

THE LINGULIDÆ OF THE QUEENSLAND COAST.

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By PROFESSOR T. HARVEY JOHNSTON, M.A., D.Sc.,
C.M.Z.S., AND OTTO S. HIRSCHFELD, B.Sc., Biology
Department, University, Brisbane.

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Plates I and II and Text-figures 1-8).

The following species of *Lingula* have been recorded from the Queensland Coast: *L. anatina* Lam. (*L. rostrum* Shaw), *L. murphiana* King, *L. tumidula* Reeve, *L. exusta* Reeve, *L. hians* Swainson, and *L. hirundo* Reeve, the first five named being reported from Moreton Bay and the last two from Port Curtis. Davidson in his list (1879, p. 402) mentioned only the second, third and fourth, while Thomson (1918, p. 43) referred to all six.

The genus is rarely found on the New South Wales Coast, only one species, *L. hians*, having been recorded from Port Jackson by Angas in 1867, and by Brazier (1879*a*, p. 370; 1879*b*, p. 402) as an extreme rarity, the latter author—a very keen and persistent collector—stating that he had found only one living specimen in Sydney Harbour during his 25 years' experience collecting there. Mr. C. Hedley, who succeeded Mr. Brazier as Conchologist to the Australian Museum, Sydney, informed us recently that he had never collected *Lingula* in Sydney, the only specimen from New South Wales that he had seen being the solitary form obtained in 1866 by Brazier who determined it.

Hedley in his catalogue of the marine mollusca of Queensland (1909, p. 371) evidently considered that one species alone was present, since his list contains only *L. anatina*, while in his check list of the marine molluscan fauna of New South Wales (1917, p. 113) he referred to *L. rostrum* Shaw (syn. *L. anatina*) alone. He, however, mentioned (1916, p. 695) that the species of *Lingula* had been discriminated usually from dry and probably distorted material and that little attention has been given to change in appearance at different stages of growth. "It may be, therefore, still a matter for investigation whether the names assigned to Australian forms, *L. tumidula* Reeve, *L. murphiana* Reeve, *L. exusta* Reeve, and *L. hirundo* Reeve, represent distinct species, geographical races, or growth forms of a single species."

Lingula rostrum Shaw.

This is better known as *L. anatina* Lam. but Hedley (1916, p. 694) has recently shown that Shaw's name has priority. The latter author described material from the Philippine Islands under the name of *Mytilus rostrum* in 1797.

Hedley evidently inclines to the view that there is only one species on the Queensland coast, since, as already stated above, he listed only *L. anatina* in 1909 (p. 371). Von Martens (1889, p. 263) stated that while the "Gazelle" was in quarantine at Peel Island, Moreton Bay, her naturalists found *L. anatina* to be common in the mud there; but the reference should be to *L. murphiana* King which is the representative of *L. anatina* in south-eastern Queensland. Thomson (1918, p. 43), following Hedley (1916), quoted Moreton Bay as an Australian locality for *L. rostrum*, but both of these records relate to *L. murphiana*.

Brazier (1879a, p. 390) rejected Schmeltz's record (in Mus. Godefroy Catalogue 5, p. 171) of *L. anatina* from Sydney, pointing out many other inaccuracies in the catalogue in regard to the localities given for certain mollusca. He stated, however, that *L. anatina* was rather common in mud flats in Moreton Bay and in New Caledonia. The former record may refer to either *L. hians* or *L. murphiana*:

both of which occur in Moreton Bay, but it is more likely to be *L. murphiana*. We suspect that his New Caledonian *Lingula* record should be referred to *L. hians* (see below).

The species very rarely met with in Port Jackson and identified by Angas (1867, p. 935), Brazier (1879*a*, 1879*b*) and Whitelegge (1889, p. 294) as *L. hians* was considered by Hedley (1916, p. 694 ; 1917, p. 113) to be *L. anatina* (= *L. rostrum*), but re-examination has proved that the species is *L. hians*. The same author (1898, p. 369) regarded as belonging to *L. anatina* some specimens collected in British New Guinea but they belong to *L. exusta*.

L. anatina has been described anatomically by Vogt (1845), Gratiolet (1860), King (1873), Hancock (1858), Davidson (1888), Blochmann (1900), and others ; and referred to incidentally by Morse (1902) and Yatsu (1902).

The habitat given by Davidson (1888, p. 207) includes the Indian Ocean ; Moluccas (between tide marks) ; off Yedo, Japan ; Philippines (where it is sometimes very common in sandy mud between tide marks) Timor and Fiji. Yatsu referred to its abundance in certain parts of Japan, as did also Morse. Reeve (1859) and Dall (1873, p. 203) mentioned only the Philippines and Moluccas, while Sowerby (p. 338) gave the latter locality and the Indian Ocean.* Semper (1862, 1864), Yatsu (1902) and Francois (1891) published an account of its habits in the Philippines, on the Japanese coast, and in the vicinity of Noumea, New Caledonia, respectively. There seems to be little difference in habits amongst the Lingulidæ, as far as known (Smith 1878 for *L. hians* ; Morse 1870 for *Glottidia pyramidata* ; Morse, 1902, for *G. pyramidata* and *L. lepidula*).

It is not unlikely that more than one species is included under the term *L. anatina* by the abovenamed authors. The type locality is the Philippines. †Blochmann, stated

*The " Indian Ocean " is of little value as a record. We do not know of any definite locality (if we exclude Timor) in the Indian Ocean where *Lingula* has been found, though no doubt it occurs in suitable situations on those parts of the East Indies whose shores are washed by the Indian Ocean.

†Zur. Systematik u. geogr. Verbreitung d. Brachiopoden. Z.f. wiss. Zool. 90, 1908 pp. 596-644—quoted by Thomson 1918, pp. 38-9.

that all known brachiopod larvæ except those of *Lingula* and *Discina*, were devoid of a mouth during their free swimming stage which, therefore, could not be long and, as a consequence, such species could not be distributed across ocean basins; moreover the majority of brachiopods occur on the submarine slopes of continents and adjacent islands and such cannot cross the ocean floor where the depth is too great. It would be of interest to know how long the larval *Lingula* can live prior to settling down. Judging from our findings regarding the distribution of some species (e.g. *L. murphiana*) on the Queensland coast, we suspect either that this period must be very short or else such larvæ are very susceptible to temperature changes; while in other cases (e.g. *L. hians*) the larvæ must either be more hardy or more long-lived and thus allow of greater distribution to the species.

A careful examination of forms of the *L. anatina* type from the East Indies (Moluccas and Timor) and from Japan might lead to the discovery of specific differences. Yatsu referred to variations in size in Japanese specimens, some agreeing with *L. anatina* and others with *L. murphiana*. We have found the ratio of length to breadth to be a fairly constant character and one that can be readily utilised to separate species which closely resemble each other in appearance, e.g. *L. murphiana* and *L. bancrofti* from the Queensland coast. The Fijian species is not likely to be *L. anatina*.

Davidson gives as sizes, one inch ten lines by ten lines, i.e., a ratio of 2.2. Yatsu's largest specimen (1902, p. 62) measured 45 mm. by 20 mm., i.e., a ratio of 2.25. Figures given by Adams (1858) Chenu (p. 234, fig. 1,203), Woodward (1910) and others, are too diagrammatic for measurements to have much value. Francois' figure (1895 fig. 315) gives a ratio of about 2.2 Sowerby's figures show a ratio from about 2.1 to 2.4.

We think it unlikely that *L. anatina* (*L. rostrum*) occurs on the coasts of New South Wales or of Southern Queensland. In view of the record (if correct) of the species from the Moluccas and Timor, its occurrence on the Northern Australian coasts is possible. For the present it should be struck off the list of known Australian Brachiopods.

L. tumidula Reeve.

Syn. *L. tumida* Davidson 1852, p. 377.

L. tumida Adams 1858, p. 586.

This large species was originally described and figured by Reeve (1841, p. 180, pl. 125, fig. 4; 1841a, p. 100 Sowerby 1846, p. 339, pl. 67, fig. 7), New Holland being mentioned as the locality. In 1859 Reeve mentioned a few of the shell characters and figured a specimen (pl. 1, figs. 2a 2b) from "Moreton Bay." As an additional locality he gave Masbate, Philippine Islands, where specimens were collected by Cuming in sandy mud at low water, these being at first regarded by Reeve (1841a, p. 100) as belonging to a distinct species, *L. compressa*, but subsequently he considered them as a synonym or as a variety of *L. tumidula* (Reeve 1859; Sowerby 1846, p. 339). Dall (1871, p. 156) in referring to the species stated that, judging from Reeve's figure, it differed materially from the other species figured by him, in the broad form, the emarginations of the beaks, as well as in the size and position of the muscular impressions: *L. compressa* was mentioned as a variety from the Philippines.* Chenu (1862, figs. 1200, 1201) republished Reeve's figure. Adams (1863, p. 100) referred to finding the species in seven fathoms in mud in the Korean Archipelago. A single shell was present in Adams' original collection when re-examined in 1871 by Davidson who gave an account and figure of it (1871, p. 310, pl. 30, fig. 1, and 1888, p. 218, pl. 28, fig. 19). This led Dall (1873, p. 202) to regard it as distinct from *L. tumidula* and he consequently renamed Adams' shell as *L. adamsi*, the name being accepted by Davidson (1888, p. 219) who added another locality, viz. off Formosa. The only locality given by Dall (1873) for *L. tumidula* is "Moreton Bay" Davidson (1888, p. 216) mentioned the Philippines as well, one of his figures (pl. 28, fig. 14—from Sowerby) being drawn from a Philippine specimen and the other (fig. 15—copied from Reeve) from a Queensland shell. The former was apparently not distorted while the latter obviously was. The sizes given

*Thomson (1918, p. 43) has erroneously mentioned the Philippines as the type locality for the species, while Davidson in 1858 (p. 377) confused the two localities, giving its habitat as Masbate, New Holland.

by him are length 2 inches 2 lines and breadth 1 inch 5 lines—the ratio thus being 1.53. These dimensions agree with his fig. 14 (Philippine specimen—Sowerby's figure) which shows a ratio of 1.6. The "Moreton Bay" shell figured measures about 2.2 inches but owing to distortion, the true breadth cannot be measured, but the figure gives a ratio of about 1.6. In Reeve's original account (1841, 1841a) the sizes are given as 2.1 inches by 1.3, the ratio thus being 1.6.

In the Queensland Museum there are a few specimens of *L. tumidula* collected by Mr. C. Hedley in the Boyne River (Port Curtis)* and by Miss S. Lovell at Frazer Island (Great Sandy Island), Harvey Bay.

The species is characterised by the possession of large thin, horny, scarcely calcified shells whose edges (especially laterally) become curled dorsally as a result of drying†, such dried distorted specimens resembling Davidson's figure (1888, pl. 28, fig. 15—from Reeve 1859, pl. 1, fig. 2b). The colour of the Museum specimens is a dark brownish red with very distinct black lines of growth. Reeve stated that it was burnt olive red (1841). Davidson mentioned that the colour was coppery brown or reddish blue, sometimes bright green near the posterior margin. We suspect that he was referring to a Philippine form, since Sowerby's figure shows a brown colouration with a well defined green band along the margin of the free extremity of the shell. The lines of growth on our specimens are much more like those figured by Davidson for *L. adamsi* (pl. 28, fig. 19) than those figured for *L. tumidula* (fig. 14).

The umbones are distinct, though small, when the valves are fairly well preserved, but in most of the specimens examined by us they were scarcely recognisable. The least distorted of the few paired valves available measured 46 by 30.5 mm. the ratio of length to breadth thus being 1.51.

*Mr. Hedley has informed us that he found the specimen dead at low tide on the beach at Boyne Island, immediately north of the mouth of the Boyne River, Port Curtis.

†Reeve in his original description (1841) mentioned the irregularly reflexed margin as being a character of the species.

Its outline resembled that figured by Davidson (1888, fig. 14, and Sowerby, fig. 7). Others measured 54 by 13 (ratio 1.58) ; 65 by 41 (1.59).

We have examined a specimen in some respects intermediate between *L. tumidula* and *L. adamsi* as figured by Davidson. Perhaps the latter may be a young form of the Philippine *L. tumidula*. The proportions however are not quite the same (ratio in *L. adamsi* = 1.7), while the described coloration is distinct and—judging from the figures—the degree of calcification is different. Whether the Philippine and the Queensland forms belong to distinct species we are not at present able to definitely decide, but we are of opinion that an examination of fresh undistorted material from each locality would show specific differences. In such case, Reeve's name *L. compressa* would be available for the Philippine *Lingula*.*

Davidson stated (p. 216) that *L. tumidula* was the largest and finest recent species of the genus with which he was acquainted, being broader in proportion than any known recent form. Davidson's sizes were 2.15 inches in length and 1.4 in breadth. One valve examined by us reached 2.6 inches in length and 1.64 in width. The specimen which came from Hervey Bay, appears then to be the largest recent *Lingula* valve of which there is any record.

We do not know what on grounds Davidson considered *L. tumidula* to be closely related to *L. murphiana* (1888, p. 216). In 1879 (p. 402) he went so far as to state “*L. tumidula* and *L. murphiana* occur in the same locality and are of the same colour. I often ask myself whether they are distinct species or whether *L. tumidula* may not be a very wide variety of *murphiana*. This is a point which Australian zoologists must decide, as I have no opportunity of so doing as there are only two specimens of the form

*In his original account of *L. compressa* Reeve (1841) gave the dimensions as 1.8 and 1.1 inches respectively, the ratio thus being 1.63. The shell was stated to be brown olive, subquadrate oval, attenuated towards the apex, with the valves remarkably compressed and rather closely united all round ; whereas the shell of *L. tumidula* was described as being burnt olive red in colour, subquadrate, and only slightly attenuated towards the apex.

tumidula in the British Museum ; the form *murphiana* is common, I have two or three specimens." The two species are quite dissimilar in their shell characters (see later under *L. murphiana*) and moreover, as far as we know, they do not occur in the same locality. All early records of plants and animals from "Moreton Bay" should be critically re-examined since the name was given, not only to the bay in South-eastern Queensland, but also to a very large district (the Moreton Bay District) embracing the whole of North-eastern Australia, which became subsequently (December, 1859) separated from New South Wales as a distinct colony under the name of Queensland. Our records show that *L. tumidula* occurs in Hervey Bay, which is in the vicinity of the main line of junction of the Indo-Pacific and southern elements of the Eastern Australian fauna, Frazer Island (Great Sandy Island) forming the boundary.

L. hirundo Reeve.

This was briefly described as a little semi-transparent species, length 11 lines, breadth $4\frac{1}{2}$ inches ; with the shell oblong square, thin, greenish, posteriorly abruptly attenuated, and umbones rather sharp. (Reeve 1859, pl. 2, fig. 7 ; Sowerby 1846, p. 339 ; Davidson 1888, p. 220, pl. 28, fig. 22). Reeve's material came from Port Curtis.

Davidson, who published Reeve's account and figure, placed it among the uncertain species, though Dall (1873, p. 203) accepted it as valid. Adams (1863, p. 101) in his very brief unfigured account of *L. smaragdina* Adams from mud from 10 fathoms from Japan and the China Seas, mentioned that it more closely resembled *L. hirundo*. Adams' species was subsequently figured by Davidson (1888, p. 220, pl. 28, fig. 25 ; 1875, p. 310, pl. 30, fig. 2), but an examination of it does not show any resemblance to *L. hirundo*. Davidson (1888) mentioned that the Japanese specimens examined by him bear much resemblance to the young of *L. anatina*. The ratio of length to breadth as published for *L. hirundo* is 2.44. The form and proportions do not agree with young specimens of *L. bancrofti* from Burnett Head which is in the vicinity of Port Curtis, whereas the ratio as well as the colour and shell characters

as far as they have been noted, agree with *L. hians*. The ratio of length to breadth in the case of the latter (length 1 inch 10 lines, breadth 9 lines—Davidson 1888, p. 217) is also 2.44.

We have no hesitation in placing *L. hirundo* as a synonym of *L. hians* and consider it to be based on young specimens. *L. hians* is definitely recorded from a number of Queensland localities, including Port Curtis.

L. hians Swainson.

Syns.* *L. hirundo* Reeve, Port Curtis.

L. hians Brazier 1879, Pt. Jackson, Pt. Curtis, Noumea.

L. hians Angas 1867, Pt. Jackson, New Caledonia, Fiji.

L. hians Shirley 1910, Moreton Bay.

L. rostrum Hedley 1916, in part; 1917, Pt. Jackson.

L. anatina Hedley 1916, Pt. Jackson.

L. exusta Tapparone—Canefri 1873, Australia.

L. anatina Francois 1891, Noumea.

L. anatina Brazier 1879*b*, Noumea.

L. anatina Davidson 1888, Fiji.

Lingula sp. Jukes 1847, Cape York.

This species was recorded from Sydney Harbour by Angas (1867, p. 935) and Brazier (1879) and is mentioned by Whitelegge (1889, p. 295), but Hedley, as already stated earlier in this paper, regarded the specimens as belonging to *L. anatina* (= *L. rostrum*). Angas gave a brief description of the shell which was found in sandy mud in Middle Harbour, Port Jackson, mentioning as additional localities, Fiji, New Caledonia, China and the Philippines. Brazier (1879*b*, p. 402) referred to its presence in Port Curtis as well as in Port Jackson and New Caledonia, stating (1879*a*, p. 390) that *L. hians* was the only species found in Sydney Harbour and was so rare that he had found only one living specimen in 25 years' collecting there. Thanks to the courtesy and assistance of Mr. C. Hedley, we were able to re-examine Brazier's material from Noumea, and found it to be *L.*

*Only Australasian synonymy is quoted in each case.

hians. Mr. Hedley thereupon obtained from Mr. Brazier the solitary specimen that he had collected in 1866 in five fathoms of water off Sow and Pigs Reef, Port Jackson, compared it at our request with *L. hians* and informed us that it, as we had suspected, belonged also to that species as stated by Brazier (1879). We can accept the latter's record of *L. hians* from Port Curtis too.

Dr. Shirley who reported its occurrence in Moreton Bay (1910, p. 102) kindly allowed us to see his specimens which came from the Bribie sand banks, as well as some from Yeppoon. Keppel Bay. We confirm his identification. As already pointed out by us, *L. hirundo* Reeve from Port Curtis is based on young specimens of *L. hians*. In the Queensland Museum collection were many shells labelled as *L. hians* from Moreton Bay, but on examination they were all found to be *L. murphiana*.

The valves of *L. hians* have been described by a number of workers including Sowerby (1846, p. 338, pl. 67, fig. 4); Reeve (1859, pl. 2, fig. 12a and b); Chenu (1862, p. 234, fig. 1202, 1204); and Davidson (1886 p. 217 pl. 29 figs. 12, 13). Gratiolet (1860) referred to certain points in its anatomy and published figures. The locality generally given for the species is the China Seas while Dall (1873) adds Amboyna in the Moluccas.

In the Queensland Museum collection are many specimens of *L. hians*, two of which were in the same box as *L. exusta* from Torres Straits and were presumably from that locality. There are no data regarding the remainder, but they are probably from Moreton Bay, since Dr. Shirley has informed us that *L. hians* is not uncommon on certain of the banks there.

The specimens were all characterised by a thin horny translucent shell of a very pale green colour, with the lines of growth sometimes of a deeper green. Occasionally one noticed a splash of coppery or rusty tint near the middle of the shell. The edges were almost colourless, while the centre portion was whitish or creamy owing to calcification in the region of the main muscle insertions. The remainder of the shell was very little mineralised and, as a consequence, dried specimens became more or less distorted (hence the

name *hians*), especially towards the umbonal end, where the valves contracted laterally in such a way that this portion of each became higher, narrower and much more pointed than under natural conditions. By placing such valves for a few minutes in warm water, they resumed their proper shape. All our measurements were made from specimens so treated and subsequently carefully wiped dry. The beak was much more pronounced on the ventral valves.

The length, breadth and ratio of length to breadth were as follows:—ventral valves—43 mm. by 18 mm. (2.38); 39 by 16 (2.43); 42 by 17 (2.47); 42 by 17 (2.47); 47 by 19.5 (2.41); 42 by 17.5 (2.40); 42 by 17.5 (2.40); dorsal valves—45 by 19 (2.37); 43 by 18 (2.38); 42 by 18 (2.33); 42 by 18 (2.33). Our specimens then ranged from 39 to 47 mm. in length and 16 to 19 mm. in breadth; the smallest ventral valve being 39 by 16 mm., *i.e.* 1.56 inch by 0.64 inch; and the longest 47 by 19.5 mm., *i.e.*, 1.88 inch by 0.78 inch. Davidson's sizes are 1 inch 10 lines by 9 lines, *i.e.*, 1.83 by 0.75 inch, the ratio being 2.44. His ratio falls within the limits observed by us for ventral valves, *viz.* 2.38 to 2.47. Most of ours were about 1.7 inches long and 0.72 inch wide.

In fully relaxed specimens the sides were practically parallel for the greater part of their length and were then greatly attenuated towards the apex. The lines of growth showed up quite distinctly through the very translucent shell, if held up to the light. They were wavy and could be readily noticed even on the inside of the shell. Davidson's fig. 12, pl. 29, was evidently based on a dried and rather distorted specimen.

Tapparone-Canefri (1873, p. 255) identified as *L. exusta* a shell given by Dr. J. C. Cox as *L. murphii*. In the short account, kindly transcribed for us by Mr. Chas. Hedley, mention is made of the subrostrate apex and of its form approaching that of *L. hians* from the China Seas and that there could thus be no doubt that the shell should be referred to *L. exusta*, the Australian representative of that species. He noted, however, that the colour differed from Reeve's account, there being concentric zones of a fine green colour. From these scanty remarks we think

it probable that the correct determination should be *L. hians* since the remarks quoted do not apply to *L. exusta* as well as they would to that species which is now known to be so widely distributed.*

L. hians extends from the China Sea to Torres Straits, thence down the Eastern Australian coasts to Moreton Bay and occasionally to Port Jackson ; and also easterly to New Caledonia. There can be little doubt but that it occurs in suitable situations in New Guinea, the Solomons and New Hebrides. Perhaps the Fijian *L. anatina* may be *L. hians*.

At Noumea, both *L. hians* and *L. anatina* have been reported by Brazier (1879b, p. 402) and Francois (1891) respectively. The former mentioned in an earlier paper (1879a, p. 390) that *L. anatina* was rather common in mud flats there. His material was, as already stated, *L. hians*. We have not had access to Francois' original papers and therefore cannot pass definite opinion regarding his identification, though we doubt the likelihood of *L. anatina* occurring in that locality. A brief note regarding the habits of *L. hians* in the China Sea was published by E. A. Smith (1878, pp. 820-1) who stated that it lived in mud or sandy clay at low water mark, its presence being indicated by the occurrence of oval orifices in the mud.

The wide distribution of the species suggests that the larva has a fairly extended life and is able to adapt itself to rather wide limits of temperature, since the adult occurs in tropical, sub-tropical and warm temperate waters in the Eastern Pacific.

Lingula sp.

Jukes† in his "Voyage of the Fly" (1847, p. 144) gave the following account of a *Lingula* occurring near Cape York, North Queensland :—"I procured also from a muddy bay, to the east of Evans Bay, a number of the genus *Lingula* alive. The shells lay buried in a close unctuous mud.

*Dr. J. C. Cox in his privately issued "Exchange list of Land and Marine Shells from Australia and the adjacent Islands" 1863, mention is made on p. 30 of No. 456, *Lingula hians* Swainson, Middle Harbour (Port Jackson)—*fide* Mr. C. Hedley. It was in this locality that Angas obtained his specimens.

†We are indebted to Mr. C. Hedley for this reference.

two or three inches deep. They were always in a vertical position, with the beak downwards. The fleshy or gelatinous pedicle which passed from between the beaks was five or six times as long as the shell and passed down into the mud, ending in a thickened knob. These pedicles did not appear to be attached to anything. On pulling at the shell, a slight resistance was felt, but not more than would be caused by the knob being drawn through the narrower hole in which the pedicle lies." This description does not allow one to identify the animal but the species was probably either *L. hians* or *L. exusta*. The very long peduncle suggests the former, since this organ is short in the latter.

Lingula murphiana King.

(Text-figure 8 ; Plate 2, figs. 5 and 6).

Syns : *L. anatina* Hancock 1858.

L. anatina Dall 1871 (in part).

L. anatina Brazier 1879a—Moreton Bay.

L. anatina Martens 1889—Peel I., Moreton Bay.

L. anatina Hedley 1909 (in part), Moreton Bay.

L. rostrum Hedley 1916—Moreton Bay.

L. rostrum Thomson 1918—Moreton Bay.

L. murphiana of authors.

The species was described by Reeve (1859, pl. 1, fig. 3) who retained the MS. name given to it by Capt. King, one of the early explorers of Australia. Some of Reeve's information was published by Chenu (fig. 1199, p. 233). Davidson gave a very good account and several excellent figures of the shell (1888, p. 215-6, pl. 29, fig. 11 ; pl. 30, figs. 1-3), at the same time expressing the belief that Hancock (1858) had described the anatomy of this species under the name of *L. anatina* and that his *L. affinis* was probably *L. anatina* Lam. Hancock's specimen of the former was examined by Davidson who stated (p. 215) that its size and colour agreed with those of *L. murphiana*, but that the identity could not be settled until the animal of *L. murphiana* had been again examined.

Davidson's concise account of the shell is as follows:—
 “Shell large, squarish oblong, longer than wide, sides almost parallel, slightly curved inwards towards the middle of their length. Anterior edge gently rounded, with angular projection in the middle; beaks attenuated, that of the ventral valve pointed and the longest. Valves about equally convex, with a flatness commencing close to the beaks and extending to the front and on each side, sloping to the lateral edges. Colour coppery red, with bands of different shades of green and brown. In the interior of the valves, the muscular area is white, the remainder of the surface light and dark green. Shell structure horny and calcareous. Length of shell 2 inches 6 lines, breadth 1 inch 1 line; length of peduncle $6\frac{1}{2}$ inches.”

L. murphiana is not uncommonly found in the sandy mud between tide marks at certain localities in Moreton Bay, e.g., at Sandgate (to the north of the mouth of the Brisbane River), and at Burpengary Creek, Deception Bay.

In addition to our own material, we examined a number of specimens belonging to the Queensland Museum collection, all from the same localities. Marten's *L. anatina* from Peel Island, Moreton Bay, almost certainly belongs to this species which resembles *L. anatina* rather closely. As already mentioned, the brachiopods from Moreton Bay referred to under the latter name by Brazier (1879a) and Hedley (1909), and as *L. rostrum* by Hedley (1916), and Thomson (1918), belong to *L. murphiana*. Dall (1871, p. 55) doubted the validity of the species stating that “this species (?) much resembles *L. anatina*,” while in 1873 (p. 203) he included it as a ?synonym of the latter, but omitted to include Moreton Bay amongst the known localities.

The length, breadth and ratio of length to breadth of specimens and ventral valves examined by us, were as follows:—59 mm. by 26, ratio 2.27; 59 by 26 (2.27); 59 by 25.5 (2.31); 57 by 26 (2.19); 57 by 25.5 (2.23); 57 by 25 (2.28); 57 by 25 (2.28); 55 by 26 (2.1); 54 by 24 (—a shrunken specimen—ratio 2.25); 52 by 23 (2.26); 51 by

23 (2.22) ; 50 by 22 (2.27).^{*} Through the kindness of Professor Sir Baldwin Spencer F.R.S., we were able to examine two specimens in the Melbourne University collection (locality, ?Brisbane), measuring 58 mm. by 25 mm. (ratio 2.32), and 50 by 21 mm. (ratio 2.38) respectively. Davidson mentioned as sizes 2 inches 6 lines by 1 inch 1 line, the ratio being 2.3. The ratio of all measured specimens is then practically constant being between 2.1 and 2.3. *L. anatina* has much the same viz. 2.2, but as already mentioned, its valves are less strongly calcified and do not attain to the same length and breadth, while the outline is not so square at the free extremity.

The valves of *L. murphiana* are strongly calcified, relatively thick and practically opaque. Even after prolonged treatment (for several weeks) in 5 per cent. acid alcohol, they do not lose their form as a result of subsequent drying, whereas the shell of *L. bancrofti* does under such conditions. The rectangular outline has been already referred to and is well illustrated by Davidson. The entire animal is comparatively thick and a transverse section shows a more or less elliptical outline, there being no depressed area on each side of the mid region of each valve. A considerable overlap of the dorsal valve by the ventral was commonly noticed, the amount being about two millimetres.

The deltidial region is very well developed and the muscle scars quite prominent, the median ridge being well marked especially on the dorsal valve. This was noted by Davidson (1888, p. 211) who published excellent figures showing the inner faces of the valves (pl. 30, figs. 1-3). The projecting point shown in his figure (pl. 30, fig. 1) is fairly characteristic, though not usually as sharply marked as indicated therein. It is best seen on the dorsal valve. The shell occasionally gapes slightly. The colouration has been noted by Reeve and Davidson. We found, however, that the amount of green present varied, but that the coppery red tint predominated and was often blotchy.

^{*}There is also a specimen (?locality) measuring 43.5 by 20 mm. (ratio 2.17) which may belong to *L. murphiana* but we are inclined to regard it as *L. exusta*.

The entire shell may be red brown to pinkish, interspersed with shades of green. The general colour is very like the brown variety of *L. bancrofti*. There is commonly a deposit of thick, almost black, readily removable, pigment on the surface of the valves, especially in the vicinity of the peduncle. The latter is rather long and fleshy, measuring from 110 to 155 mm. in length in our preserved specimens. A tube of sand covers only the cylindrical ampulla at its extremity.

The setæ are arranged at the free end as in *L. anatina* while the laterals are short and the postero-laterals well marked. We were unable to detect pallial pigmentation in our material which had been preserved several years. Perhaps the densely calcified condition of the shell may be correlated with the lack of pigment, if this feature be normal. The arrangement of the musculature resembles in detail that figured (under the name *L. anatina*) by Hancock whose excellent drawings show also the typical form of the cœlome as seen when either the dorsal or ventral valve is removed.

The intestine, which is relatively wider and thinner walled than in *L. bancrofti*, is thrown into a few wide loops differing in position from those of that species and *L. anatina*. The anus lies somewhat dorsally on the right side anteriorly to the insertion of the oblique muscles. It is not situated on a distinct elevation and is, as a consequence, inconspicuous. The liver and gonads occupy positions as shown by Hancock. The nephridia are maroon coloured organs, covered in greater part by the gonads.

Occasionally one notices specimens in which only a few of the pallial sinuses branch in the manner figured by Hancock (pl. 64, fig. 4) ; but in many cases, a fair number of the most anteriorly situated vessels divide up to a considerable degree, so that a plexus-like condition is seen. There may be frequent anastomoses. Between the anterior termination of each main sinus is a space which to the naked eye appears as a non-vascular whitish area, on account of the absence of prominent branches from the inner aspect of each terminal sinus. The majority of the outer vessels from each pallial sinus travel outwardly

almost in a straight line. The posterior pallial sinuses are relatively large branching vessels which may be gorged with purplish blood. A well defined visceral vessel is also at times readily recognisable, its appearance reminding one of that figured by Hancock (pl. 64, fig. 1).

This latter condition was not observed in any of our specimens of *L. bancrofti*. The form and position of the canals in the arms (text-figure 8) is different from that described for the last named species. In *L. murphiana* the anterior canal, as seen in section, is not circular, while the posterior canal is less extensive, and the brachial fold is rather thin and narrow.

The habits of *L. murphiana* as far as we know them, resemble those of *L. anatina* and other littoral species of *Lingula*.

Relationships :—Reeve (1859) remarked "whether this should be regarded as an Australian form of *Lingula anatina* or as a distinct species, it is certain that the differences are obvious and constant." He went on to say that all the specimens examined by him were distinguished from *L. anatina* which is common in the Bay of Manila, Philippine Islands, by a more square outline and a peculiarly coppery-red tone of colour.

Davidson (1888, p. 216) referred to the shell being wider in comparison to its length, thicker and differing in colour. He thought it nearly allied to *L. tumidula* and in a letter to Brazier (Davidson 1879, p. 402) had doubted whether the two species were really distinct, suggesting that as they occurred in the same locality and were of the same colour, *L. tumidula* might be only a very wide variety of *L. murphiana*. As pointed out by us when dealing with the former, there is no resemblance either in colour, consistency of shell, or shell proportions; and, moreover, they do not occur in the same locality as far as we know, though the name "Moreton Bay" was stated as the locality in each case. We have mentioned elsewhere the likelihood of confusion between Moreton Bay, an inlet in the south-eastern corner of Queensland, and Moreton Bay, the district which subsequently became the colony of Queensland.

Blochmann (1900, pp. 94-5 ; quoted by Yatsu 1902) enumerated several distinguishing characters separating this species from *L. anatina*, but Yatsu believed the mode of branching to be the only reliable criterion, considering the remaining points to be mere individual differences. He found that Japanese forms, regarded as *L. anatina* varied in their proportions of length, breadth, and thickness so that some agreed with *L. anatina* and others with *L. murphiana*. We regret that we have not been able to consult Blochmann's paper either in Brisbane or Sydney.

L. exusta Reeve.

Syns :—*L. anatina* Hedley 1898, Brit. New Guinea

L. anatina Banfield 1918, Dunk I., N.Q.

L. exusta Tapparone-Canefri, 1873.

The best account is that published by Davidson (1888, p. 217-8, pl. 28, figs. 20, 21, 21a), the original being very short (Reeve 1859, pl. 2, fig. 9 ; Sowerby, 1846, p. 339). Reeve considered it related to *L. hians* and thought that it was perhaps the Australian representative of that species. The description given by Davidson is as follows :—" Shell oblong, much longer than wide, a little broader anteriorly ; sides almost subparallel, slightly curved inwards near the middle of their length ; front line very gently curved, with a projecting angle in the middle. Valves convex, beaks obtusely angular, surface smooth, shining, darkish coppery yellow-brown, especially towards the lateral and frontal margins. Length of shell 1 inch 7 lines, breadth 8 lines." The ratio of length to breadth is then 2.37. The only locality mentioned for the species is " Moreton Bay." Davidson remarked that he had seen a number of specimens and that they all presented the same shape and marked dark colour. In addition to republishing Reeve's figure, he illustrated a shell from the British Museum collection (pl. 28, fig. 21, 21a), the locality being given as Moreton Bay.

We have examined a number of valves belonging to the Queensland Museum, collected by Hartmann in Torres Straits. These agree with Davidson's account and figure. The shell is strongly calcified especially when adult, maintaining its form when dry. In these two points the species

is quite distinct from *L. hians*. Though its proportions may approximate those of the latter, the consistency and colour of the valves are more suggestive of *L. analina*. There is usually a very deep green margin and a green tinge is common throughout the shell, especially in its anterior half. Sometimes a distinct metallic appearance is visible on parts of the valves. This has been referred to by Reeve as a peculiar coppery redness which assumes in this species "a dark, shining, swarthy tone of colour." This is at times very evident in old specimens, especially anteriorly and around the margins, when the green colour then becomes much less noticeable. The muscle impressions are very obvious.

L. exusta is the smallest species known from the Queensland coast. The following is a list of measurements (length, breadth and ratio of length to breadth) made by us from odd valves: ventral valves—37 mm. by 15 mm. (2.46); 34 by 13.5 (2.52); 32 by 13 (2.46); 32.5 by 13.5 (2.41); dorsal valves—31 by 14 (2.21); 31 by 13 (2.38). Occasionally the free margin was the widest portion of the shell.

There is in the Queensland Museum collection a specimen collected by C. J. Wild, at Port Douglas, North Queensland, measuring 42 mm. by 19 mm., the ratio being 2.2. It has a strongly calcified shell, brownish and greenish in colour, with the sides practically parallel. Its general appearance agrees sufficiently closely with that of *L. exusta*, though in some points it suggests *L. murphiana*.

Owing to the kindness of Professor S. J. Johnston, of the Zoology Department, University, Sydney, we were able to examine two specimens of *Lingula* which Professor W. A. Haswell, F.R.S., informed us were given to him in 1883, by Rev. J. E. Tenison-Woods. The latter said that these had been obtained in Port Jackson. They proved to be *L. exusta*. Their measurements were as follows: length 37 and 34 mm.; breadth 14.5 and 14 mm.; peduncle 42 and 37 mm. respectively. The ratios of length to breadth were thus 2.55 and 2.43. The well calcified valves had a slight coppery appearance but were yellowish and greenish towards the free end which was slightly widened and bore a small but distinct median prominence. They curved

gently on each side from the midline so that the cavity of the shell was comparatively deep, as in *L. murphiana*. The anterior setæ were seen to be arranged in three groups as in *L. anatina*. The brownish peduncle terminated in a small ampullary region enclosed in a sandy tube about 5 mm. long. Since Tenison-Woods collected extensively in Northern Queensland, and seeing that all definitely known Australian localities for the species are in that region, it is quite probable that confusion in regard to localities has arisen. We feel justified in declining to recognise Port Jackson as a habitat, Prof. Haswell agreeing with our action in this matter.

E. J. Banfield in his recent book "Tropic Days" 1918, pp. 106-7) referred to the occurrence of a *Lingula* on Dunk Island, to the north of Rockingham Bay, North Queensland. "In the mud close to the edge of the beach sand one of the most singular of marine animals exists and often its empty, horny, flexible semitransparent shell always tinted green, may be found. It is known in some works as *Lingula anatina*, and by the natives of this Isle, by whom a certain part is eaten, as 'Mill-ar-ing.' A pinhole in the mud indicates the presence of the animal and the hungry black boy, thrusting his hand with outspread fingers below it, closes the fingers and withdraws anything but an inviting morsel. To the tongue-shaped shell is attached a pedicle or stalk, attaining a length of ten inches, opaque and tough, which is broken off, seared over the fire, and eaten with apparent relish. It is remarkable that in localities where this mollusc is found, a seaweed occurs similar in shape and size, the chief difference in appearance being in the length of the stalk which in the plant is thin and membranous." (? *Halophila ovata* T.H.J.).

The "empty horny, flexible, semitransparent shell, always tinted green" suggested *L. hians*, but in answer to our request for specimens, Mr. Banfield kindly sent down a goodly number collected in a few minutes in sandy mud near Brammo Bay, Dunk Island. The species has been determined by us as *L. exusta*. Either *L. hians* occurs in addition, or the above remarks regarding shell characters relate to young specimens of *L. exusta* which are rather difficult to distinguish from *L. hians*. The adults are quite

distinct and readily separable. Three young animals all with rather thin, horny, semitransparent valves through which the viscera, pallial pigmentation and pallial sinuses could be seen, were found to measure 26 mm. by 12.5 mm. (ratio 2.08) ; peduncle 35 mm. ; 29.5 by 14.5 (ratio 2.03) ; 32 by 14.5 (ratio 2.20) ; peduncle 32 mm., this specimen showing the presence of dark green pigment at the free extremities while the rest of the valves was yellowish brown, the shell being more calcified than those of the other two just referred to. Eight others, all adults with strongly calcified valves, were measured :—38 by 16.5 (ratio 2.30) ; 39 by 17.5 (2.23) ; 39 by 18 (2.17) ; 40.5 by 18.5 (2.19) ; 40.5 by 19 (2.13) ; 41.2 by 19.5 (2.22) ; 42 by 17.7 (2.37) ; 42 by 19.2 (2.3). The contracted peduncle in this species is small, ranging up to 70 mm. but usually much shorter. All adults examined showed the same general colouration—a very dark green pigmentation, especially towards the free extremities, with green, golden and pale yellowish areas elsewhere. Occasionally a coppery tint was to be observed. The form of young shells was practically elliptical though somewhat broadened anteriorly, while that of adults was more rectangular with the sides subparallel and corners obtusely rounded, the anterior border possessing a well marked median prominence. Erosion of valves was commonly seen. The ratio of length to breadth varies within considerable limits even in adults. Young forms are relatively broader. Since these measurements were made from preserved animals, they are more likely to be correct than those previously given, based on separated valves. The ranges of sizes in the two cases overlap, however, the ratios varying from 2.03 to 2.20 in young transparent forms, 2.13 to 2.37 in preserved adults ; and 2.37 to 2.52 in the case of separated ventral valves. No doubt amongst the latter there has been a slight lateral contraction owing to drying, and this would cause the shell to appear longer and the ratio greater.

Since this paper was practically completed before Mr. Banfield's specimens arrived, we have not included an account of the anatomy of *L. exusta*. The pallial pigmentation is very heavy and is characteristically arranged

being intermediate between that figured by Morse (figs 10 and 11) for *Lingula* sp. from Nagasaki, Japan, and that for *L. anatina*.

Mr. Hedley sent us a small specimen collected at Fyfe Bay near the south-eastern corner of British New Guinea (Lat. $10^{\circ} 35'S.$, Long. $150^{\circ} E.$) and recorded by him as *L. anatina* (1898, p. 369). It measured 34 by 14.5 mm. (ratio 2.34) and had a small peduncle 28 mm. long. The shell characters were those of a young *L. exusta*.

As already mentioned when dealing with *L. hians*, Tapparone Canefri identified an Australian specimen sent by Dr. Cox under the name of *L. murphii* as being *L. exusta*, but we believe it to have been *L. hians*.

Lingula bancrofti n.sp.

(Text-figures 1-7 ; pl. I, figs. 1-4).

Representatives of this new species were collected by Dr. T. L. Bancroft and Miss M. J. Bancroft in December, 1916-January, 1917, at Burnett Head. They obtained their specimens by digging a large hole in the wet sand and then picking out *Lingula*, *Thalassema* and other invertebrates as the sides of the excavation fell in. By this means several very small brachiopods were gathered. We subsequently visited the locality on different occasions during 1918 and obtained additional material. Two dead *Lingulas* collected by Miss G. James on Pialba beach to the southward, belonged to the same species. No doubt *L. bancrofti* will be found to occur on many of the same mud flats on the shores of Hervey Bay, of which Burnett Head constitutes one boundary.*

This *Lingula* was met with at the Head in a portion of a bay-like area, exposed at low tides, and partly enclosed by the breakwater on the southern side of the entrance to the Burnett River. Its presence was detected by the occurrence of slit-like apertures in the mud from about ten yards from high water mark down to the furthest limit of low tide. The animal appeared to be social in habit. It is worthy of note that the mud-inhabiting crabs were

*Miss James has forwarded others collected at Torquay and Urangan, on the coast of Hervey Bay (June, 1919).

absent from the places where *Lingula* was plentiful though they were very abundant on other portions of the sand-mud beach. As *Lingula* was found to be very common in a gutter which contained water, while the banks were exposed, observations on its habits were made. In such a situation the brachiopods could be located owing to the reflection of light from the waving setæ projecting just above the surface of the mud. The setæ and the rounded portion of extremity of the valves could be protruded above the surface of the mud, so that about $\frac{1}{4}$ inch of shell projected under favourable conditions. The habits were similar to those described for *L. anatina*.

A few specimens were obtained in rather soft mud, but nearly all were collected in muddy sand. A greenish form was more common where the beach was rather muddy, while a brownish variety was commoner where the ground was more sandy, but both kinds were in abundance in a little gutter.

The shell corresponds rather closely with the account of that of *L. anatina* given by Davidson (1888, p. 207), Gratiolet (1860, p. 52, figs. 1 and 2) and Reeve (1895, pl. 2, fig. 10). Some dried specimens which had been previously preserved in spirit, coincide with certain of Sowerby's figures of *L. anatina* (figs. 9 and 10). Occasionally the valves are slightly wider near the beak than more distally. They are approximately equally convex and possess a ridge on their inner surfaces. The ventral valve extends slightly beyond the dorsal at the distal free pallial edge. The shell is quite smooth, though the lines of growth are readily noticed. Umbones are distinct.

The angles of the valves project so that the free extremity is rather squared, although there is often a slight median prominence. The shape of this portion is more like that figured by Sowerby's (figs. 9 and 10) for the dark and brown varieties of *L. anatina* than his fig. 2 and 3, although occasionally that shape is to be seen too. The free end is rounded in very young specimens. The general colour is like that of *L. anatina* (Davidson, Reeve). In some the prevailing tint is distinctly brown, in others brown with some green, in others bright green with some brown.

None were found to be entirely brown though that colour predominates in the thicker parts of the shell of all specimens and in preserved material tends to become dominant. Sometimes the colour is almost a pure pale green, but brown tints are visible in the central portion of the valves. Longitudinal lines and also lines of growth are readily seen in decalcified valves.

Morse (p. 320) in speaking of *L. anatina* from Japanese waters mentioned that he found a proportion of the shells thickened, discoloured and eroded, forming a marked contrast to other specimens, equally large, but with clear green shells, thinner in texture and more perfect in condition. He believed that the animals with rougher and thicker valves were probably a year or more older than the others. We found such eroded thicker shells amongst the rather thinner shelled forms.

Our smallest specimens measure 10.5 by 5.0 mm. with a peduncle of 100 mm. long, the ratio of the length of the ventral valve to its breadth being 2.1 ; 13.5 by 6.4 mm. (ratio 2.11), peduncle 20 mm. ; 12 by 5.6 (ratio 2.14) ; 20.5 by 10 (ratio 2.05), peduncle 35 mm. ; 21.0 by 10.8 (ratio almost 2) ; 23 by 11 (ratio 2.1). Many of the collected specimens measured about 41 mm. in length by 20.5 mm. in breadth (ratio 2.0). A few large forms with thickened shell and light coppery tint reminding one of *L. murphiana*, measured 50 by 24 mm. (ratio 2.08). Another with a typical greenish shell not specially thickened had the same measurements. Of the 45 adults measured, 29 were between 40 and 50 millimetres in length, 35 were between 32 and 48 mm. The majority were between 43 and 46 mm. Thirty-eight had a breadth ranging between 20 and 24 mm. We find that the ratio of length to breadth is a very useful character in distinguishing Lingulids, being, at least in some species, a comparatively constant feature. Out of the 45 specimens measured, in two cases it was 1.9 ; in 19, 2.0 ; 14, 2.1 ; 6, 2.2 ; 3, 2.3 ; while in one it was 2.4. The average was 2.08. In 33 the ratio was between 2.0 and 2.1. In the longest specimen it was 2.08. Even in all the young animals measured it was found to range between 2.0 and 2.14. Owing to the horny nature of the edges, the sides of

the valves may undergo some distortion during drying. All the foregoing measurements, however, were taken from preserved animals.

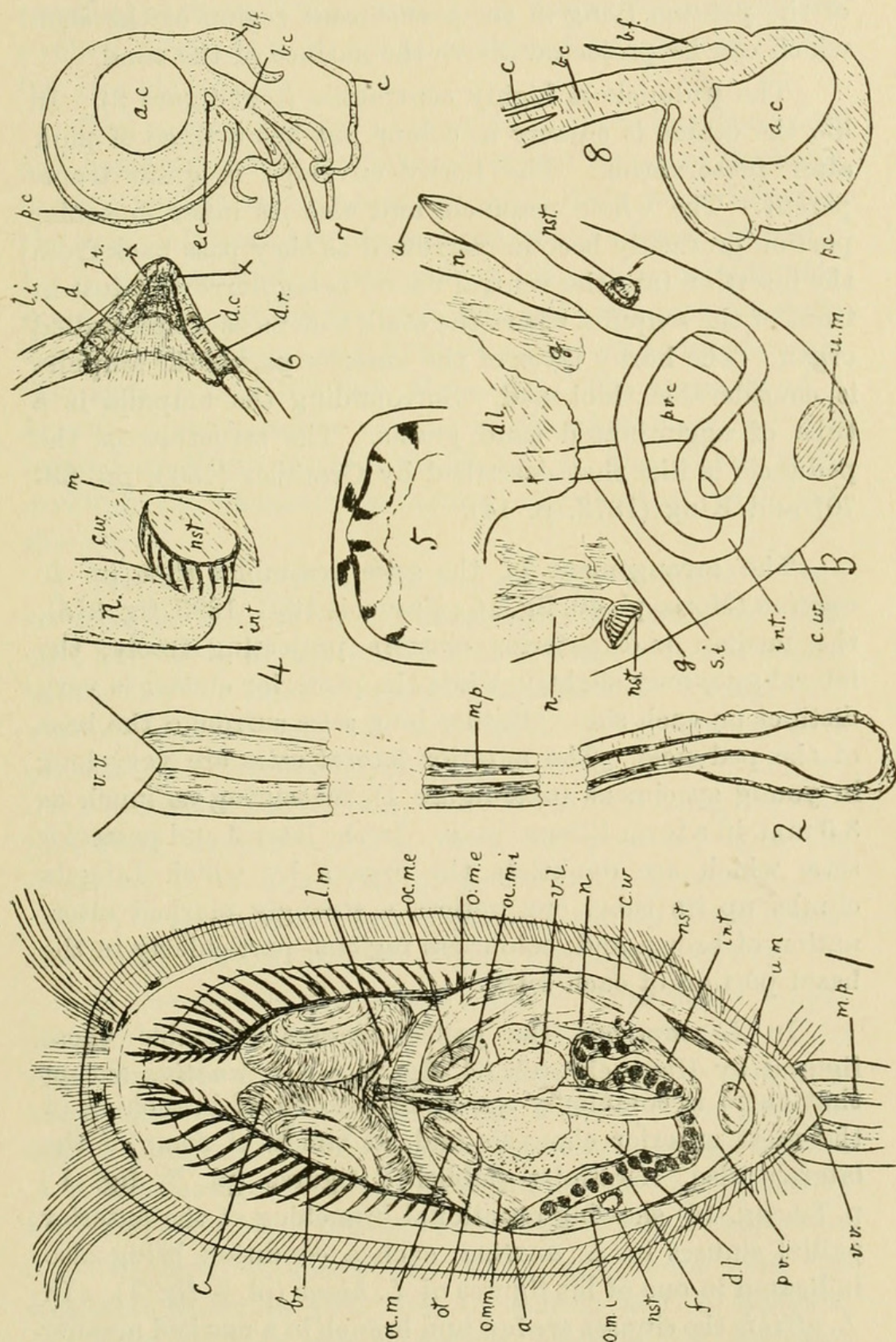
The sizes mentioned and the figures published for *L. anatina* by Davidson, Yatsu and others show a ratio of 2.2. Sowerby's fig. 3, has a ratio of 2.4, while figs. 9 and 10 (brown and dark varieties respectively) show a ratio of 2.1. *L. bancrofti* then can usually be distinguished from *L. anatina*, which it closely resembles in most of its shell characters, by its ratio of length to breadth being rather less. *i.e.*, the shell is relatively somewhat broader. Sowerby's figs. 9 and 10 are very suggestive of our species.

In *L. murphiana*, the other Queensland species with which the shell might be confused, the ratio is about 2.3, and, moreover, the adult shell is longer, thicker, more mineralised and the coppery colour more pronounced. Besides, just distally from the umbones, a section of the paired valves is more rounded than in *L. bancrofti*, a depressed area being present on each side of the mid-region of the valve in the latter species. There are also marked anatomical differences to be noted later.

The proportions correspond with those of *L. jaspidea*, *viz.*, 2.0, and *L. reevei*, 2.1 (Davidson pl. 28, fig. 23, 24 and fig. 18 respectively), but the form is quite different in the three species. In young individuals the shell is sufficiently transparent to allow one to see the arms, pallial sinuses, nephridia, rectum, liver and muscle impressions. The anatomy of small and medium sized specimens can be easily studied in Canada balsam after prolonged decalcification in rather strong acid alcohol (70 per cent. alcohol with 3 per cent. HCl.) followed by gradual dehydration and clearing in clove oil. The use of a weak solution of Ehrlich's or Delafield's hæmatoxylin followed by careful and prolonged decolorisation, gives a very good result.

The muscle scars are arranged as in *L. anatina*. No marked submarginal scar for the insertion of the setæ musculature was recognised. King (p. 12, fig. 5) did not observe it in *L. anatina*. The deltidial region (text-figure 6) resembles in most details that described by this author for *L. anatina*.

The pallial pigment is constant in position (text-figure 5), resembling somewhat that figured by Morse (pl. 52, fig. 10) for the Japanese *L. anatina*. Sometimes the pigmentation is not so heavy and consequently not so evident



TEXT-FIGURES 1-8.

but the general disposition of the patches is constant. Morse believed the arrangement to be of specific value. We agree with his suggestion (p. 349) that these areas are probably sensitive to light. They are restricted to those portions of the pallium lying in the translucent region of the shell which can be projected above the surface of the sand.

The peduncle is highly contractile (text-figure 2). In life the centre is creamy in colour but has a tinge of pink after preservation. The horny envelope is quite transparent. The whole peduncle and also its inner muscular portion gradually become narrowed as they pass back from the insertion into the ventral valve, being narrowest just in front of the ampulla where the stalk widens as a thin walled organ. The horny layer of the anterior part of the ampulla is considerable thickened. Surrounding the ampulla is a tube of agglutinated sand grains. The structure of the peduncle is like that described by Gratiolet (1860, pp. 63-70) and King (1873, p. 14).

The arrangement of the setæ resembles that in *L. anatina* (Morse pl. 40, fig. 16 ; Francois 1891, 1895, fig. 315), the median and anterior clusters projecting freely, the lateral setæ only slightly, while the posterior cluster is very distinct on each side. Rather long setæ surround the base of the peduncle. The anterior lateral setæ are very long in young specimens (text-figure 1), measuring as much as 3.5 mm. in a form 12 mm. long. In the lateral and posterior setæ which are doubtless the organs by which *Lingula* climbs up its tube, one notices a strongly marked alternation of brown and colourless regions, particularly in the basal portion of each seta.

In *L. bancrofti* the pallial sinuses resemble those figured by Hancock* (pl. 64, fig. 3) for *L. anatina* except that there is commonly a certain amount of branching of the most anterior channels and, at times, of some of the laterals also. Gratiolet published figures (pl. 7, fig. 1 ; p. 89, fig. 15) showing occasional branching of the anterior pallial sinuses in *L. anatina*, such a condition being also indicated in one of his figures of *L. hians* (pl. 9, fig. 1). In *L. affinis* the sinuses are few and branch in a marked manner

*Hancock's *L. anatina* is not *L. anatina* Lam. but *L. murphiana*.

(Hancock, pl. 66, figs. 1, 2, 3 ; Davidson pl. 29, fig. 9). The arrangement in New Caledonian specimens of *L. anatina* is shown in Francois' figure (1895, p. 315) as being simple ; likewise also in Woodward's figures. Occasionally the terminal portions of the sinuses in *L. bancrofti* are somewhat swollen, resembling the condition figured by Gratiolet (p. 89, fig. 15 ; pl. 8, fig. 1).

The posterior pallial sinus on each side is inconspicuous and bears very short branches since this region of the body is very narrow owing to there being little room between the oval perivisceral cavity and the lateral edge of the body. In *L. anatina* and *L. murphiana* there is a considerable space in this position on each side and the posterior sinus is consequently large and gives off numerous short branches (Francois, King, Gratiolet, Hancock). The structure of a branch of the anterior sinuses is like that described and figured by Morse (p. 351, pl. 53, fig. 4), the ciliate ridge dividing the channels or lacunæ being rather wide and shallow.

The arms or brachia do not call for comment. They are pearly, whereas in *L. anatina* Morse states (p. 332) that they are pure white with a border and collar of a dark brown and the sides of the cirri also brown. Though this author recorded that the arms could be protruded to a considerable distance beyond the shell (pl. 40, fig. 17), we did not observe such action, some of the cirri being the only projecting structures. Yatsu (p. 64) reported that the Japanese *L. anatina* could project only the comb-like row of cirri of the largest whorl of the arm, the tip of the brachium being always retained within the mantle cavity.

If a section be cut across an arm (text-figure 7), the anterior canal (which is circular in section) is seen to be comparatively large while the posterior canal is long and very narrow, lying just below the surface. The brachial fold is prominent. The general appearance is like that of *L. anatina* as figured by Gratiolet and that given by Hancock for his *L. anatina* (pl. 65, fig. 7) which is really *L. murphiana*.

We have compared the muscular system with the available accounts given for *L. anatina* and *L. lepidula*, but have not been able to consult Blochmann's important paper on the subject (1900).

The anterior oclusors (central muscles of King and Davidson), as seen on removing the dorsal valve, are relatively larger and more distinctly pyriform than they are in *L. anatina*, while the anteriorly directed narrow portion of each approximates its fellow so that a very narrow interval separates them from each other and from the hinder border of the lateralis muscles (anterior laterals of King and Davidson). These anterior oclusors are relatively larger than those of *L. lepidula* (Morse, pl. 48, fig. 2) and of about the same relative size as those of *L. affinis*, but they approach each other more closely in *L. bancrofti* than in the last-named species. The lateralis is relatively smaller than in *L. anatina* (Hancock, Woodward, King) and *L. lepidula* (Morse). The posterior oclusor (umbonal) muscle is well developed and is circular or elliptical in outline.

If the ventral valve be removed the appearance of the muscular system is somewhat like that figured by Hancock (pl. 64, fig. 2) for his *L. anatina* (which is really *L. murphiana*) except that the posterior lateral pallial region is much narrower and the lateralis better developed in *L. bancrofti*. In the latter the internal oblique (transmedian of King and Davidson) is more powerful and covers the posterior parts of the nephridium, while the anteriorly situated band of its divided fellow of the opposite side is considerably wider than the posteriorly directed portion, reminding one of the condition figured by Gratiolet (p. 77, fig. 11) for *L. anatina*, and by Morse (pl. 48, fig. 2) for *L. lepidula*. In *L. affinis* they are subequal (Hancock, pl. 65, fig. 2).

The mouth, an elongate aperture with a crenate border, leads into an œsophagus which is thick walled, especially near the mouth and in the vicinity of the insertion of the mesentery. The stomach is more marked than in Hancock's figure (pl. 65, fig. 4) but less pronounced than in *L. lepidula* (Morse pl. 47, figs. 5 and 6). The gastric or stomachal glands ("liver" or hepatic diverticula) occupy a great deal of the perivisceral coelome, the dorsal portion being more extensive than the ventral. The straight intestine proceeds posteriorly in line with the œsophagus and stomach, but just in front of the umbonal muscle it becomes bent forwards on the left side sometimes reaching

the ventral lobe of the liver. In young specimens (text-figure 1) it then bends backwards to travel between the straight intestine and the first loop, or else above the straight intestine (*i.e.*, on the left side of the cœlome). It then crosses above the latter to travel obliquely forward to terminate at the arms on the right side. In adult animals (text-figure 3) the intestine appears to have elongated to a much greater extent than the cœlome and as a consequence has become thrown into a pronounced loop which is barely indicated in young specimens. The tube after reaching the vicinity of the liver forms a large open loop extending dorsally into the right side of the cœlome above the straight intestine and commonly above the rectum also, returning to the left side to form another loop before continuing as the rectum which has the same relative position as in young animals. The coiling of the intestine resembles that described by Gratiolet for *L. hians* (fig. 19, p. 133) rather than that figured for *L. anatina* (Woodward), and *L. affinis* (Hancock, pl. 65, fig. 4). In these two species the loops are closer, the coils forming a loose ball. In the adult of *L. bancrofti* the coiling is intermediate between the condition seen in *L. hians* and *L. anatina*.

The intestine, stomach and gastric glands of several small specimens which had been cleared and mounted were found to be filled with the valves of a number of different genera of diatoms. The contents of the posterior half of the intestine were arranged in more or less rounded faecal pellets in which diatoms could be seen.

In a young decalcified specimen in a position similar to that in which Morse found an otocyst in *L. lepidula* (pl. 47, figs. 5 and 6) we observed a small spherical organ 0.15 mm. in diameter. This otocyst was situated just behind the occlusor and laterally from the stomach. Morse noted its presence in *L. anatina* also (p. 348) but mentioned that he had not been able to see them in any *Lingulas* preserved in alcohol. We observed them in only two out of several submitted to microscopical examination.

The gonads are obvious structures in adults but are not recognisable in our smallest specimens. They occupy

positions similar to those of *L. anatina*, the ovary being pale brownish and the spermary whitish or faintly pinkish.

The glandular portion of each nephridium is flattened and brightly coloured—red brown to deep orange—especially towards the nephrostome, shading into a pale yellow towards its outer opening (text-figures 3 and 4). This coloured part can be readily seen through the valves in most specimens the colour persisting in specimens which had been over two years in alcohol and formalin. In *L. anatina* it is marked by dark maroon lines (Morse p. 361). In one of our specimens, a young adult, a few deeper coloured longitudinal lines were noticed, but whether they were merely accidental folds or not we are unable to say. There is a sharp line of demarcation between the coloured glandular nephridium and its colourless nephrostome, a deep constriction separating the two. The latter, which is about a millimetre in diameter, in a specimen 35 mm. long, is intermediate in form between those of *L. anatina* and *L. lepidula* as figured by Morse (pl. 54, fig. 11 ; pl. 55, fig. 1). The margin is simple and the rim is bent over outwardly, one part of the rim being confluent with the body wall. The vessels in the wall of the nephrostome stain readily with hæmatoxylin.

A characteristic difference between *L. bancrofti* and most other species whose anatomy is known, relates to the form of the perivisceral cœlome as seen when either valve is removed. If one compares its shape (figs. 2 and 3 and text-figure 1) with the figures of *L. anatina* (King, figs. 1 and 2 ; Gratiolet, fig. 11 ; Hancock, pl. 64, figs. 1 and 2 = *L. murphiana*) and *L. affinis* (Hancock, pl. 66, fig. 1), it will be noted that the portion of the body cavity lying posteriorly to a line joining the insertions of the oblique muscles is greatly narrowed in the two species referred to, particularly when viewed from the dorsal surface. Consequently the oblique muscles and the nephridia lie in a wide cœlomic bay. In *L. bancrofti* the sides of the body wall do not project inwards to the same degree, the curvature being much more gradual. In this respect it is rather like *L. lepidula* where it is almost circular according to Morse. In the Burnett species it is a short oval if viewed in its mid

horizontal region, since the lateral projections do not involve this portion but cover the dorsal and ventral postero-lateral edges as a thin sheet. We have used the term "perivisceral coelome" widely so as to include the perigastric cavity. The pericesophageal cavity does not call for comment.

L. bancrofti is closely related to both *L. murphiana* and *L. anatina* (*L. rostrum*). Type specimens have been deposited in the collections of the Queensland Museum, Brisbane, and the Australian Museum, Sydney.

GENERAL REMARKS.

Our brief acquaintance with the Lingulidæ has led us to regard the following features as being of value for specific determination. *Shell characters* :—Opacity or transparency of the adult shell ; degree and extent of calcification ; general form of valves ; convexity of valves ; ratio of length to breadth ; maximum length ; character of the umbonal regions ; presence or absence of well marked median ridges on the valves internally ; prevailing colour. *Anatomical characters* :—shape of coelome ; arrangement of musculature ; disposition of setæ ; branching of pallial sinuses ; pigmentation of pallium ; shape of nephrostome ; coiling of intestine. The peduncular length should also be noted.

The Queensland species fall into four groups, (a) *L. tumidula*, (b) *L. hians*, (c) *L. murphiana* and *L. bancrofti* which resemble *L. rostrum* in general appearance, (d) *L. exusta* which reminds one of a small and very narrow *L. rostrum*.

Key to Queensland species of *Lingula*, based on shell characters :—

1. Breadth of valves considerably more than half the length ; shell thin, reddish brown..... *L. tumidula*
2. breadth of shell not more than half length, shell greenish or copper coloured..... 3
3. a. valves very thin, horny, readily distorted so that beaks become very prominent in dried

specimens, shell translucent, colour pale green
and bright green

L. hians

b. valves more or less calcified, maintaining
form more or less completely. 4

4. a. large opaque strongly calcified valves of pale
or coppery red colour, ratio of length to breadth
2.2 to 2.3—no depression on either side of mid-
line

L. murphiana

b. fairly large shells, well calcified, translucent at
free end, greenish or copper coloured, slight
depression on either side of midline, ratio
generally 2.0—2.1

L. bancrofti

c. Shell small, narrow, valves generally dark
green at free extremity, rest may be coppery
in tint, free extremity rather squared with median
prominence, ratio of length to breadth variable,
2.2 to 2.5 in adults

L. exusta.

Thomson (1918, p. 51) in referring to the distribution of Brachiopods in the Southern Hemisphere, stated that, if we exclude deep sea forms, there were few species common to the Southern and Northern Seas and that in the case of *Lingula* and of *Platidia*, the identifications of the southern forms were in need of confirmation. In the list of five such species mentioned by him are three of *Lingula*, viz., *L. rostrum* from Moreton Bay, the Indian Ocean and Japan; *L. hians* from Port Jackson and the China Sea; *L. tumidula* from Moreton Bay and the Philippines. We have shown that there is no undoubted record of *L. rostrum* (*L. anatina*) from Australia; that *L. hians* is widely distributed in north eastern Australia and adjacent islands; and that *L. tumidula* occurs in Hervey Bay and is probably quite distinct from the Philippine species *L. compressa*.

The following table represents an attempt to show the relationships of different species in various Eastern Pacific regions. We think that a comparison of the East Indian and Japanese *L. rostrum* with the Philippine typical form should be carefully made—hence our query regarding such identifications.

Australasia	E. Indies	Philippines	S. Japan
<i>L. hians</i>	<i>L. hians</i>	?	?
<i>L. murphiana</i> } <i>L. bancrofti</i>	? <i>L. rostrum</i>	<i>L. rostrum</i>	? <i>L. rostrum</i>
<i>L. tumidula</i>	?	<i>L. compressa</i>	<i>L. adamsi</i>
<i>L. exusta</i>	?	?	?

SUMMARY.

1. There are at least five species of *Lingula* known from the Eastern Australian coast :

- (a) *L. hians* Swainson—Torres Straits ; Keppel Bay ; Port Curtis ; Moreton Bay ; ?Cape York ; also from Sydney Harbour as an extremely rare animal.—(New Caledonia).
- (b) *L. murphiana* King—Moreton Bay.
- (c) *L. bancrofti* Johnston and Hirschfeld—Burnett Head, Urangan, Torquay and Pialba (Hervey Bay).
- (d) *L. exusta* Reeve—Torres Straits ; Dunk Is., N.Q.—(British New Guinea).
- (e) *L. tumidula* Reeve—Hervey Bay ; Port Curtis. This is probably not a littoral species but an inhabitant of comparatively shallow waters.

2. There are no undoubted records of *L. anatina* (i.e., *L. rostrum*) from Australian waters.

3. The ratio of length to breadth is fairly constant for the species. In the case of ventral valves of adults of Australian Lingulids they are as follows :—*L. hians* 2.3 to 2.47, variable ; *L. murphiana* 2.2 to 2.3 (practically the same as *L. anatina*, 2.2) ; *L. bancrofti* 2.0 to 2.1 ; *L. exusta* 2.2 to 2.5, variable ; *L. tumidula* apparently about 1.5 to 1.6.

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LETTERING AND EXPLANATION OF PLATES.

Text-figures 1-7, *L. bancrofti*, fig. 8 *L. murphiana*. All except text-figure 5 are from camera lucida drawings.

1. *L. bancrofti*, young specimen 13.5 mm. long, stained and viewed from ventral aspect as a transparent object.
2. part of peduncle of specimen shown in fig. 1 (full length 20 mm).
3. part of cœlome showing anatomy.
4. nephrostome and portion of nephridium.
5. free extremity of pallium of a small adult, to show arrangement of pigment (freehand sketch).
6. deltidium.
7. T.S. brachium (basal portion) of *L. bancrofti*.
8. T.S. brachium of *L. murphiana*.

PLATE 1. *L. bancrofti*.

- Fig. 1. view of entire adult animal.
 2. dorsal do. do. do. dorsal valve removed.
 3. ventral do. do. do. ventral valve removed.
 4. view of entire adult animal, pallium reflected, to show brachia
 pigmentation of pallium, pallial sinuses, etc.

PLATE 2. *L. murphiana*.

- Fig. 5. dorsal view of animal, dorsal valve removed.
 6. ventral do do ventral do do.

REFERENCES TO LETTERING ON TEXT-FIGURES AND PLATES.

a., anus; *a.c.*, anterior canal of brachium; *b.c.*, base of cirrus; *b.f.*, brachial fold; *br.*, brachium; *c.*, cirrus; *c.w.*, cœlomic wall; *d.*, deltidium crossed by alternating pale and yellowish-brown bands; *d.c.*, deltidial callosities on deltidial ridges; *d.l.*, dorsal portion of "liver"; *d.r.*, deltidial ridge; *e.c.*, efferent canal of cirrus; *f.*, faecal pellet; *g.*, gonad; *int.*, intestine; *l.i.*, "lineated impression" (of King), marking position of anterior end of

horny layer of peduncle : *l.m.*, lateralis muscle ; *m.*, muscle ; *m.p.*, musculature of peduncle ; *n.*, nephridium ; *nst.*, nephrostome ; *o.m.e.*, external oblique muscle ; *o.m.i.*, internal oblique muscle ; *o.m.m.*, median oblique muscle ; *oc.m.*, occluser (anterior occluser) muscles ; *oc.m.e.*, external occluser ; *oc.m.i.*, internal occluser ; *ot.*, otocyst ; *p.c.*, posterior canal of brachium ; *p.v.c.*, pervisceral cœlome ; *s.i.*, straight portion of intestine ; *u.m.*, umbonal (posterior occluser) muscle ; *v.l.*, ventral portion of "liver" ; *v.v.*, ventral valve ; *x.*, marks limits of aperture through which the peduncle passes to its insertion into the ventral valve.

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