

VIII.—*On Some Foraminifera from the North Sea, etc., dredged by the Fisheries Cruiser 'Goldseeker' (International North Sea Investigations—Scotland). I. On Some New Astrorhizidæ and their Shell-structure.*

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(Read June 19, 1912.)

PLATES V. AND VI.

Family **Astrorhizidæ.**

Sub-family PILULININÆ.

*Technitella* Norman.

*Technitella legumen* Norman.

*Technitella legumen* Norman, 1878, Ann. Mag. Nat. Hist. ser. v. vol. i. p. 269, pl. xvi. figs. 3, 4.

Ditto. (Norman) Brady, 1884, Foram. 'Challenger,' p. 246, pl. xxv. figs. 8-12.

Ditto. (Norman) Heron-Allen and Earland, 1909, Journ. Quekett Micr. Club, ser. ii. vol. x. pp. 406, 408, 412, pl. xxxiv. fig. 10.

WE take the present opportunity of figuring for the first time the method of construction in this species, as it represents, in our opinion, the acme of "selective power" in the Foraminifera. It was briefly alluded to in our paper published in 1909 (*suprà*).

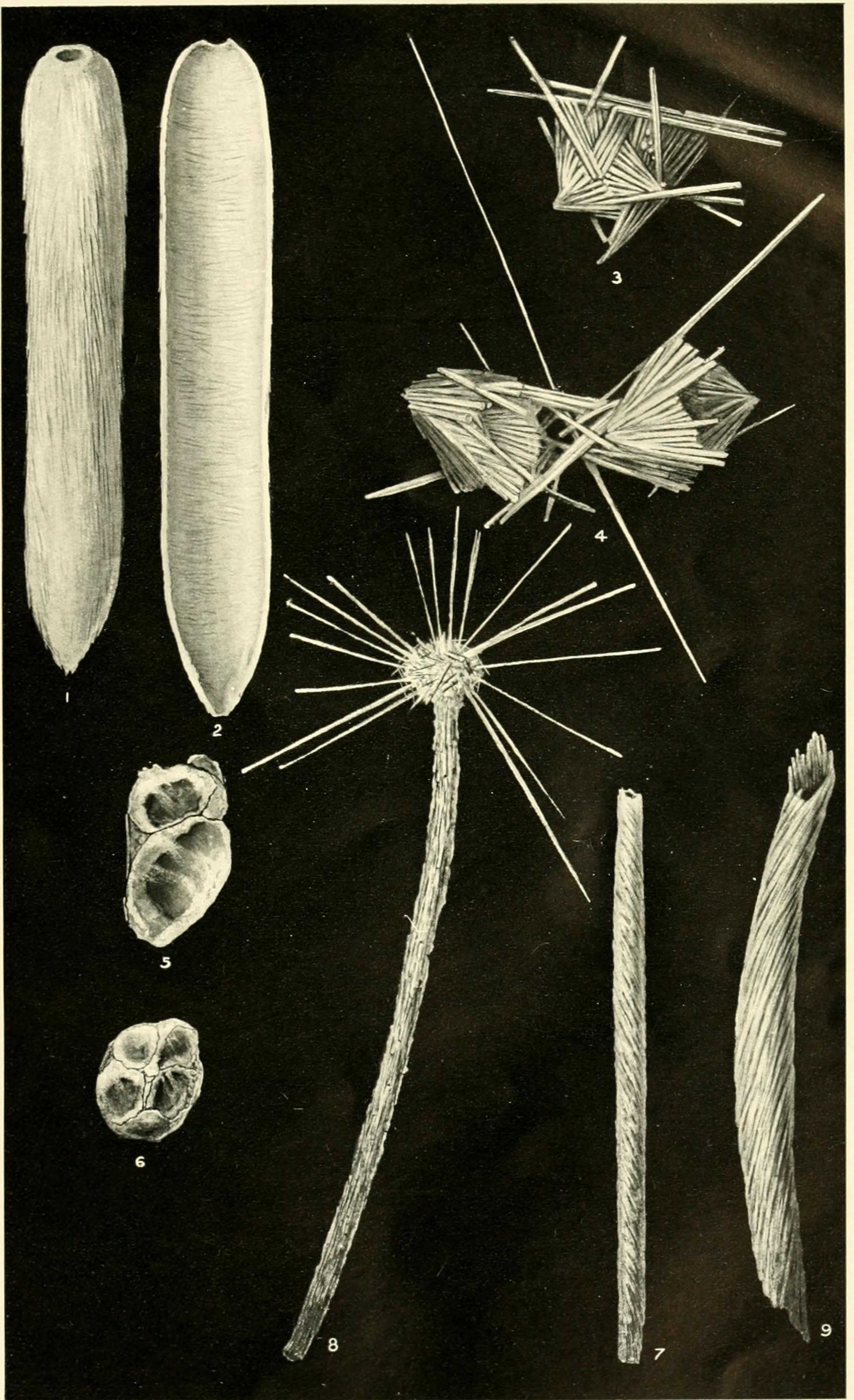
The original description of the species, as given by Norman, states that the shell wall ". . . is beautifully built up of the fragments of minute acerate spicula, laid in regular order side

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EXPLANATION OF PLATE V.

- Fig. 1.—*Technitella legumen* Norman. Showing external surface of test.  
 „ 2. Ditto. Section of test, showing internal surface.  
 „ 3.—*Psammosphæra rustica* sp. n.  
 „ 4. Ditto. Abnormal double specimen.  
 „ 5.—*Psammosphæra Bowmanni* sp. n. Side view.  
 „ 6. Ditto. End view.  
 „ 7.—*Marsipella spiralis* sp. n.  
 „ 8.—*Marsipella cylindrica* Brady.  
 „ 9. Ditto. A fragment of a specimen, showing a spiral arrangement of the constituent sponge-spicules.

Note.—All the figures in this plate are drawn from opaque specimens to a magnification of 40 diameters.



by side, and cemented with a mortar composed probably of the finest dust of quartz, so that the whole test is of exquisite snowy whiteness. . . .”

As a matter of fact, the shell wall consists of two distinct layers of spicules: an outer layer, in which the spicules are all laid with their long axes parallel to the long axis of the test; and an inner layer of spicules laid with their long axes at right angles to the outer layer. We thus get as close an approximation to “woof and warp” as is possible with a rigid, non-flexile material, and it is obvious that the strength of the test must be enormously increased by the crossing of the two layers, as resistance to tensile strain is given in two directions instead of one.

The interstitial cement used by the animal is apparently a very fine homogeneous mud, similar in colour and origin to that employed by *Marsipella spiralis* and *Bathysiphon filiformis* (Sars). Very little of the cement is visible in the external layer, but the spicules of the internal layer are deeply embedded in it, so that, as a rule, only the middle portion of the spicule is visible when the interior of the laid open test is viewed as an opaque object. This led us, in 1909, to suppose that the interior layer consisted of shorter spicules than the exterior layer. But the examination of a large series of specimens has proved that identical spicules are used for the exterior and interior walls.

It is, moreover, noticeable that *Technitella legumen* rarely employs broken spicules. Unlike *Marsipella spiralis*, which seems to select fragments of approximately equal length, *Technitella legumen* chooses minute but perfect acerate spicules of 0·1–0·2 mm. length, and thus secures material of practically constant standard size.

#### Sub-family SACCAMMININÆ.

##### *Psammosphæra* Schulze.

##### *Psammosphæra rustica* sp. n.

Test free, monothalamous, consisting of a polyhedral chamber constructed almost entirely of sponge spicules, whole or fragmentary, neatly cemented together in a single layer, and with a minimum quantity of ferruginous cement. The cement is confined to the actual line of attachment between the edges of the spicules, and does not extend over the outer or inner wall of the test. There is no definite oral aperture. Average size, 0·3–0·5 mm. (chamber only).

This beautiful and interesting form is not easily described, but the illustrations will serve to demonstrate its extremely variable (yet, within certain defined limits, constant) appearance, and the method of its construction.

Hardly any two specimens exhibit an identical shape or external appearance. This diversity is due to the methods of construction and the material employed. The apparent mode of construction is to select a number of long slender spicules often 2 or 3 mm. or more in length. These are placed like tent poles at various angles about 0·5 mm. apart, forming a rough open-work figure enclosing a central space between the points of intersection of the poles. The open spaces in the wall are then filled in with shorter fragments of spicules carefully selected for length, so as just to fill the required space. The animal thus secures the nearest possible approach to a spherical chamber obtainable with the material employed, the salient angles being the points where two or more of the "tent-poles" join. The long spicules employed as "tent-poles" project irregularly all over the surface of the test in perfect specimens, and probably serve a secondary purpose as catamaran spars in supporting the animal in the surface layer of ooze. They are, however, very fragile, and are frequently more or less damaged, if not destroyed, in the process of cleaning the dredged material.

The internal cavity of the test is quite devoid of projecting spicules and is not coated with cement.

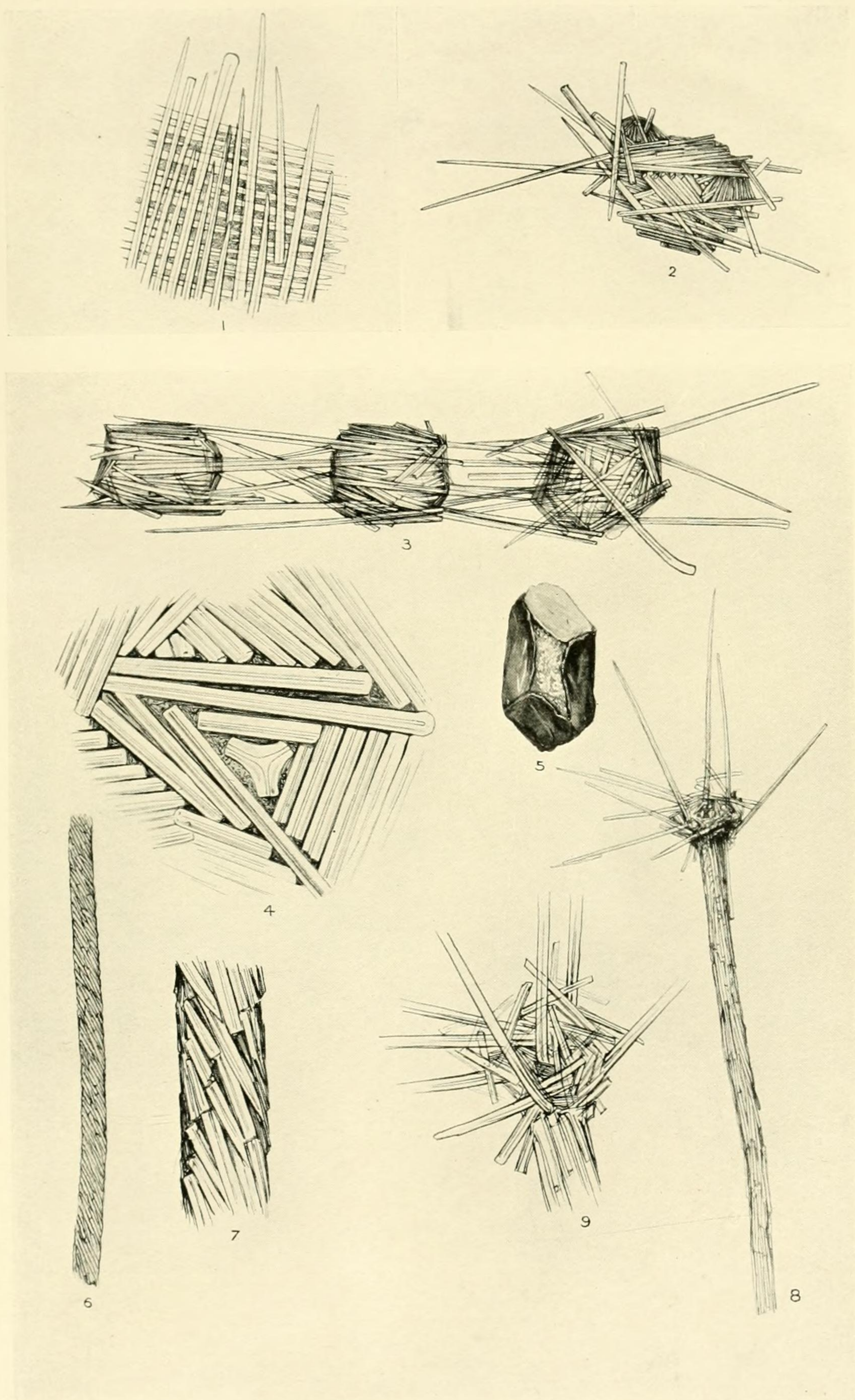
As a rule spicules only are employed in the construction of the test, but occasionally a minute grain of sand or flake of mica is used to close the little corner space where two or more "tent-pole" spicules meet at an acute angle. Still more rarely this angular space is left unclosed, thus constituting an aperture to the test. The presence of such apertures must, however, be regarded as abnormal. As in *Psammosphæra fusca* (Schulze) there is not any

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#### EXPLANATION OF PLATE VI.

- Fig. 1.—*Technitella legumen* Norman. Showing the differential arrangement of the sponge-spicules in the external and internal layers. The interstitial cement is represented by the shading.  $\times 140$ .
- „ 2.—*Psammosphæra rustica* sp. n.  $\times 40$ .
- „ 3. Ditto. An abnormal triple specimen.  $\times 40$ .
- „ 4. Ditto. Detail showing the method of construction in a "panel" of the test. The central space has been filled in by a fragment of a triaxial sponge-spicule. The interstitial cement is represented by dark shading.  $\times 140$ .
- „ 5.—*Psammosphæra Bowmanni* sp. n.  $\times 40$ .
- „ 6.—*Marsipella spiralis* sp. n.  $\times 40$ .
- „ 7. Ditto. Detail showing the method of construction of test.  $\times 140$ .
- „ 8.—*Marsipella cylindrica* Brady.  $\times 40$ .
- „ 9. Ditto. Detail showing the loosely-constructed terminal crown. The constituent spicules are not embedded in cement.  $\times 95$ .

*Note.*—All the figures in this plate are drawn from transparent balsam-mounted specimens, and for the purpose of clearness the focal plane has been more or less disregarded in figs. 1, 4, 7, and 9.



definite oral opening, and in the absence of such the protoplasmic extensions (pseudopodia) must pass through the porous cement of the test.

Many composite specimens have been found consisting of from two to five individuals growing in an irregular mass. In no case, however, is there any sign of a stolon tube or other connexion between the individuals, their only bond of union being the fact that two individuals have utilized the same spicule or spicules as "tent-poles" for building purposes. In one instance which we figure three individuals have joined together in a straight line. In the absence of other evidence this specimen might easily have been mistaken for a species of *Reophax*. As a rule, however, the aggregations of individuals are quite irregular in their appearance.

The protoplasm is dark and full of rounded opaque granules of secreted matter (digestion products), as in other arenaceous Foraminifera.

We have experienced some hesitation in allotting this interesting species to its genus. In spite of the selective power displayed, the test is evidently of the simplest type of Rhizopod structure, and the absence of a definite oral aperture combined with the evidence which we have discovered of selective power in another unquestionable species of *Psammosphæra* (*P. Bowmanni* sp. n.), has guided us in our decision to refer the species to the genus *Psammosphæra*.

*Psammosphæra rustica*, though never of very frequent occurrence, is met with at several of the 'Goldseeker' stations round the coast of Scotland. It occurs most frequently at Stations IX and IXB in the North Sea ( $61^{\circ} 34' N. 2^{\circ} 4' E.$ , 390 metres), and Stations 53 ( $59^{\circ} 36' N. 7^{\circ} W.$ , 1000 metres), and Haul 228 ( $57^{\circ} 59' N. 10^{\circ} 34' W.$ , 1600 metres) on the West Coast of Scotland, but occasional specimens are to be met with at intermediate localities and depths.

The nearest ally of our form is apparently *Rhaphidoscene conica* Vaughan Jennings,\* described as "a tent-shaped structure, composed entirely of sponge spicules." *Rhaphidoscene*, however, is a sessile form, and the figures show that the spicules were arranged in a regular cone without extensions beyond the test. It was described from one of the 'Porcupine' dredgings, not far from 'Goldseeker' Station 53.

*Psammosphæra Bowmanni* sp. n.

Test free, monothalamous, consisting of a more or less irregularly polyhedral chamber, constructed of small flakes of mica cemented together at the edges by a light grey mud-like cement. No definite oral aperture. There is often a small opening where two or three of the mica plates meet at an acute angle, due to absence of cement

\* Jour. Linn. Soc., xxv., pp. 320-1, pl. x.

at the point of junction. This opening, however, appears to be merely accidental and is not present in the majority of specimens. The cement used is not ferruginous, but appears to consist of very fine homogeneous mud. It is absorbent and very easily broken up, and is no doubt very porous, thus serving for the passage of the protoplasmic extensions.

As with *Psammosphæra rustica*, it is not easy to give a verbal description of this species, because owing to the nature of the material hardly any two specimens are exactly alike. As will be seen from the figures the mode of construction is apparently to select a number of small flakes of mica (an abundant constituent in most North Sea dredgings). These are arranged so as to make as nearly as possible an oval or flask-shaped enclosure, and the gaps between the edges of the plates are then filled up with a thin framing of mud-like cement. Owing to the irregular shape and size of the mica flakes the amount of cement used in different parts of the test varies from a narrow strip joining two parallel edges of mica, like the putty round a square of glass in a window, to a broad flat layer stretching across a gap between two adjacent mica plates. In the latter case the edges of the mica plates usually project slightly from the edges of the test, forming salient angles, the cement being attached to the inner edge of the flake. There is no attempt to fill in such cavities by the selection of a suitably small flake of mica, in the neat manner in which *Psammosphæra rustica* matches its constituent spicules to the space required to be filled.

The final result attained by the worker is the construction of an irregularly oval flask with from four to eight flattened "windows" in the sides.

The protoplasm is very dark and opaque, and fills about one half of the internal cavity.

The specimens vary considerably in shape and size, but the most usual form has a length about twice its breadth. Average length 0·4–0·6 mm., breadth 0·25–0·35 mm.

*Psammosphæra Bowmanni* occurs only in a single area so far as our observations go. It is confined to the deep water in the bottom of the gully off Burghead, in the Moray Firth. ('Gold-seeker': Haul 73, Burghead, S.  $\frac{1}{2}$  W., 3 miles, 35 fathoms; and Haul 7791, Burghead, S. by E., 2 miles, 55 metres.) The material consisted of a black mud with abundant Foraminifera, including many rare and interesting types, such as *Botellina labyrinthica* (Brady) and *Hippocrepina indivisa* (Parker). Specimens are fairly frequent in this gully, but owing to the fragile nature of the cement the majority are broken in the process of cleaning the material.

Mica is a somewhat favourite building material with a few Foraminifera, which show selective tendencies. *Reophax Scottii* (Chaster) builds its elegant, many-chambered shell entirely of

minute flakes of mica, rarely using any other material. *Reophaax fusiformis* (Williamson) also makes considerable use of larger flakes. But as a general rule, and in spite of its abundance in most muddy dredgings, the use of mica is avoided by arenaceous Foraminifera. The reason is fairly apparent after examining a large series of specimens of *Psammosphæra Bowmanni*. The smooth surface of the flake offers but a weak attachment for the cement, with the result that the flakes are readily detached from the shell.

We have much pleasure in associating this curious little form with the name of Dr. Alexander Bowman, Assistant to Professor D'Arcy W. Thompson, C.B., the Director of the North Sea Investigations Committee (Scotland), in acknowledgment of his many kindly services rendered in connexion with the dredgings made by the 'Goldseeker.'

#### Sub-family RHABDAMMININÆ.

##### *Marsipella* Norman.

##### *Marsipella spiralis* sp. n.

Test free, monothalamous, consisting of an undivided tube, which is built up of minute fragments of sponge spicules embedded in a light grey cement, and arranged transversely to the long axis of the tube. The spicules are built in a single layer, and have a distinctly spiral arrangement when the specimen is examined either as an opaque object or in a balsam mount. Viewed as an opaque object under a 12 mm. objective, *Marsipella spiralis* looks exactly like a piece of white string.

The protoplasm is dark brown in colour, and appears to run the entire length of the tube.

*Marsipella spiralis* is one of the most interesting species we have met. The use of sponge spicules, either entire or fragmentary, as building material is of frequent occurrence in the Foraminifera, but we know of no other species, except its near relative, *Marsipella cylindrica* (Brady), and *Technitella legumen* (Norman), in which sponge spicules are employed in a manner or for purposes which, in any organism of higher development than the Foraminifera, would presuppose "intelligence" on the part of the builder.

The sponge spicules employed by *Marsipella spiralis* are almost without exception fragments. They are selected of practically uniform length, 0·06–0·1 mm., and arranged at angles between 30° and 45° around the tube. The spiral is always left-handed. It is obvious that the strength of the tube is greatly increased by the spiral arrangement of the spicules; indeed, *Marsipella* has made the same great discovery as the man who first observed that a twisted string was stronger than an untwisted wisp of fibres.

*Marsipella spiralis* is confined to a limited area, so far as our



observations go. It occurs rarely in a rich foraminiferous mud dredged by the 'Goldseeker' in the North Sea (Haul 145, Station IXB, depth 330 metres), and an occasional specimen is to be found at adjacent stations, especially Station IX (61° 34' N., 2° 4' E., 390 metres). No specimen has yet been found showing definite initial or final portions of the tube, all being more or less fragmentary; but the fact that nearly all the fragments were living when dredged, as was proved by the presence of protoplasm in the tube, seems to show that the tube may grow indefinitely, and that injuries to the extremities of the tube do not affect the life of the animal. The tube is doubtless flexible when living, like *Bathysiphon filiformis* (Sars). The fragments vary from 1–4 mm. in length. The average external diameter of the tube is 0·08 mm.

*Marsipella cylindrica* Brady.

*Marsipella cylindrica*, Brady, 1884, Foram. 'Challenger,' p. 265, pl. xx. figs. 20–22.

This species was described and figured by Brady from specimens dredged by the 'Knight Errant' in the warm area of the Faroe Channel, 530–542 fathoms. He describes his specimens as tubes of tolerably even diameter, rarely exceeding  $\frac{1}{4}$ -in. in length, and varying from  $\frac{1}{200}$ – $\frac{1}{100}$  in. in breadth, "manifestly only portions of an organism that might be continued almost indefinitely."

The species is abundant in most of the deep-water dredgings made by the 'Goldseeker' in the Faroe Channel and also at Station IX in the North Sea. But when dredging to the west of St. Kilda in 1910, Earland discovered the perfect organism, which we take the present opportunity of figuring.

As figured by Brady the tube of *Marsipella cylindrica* is open at both ends, but in perfect specimens the oral extremity terminates in a club-shaped head of *loosely aggregated* sponge spicules, from which a number of long spicules 0·5–0·8 mm. in length radiate in all directions. The club-shaped head is from two to three times the diameter of the tube; the tube often reaches over  $\frac{1}{2}$ -in. in length.

The spicules forming the knob are not cemented together or to the tube, but are merely felted together and are easily broken down. This no doubt explains why the test is so seldom found in a perfect condition. It is very probable that other Foraminifera may present a similar terminal appendage when living.

The purpose of the club-shaped head or knob is not very apparent, but probably it serves two purposes. The aggregation of loose spicules closing the mouth of the tube will prevent the ingress of worms and other predatory animals, while the longer spicules may serve the double purpose of defensive spines and "stays" to support the radiating pseudopodia in their quest for food. As the tube

grows in length the spicules are absorbed and built into the wall of the tube, other spicules being collected to serve in their place.

*Marsipella cylindrica*, although a neat builder, does not show the skill and constructive ingenuity of its relative, *M. spiralis*. Sponge spicules enter largely but not entirely into its construction, being mixed indiscriminately with some sand-grains, mica, etc., in varying proportions. Individual specimens vary greatly in the neatness of their construction, some showing a slight tendency towards a spiral arrangement of the fragments. We figure one fragment in which this spiral twist is strikingly manifest. The absence of the cement which characterizes *M. spiralis* proves that the fragment should be referred to *M. cylindrica* and not to *M. spiralis*. Moreover the spiral is right-handed.

The question might arise whether the presence of the terminal club-shaped head in *Marsipella cylindrica* does not necessitate the transference of the species to a separate genus. In view of the fact that the terminal portion is so loosely constructed that it cannot be said to *close* the tube, we see no reason at present for the transfer of the species. We would, however, suggest that Norman's definition of his genus *Marsipella*, now quoted,\* should be amplified by the inclusion of the words we have inserted in italics.

\* Norman, A. M., "On the Genus *Haliphysema*, with description of several forms apparently allied to it." *Ann. Mag. Nat. Hist.*, ser. 5, i. p. 281.

Genus *Marsipella* n. g.  
(μάρσιπος, a purse.)

"Test elongated, fusiform (*or cylindrical*) centrally cylindrical and drawn out to gradually attenuated extremities, open at both ends (*or closed anteriorly by a loosely aggregated knob of spicules*) monothalamous; anterior extremity much produced into a narrow contracted mouth-opening. Extraneous matter of body-wall consisting for the most part of sand-grains, but at the oral extremity composed almost solely of fragments of sponge-spicules longitudinally arranged."

# Journal of the Royal Microscopical Society

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AND

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(principally Invertebrata and Cryptogamia)

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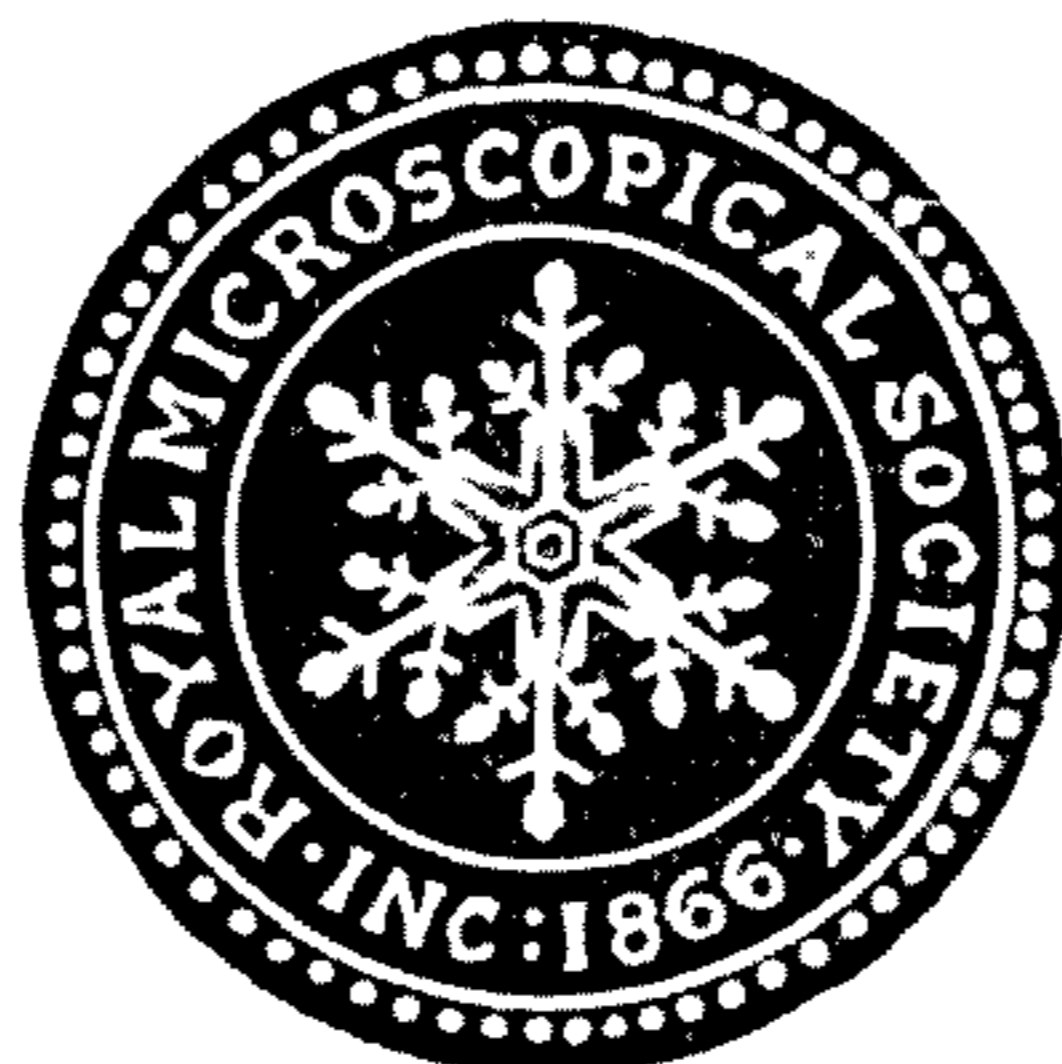
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quas qui fugit pariter Naturam fugit.—*Linnaeus.*

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