOUR: In life this species is variegated usually with pastel colours, mauve, orange and yellow appearing to predominate (Pope, 1951), though Shepherd (1968) records the colour as purple and red, and Powell (1937) describes the colours including chrome, vermilion and purple.

DISTRIBUTION: South and south-east coast of Australia, New Zealand to the Kermadec Islands, 14-792 m.

REMARKS: The form of the superomarginal plates, abactinal tuberculation and single series of subambulacral spines separates *truncatus* from all other species described in this paper.

Fisher (1919) considered *truncatus*, amongst the three species of *Asterodiscus* known at that time, to be the most closely related to his new species *A. helenotus*. However, the features indicated above and additionally the non spatulate form of the actinal tubercles and the low number of inferomarginal plates (4-5) under the distalmost superomarginals in *truncatus* easily separates the two species.

In some respects, *A. truncatus* shows affinities with *Amphiaster insignis* Verrill. The convexity and shape of the superomarginals, low furrow spine number and single subambulacral series are all similarities. However, I believe that the shape and extent of the abactinal and actinal tuberculation, the larger size of the distalmost superomarginal compared with the proximal three superomarginals and the very widely spaced marginal plates separate the two generically.

In his description of the species, Coleman (1911) clearly describes one specimen in detail (A.M. No. J1053) (fig. 3e-g) and compares a larger specimen (A.M. No. J2047), with the aid of figures of the latter specimen, with the smaller specimen. Both of these specimens are held in the Australian Museums collections. These two specimens are considered here as the only authentically described type-specimens (syntypes), material from other localities listed by Coleman merely indicating recognition by Coleman that those specimens also represent his newly described species but which have *not* served any part in the description of the species.

Asterodiscides helenotus (Fisher)
Figs 3h-i, 4a-b

Asterodiscus helenotus Fisher, 1913, p. 210; 1919, p. 357, pls 95 fig. 1, 1a; 96 figs 1-2.

A. hiroi Hayashi, 1938, p. 277, pl. 1 figs 5-7.

DIAGNOSIS: Stellate form, R/r = 1.6-2.0, R up to 98mm; 4 superomarginal plates, proximal three only obvious on juveniles, distalmost massive, flat, squarish, h.d. = no more than 1/5R, adjacent superomarginals at arm tip broadly contiguous abactinally above the terminal plate; 9 (juvenile) - 18 inferomarginal plates of which 8-9 underlie the distalmost superomarginal plate in adult specimens; abactinal tubercles inverted cone-shaped, rounded, not forming mosaic pattern when viewed from above; actinal plates each with single prominent spatulate tubercle; furrow spines 3-4, subambulacral spines in 2 series, one spine in each series per plate; pedicellariae, when present, slender, forceps-like.

DESCRIPTION: The descriptions of the holotype (U.S.N.M. No. 32633) (figs 3h-i, 4a) given by Fisher (1913; 1919) do not require repetition here. However, I have also had the opportunity of examining two juvenile specimens collected from the Sulu Archipelago, Philippines which I believe to be referable to *O. helenotus,* (W.A.M. Nos. 1080-74 and 1081-74).

The smaller specimen (1081-74) measures R = 14.4 mm, r = 8.6 mm, R/r = 1.67. The central-abactinal plate, ring of primary radial plates and somewhat larger interradial plates are obvious. As in the juveniles of *A. culcitulus* (p194) the interradials are precluded from contact with the central-abactinal plate because of two intercalary radial plates between each primary radial and the central plate. Each radial plate has a tubercle obscuring it and the interradials bear 1-2 small tubercles. There is a carinal row of seven tuberculate plates and three lateral rows, one or two plates are found in the interradial areas between adjacent arms. The plates bear a peripheral ring of small granules and a single, rounded tubercle. There are a few small tubercles scattered between the larger plates. The marginal plates are prominent. The distalmost superomarginal is larger than any of the others (2.2 mm h.d. × 2.0 mm v.d.). These superomarginals meet widely abactinally above the terminal plate. Each has a peripheral ring of small granules, there being a double row where the superomarginals are contiguous. There are three proximal superomarginals but two vertically placed tubercles occur between the second and third superomarginals and a line of three tubercles separate the third marginal from the distalmost superomarginal. In at least three cases the second superomarginal appears vertically divided, giving the impression of 5 plates. The tuberculate plates between the third and fourth superomarginals give the impression of being part of the series of plates, but the superomarginals are always distinctively larger and bare and with a peripheral ring of small granules. There may be 1-3 tubercles on the actinal edge of the superomarginal plates. There are 9 inferomarginal plates, four occurring under the distalmost superomarginal. The plates are conspicuously bare, with a peripheral ring of small granules and a conical tubercle on the abactinal edge. This tubercle becomes spiniform on the distal inferomarginal plates, especially on the plates underlying the distalmost superomarginal. A single line of intermarginal tuberculate plates is present, each plate being placed in the angle between the more or less vertically aligned marginals. These intermarginal plates extend to the fourth inferomarginal.

There are 5 rows of actinal plates each plate bearing 6-8 granules surrounding a rounded tubercle.

The adambulacral plates (35) each bear 3 or 4 furrow spines and two subambulacral spines. The inner subambulacral spine on each plate is large and longitudinally flattened, but tapering to the tip. The second spine is an enlarged granule, the middle one of three on the outer edge of the plate. There are usually 2-3 small granules additionally on the plate.

The oral plate bears seven furrow spines, three actinal spines and three or four prismatic granules. There are no pedicellariae on this specimen.

The second specimen (1080-74) measures R = 16.4 mm, r = 8 mm, R/r = 2 (fig. 4b). It has slightly narrower arms and the abactinal primary tubercles are more spaced, with secondary tubercles scattered between (roughly in alternating rows). The primary plates are not as obvious, but can be detected with careful examination. There are eleven inferomarginal plates. Apart from these small differences, due obviously to growth, the two juveniles are very similar.

I believe that the specimen from the vicinity of Seto, south western tip of Japan, which Hayashi (1938) described as *Asterodiscus hiroi*, is a small *helenotus*. The differences outlined by Hayashi do not seem tenable to me. The absence of pedicellariae is not unusual, the fewer abactinal tubercles and differences in the adambulacral armament can be explained by the difference in size between Hayashi's specimen and the holotype of *O. helenotus*. Hayashi's specimen was just over twice the size of the juvenile specimens described above.

DISTRIBUTION: Philippine Islands to the S.W. tip of Japan, 18-81 m.

REMARKS: *O. helenotus* is clearly most closely related to *O. tessellatus*. The differences are discussed on p.204 and can be seen in the dichotomous key on p.191.

Asterodiscides tessellatus sp. nov.
Fig. 4c-g

Asterodiscus elegans, Bell, 1909, p. 19 (part), (non *A. elegans* Gray, 1841).

Asterodiscus helenotus, Clark and Rowe, 1971, pp. 34, 40 (part); Grzimek, 1974, p/pl. 379, (non *A. helenotus* Fisher, 1913).

DIAGNOSIS: Stellate form, R/r = 2.2-2.5, R up to 47 mm; 4 superomarginal plates, proximal three small, obscured unless arm denuded, distalmost massive, flat, squarish, h.d. = 1/3R, adjacent superomarginals at arm tip broadly contiguous abactinally above the terminal plate; 14-16 inferomarginal plates, with 8-9 under distalmost superomarginal; abactinal tubercles inverted cone-shaped, flat-topped, polygonal in cross-section, forming a mosaic pattern when viewed from above; actinal plates each with single spatulate tubercle; furrow spines 3, subambulacral spines in 2 series, one spine per plate in each series; pedicellariae slender, forceps-like, only observed actinally.

DESCRIPTION: Holotype B.M. No. 1907.7.1.45 (part); Saya da Malha, western Indian Ocean, 99 m., Stanley Gardiner Expedition.

The body is stellate, R = 40-46.6 mm, r = 18.5 mm, R/r = 2.2-2.5 (fig. 4c-e). The arms have more or less parallel sides. Abactinal tubercles are in three sizes and are not regularly arranged. All the tubercles are flat-topped, polygonal in cross-section and inversely conical. The arrangement of the tubercles is such that they form a mosaic when viewed from above. The base of each tubercle is surrounded by a ring of small granules and no other granules are present abactinally. The largest tubercles have an apical diameter of c. 2 mm and stand about 1 mm high. The madreporite is small and almost hidden under adjacent apically expanded tubercles. There are no abactinal pedicellariae.

The superomarginal plates are not conspicuous unless denuded, except for the distalmost one (fig. 4d). There are four superomarginal plates, the proximal three are small, 1.75 mm h.d. × 1.75 mm v.d. but the distalmost superomarginal is massive, 15-16 mm h.d. × 11-11.5 mm v.d., flattened and widely contiguous abactinally above the terminal plate. In

the depression between the abactinally joined plates are six rows of small granules. The superomarginal plates form a lip with their outer edge, under which are two rows of small granules (fig. 4e). There are three plates between the third superomarginal and distalmost superomarginal plates. There are 14-16 inferomarginal plates, of which about 9 occur under the distalmost superomarginal. (The first five inferomarginal plates each have h.d. × v.d. = 1.75 mm × 1.75 mm). The superomarginal and inferomarginal series are separated by two rows of plates.

Actinal plates in 3-4 rows. Each plate bears a single, large spatulate tubercle and a peripheral ring of small, wedge-like, unequal granules (fig. 4e). One or two plates carry a slender pedicellaria.

Adambulacral plates (c.54) extend on to the abactinal surface at the tip of the arm. Each plate bears 3 furrow spines, the first of which is shorter than the other two which are equal in length. There are two subambulacral spines, which form two rows along the length of the arm. The first subambulacral spine on each plate is elongate, longitudinally flattened and standing at an oblique angle to the furrow. The second, outer, spine stands just forward obliquely from the first spine, is about $\frac{1}{2}$-$\frac{1}{3}$ length of the first spine, longitudinally flattened but with the flat edge parallel to the furrow (fig. 4e). The remaining periphery of the plate bears small, wedge-shaped granules. No pedicellariae occur on the adambulacral plates.

The oral plate bears 7 furrow spines and 2 actinal spines.

Paratype B.M. No. 1907.7.1.45 (part); locality same as holotype.

The paratype (fig. 4f-g) differs in only a few minor details from the holotype: R = 33-35 mm, r = 17.5 mm, R/r = c.2. The distalmost superomarginals measure 10.5 mm h.d. × 8.5 mm v.d. There are only 3 rows of actinal plates and about 44 adambulacral plates.

COLOUR: The holotype is preserved in alcohol and is uniformly cream. The colour of the paratype in alcohol is uniformly light coffee brown.

DISTRIBUTION: Saya da Malha (Western Indian Ocean), to 99 m.

ETYMOLOGY: *tessellatus* (Lat.) = referring to the mosaic pattern of abactinal plates.

REMARKS: *A. tessellatus* is closely related to *A. helenotus*. Bell (1909), however, identified these specimens as *Asterodiscus elegans*. Clark (in Clark and Rowe, 1971) re-identified the two specimens as *A. helenotus* Fisher. However, it seems to me that the specimens represent a new species, differing from *helenotus* principally in the shape and arrangement of the abactinal tubercles, the massive distalmost superomarginal (equalling 1/3R) and in the general size. I do not believe that the features used to separate the species *tessellatus* from *helenotus* can be attributed to size difference, particularly after having examined two, small, juvenile specimens of *helenotus*.

A coloured photograph of *A. tessellatus* (labelled *A. helenotus*) is included in Grzimek's (1974) *Animal Life Encyclopaedia*, Volume 3, page/plate 379. It shows the animal to be a salmon-pink colour in life. The locality of the specimen photographed is unknown (Dr H. Fechter, pers. comm.).

Asterodiscides pinguiculus sp. nov.
Fig. 4h-j

DIAGNOSIS: Stellate form, R/r = 1.6, R up to 58.5 mm; only marginal plates discernable are the flat, pear-shaped distalmost superomarginals and the underlying 4-6 distal inferomarginals; between the proximalmost inferomarginal and the proximal curved edge

of the superomarginal above is a triangle of about 15 tuberculate plates, noticeably larger than the adjacent plates of the side of the arm; abactinal tubercles small, closely packed, 2 sizes; actinal plates each with 1-2 large, central tubercles, markedly larger than abactinal tubercles; furrow spines 3-5, subambulacral spines in 2 series, one spine in each series per plate, rarely a third spine develops from granule on outer edge of adambulacral plate; pedicellariae sometimes present.

DESCRIPTION: Holotype W.A.M. No. 1079-74; N.E. of Bernier Is., Shark Bay, Western Australia, 23-27 m., 25.vi.71. D. Heald.

The holotype is stellate, measuring R = 92.5 mm, r = c.58.5 mm R/r = c.1.6, (fig. 4h-j). The arms are obese, with well rounded tips, Br = 66 mm. The adambulacral furrow recurves abactinally at the arm tip so as to be visible when the animal is viewed from above. Abactinal tubercles are closely packed and of only two distinct sizes. The largest tubercles are sharply conical (h.d. = 1.75 mm × v.d. = 1.75 mm) and are surrounded at the base by a ring of small granules. Three rows of these tubercles extend along about 1/3R (6-7 per row, well spaced). The closely packed smaller tubercles are circular when viewed from above, but mushroom-shaped when viewed from the side. Interstitial granules are scattered between the tubercles. The madreporite is oval (6 mm × 4 mm).

With the exception of 4-6 distal inferomarginal plates under the prominent distalmost superomarginal plate, the actual number of superomarginal and inferomarginal plates cannot be stated since none of the other marginal plates are discernable, even after denuding the side of the arm (fig. 4i). The distalmost superomarginals are pear-shaped, flat (h.d. = 7 mm × v.d. = 12 mm) and each is surrounded by a peripheral ring of small granules. There are 4-6 small inferomarginal plates below each of the distalmost superomarginal plates, but between the proximalmost of these inferomarginal plates and the proximal curved edge of the adjacent superomarginal is a triangle of about 15 plates which are noticeably larger than the adjacent plates of the sides of the arms (fig. 4i). Each of these larger plates bears a large conical tubercle (c. 1.75 mm × 1.75 mm). There is a sharp delimitation between the end of the smaller tubercles of the abactinal surface and the very much larger actinal tubercles at the actinal / abactinal edge of the arms and disc. This is also marked by an abrupt colour change.

The actinal plates bear usually one large conical tubercle (measuring up to h.d. = 2.75 mm × v.d. = 2.75 mm) and a peripheral ring of variously sized, subquadrate granules. Adjacent to the furrow the plates usually bear two large tubercles, (fig. 4j).

The adambulacral plates (c. 50) bear 3-5, usually 5, furrow spines for the first 35 plates, thereafter 4 or 3. The proximal spine is smaller than the others which are almost equal in size. There are two series of subambulacral spines. The inner one on each plate is flattened and the outer one tapering. The outer edge of each adambulacral plate usually has three large granules of which, occasionally, the central granule is enlarged to a spine of equal size to the other two subambulacral spines on the plate. Prismatic granules occur on the proximal and distal edges of the plates. Occasionally two subequal subambulacral spines occur on each plate in the first series of spines (fig. 4j).

The oral plates bear 10 furrow spines and 5-6 large actinal spines.

No pedicellariae occur on the holotype.

A second specimen, collected from Exmouth Gulf, measures R = 61, r = 41, R/r = 1.5, (W.A.M. 361-76). It differs little from the holotype except that it has numerous pedicellariae.

COLOUR: The colour in life is a deep, uniform maroon abactinally, slightly lighter actinally (photograph provided by Mrs. L. M. Marsh, Western Australian Museum); the dried specimen is similarly coloured.

DISTRIBUTION: Shark Bay to Exmouth Gulf, Western Australia, 7-27 m.

ETYMOLOGY: *pinguiculus* (Lat.) = fattish, referring to the general shape of the animal.

REMARKS: The size and shape of *pinguiculus,* the small, crowded abactinal tubercles, the apparent lack of proximal superomarginal plates and the marked distinction between the size of the abactinal and the larger actinal tubercles sets this species apart from any of the other known species in this genus. The most closely related species appear to be *A. lacrimulus, A. grayi* n. spp. and *A. tuberculosus* (Fisher).

Asterodiscides lacrimulus sp. nov.
Fig. 5a-c

DIAGNOSIS: Stellate form, R/r = 1.5, R up to 68 mm; 4 bare superomarginal plates, proximal 3 produced into abactinally directed cone housing slender pedicellariae in crescentic depression, distalmost superomarginal largest, flat, tear-shaped; 11-12 bare inferomarginal plates, proximal 6-8 with actinally directed cone; abactinal tubercles fine, acutely conical, 3 sizes; actinal plates each with 8-12 subequal granules, none are tuberculiform; furrow spines 5, subambulacral spines in 2 series, first series 2 spines per plate, second series 1 spine per plate; pedicellariae slender, forceps-like.

DESCRIPTION: Holotype U.S.N.M. No. E15833; Stn 444, Cruise 9, 09° 36′ N, 51° 01′ E (off Socotra, N.W. Indian Ocean), 78-82 m, 16.xii.64, 'Anton Bruun' (I.I.O.E.).

The animal is distinctly stellate, measuring R = 57.5 mm, r = 37.5 mm, R/r = 1.53, (fig. 5a-c). The arms are triangular, with a fairly acute tip. The adambulacral furrow recurves abactinally at the arm tip so as to be just visible when the animal is viewed from above. The abactinal tubercles are acutely conical and of three distinct sizes. The largest are spaced in a carinal and two lateral rows along the length of the arms and measure h.d. = 1.7 mm × v.d. = 2.4 mm. A ring of small granules occurs around the base of each of these and the two lesser sized tubercles. These latter tubercles are scattered, without regular order, between the larger tubercles. Interstitial granules are scattered between the tubercles. A slender pedicellaria is associated with many of the tubercles.

The marginal plates are not immediately obvious amongst the tuberculation, except the distalmost superomarginals (h.d. = 3.3 mm × v.d. = 6.0 mm) which are narrow, tear-shaped (fig. 5a-b). The pair at each arm tip are just contiguous above the terminal plate. Each superomarginal plate is surrounded by a peripheral ring of small granules. There are three proximal superomarginal plates, each usually predominantly bare and with the surface produced into an abactinally directed cone. On the abactinal edge, seated in a crescentic depression, is a slender pedicellaria. On the actinal edge are two conical tubercles of similar size to the larger abactinal tubercles. Each plate has a peripheral ring of small granules. The second superomarginal is 4 mm from the first and 7 mm from the third, the third superomarginal is 12 mm from the distalmost plate. Each of the proximal superomarginal plates measures h.d. = 2.2 mm × v.d. = 2.2 mm. There are 11 or 12 inferomarginal plates, of which 4-5 lie under the distalmost superomarginal. The shape of the plates is similar to that of the proximal superomarginals but with the cone directed actinally. Each of the first five inferomarginal plates measure h.d. × v.d. = mm: 2.2 × 2.75. The marginal series are separated, at least proximally, by about three rows of plates (fig. 5b).

The actinal plates bear 1 or 2 central granules surrounded by 8-10 subequal, subquadrate granules. There are *no* prominent granules on the plates except towards the inferomarginal line, where one granule becomes larger and rounded and may be

considered as a tubercle. The actinal plates are seen to be in distinct lines because of the more even size and distribution of the granules on each of the plates (fig. 5c). Most of the plates bear a pedicellaria.

The adambulacral plates (60) bear five furrow spines for at least the first 30 plates, thereafter 4 then 3 distally. The first spine is generally about one half the length of the second, which is slightly shorter than the other three spines. The subambulacral spines are in two series. The first series comprises two obliquely aligned spines on each of the first 30 plates, after which the proximalmost of the two spines becomes small and insignificant. The second series comprises a single spine, behind the first pair on each plate, which is broadly flattened, being equal in width to the inner pair of spines. Distally this spine becomes spiniform and tapering (fig. 5c). The proximal, distal and outer edges of the adambulacral plates bear prismatic granules.

The oral plates bear 9 furrow spines and 5 actinal spines.

Paratype A.M. No. J9792; Stn. 463, Cruise 9, 11°24'N, 51°35'E (off Socotra, N.W. Indian Ocean), 75-175 m, 17.xii. 64, 'Anton Bruun' (I.I.O.E.).

The paratype differs in only a few minor details from the holotype: R = 68 mm, r = 46 mm, R/r = 1.49. The largest abactinal tubercles measure h.d. = 1.7 mm × v.d. = 3.0 mm. The distalmost superomarginals measure h.d. = 3.0 mm × v.d. = 6.6 mm. There are about 65 adambulacral plates. The specimen is dried and of similar colour to the holotype.

COLOUR: The holotype is dried and is a dirty brown above, lighter actinally. The colour in life is not recorded.

DISTRIBUTION: Off Socotra, Indian Ocean, 75-175 m.

ETYMOLOGY: *lacrimulus* (Lat.) = little tear, referring to the shape of the distalmost superomarginal plates.

REMARKS: This species appears to be most closely allied to *A. tuberculosus* (Fisher), and *A. grayi* sp. nov. It differs from both in the finer abactinal tuberculation, the arrangement of the granules on the actinal plates, the fewer furrow spines, the distinctive shape of the proximal superomarginal and inferomarginal plates and the flatness of the distalmost superomarginal plate. *A. lacrimulus* is also distinguished from *grayi* by its lower R/r ratio

Asterodiscides tuberculosus (Fisher)
Fig. 5d

Asterodiscus tuberculosus Fisher, 1906, p. 1075, pl. xxvi figs 2, 2a; pl. xxviii fig. 3; pl. xxxii figs 3, 4; pl. xxxiii fig. 2; pl. xxxiv figs 1-2.

DIAGNOSIS: Stellate form, R/r = 1.5, R up to 69 mm; 4 bare superomarginal plates, distalmost superomarginal largest, oval, slightly convex, adjacent superomarginals at arm tip just contiguous abactinally above the terminal plate; 10-11 inferomarginal plates predominantly bare; abactinal tubercles bluntly pointed — subspherical, 3 sizes; actinal plates with up to 2 tubercles; furrow spines 5-6, subambulacral spines in 2 series, first series 2 spines per plate, second series 1 spine per plate; pedicellariae slender, forceps-like.

DESCRIPTION: There is nothing to add to Fisher's description of the holotype (fig. 5d), and two juvenile specimens. I have re-examined the holotype (U.S.N.M. No. 21172) and a third juvenile specimen collected from off Rabbit Island, Oahu in 396 m of water (B.P.B.M. No.

W1148). This latter specimen is smaller than Fisher's juveniles, measuring only R = 7.5 mm, r = 5 mm, R/r = 1.5, but corresponds very closely to the description given by Fisher for his specimens measuring R = 10 mm, r = 6.5 mm, R/r = 1.54.

DISTRIBUTION: Off Hawaiian Islands, 59-396 m.

REMARKS: *A tuberculosus* is most closely related to *A. grayi* sp. nov. and *A. lacrimulus*. The differences are outlined under those two species and are evident from the dichotomous key (p.192).

Asterodiscides grayi sp. nov.
Fig. 5e-f

DIAGNOSIS: Stellate form, R/r = 2.0, R up to 75 mm; 4 bare superomarginal plates, distalmost superomarginal largest, oval, slightly convex, adjacent superomarginals at arm tip just contiguous abactinally above the terminal plate; 10 inferomarginal plates obscured under granules; abactinal tubercles sharply pointed — subspherical, 3 sizes; actinal plates with up to 12 tubercles; furrow spines 5-7, subambulacral spines in 2 series, first series 2 spines per plate, second series 1 spine per plate; pedicellariae slender, forceps-shaped.

DESCRIPTION: Holotype A.M. No. J8719; Stn 2, 27°27'22"S, 153°39'E, Moreton Bay, Queensland, 75 m, 29.iii.69, H.M.A.S. 'Kimbla' (Dr. Ponder).

The specimen is distinctly stellate but contorted, with one mutilated arm, but measures R = c.65 mm, r = c.30 mm, R/r = c.2.2 (fig. 5e-f). The arms are relatively slender, tapering to a fairly acute tip. The abactinal tubercles are rounded to sharply conical, and in three distinct sizes. The largest (h.d. = 2.35 mm × v.d. = 2.75 mm) are acutely conical and form a carinal and two lateral rows along the length of the arms, a third lateral row being more or less evident. Each tubercle has a ring of small granules around its base. The tubercles are largest on the disc, diminishing in size towards the arm tip. Between these tubercles are the closely packed rounded tubercles of the two lesser sizes. The three largest sizes of tubercles tend to form alternating longitudinal rows along the arms. Small granules surround the base of the smaller tubercles. Interstitial granules occur between the tubercles. Pedicellariae are common abactinally, one being closely associated with most of the two largest-sized tubercles.

The marginal plates are not conspicuous amongst the tuberculation excepting the distalmost superomarginal plates which measure h.d. = 4.75 mm × v.d. = 6.75 mm and are bare and slightly convex. There are three proximal superomarginal plates. The innermost is close to the interradial line, the second is about 5 mm from it and the third is about 8 mm from the second and 35 mm from the distalmost plate. The three proximal plates vary in shape from sub-circular to distinctly vertically elongate. Each is strongly convex, bare and surrounded by a ring of small, subquadrate granules, these being at least twice the size of those around the base of the tubercles (fig. 5f). A pedicellaria is associated with each of the proximal superomarginals.

There are ten inferomarginal plates which are of similar size to the proximal superomarginals. Each is surmounted by about twelve granules of which one, two or three are conical to rounded and distinctly larger and tuberculiform. A pedicellaria is associated with most of the inferomarginal plates (fig. 5f). The actinal plates bear up to seven tubercles of various sizes, surrounded by a peripheral ring of small granules. Usually 1-4 of the tubercles are larger than the others and are quite prominent. The actinal plates do not appear to be arranged in any apparent order, with the exception of the row adjacent to the adambulacral plates. This is marked by the prominence of two large conical tubercles on proximal plates, and one on distal plates. A pedicellaria is associated with most of the actinal plates.

The adambulacral plates bear 6 or 7 furrow spines on the first 22-24 plates, reducing to five and distally four spines. The distal three spines are of about the same size but the three or four proximal spines decrease in size adorally so that the innermost spine is only about one half the length of the outermost spine. The subambulacral spines form two series. The inner series comprises two subequal spines on each plate which are aligned parallel with the furrow. The spines are stout, blunt and proximally the adoral spine is smaller than its companion. However, after about the tenth to twelfth plate the aboral of the two spines is the smaller, this spine becoming minute near the tip of the arm. The remaining adoral spine becomes slender and spiniform. The outer series of subambulacral spines comprises a single spine on each plate. This spine is flattened, equal in length to the two inner spines on the plate and equal in width to the inner pair of spines. This spine similarly becomes slender and spiniform distally. Small, wedge-shaped granules occur on the proximal, distal and outer edges of the adambulacral plates.

The oral plates bear twelve furrow spines and seven to eight actinal spines.

A specimen from the Kermadec Islands (N.M.W. No. Ech1280), measuring R = 75 mm, r = 37 mm, R/r = 2.0, differs from the holotype in the form of the armament of the skeletal plates. The abactinal tubercles are subspherical with only those nearest the tip of the arm showing any slightly conical shape. The actinal plates bear usually only five tubercles, of which one is much larger, though they are all more or less equal in height. Each of the plates adjacent to the adambulacral plates bears 4-5 tubercles of which one practically dominates the whole plate. This row of large tubercles stands out clearly. The inferomarginal plates are also each dominated by usually one, rarely two, subspherical tubercles, the rest of the plates bearing 5-8 small, unequal granules. Until more comparative material is available, I do not think that these features alone are of sufficient importance to justify the recognition of this specimen as a species which is distinct from *A. grayi*. Two specimens collected from Norfolk Island (New Zealand Oceanographic Institute collection) intergrade in the form of armament between the two specimens described above.

COLOUR: The holotype of *A. grayi* is preserved in alcohol and is uniformly off whitish, the colour in life is not recorded. The other specimens of *A. grayi* are dried and uniformly muddy brownish, the colour in life is not recorded.

DISTRIBUTION: Moreton Bay, N.E. Australia, to Norfolk Island and the Kermadec Islands, 70 to 75 m.

ETYMOLOGY: *grayi* = named after J. E. Gray who described many asteroid taxa including the type species of *Asterodiscides*.

REMARKS: *A. grayi* appears to be most closely allied to *A. lacrimulus* and *A. tuberculosus*. It differs from *lacrimulus* in the higher number of furrow spines, course abactinal tuberculation, the more slender arms and in the actinal plate armament. It differs additionally from *tuberculosus* in the tuberculation of the inferomarginal plates. Differences with the other species included in this genus are evident from the dichotomous key (p.192).

Genus **Paulia** Gray, 1841

Paulia Gray, 1840, p. 278; Sladen, 1889, p. 343; Ludwig, 1899, p. 690; Döderlein, 1935, p. 73; 1936, pp. 311, 318; Spencer and Wright, 1966, p. U63.

Goniodiscus (part) Müller and Troschel, 1842, p. 57.

Nidorellia, Perrier, 1875, p. 251 (part) (non *Nidorellia* Gray).

?Pauliella Ludwig, 1905, p. 151.

DIAGNOSIS: Body form stellate, R/r = c.2.0; all 4 (? 3 in juvenile) superomarginal plates bare and of similar size; distalmost superomarginal plates separated from the terminal plate by a large spiniferous plate; abactinal plates with large, acute spines, h.d. = 3 mm (at base) × v.d. up to 6 mm; actinal plates with 1-2 tubercles surrounded at the base by granules; intermarginal papulae absent; furrow spines 4-5; subambulacral spines in 2 series.

TYPE-SPECIES *P. horrida* Gray, 1840 (by monotypy).

REMARKS: The skeletal plate armament of this genus is similar to *Amphiaster*, but the arrangement of the distalmost superomarginal plates, the distribution of the papulae and the triserial as opposed to biserial adambulacral armament will distinguish *Paulia* from *Amphiaster*. Differences in skeletal armature, additionally will separate *Paulia* from *Asterodiscides*.

Paulia horrida Gray
Fig. 5g-i

P. horrida Gray, 1840, p. 278; 1866, p. 8; Ludwig, 1899, p. 690; H. L. Clark, 1902, p. 523; 1910, p. 333; Döderlein, 1936, p. 318; Spencer and Wright, 1966, p. U63.

Nidorellia horrida, Perrier, 1875, p. 254.

P. horrida var. *galapagensis* Ludwig, 1905, p. 143, pls XIII figs 63-64; XXIV figs 135-137, XXV figs 142-143.

?Pauliella aenigma Ludwig, 1905, p. 151, pls XII figs 58-60, XXIII fig. 133, XXIV fig. 138, XXV fig. 144, XXVI fig. 145.

DIAGNOSIS: As for genus.

DESCRIPTION: The species was described very summarily by Gray (1840). Perrier (1875) redescribed Gray's type-specimen. Ludwig (1905) gave a detailed description of both his variety *galapagensis* and of *Pauliella aenigma*.

The specimen at hand (A.M. No. J9654) (fig. 5g-i) is from Tagus Cove, Albemarle Island. Galapagos (Velero stn 330-35). The specimen measures R = 60 mm, r = 31 mm, R/r = c.2.0. The abactinal spines are in a carinal and two lateral rows, with 4-5 small spines in the interradial angle between adjacent arms. Around the base of each spine are one or two rings of small granules. Between the spined plates are smaller plates hidden under a covering of granules (fig. 5g). There are four superomarginal plates, which are tumid, bare and with two peripheral rings of granules. The plates are of similar size and the distalmost is separated from the terminal plate by a large spinebearing plate. There are eight inferomarginal plates, of which the distal 4-5 bear a spiniform tubercle. The marginal series are separated by two rows of spine bearing plates, at least proximally, amongst which are scattered smaller plates. Adjacent superomarginal plates and adjacent inferomarginal plates are likewise separated (fig. 5h). The actinal plates form 3-4 chevrons in the actinal intermediate areas. Each plate bears one to two stout apically rounded tubercles and two rings of granules. The adambulacral plates bear four furrow spines and two subambulacral spines, the remaining periphery of the plate bearing small granules. Occasionally the first subambulacral spine is accompanied by a small, aborally placed spine, or else a large, foraminate pedicellaria of similar size to the subambulacral spine (fig. 5i). Small foraminate pedicellariae occur on the actinal and marginal plates. The

papulae appear isolated, but are, in fact, in small groups of about 6-8. They are abactinal only and do not extend beyond the superomarginal line.

DISTRIBUTION: Punta Santa Elena, Ecuador, Peru, Galapagos Islands, Cocos Islands, Lower California.

REMARKS: Ludwig (1905) considered that the specimens from Galapagos Islands, which are smaller than the type-specimen from Ecuador, represent a variety of *P. horrida*. In lacking comparative material to verify Ludwig's proposal, I follow Döderlein (1936) in not recognising the status of *galapagensis*.

Ludwig (1905) painstakingly described *Pauliella aenigma* from two juvenile specimens from Cocos Islands (tropical eastern Pacific). He considered that they might represent juvenile *Paulia*, of which nothing at present is known. *P. aenigma* has not been reported since it was first described and the species has subsequently been considered a synonym of *P. horrida* (Döderlein, 1936). However, *Pauliella* has only *three* superomarginal plates (at R = 13.5 mm-16.5 mm) whereas *P. horrida* has four superomarginal plates. Examination of three specimens of *Amphiaster insignis* has shown an increase from four superomarginals (at R = 27.5 mm) to five superomarginals (at R = 38.5 mm and above). A study of a large series of juvenile to adult forms of *Asterodiscides culcitulus*, as well as several juveniles of one or two other species of that genus, indicates that the number of superomarginals does *not* increase above the number seen in the juvenile specimens (at least from R =6.5 mm). Also, the R/r ratio appears to remain pretty constant from juvenile to adult. The ratio in the young *P. aenigma* is 1.3-1.4, whereas in the adult *P. horrida* it is about 2.0, an increase of about 50%.

It seems, therefore, that until a representative collection of *P. aenigma* and of juvenile specimens of *P. horrida* is available for comparison, there must be some doubt about the conspecificity of the two species.

Should the validity of *Pauliella* need to be recognised, then a substitute name will have to be found since Ludwig's genus name is a homonym of *Pauliella* Munier-Chalmas, 1895 (Mollusca).

Genus **Amphiaster** Verrill, 1868

Amphiaster Verrill, 1868, p. 372; 1914, p. 294; Sladen 1889, p. 343; Ludwig, 1899, p. 689; Fisher, 1911, p. 170; Boone, 1928, p. 4; Spencer and Wright, 1966, p. U63.

DIAGNOSIS: Body form stellate, R/r = c.2.0; 4-5 superomarginal plates of similar size; distalmost superomarginal adjacent to the terminal plate and the opposite pairs at each arm tip are broadly contiguous above the terminal plate; abactinal plates with large, acute spine, h.d. 3 mm (at base) × v.d. up to 6 mm; actinal plates with 1-2 tubercles surrounded at the base by granules; intermarginal papulae few or absent; furrow spines 3-5 (usually 3); subambulacral spines in a single series.

TYPE-SPECIES: *A. insignis* Verrill, 1868 (by monotypy).

REMARKS: This genus is separated from *Paulia* on the basis of the arrangement of the superomarginal plates, the single series of subambulacral plates and the extension of the papulae to the inferomarginal line (at least in specimens where R = 38 mm and above). Whether this separation is justified is difficult to determine. Considering the amount of variation seen to occur in the genus *Asterodiscides*, it is thought that *Amphiaster* would probably fall under the range of variation which might be expected to be exhibited by *Paulia*. However, principally because of the lack of sufficient comparative material to clarify this issue, a conservative attitude is adopted here in respect of the recognition of these two genera.

Amphiaster insignis Verrill

A. insignis Verrill, 1868, p. 373, pl. IV fig. 10; 1914, p. 294, pl. XCVIII fig. 2; Ludwig, 1899, p. 689; H. L. Clark, 1913, p. 194; 1923, p. 150; Boone, 1928, p. 4, pl. 2; Spencer and Wright, 1966, p. U63

?*Nidorellia armata*, Brusca and Smith, 1973, p. 310, fig. 12.3. (non *N. armata* Gray, 1840).

DIAGNOSIS: As for genus.

DESCRIPTION: *A. insignis* has been well described by Verrill and is an easily recognised species. I have had the opportunity of examining three specimens collected from Lower California and identified by A. H. Clark (U.S.N.M. No. 3350). The smallest specimen (R = 27.5 mm) has four superomarginal plates whilst the two larger specimens (R = 38.5 mm and 50 mm respectively) have five. In the largest specimen, the innermost superomarginal of adjacent arms are contiguous, as are superomarginals 3-4 or 4-5 distalward along the arms, whilst 1-2, 2-3 and sometimes 3-4 are separated by a prominent spine-bearing plate. In the smallest specimen 2-3 are separated by a small plate and in the middle-sized specimen superomarginals 3-4 are likewise separated. There are six inferomarginal plates in the smallest specimen (R = 27.5 mm) and seven in the two larger. The proximal plates are flat but the distal 4 or 5 are either tumid or bear a stout spine on the actinal edge. The first inferomarginal plate of adjacent arms are in contact. Distalward, 1-2, 2-3, 3-4 and 4-5 on each arm are separated by a spine-bearing plate but 5-6 and 6-7 are contiguous. Each marginal plate has a peripheral ring of granules. The marginal series are separated by two vertically aligned large, spine-bearing plates, with a smaller plate between these adjacent pairs of plates. Some inferomarginal plates carry pedicellariae. Each actinal plate has a very prominent spine and three rings of granules. The adambulacral armament comprises 3 furrow spines and 1 subambulacral spine and accompanying peripheral granules. Papulae occur in groups of 5-6 and, at least in the two larger specimens a few extend to the inferomarginal line.

DISTRIBUTION: Lower California.

REMARKS: Verrill obviously mistook the number of superomarginal plates present, including the intercalating spine-bearing plates as marginals. He did not describe the presence of intermarginal papulae nor did he mention the intermarginal plates (which he considered as marginals).

This species has been recorded only a few times since it was described (H.L. Clark, 1913, 1923; Boone, 1928). Steinbeck and Ricketts (1941) did not meet with it on their travels in the 'Sea of Cortez'. More recently, Brusca and Smith (1973) recorded *Nidorellia armata* Gray from the Gulf of California. They described the living colour as a 'beautiful lavender to red-orange' and 'abora! spines usually purple with dark tips'. They mentioned that the star had heavy marginal plates and large, movable spines. It is unfortunate that the figure accompanying the description obviously represents *Amphiaster insignis*. It is difficult to decide which species was available to Brusca and Smith.

DISCUSSION

During an investigation of the genera described in this paper, two points became clear. Firstly, there have been varied opinions as to the true relationships between *Asterodiscides*, *Paulia* and *Amphiaster* and between them and members of the families Goniasteridae and Oreasteridae. Secondly, it is obvious that since Viguier, Perrier and Sladen each propounded their own methods of classifying asteroids, subsequent authors have used the combination of these three authors ideas to classify asteroids up to the present time. If one

continues to use the same method of classifying asteroids (none better has so far been devised) then it becomes clear that the combination of characters exhibited by *Asterodiscides, Paulia* and *Amphiaster* stand them apart from any other group of asteroids.

It would be extremely difficult to place the genera satisfactorily in either of Sladen's Phanerozonia or Cryptozonia because of the peculiar development of the marginal plates, the distribution of the papulae (to the inferomarginal line in *Asterodiscides* and *Amphiaster,* but only to the superomarginal line in *Paulia*) and the distinctive adambulacral armature. The armament of the abactinal and actinal plates seems also to be a distinctive feature of these three genera. In the systems of classification used, perhaps the weakest character to rely on is the form of the pedicellariae, because of absence of these organs from some specimens. However, when they are present it can be seen that the genera dealt with here fall in the Order Valvatida (spelling of the order adopted by Spencer and Wright). The arrangement of the marginal plates is absolutely distinctive and not known in any other group of asteroids. The armament of the abactinal and actinal plates and of the adambulacral plates is also distinctive, the only other genus with similarly armed plates being *Calliaster.* In this case it is very interesting to note that Spencer and Wright (1966) were unable to classify *Calliaster,* listing it, with *Amphiaster,* in the group of genera belonging to unnamed sub-families within the family Goniasteridae. The continuous margin of many, contiguous marginal plates, the low, squat form of the pedicellariae and the more varied occurrence of tubercles or spines on the abactinal plates immediately separates *Calliaster* from the genera dealt with here. I do not think that *Calliaster* can be placed in the same family as *Asterodiscides, Paulia* and *Amphiaster* but it should obviously be placed in a closely related family. Under Spencer and Wright's system the genera are included in the sub-order Granulosina, Order Valvatida, the main features of which are that the marginals are conspicuous, fewer than the adambulacrals and in two *opposite* series, the abactinal plates are not usually in a regular order in the adults, the plates usually bear spines or granules in shallow sockets and the pedicellariae, when present, are usually valvate and sunk in the ossicles. Within this higher grouping Spencer and Wright placed *Asterodiscides* and *Paulia* together in one family but were uncertain of the true affinities of *Amphiaster.* Although I agree with placing the three genera within the Order Valvatida, I consider that the diagnosis of the sub-order Granulosina has to be expanded to include these forms having *fewer* superomarginals than inferomarginals, *not* in two opposite series and spaced from each other horizontally and vertically; otherwise a new sub-order must be described. Within the sub-order Granulosina I do not believe that they can be placed in either of the families Goniasteridae or Oreasteridae, and propose the new family Asterodiscididae.

From the study of the fairly large collection on hand, it has been seen that young specimens resemble the goniasterids (particularly *Tosia*). Indeed adult *Amphiaster,* resembling *Calliaster,* may be considered as perhaps the least specialised member of the new family. In the juveniles the number of marginal plates is low (3-5) and does not usually increase from the number seen in the juvenile (the number at metamorphosis is not known, but is likely to be the same) except in *Amphiaster* where the number increases from four to five (see p.212).The distalmost superomarginal may be adjacent to the terminal plate or separated from it by one or two plates. Also, the distalmost superomarginal may be very large and prominent, larger than the other superomarginals. There is no evidence at present to suggest that the enlarged superomarginal is developed from a fusion of smaller plates during development, or that it has had any dominating effect on the development or distribution of either the remaining superomarginal plates or the inferomarginal plates. The proximal 2-3 superomarginals may become inconspicuous amongst the other skeletal plates. The number of inferomarginal plates exceeds that of the superomarginal plates, there being from 8-18 in adults of the species so far described. The number increases slightly with growth of the animal. The inferomarginals usually decrease regularly in size distalwards, with 4-9 underlying the large superomarginal at the end of the arm. Intercalary

plates separate the marginal plates from their adjacent neighbours both vertically and horizontally. The spacing of the marginal plates is not known in any group of genera. The spacing of the marginal plates would indicate a structural weakening of the margin of these asteroids. This appears to be compensated by the compactness of the abactinal skeleton and its thick, investing integument. The significance of this departure from a solid marginal boundary is not known, though it would certainly have facilitated the extension of the distribution of papulae to the inferomarginal line, and greater flexibility of the abactinal surface. Until more is known of the ecology of these asteroids little can be added that would not appear too speculative.

The abactinal plates, although appearing in contact in juvenile specimens, become separated but connected by radiating (usually 6) ossicles. These radiating ossicles can form into a dense supporting meshwork in larger animals, similar to that found in large specimens of oreasterids such as *Culcita*. Each of the abactinal plates usually bears a large central spine or tubercle surrounded at the base by one or two rings of granules. The skeleton, excluding the tubercles and granules which are covered by a thin epidermis, is invested by a thick integument.

Papulae occur in groups and may extend to the inferomarginal line. The presence of intermarginal papulae has been considered by Fisher (1911) to be sufficiently important to recognise the sub-family Nectininae in the family Goniasteridae. He also noted the presence of superambulacral plates but does not appear to have considered these in relation to the recognition of the sub-family. Spencer and Wright diagnosed the sub-family Nectininae using *both* of the characters. Certainly the presence or absence of papulae alone would make it difficult to justify recognising a sub-family when the distribution of papulae within the valvatulid family Ophidiasteridae is used only to separate genera. (It is interesting to note that the genus *Hacelia* Gray has superambulacral plates and has not so far been considered as belonging in anything other than the family Ophidiasteridae). I think, therefore, that there is no justification for splitting the new family into sub-families in order to distinguish *Paulia,* with its papulae confined abactinally above the superomarginal line, from *Asterodiscides* and *Amphiaster* with the papulae extending to the inferomarginal line.

The membranous interbrachial septum and absence of spicules from the tube-feet have been features considered by such recent authorities as Fisher, Döderlein and Spencer and Wright as being of sufficient importance to be used to distinguish the families Goniasteridae and Oreasteridae. In this regard the genera considered in this paper cannot be placed in the latter family. The adambulacral armature is distinctive in that each plate bears a furrow fan backed across the plate by 1 or 2 + 0 or 1 (rarely 2) + 0 or 1 large, truncate subambulacral spines, the rest of the plate bearing prismatic granules. I have been able to find a similar arrangement of adambulacral armament only in the genus *Calliaster* which Spencer and Wright (1966) were unable to assign (as was the case with *Amphiaster*) to a sub-family within the family Goniasteridae. The shape of the pedicellariae is closer to those of *Pentagonaster* than to those found in the Oreasteridae, but some specimens may lack pedicellariae altogether.

The R/r ratio remains relatively constant from juvenile through to adult. Each of the species of *Asterodiscides* described in this paper is well marked. It is probable that the full specific potential of the genus is not yet realised, when the number of specimens available and their scattered distribution is considered. This must be particularly apparent when it is seen that the specimens from practically each of the separate localities collected appear to represent separate species or sub-species.

The characters used in the classification of the Order and Sub-order and in the argument to establish the new family, to which *Asterodiscides* belongs have been outlined, in some detail, above. The characters used to distinguish between the species have been:

1. R/r ratio.
2. Shape of the abactinal and actinal tubercles.
3. Relative size of the distalmost superomarginal plate to the proximal 2-3 superomarginal plates, number of superomarginal and inferomarginal plates.
4. Relative amount of contact between adjacent superomarginal plates at the tip of the arm, including the relationship between the distalmost superomarginal plate and the terminal plate; shape of the distalmost superomarginal plate.
5. Specific furrow spine number and extent of subambulacral armament.

These features have grouped several species closer to each other than to some of the other species, as can be seen in the dichotomous key: e.g. *tessellatus* and *helenotus; elegans* and *culcitulus; tuberculosus, grayi* and *lacrimulus; pinguiculus* and *truncatus* appear to stand alone. I do not think that these groupings should be considered, at least at the present time, to represent higher taxonomic (generic) groupings, since this would involve the erection of one or more monotypic genera, thus indicating that too much weight *may* have been placed on the characters used to establish those genera.

The inclusion of *Paulia* and *Amphiaster* in the same family with *Asterodiscides* has been justified above. The retention of those genera as valid supra-specific taxa distinct from *Asterodiscides* is justified here on two major points; the form of the plates armature and the arrangement of the superomarginal plates. The limited extent of the intermarginal papulae may also be a feature used to distinguish these two from *Asterodiscides.* The lack of intermarginal papulae and the different arrangement of the superomarginal plates and the number of series of subambulacral spines are features used to separate *Paulia* from *Amphiaster.*

No overriding character or characters have been seen in the Indo-west Pacific Ocean specimens, on which to place reliable generic weight. This is probably principally due to the low number of specimens obtained from each locality (except for *A. culcitulus,* which has, in fact, shown how relatively constant the features of a species may be) and the distinctness of each of the local phenotypes. Until more material is available from the same and from intermediate localities, it is considered that, despite some apparent inconsistency in the taxonomic weight placed on some of the characters exhibited by these asteroids, a conservative attitude should be adopted towards retaining presently accepted taxa and the establishment of new taxa.

The distribution of the Asterodiscididae appears to be generally tropical-sub-tropical Indian and Pacific Oceans, with the notable exception of *Asterodiscides truncatus* from the more temperate southeastern Australia and northern New Zealand waters. It is perhaps interesting that *Paulia* and *Amphiaster* are restricted to the extreme eastern, tropical area of the Pacific (Galapagos — Lower California — Peru) and that these seem to be the least specialised forms of the family. *Asterodiscides,* with the exception of *A. truncatus,* extends through the Indian Ocean to the northeastern coast of Australia and northward to the Philippine Islands and to southern Japan. It extends east to the Hawaiian Islands in the north and to the Kermadec Islands in the south Pacific but has not so far been found in the East Indies region or from the islands of the central Pacific. *Paulia* and *Amphiaster* can be collected from shore line to about 20-30 m depth whereas *Asterodiscides* occurs down to about 792 m, though more usually around 50-100 m, and has only once been recorded as occurring on the shore.

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List of Specimens Examined

No. specimens	Locality and Remarks	R/r = mm
	Asterodiscides culcitulus n. sp.	
1	Stn 104, 29°29'S, 114°12'E, W.S.W. Dongara, Western Australia, 108 m., 8.xii.70, H.M.A.S. 'Diamantina'. HOLOTYPE W.A.M. 1063-74	54/49
11	Stn 107, 30°29'S, 114°40'E, S. W. of Jurien Bay, Western Australia, 144 m, 9.xii.70, H.M.A.S. 'Diamantina'. PARATYPES W.A.M. 1116-74	34-57.7/ 26.5-47.7
1	Shark Bay, Western Australia, trawled, 6/63, colld W. and W. Poole. W.A.M. 1078-74	97/75
1	Stn 55, off Pelsart Group, Western Australia, 180 m, 16.ii.64, H.M.A.S. 'Diamantina'. W.A.M. 1077-74	93/71.5
1	Cottesloe, 40 km W. of Fremantle, Western Australia, c90 m in crayfish pot, 23.i.64, Mr Lyon. W.A.M. 1069-74	83/63
8	Stn 107, 30°29'S, 114°40'E, S.W of Jurien Bay, Western Australia, 144 mm, 9.xii.70, H.M.A.S. 'Diamantina'. W.A.M. 118-74	26-63/22-54
13	Stn 107, 30° 29'S, 114°40'E, S. W. of Jurien Bay, Western Australia, 144 mm, 9.xii.70, H.M.A.S. 'Diamantina'. W.A.M. 1117-74	13.5-57.7/ 11.5-44.5
2	Stn 109, 30°29'S, 114°40'E, S.W. of Jurien Bay, Western Australia, 100 m, 9.xii.70, H.M.A.S. 'Diamantina'. W.A.M. 1120-74	18.5-47.5/ 13.5-37.8
1	Stn 68/1, 30°37'S, 114°44'E, Western Australia, 139-146 m, 22.iii.72, H.M.A.S. 'Diamantina', W.A.M. 1072-74	45/39
2	Stn 41, 30°38'S, 114°46'E, N.W. of Green Is. Western Australia, 144 m, 27.xi.70, H.M.A.S. 'Diamantina'. W.A.M. 1064-74	22-41/32-34

4	Continental shelf between Cape Naturaliste and Shark Bay, Western Australia. December 1970, H.M.A.S. 'Diamantina'. W.A.M. 1071-74	33.5-40/ 30-40
1	Stn 46, off Lancelin Is, Western Australia, 117 m, 5.ii.64 H.M.A.S. 'Diamantina'. W.A.M. 1073-74	38/33.7
1	Stn 68/3, 30°34'S, 114°44'E, N.W. of Green Is, Western Australia, 128 m, 22.iii.72, H.M.A.S. 'Diamantina'. W.A.M. 1123-74	36.5/29.5
3	Stn 55, 29°15'S, 114°01'E, West of Dongara, Western Australia, 146 m, 20.iii.72, H.M.A.S. 'Diamantina'. W.A.M. 1068-74	22-34.5/ 18.6-28
1	Stn 80, 27°35'S, 114°04'E, W. of Gautheaume, Western Australia, 114 m, 6.xii.70, H.M.A.S. 'Diamantina'. W.A.M. 1121-74	33/27.5
1	Stn 46, off Lancelin Is, Western Australia, 117 m, 5.ii.64, H.M.A.S. 'Diamantina'. W.A.M. 1074-74	31/25
2	Stn 37, 30°55'S, 114°48'E, W. of Lancelin Is, Western Australia, 144 m, 26.xi.70, H.M.A.S. 'Diamantina'. W.A.M. 1065-74	14-31/ 11-26.5
2	N.W. of Rottnest Is, Western Australia, 144 m, 15.ix.65, 'Bluefin'. W.A.M. 1066-74	13.7-27.5/ 10.5-23.5
2	Stn 8, 32°57.5'S, 114°48'E, Western Australia, 122-139 m, 15.iii.72, H.M.A.S. 'Diamantina'. W.A.M. 1070-74	18.0-23.0/ 14.5-18
1	Stn 55, 29°15'S, 114°01'E, W. off Dongara, Western Australia, 139-146 m, 20.iii.72, H.M.A.S. 'Diamantina'. W.A.M. 1122-74	20/16
1	Between 30°34'S and 34°04'S, Western Australia, 45-180 m, 23-8.xi.70, H.M.A.S. 'Diamantina'. W.A.M. 1067-74	19.5/14.5
1	Stn 56, 29°18'S, 114°04'E, Western Australia, 170-174 m, 10.iii.72, H.M.A.S. 'Diamantina'. W.A.M. 1075-74.	14.5/12.5
1	Stn 68/1, 30°37'S, 114°44'E, Western Australia, 139-146 m, 22.iii.72, H.M.A.S. 'Diamantina'. W.A.M. 1076-74	14.5/12.5
1	Stn 46, off Lancelin Is, Western Australia, 117 m, 5.ii.64, H.M.A.S. 'Diamantina'. W.A.M. 1084-74	13/9.5
1	W.N.W. of Rottnest Is, Western Australia, 171-173, 14.viii.62, colld R. W. George. W.A.M. 1088-74	12.5/9.5
1	Stn 46, off Lancelin Is. Western Australia, 117 m, 5.ii.64, H.M.A.S. 'Diamantina'. W.A.M. 1083-74.	12/9.3
2	Stn 46, off Lancelin Is, Western Australia, 113-120 m, 1964, H.M.A.S. 'Diamantina'. W.A.M. 1124-74	11.5/8.5

1	Stn 46, off Lancelin Is, Western Australia, 117 m, 5.ii.64, H.M.A.S. 'Diamantina'. W.A.M. 1087-74	11/8.5
1	As above. W.A.M. 1085-74	10/8.3
1	As above. W.A.M. 1082-74	10/7.6
1	As above. W.A.M. 1086-74	6.5/4.5
	A. elegans elegans (Gray)	
1	No locality, Purchd. Argent. HOLOTYPE. B.M. 1845.3.5.353	36/24
1	'N. China', Purchd Fortune, Figured by Gray, 1866, pl.12, fig. 2. B.M. 1847.6.18.4	24/16
1	'Albatross' stn 5482, between Samar and Leyte, vicinity of Surigar Strait, Philippine Islands, 120 m, 30.vii.09. U.S.N.M. 40544	36/24
1	'China', Purchd Cuming. B.M. 1849.1.31.4	62/47
1	'N. China', Purchd Cuming. B.M. 1849.1.31.3	64/49
1	Zamboangan, Philippine Islands, 18 m, 'Challenger' Expedition. B.M. 1890.5.7.501	90/67
	A. elegans belli n. subsp.	
1	Amirante Is, Western Indian Ocean, 46 m, Stanley Gardiner Expedition. HOLOTYPE. B.M. 1907.7.1.46	62.7/47
1	As above, 80 m. PARATYPE formerly B.M. 1907.7.1.44, donated to the Australian Museum, J9734	68/60
1	Saya da Malha, Western Indian Ocean, Stanley Gardiner Expedition. B.M. 1907.7.1.45 (part)	60/44
2	Madras, India, colld E. Thurston. B.M. 1890.1.13.11-12 (part), A.M.J.9735 (one donated to The Australian Museum)	65.5/50 (A.M.) 83/73 (B.M.)
	A. truncatus (Coleman)	
1	Off Coast of New South Wales, Australia, F.I.S. 'Endeavour' SYNTYPE. A.M. J1053	104/48
1	Off East Coast of Victoria, Australia, F.I.S. 'Endeavour' SYNTYPE. A.M. J2047	131/61
1	Tollgate Ids, Bateman's Bay, New South Wales, Australia, 6.x.57, B. Dew and E. Slater. A.M. J6910	44/20
1	Off Norah Head, New South Wales, Australia, 47-68 m, McNeil and Livingstone. A.M. J3476	70/30

2	Tollgate Ids, Bateman's Bay, New South Wales, Australia, intertidal, E. Slater. A.M. J6977	71-73/33-34
1	Bass Point, New South Wales, Australia, 30 m, sponge and coral cover, 23.3.75, B. Clark. A.M. J9179	86/46
1	Off Norah Head, New South Wales, Australia, 47-68 m, McNeil and Livingstone. A.M. J3474	87/40
1	Great Australian Bight, 144-216 m, F.I.S. 'Endeavour' A.M. E3641	92/38
1	As above. A.M. J3071	101/47
1	4-6.4 km off Botany Bay, New South Wales, Australia, 59-101 m, Livingstone and Fletcher. A.M. 3865	102/48
1	As above. A.M. J3868	102/48
1	As above, McNeil and Livingstone, A.M. J3489	105/49
1	Off Norah Head, New South Wales, Australia, 47-68 m, McNeil and Livingstone. A.M. J3473	108/47
1	4-6.4 km off Botany Bay, New South Wales, Australia, 59-101 m, Livingstone and Fletcher, A.M. J3867	111/55
1	As above, A.M. J3866	115/56
1	Terrigal, New South Wales, Australia, 19 m, 24.vi.65. colld R. Dawson, don. J. Campbell. A.M. J8767	115/50
1	Off Norah Head, New South Wales, Australia, 47-68 m, McNeil and Livingstone. A.M. J3475	115/50
1	As above. A.M. J3472	118/48
1	Terrigal, New South Wales, Australia, 20 m, 24.vi.65, colld R. Dawson, don. J. Campbell. A.M. J8764	118/51
1	Off Norah Head, New South Wales, Australia, 47-68 m McNeil and Livingstone. A.M. J3470	121/55
1	4-6.4 km off Botany Bay, New South Wales, Australia, 59-101 m McNeil and Livingstone. A.M. J3491	121/57
1	19.2-35.2 km N., 0.8 km E. from Green Cape, New South Wales, Australia, 70-83 m, Livingstone and Fletcher. A.M. J4594	127/61
1	As above. A.M. J4595	129/56

1	As above A.M. J4596	138/63
2	32 km E. of Broken Bay, New South Wales, Australia, 774-792 m, 2.iv.75, F.I.S. 'Kapala'. A.M. J9173	110-135/ 55-60
1	Eastern slope of Bass Strait, Australia, 144-360 m, F.I.S. 'Endeavour'. A.M. J4680	152/81
2	Locality unknown, F.I.S. 'Endeavour'. A.M. E5284-5	141-159/74-76
1	9.6 km east of Cape Hawke, New South Wales, Australia, 84-90 m F.I.S. 'Endeavour'. M.C.Z. 2484 (formerly A.M. E1645, donated to M.C.Z.). Labelled 'Cotype' but see p.	80/40
1	Stn 56, Botany Bay, New South Wales, Australia, 14.2-144 m, H.M.C.S. 'Thetis'. M.C.Z. 1998. Labelled 'Cotype' but see p.	126/55
1	Great Australian Bight, 162 m, D. L. Serventy. M.C.Z. 3174	70/35
1	Eastern Slope, Bass Strait, Australia, 144-360 m, F.I.S. 'Endeavour'. M.C.Z. 2483 (formerly A.M. J4679, donated to M.C.Z.)	150/73
1	Auckland, New Zealand, 1964, John Graham, U.S.N.M. E10144	c.82/42.5
1	Raoul Is, Kermadec Islands, N. of New Zealand, A. N. Baker, N.M.N.Z. ECH1281	64/32
	A. helenotus (Fisher)	
1	Stn 5149, off Sirum Id, vicinity of Siasi, Sulu Archipelago, Philippine Is., 18 m, U.S.F.S. 'Albatross'. HOLOTYPE U.S.N.M. 32633	98/48
1	Sulu Archipelago, Philippine Is., 52 m, sand and *Lithothamnion*, 22.II.64, B. R. Wilson. W.A.M. 1081-74	14.4/8.6
1	As above. 72-81 m, sponge and *Lithothamnion*, 22.II.64, B. R. Wilson. W.A.M. 1080-74	16.4/8
	A. tessellatus n. sp.	
2	Saya da Malha, western Indian Ocean, 99 m., Stanley Gardiner Expedition. HOLOTYPE and PARATYPE. B.M. 1907.7.1.45 (part)	40-46.6/18.5 (Holotype) 33-35/17.5 (Paratype)
	A. pinguiculus n. sp.	
1	N.E. of Bernier Is., Shark Bay, Western Australia, 23-27 m, 25.vi.71, D. Heald, HOLOTYPE. W.A.M. 1079-74 1079-74	92.5/58.5

1	Exmouth Gulf, Western Australia, 7-20 m, 1-8.v.76, J. Pennon 'Flinders' W.A.M. 361-76	61/41
	A. lacrimulus n. sp.	
1	Stn 444, Cruise 9, 09° 36'N, 51° 01'E. (off Socotra, N.W. Indian Ocean), 78-82 m, 16.xii.64, 'Anton Bruun' (I.I.O.E.) HOLOTYPE. U.S.N.M. E15833	57.5/37.5
1	Stn 463, Cruise 9, 11°24'N, 51°35'E. (off Socotra, N.W. Indian Ocean), 75-175 m, 17.xii.64, 'Anton Bruun' (I.I.O.E.) PARATYPE A.M. J9792	68/46
	A. tuberculosus (Fisher)	
1	Stn 3940, vicinity of Laysan Isd., Hawaii, 106-126 m, white sand and broken shell, bottom temperature 70°F, 16.vi.02, U.S.F.S. 'Albatross'. HOLOTYPE. U.S.N.M. 21172	69/40
1	1.6 km off Rabbit Isd, Oahu, Hawaii, 59-61 m, 14.iv.49, Brock B.P.B.M. W1148	7.5/5
	A. grayi n. sp.	
1	Stn 2, 27°27'22"S, 153°39'E, Moreton Bay, Queensland, 75 m, 29.3.69, 'Kimbla' (Dr Ponder). HOLOTYPE. A.M. J8719	c.65/30
1	Raoul Isd, Kermadec Is, N. of New Zealand, A. N. Baker. N.M.N.Z. ECH 1280	75/37
2	Norfolk Island, N.Z.O.I., Stn 190, 29°25'S, 168°05.6'E, 71 m, 23.7.75	62-65/ 35-36
	Paulia horrida Gray	
1	Stn 330-35, Tagus Cove, Albemarle Id, Galapagos Is, 21 m, 10.xii.30, 'Velero' (Allan Hancock Foundation) A.M. J9654	60/31
	Amphiaster insignis Verrill	
3	Lower California. U.S.N.M. 3350	27.5-50 (r not taken)

FIGURE 1. — A-C, *Asterodiscides culcitulus* n. sp., holotype, a. abactinal, b. lateral, c. actinal views, R = 54mm, W.A.M. 1063-74. D-H. *A. culcitulus* n.sp., abactinal views, d. R = 6.5mm, W.A.M. 1086-74, e. R = 10mm, W.A.M. 1082-74, f. R = 12.5mm, W.A.M. 1088-74, g. R = 14.5mm, W.A.M. 1075-74, h. R = 38mm, W.A.M. 1073-74. I-K. *A. culcitulus* n. sp., i. abactinal, j. lateral, k. actinal views, R = 93mm, W.A.M. 1077-74.

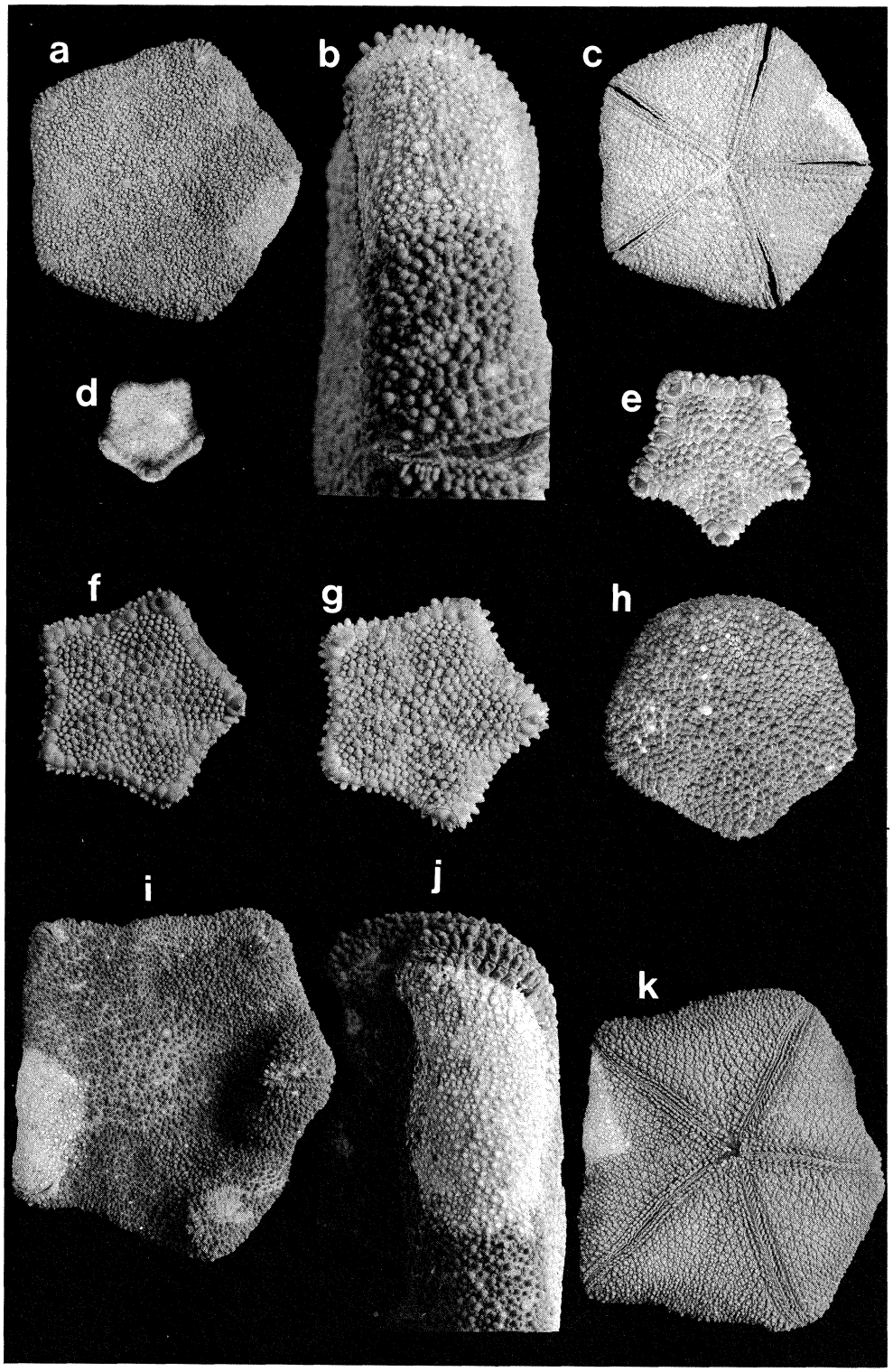
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FIGURE 2. — A-C. *Asterodiscides elegans elegans* (Gray), holotype, a. abactinal, b. lateral, c. actinal views, R = 36mm, B.M. 1845.3.5.353. D-E. *A. elegans elegans* (Gray), d. abactinal, e. lateral views, R = 36mm, U.S.N.M. 40544. F-H. *A. elegans elegans* (Gray), f. abactinal, g. lateral, h. actinal views, R = 24mm, B.M. 1847.6.18.4. I. *A. elegans elegans* (Gray), lateral view, R = 64mm, B.M. 1849.1.31.3. J. *A. elegans elegans* (Gray), abactinal view, R = 90mm, B.M. 1890.5.7.501.

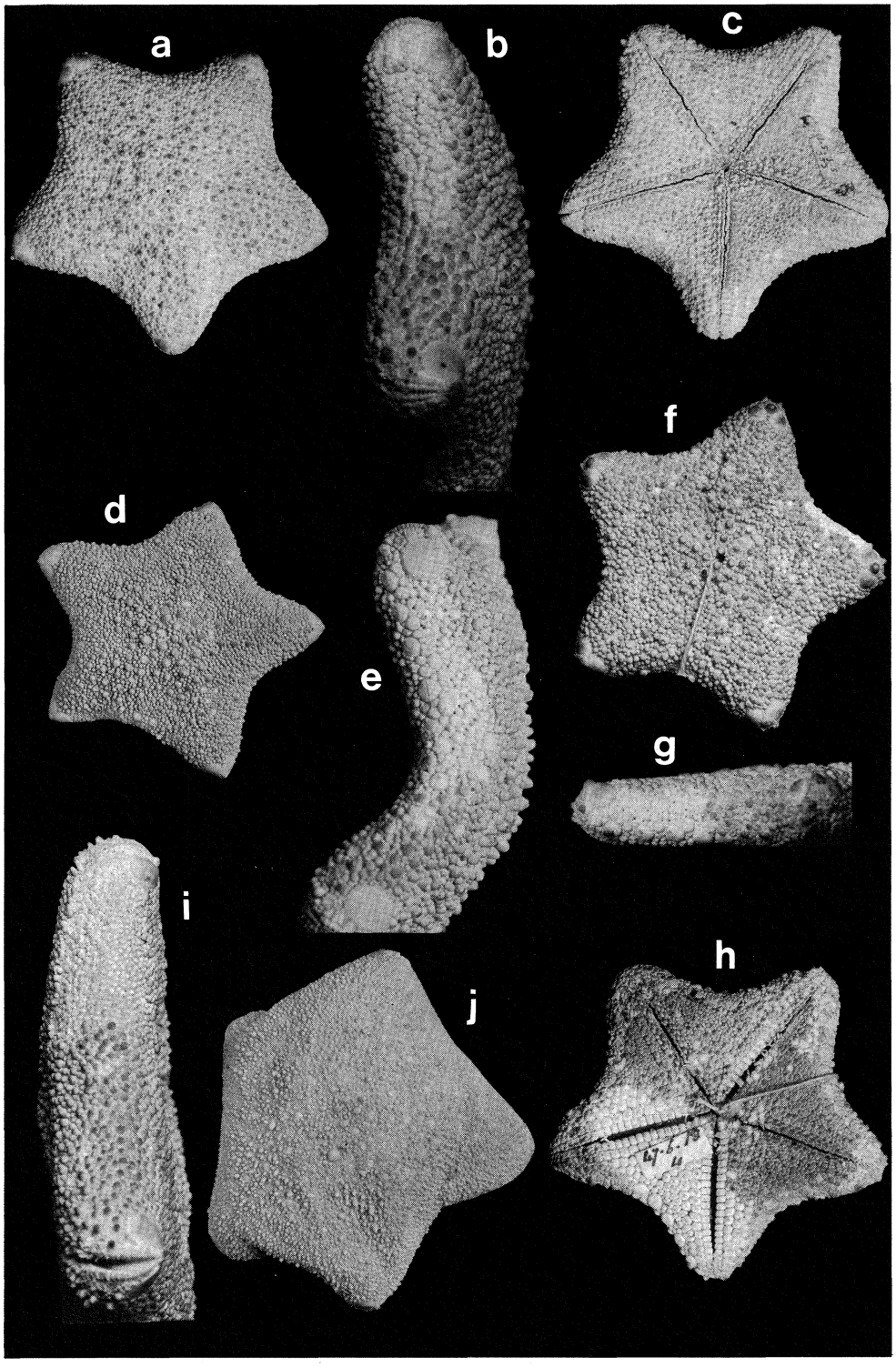
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FIGURE 3. — A-B. *Asterodiscides elegans belli* subsp. nov., holotype, a. abactinal, b. lateral views, R = 62.7mm, B.M. 1907.7.1.46. C-D. *A. elegans belli* n. subsp., c. abactinal, d. actinal views, R = 65.5mm, A.M. J9735. E-G. *A. truncatus* (Coleman), syntype, e. abactinal, f. lateral, g. actinal views, R = 104mm, A.M. J1053. H-I. *A. helenotus* (Fisher), holotype, h. abactinal, i. lateral views, R = 98mm, U.S.N.M. 32633.

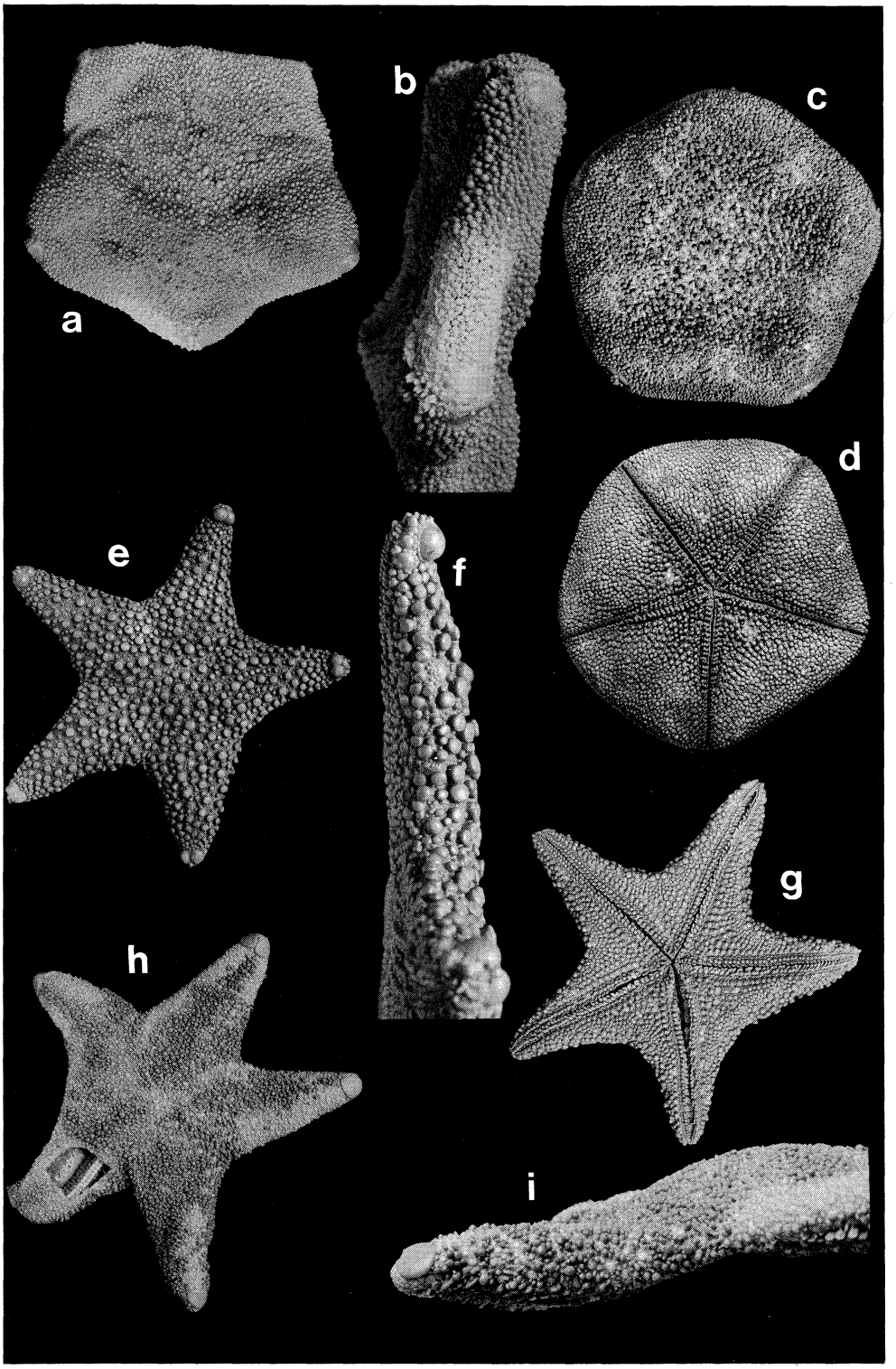
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FIGURE 4. — A. *Asterodiscides helenotus* (Fisher), holotype, actinal view, R = 98mm, U.S.N.M. 32633. B. *A. helenotus* (Fisher), juvenile, abactinal view, R = 16.4mm, W.A.M. 1080-74. C-E. *A. tessellatus* n. sp., holotype, c. abactinal, d. oblique abactinal, including partially denuded arm, e. actinal, partially denuded arm, R = 40 — 46.6mm, B.M. 1907.7.1.45 (part). F-G. *A. tessellatus* n. sp., paratype, f. abactinal, g. actinal views, R = 33-35mm, B.M. 1907.7.1.45 (part). H-J. *A. pinguiculus* n. sp., holotype, h. abactinal, i. lateral, j. actinal views, R = 92.5mm, W.A.M. 1079-74.

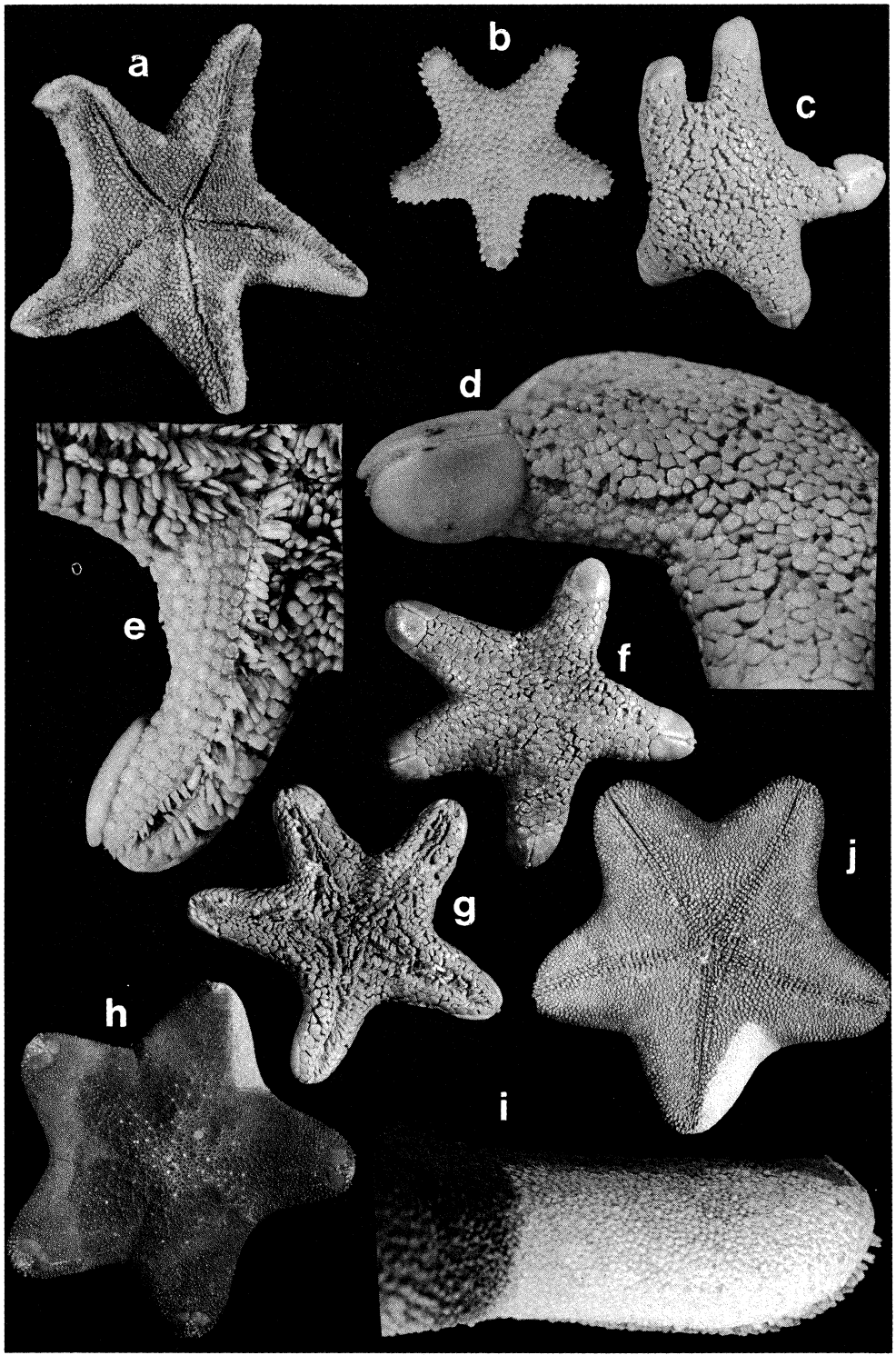
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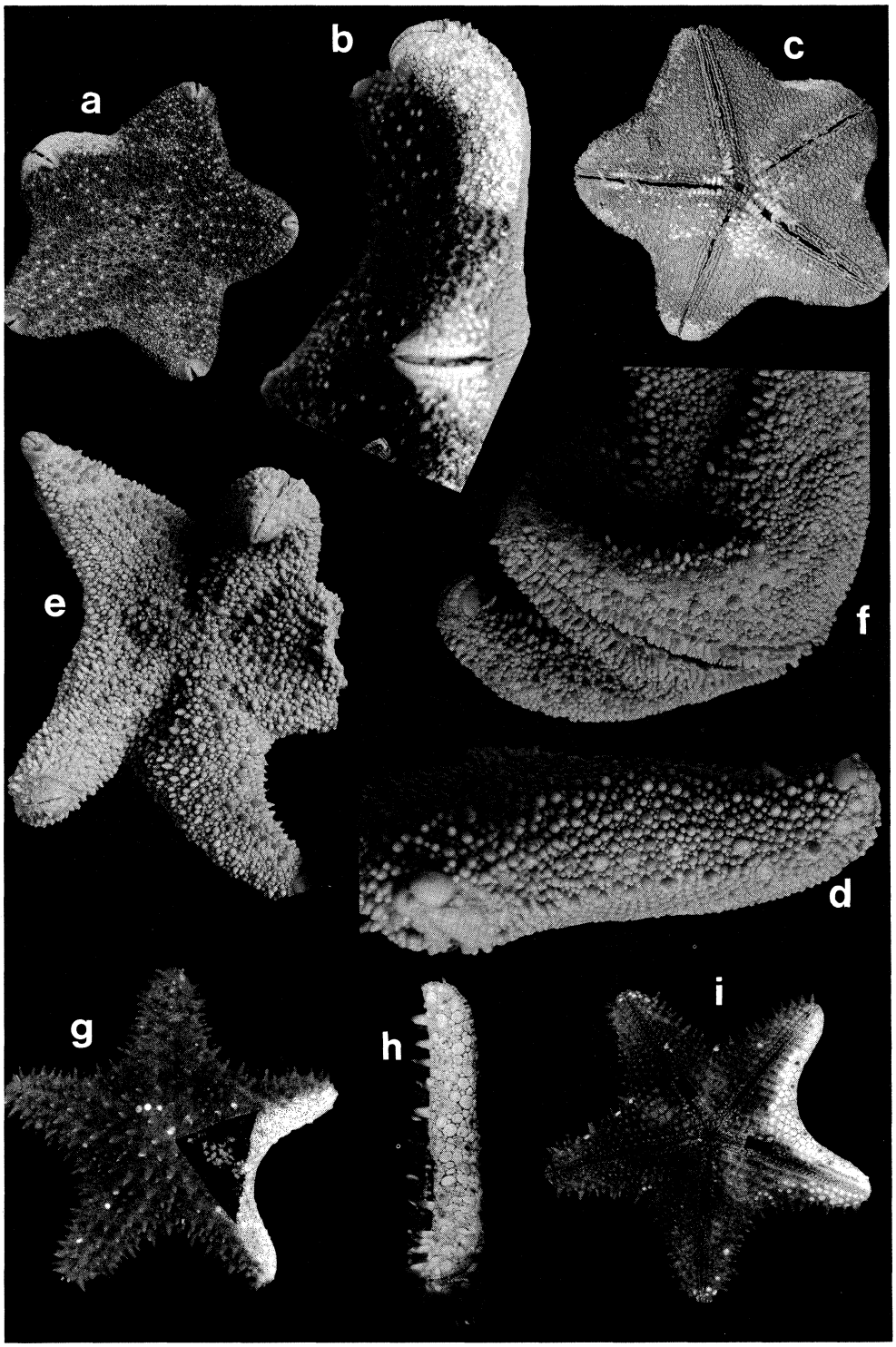
FIGURE 5. — A-C. *Asterodiscides lacrimulus* n. sp., holotype, a. abactinal, b. lateral, c. actinal views, R = 57.5mm, U.S.N.M. E15833. D. *A. tuberculosus* (Fisher), holotype, Lateral view, R = 69mm, U.S.N.M. 21172. E-F. *A. grayi* n. sp., holotype, e. abactinal, f. oblique actinal views, R = 65mm, A.M. J8719. G-I. *Paulia horrida* Gray, g. abactinal, h. lateral, i. actinal views, R = 60mm, A.M. J9654.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