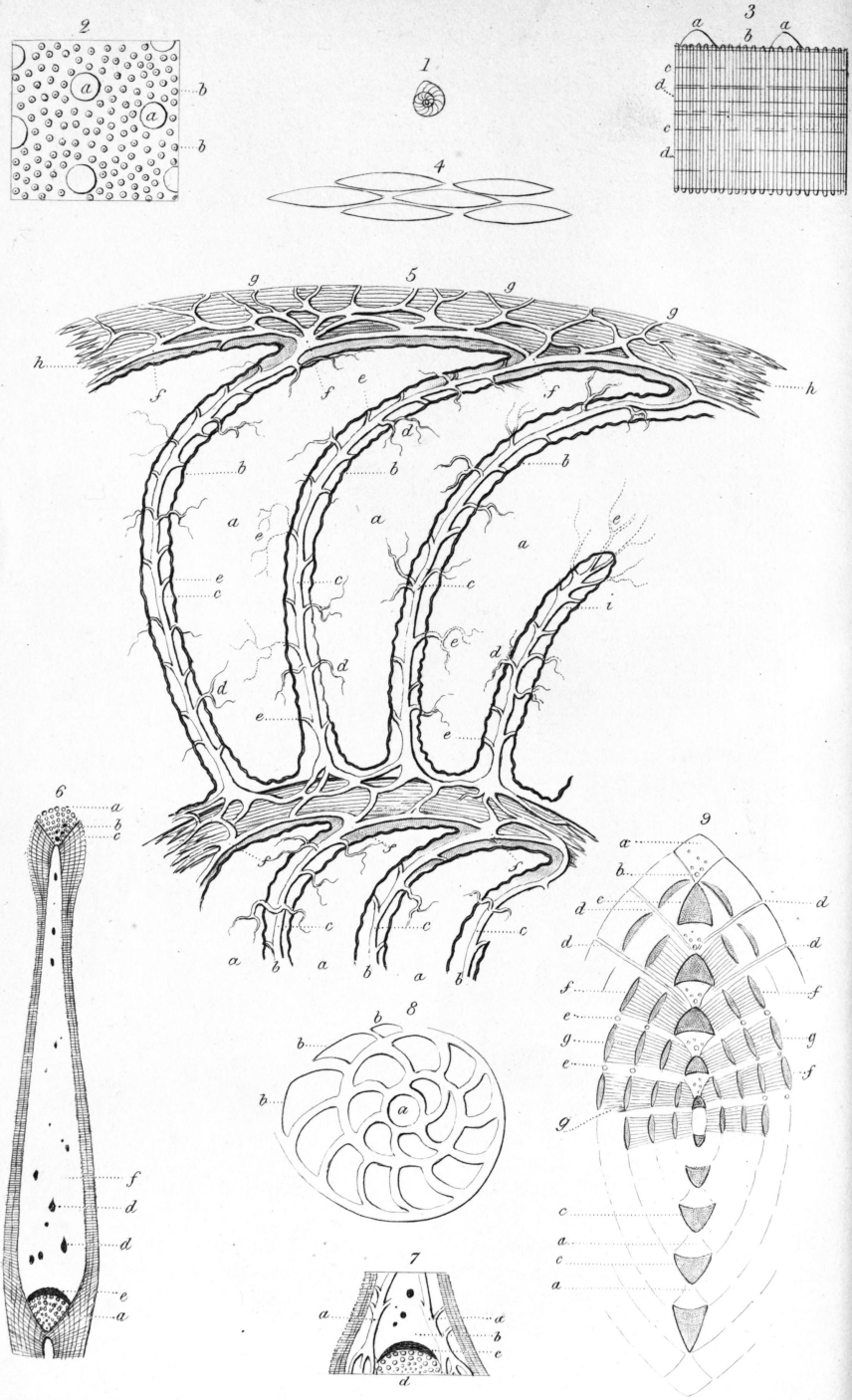

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XV.—*On the Form and Structure of the Shell of* Operculina Arabica. By H. J. Carter, Esq., Assistant Surgeon, Bombay Establishment.

[With a Plate.]

The interest which attaches to the forms and structure of Foraminifera is naturally very great, for no one can have seen their beautiful little shells and the extensive tracts in the Nummulitic series, which are almost entirely composed of their remains, without wishing to know something of the animals by which they were constructed.

Fortunately many are now living to help us out in this respect, and although for the most part very small, yet, here and there are found some sufficiently large, as will hereafter be seen, to afford us almost all the information we could expect to obtain, were the fossil species even living, in their largest forms.

In the month of June 1847, I communicated a paper to the Bombay Branch of the Royal Asiatic Society, containing, among other observations, a summary up to that time of all that was known of the structure of Foraminifera; and by way of introduction, as well as for the purpose of rendering this paper more complete and more useful, I will here insert the latter, adding what has been done since, and then a description of the form and structure of the shell of *Operculina Arabica*, which will, I think, elucidate all that has hitherto been stated of, and leave little to be added to, the general structure of Foraminiferous shells, both recent and fossil.

"For ten years after D'Orbigny gave his description of the animal of Foraminifera, no one appears to have taken much trouble to question its accuracy, until Dujardin took up the

subject in 1835, while residing at Toulon (where he had ample opportunities of testing the truth of D'Orbigny's imaginary discovery), and after having carried on his researches most perseveringly for some time, at length came to the conclusion, communicated to the Académie Royale des Sciences of Paris in the month of June of the year mentioned, that the Foraminifera were not Mollusca, nor did they belong to any of the established classes.

"In describing their organization, Dujardin stated that all their chambers were occupied by a red or orange coloured animal matter, highly contractile, and possessed of the consistence of mucus; that this was susceptible of extending itself into threads which were filled with irregular granulations, but without the presence of any organs. On carefully observing these animals in their living state, he had seen, with a high magnifying power, in *Miliola* a soft mass projecting from its aperture (analogous to the substance of the interior) which slowly underwent a change of form, and from which a tuft of minute filaments radiated from a common centre of attachment; these filaments prolonged themselves in ramifications to five times the diameter of the specimen (*Miliola*) from which they proceeded, and at length became of such extreme tenuity, as to be followed only by changing the direction of the rays of light. Further, he observed in these filaments a movement of *reptation*, by which the animal advanced from 5 to 6 millimetres per hour. The filaments appeared to be composed of a primitive animal matter, which extended itself forward in the manner of roots; hence the name *Rhizopoda* which Dujardin proposed for these animals. In *Miliola* and *Gromia* these filaments came from their aperture; in *Crestellaria* from the last chamber, and in *Vorticialia* from different pores of the disk.

"As to their manner of reproduction, Dujardin had noticed during the previous year, that in *Troncatulina*, the animal matter was grouped together in certain cases in globular masses, as the green matter of *Zygnema*.

"Finally, in concluding his communication he states, 'We see that it is impossible to keep these animals among the microscopic Cephalopoda: what rank shall be assigned to them?'*

"The discovery then of the animal of Foraminifera appears to be due to Dujardin.

"In November 1835, he exhibited at Paris several living specimens of *Vorticialia* and his genus *Gromia*†, and during that winter continued his researches into their organization with a

* Acad. Roy. des Sc. séance Juin 22, 1835.
† *Ibid.* séance Nov. 15, 1835.

view to establishing the relation that might exist between them and Infusoria.

"In comparing them with Infusoria, he states, in a note addressed to the Académie Royale des Sciences of Paris*, 'I have always been guided by an idea suggested by Bory St. Vincent, who, after having seen the living *Rhizopoda*, was struck with the great analogy which existed between the filamentous prolongations of these animals and the expansions of the *Amœba* or *Proteus*, and directed my attention to the point.'

"Lastly, Dujardin exhibited before the Acad. Roy. des Sc. at Paris in 1836† some animalcules, called by Ehrenberg *Arcella aculeata*, but which Dujardin regarded as freshwater Foraminifera, and through these he imagined the series to be continued from the *Amœba* to *Miliola*,—that is, through *Difflugia*, a species of *Amœba*, to *Arcella*, from the latter to *Gromia*, and from *Gromia* to *Crestellaria*, and thence to *Miliola*.

"After Dujardin, Ehrenberg took up the subject, and the result of his researches is as opposed to D'Orbigny's description as it is confirmatory of Dujardin's observations.

"In a memoir read at the Royal Academy of Sciences at Berlin in 1838‡, Ehrenberg stated that the Foraminiferous shells were inhabited by elegant little bodies which played an important part in nature, and the fossilized remains of which might frequently be found to number more than a million in a cubic inch of chalk; also, that after a series of observations made on recent species both living and dead in the Red Sea and elsewhere, he had come to the conclusion that their place in the animal kingdom should be among the Bryozoa.

"In the month of October 1839§, Ehrenberg also exhibited living specimens of these animals to the Academy at Berlin, [two] which were taken at Cuxhaven, and in January 1840 he exhibited ten other species of these animals ||, at the same time communicating the following observations on their organization:—

"'The first and largest cell of these animals, sometimes also the second, and occasionally as far back as the fourth, contain only the transparent part of the animal; beyond this, the cells are filled with two large organs differently coloured. One and the principal is an alimentary canal, thick, gray, greenish, which, like the whole of the body, is articulated; this extends itself from chamber to chamber, and its divisions are united by an

* Séance Fev. 1, 1836. † Séance Juin 11, 1836.

‡ *Ibid.* séance de 16 Janvier 1840. L'Institut, No. 350, Sept. 1840, p. 309.

§ Acad. Roy. des Sc. Berlin, séance de 16 Janvier 1840. Vide l'Institut, No. 350, Sept. 1840, p. 309.

|| *Ibid.* [and Taylor's Scientific Memoirs, vol. iii. p. 342.]

œsophagus or siphon. When the shell is removed by acid, the siliceous carapaces of Infusoria which the animal has swallowed may be observed (in *Nonionina* and *Geoponus*) as far back even as the last articulation of the alimentary canal. The structure of this canal is not polygastric but simple; expanded in the articulations, and possessed of a single aperture which is situated anteriorly. In *Nonionina* the articulations are distinct and connected by one siphon; in *Geoponus* they are multiple, and each set connected by its proper siphon.'

"Independently of the alimentary canal, a horny brown yellowish mass is seen in every articulation of the spire, the first excepted: this, which is granular, Ehrenberg considers to be the ovary.

"In searching for a purely negative character, Ehrenberg states that it consists in the want of pulsatory vessels; that while he has always recognized pulsations in the Mollusca and the smallest aggregated or compound Ascidia, he could never do so in *Nonionina* and *Geoponus*, the two species of Polythalamia (Foraminifera) which he more particularly examined*."—*Journ. Bombay Br. As. Soc.* vol. iii. pt. 1. p. 158.

This is all that had been discovered up to the time of my compiling this paper. I had seen the filamentous prolongations myself, and, on dissolving off the shell of a species of *Robulina* (D'Orbigny), had found a brown mass occupying the chambers (as it then appeared to me) in loops, in the largest or last formed ones, and diminishing posteriorly; it was also constricted at each end of the loop by the narrow aperture in the septum, and thus beaded, as it were, posteriorly, where there were no longer any loops, but a simple dilatation of the substance of each chamber. I will not now vouch for the complete accuracy of these observations, for they were made on board ship, with a simple lens and under considerable disadvantages; and other people have not since described the internal substance of the chambers as occurring in loops, nor have I since seen it in this form myself.

About the time I wrote this paper, MM. Joly and Leymerie were engaged in the microscopical examination of Nummulites, and the results of their investigations were made known through the 'Comptes Rendus' on the 24th Oct. 1847. Meanwhile too, Dr. Carpenter examined the fossilized remains of Foraminifera generally, and his communication on the subject was read before the Geological Society of London, 2nd May 1849, together with some extracts from Mr. Williamson's description of the animal and shell of *Polystomella crispa* (Trans. Microscop. Soc. vol. ii.

* Acad. Roy. des Sc. Berlin, séance de 16 Janvier 1840, and Scientific Memoirs, Parts X. and XI.

p. 159), which I shall here insert, with Dr. Carpenter's remarks, as the whole appears in the 'Quart. Journ. Geol. Soc.' vol. vi. pt. 1. p. 28, for I have not Mr. Williamson's paper to refer to:—

"Of the contained animal itself, which he obtained by dissolving away the calcareous matter of the shell with dilute acid, Mr. Williamson says, that it consisted 'of a very thin external membrane filled with gelatinous matter.' 'No trace of minute internal organization, such as a specially located intestinal canal, or ovaries, could be detected by Mr. Williamson; nor was he able in any instance 'to discover with certainty the presence of any foreign bodies in their interior.' The several segments are described by him as connected by a series of prolongations, which pass through the septa near their inner margins. The segments at first formed have only single connecting necks; but the number of these soon increases, and the outer segments are connected by ten or more such necks, which pass through as many distinct orifices in the septa. If all these orifices were brought together on the central plane, so as to coalesce into one, they would exactly correspond with the single perforations in the septa of Nummulites. The animal of *Polystomella* is considered by Mr. Williamson to derive its nutriment from pseudopodia, which are projected through numerous minute apertures over the whole surface of the shell. He has not clearly traced these pseudopodia, however, into connection with the segments occupying the interior whorls, which, like those of Nummulites, are invested by those of later formation; but he mentions (as Ehrenberg had done) that near the umbilicus they are projected in fasciculi; and he states that the surface of the central calcareous nucleus (which is formed by a thickening of the walls of the smallest cells) is pitted by small but deep depressions, which may be designed to facilitate the exit of the pseudopodia from the innermost convolutions. Mr. Williamson goes on to point out, that to these pseudopodia must be attributed the deposition of new matter upon that portion of the central nucleus which is not covered by the investing whorls; and in this view he is in accordance with M. D'Orbigny, who, in his recent work, 'Sur les Foraminifères Fossiles du Bassin Tertiaire de Vienne,' fully recognizes the power of the pseudopodia to secrete the calcareous covering. I may remark, that I cannot see how the investing layers covering the disk of *Nummulites complanata*, and the other species of the same group, can be formed in any other way; since in these the chambers are only marginal, the segments of the animal not extending over the disk; and we have no reason to believe in the existence of any external mantle, spreading over the whole surface, whereby these investing layers could be formed."

We now come to the structure of the shells, to which, of all others, both in description and illustrations, Dr. Carpenter appears to me to have contributed most.

MM. Joly and Leymerie seem to have gone no further, than to have shown, that in fossil Nummulites exist hemispherical granulations or little circular depressions, corresponding to granulations both on the external and internal surface of the shell, and that these are nothing more than perforations with which the shell was pierced during the existence of the animal. Also, that there existed a semilunar hole in each septum arching over the margin of the preceding whorl, and that the rest of the partition was imperforate. (Mém. sur les Nummulites, Sect. B. p. 20.)

Dr. Carpenter, however, whose investigations were carried on independently of those of MM. Joly and Leymerie, has gone much further than this, and therefore it will be as well to give a short summary of all that he has observed.

Commencing with the septa, he states (*loc. cit.*) that each consists of two layers, by which every chamber has its own proper wall, and that the intervening portion, which he terms the "*interseptal space*," "must have been vacant in the recent shell, unless occupied by the soft parts of the animal itself;"—"that each septum is perforated by an aperture, close to its junction with the margin of the preceding whorl" (as he believes was first observed by D'Orbigny, and figured first by Mr. Sowerby); and, "that these perforations pass through *both* layers of each septum, so as to establish a free communication between one chamber and another." That this case is different, however, "with regard to certain more minute apertures, which may be seen by a careful examination, under a sufficient magnifying power, to exist on the surface of every septum, though not consistent either in number or position;" "they penetrate that layer only of the septum on whose surface they open," "and establish a communication between each chamber and the adjoining interseptal spaces." "Other apertures of the same kind may be generally traced, on careful examination, in the walls of the chambers that form the surface of the whorl; and these too appear to communicate with the interseptal spaces by channels burrowed into those walls."

"Thus the cavity of each chamber communicates with that of the one before and behind it in the same whorl, by the large aperture first mentioned, which frequently appears as if made up by the coalescence of a number of smaller perforations (fig. 7 *b*), suggesting the idea that the animal substance which originally passed through it was not a single large canal, but was composed of a bundle of minute tubes or threads. This idea is

confirmed by the circumstance, that the outer margin of the included whorl (fig. 7 *c*) frequently presents a series of furrows, corresponding to the notches at the inner edge of the septum (*b*). Each cavity also communicates freely with the interseptal spaces on either side by the smaller apertures and passages last described; and from this space, as we shall presently see, there was a free passage to the external surface of the shell.

"The texture of the shell itself differs remarkably from that of any of the Mollusca with which I am acquainted, approaching that which I have described in the common Crab (Reports of the British Association, 1847, p. 129). It is everywhere perforated by a series of tubes of extreme minuteness which pass directly from one surface to another, their openings being plainly visible on each (fig. 16). The diameter of these tubes is about 1–7500th of an inch, and their distance from each other about 1–15,000th. In a thin vertical section of the shell (fig. 15) they are seen to run parallel to each other, and to be free from sinuosities or interruptions. The whole of this portion of the shell, therefore, is minutely porous. The structure in question can be seldom clearly distinguished in those Nummulites which have had their texture altered by calcareous or siliceous infiltration; but as the appearances which these present correspond closely with those exhibited by specimens of *N. lævigata* which have been subjected to the same change, I have no doubt that the tubular structure in question is common to the whole group."

"All the Nummulites which I have examined present a remarkable departure from this structure in that portion of the shell which forms the margin of each whorl. Here, instead of an assemblage of minute, closely-set, parallel tubuli, we have a much coarser arrangement, the solid substance being perforated with a smaller number of tubes of two or three times the diameter of those last mentioned, which pass in a radiating manner from the inner to the outer surface. Some indications of this difference are seen in fig. 4; but it is much more clearly displayed at *b*, *b*, fig. 15, which represents a portion of a very thin section taken in the same direction, and viewed by transmitted light. The openings of these tubes on the outer margin of the whorl are not readily discernible, partly in consequence of the somewhat oblique direction of the orifices, and partly through these being usually covered with a calcareous incrustation. When this has been removed by the application of dilute acid they are easily seen when properly looked for, as was first pointed out to me by Mr. J. Morris."

Lastly, Dr. Carpenter has observed, in addition to the tubes which run from the punctations on the surface into the chambers

of the Nummulite, another " series of perforations of considerable size, which pass directly downwards from the exterior, through the superposed investing layers of the successive whorls, however numerous, until they reach the floor and chambers of the central plane, which they do *not* penetrate." These, he feels satisfied, " always terminate *over the septa*, and actually pass into the *interseptal* spaces."

Now let us see how far these statements are confirmed by the structure of the shells of *Operculina Arabica*, which were obtained in the following way :—

While medical officer on the survey of the south-east coast of Arabia, I observed that Foraminifera were frequently brought up on the grease of the ship's sounding-lead, and after this I obtained the loan of a lead which I used to cast for this particular purpose myself. They were found to be most numerous in about 10 to 20 fathoms of water, rather in sandy than in muddy bottoms, scanty in deep water, and never (by the lead) among rocks and coral-ground. In one bed passed over, which was several miles in diameter, in about 20 fathoms of water, and about six miles off shore, the grease of the sounding-lead came up covered with them at each throw ; they were the largest living specimens I have ever seen, and principally consisted of the genus *Operculina* (D'Orbig.), *Discorbis* (Lam.). Most measured from 2 to 3–12ths of an inch in horizontal diameter, and one or two 3–10ths. Some contained animals, and others were empty ; the latter were readily distinguished from the former by their pearly whiteness ; while those which contained animals were invariably covered with a thin greenish cuticle like the deciduous epidermis of shells generally.

The following is a description of this *Operculina*, which, as it is most probably a new species, I have designated by the specific name of " *Arabica*."

Operculina Arabica (H. J. C.).

Description. Free, equilateral, oval or discoidal, thin, flat or wavy ; formed of one spire increasing gradually, not embracing ; regular, equally apparent on both sides ; consisting of 3–4 whorls, contiguous, enlarged on the outer border. Chambers numerous, 1–75, narrow, apparent on both sides, increasing gradually in length and breadth from a semitransparent, prominent, central cell ; radiating, reflected in their outer third to a point, particularly in the last-formed whorl ; divided by semitransparent septa, and covered externally with a green substance like the epidermis of shells generally.

Intercameral communications numerous in the septa of the last-formed whorl, the largest long, narrow and crescentic, arching over the margin of the preceding whorl.

Dimensions.—1–6th of an inch in horizontal, and 1–96th in vertical diameter; widest part of last whorl 1–24th of an inch (Pl. IV. fig. 1).

Observations.—This description is chiefly taken from one of the largest and most regularly formed shells I possess. They are by no means always plane, but, on the contrary, frequently wavy, like Nummulites; and the chambers sometimes increase in size more rapidly than at others, causing the shell to assume a more or less elongated or oval form; the chambers are also sometimes broader, sometimes narrower; and occasionally a septum only extends part of the way out towards the margin of the whorl, when it suddenly bends backwards to meet the preceding one, or it may stop short altogether, and then the chamber behind and before it coalesce at their outer parts. Irregularities of this kind in the formation of the chambers of Foraminifera are not at all uncommon, and apparently so usual in *Nummulites lævigata*, that they would seem to constitute a character. The imperfectly developed chamber extending from the margin of the foregoing whorl outwards instead of in the opposite direction, seems to point out the course in which the chambers are formed; and if each chamber is to be regarded only as the full development of a single animal, the imperfect one must be considered as an abortion, and those which have coalesced as a monstrosity. Most frequently there is here and there a large opening in the shell, over one or more of the chambers, which leads into the latter; they are more or less round, larger or smaller, and the smoothness of their margin would seem to indicate that they had been formed by the animal itself, if not by some other animal.

Microscopic Examination.—The chambers of the shell, after the green cuticular substance has been removed, are found to be covered externally with large and small papillæ; the former 1–2150th, the latter 1–8600th of an inch in diameter (fig. 2). The former also are about twice their own breadth apart, and the latter occupy the intervals between them; both are confined to the areæ over the chambers; they do not appear over the septa nor on the margin of the shell. The large papillæ appear to be imperforate, while the small ones appear to present each a puncture in the centre. The septal spaces, as well as the central cell, are semitransparent, and the former have a single, beaded line of semitransparent papillæ along their course.

The internal surface of the chambers merely presents the small

papillæ with their puncta; there are no large papillæ on it, and their cavities are otherwise complete, with the exception of the channels of intercameral communication, and some minute vascular apertures which will be presently mentioned.

The septa (fig. 5 *b, b*) occupy, transversely, about 1–6th of the breadth of the chambers, and each septum incloses within its walls two calcareous tubes or vessels, one on each side, some little distance below the contiguous surface of the shell (fig. 7 *a, a*); these we shall call *interseptal vessels*. They are irregular both in their size and course, though generally about 1–1900th of an inch in diameter, in the last-formed septa of a shell having the dimensions of the one described, and diminish in calibre backwards or towards the first-formed whorls. Each vessel commences in the centre of an intricate network of smaller ones, spread over its own side of the margin of the preceding whorl, and under the layers of the shell (*f, f, f*); these networks, which are joined together, we shall call the *marginal plexus*. In its course each interseptal vessel gives off two sets of *ramusculi*, and the marginal plexus one set. Of those coming from the interseptal vessel, one set terminates on the surface of the shell, particularly about the borders of the septum (*d, d*); the other goes into the walls of the shell, and through the septum, to open probably on the inner surface of the chamber (*e, e, e*); while the set from the marginal plexus opens on the margin (*g, g, g*). As this vascular system appears to extend throughout every part of the shell, and must be for the circulation of some fluid, we will call it the *interseptal circulation*. It would have been more proper to have commenced with the *ramusculi*, as we shall see hereafter that they appear to absorb the fluid which is subsequently transmitted into the larger vessels, but at this period of our description it would not have been so intelligible.

We have now to examine the internal structure of the shell, and commencing with that part forming the walls of the chambers, we observe, that it is pierced by innumerable tubes, which pass directly downwards from the small papillæ on the external, to the small papillæ on the internal, surface of the chambers (fig. 3 *d, d*). I could see no tubes passing down from the large papillæ, which I have before stated to appear imperforate, like those over the septal spaces. These tubes are about 1–9000th of an inch in diameter, and about the same distance apart; they are vertical over the centre of the area of the chamber, and slope outwards at its boundaries, but do not pass through or extend over the margin of the shell, neither over the septal spaces, nor over the central cell; hence the semitransparency of the two latter, and the fringy, beaded appearance which the tubes pre-

sent at these parts, particularly around the central cell, where they assume the form of rays.

Besides these tubes, a vertical section of the shell presents a series of horizontal lines 7–8 or more in number, parallel to each other, but not equidistant (fig. 3 *c*, *c*); these appear to be the lines of contact of the layers of which the shell is composed.

Lastly we come to the margin, which exhibits a very curious and interesting structure. It is almost entirely composed of calcareous *spicula*, arranged parallel to, but overlapping each other (fig. 4). These spicula are 1–237th inch long, and 1–900th of an inch broad, transparent, apparently hollow, and pointed at each extremity; they appear to be straight, although from their position one would be inclined to think that they must be a little curved. When a transverse section is made of the margin, we observe that it consists of upwards of 100 of these spicula, which form a triangular bundle or cord (fig. 6 *a*), the apex of which is directed inwards or towards the chambers, and the base (*a*) outwards to form the free, rounded margin of the shell; while its sides are overlapped by an extension of the walls of the chambers, which open as it were to receive it. Its base presents a regularly wavy outline (when viewed in the transverse section) from the longitudinal arrangement of the spicula, which do not appear to be covered by a layer of the shell; and parallel to its sides run the papillary tubes of the chambers (*b*), becoming more vertical as they increase in distance from this position; while towards its apex appear the divided large vessels of the marginal plexus (*c*). In the transverse section also, when reduced to a thin layer, transparent intervals appear in the form of zigzag lines radiating from the apex to the circumference of the cord, which would seem to indicate that the spicula were arranged in it in more or less horizontal planes, dipping towards the apex.

It will naturally now be asked, how this spicular cord (fig. 5 *h*, *h*), which commences with the first cell, terminates; but I regret that there is not a single specimen in my possession to afford the information. This arises probably from the extreme thinness of the last-formed chamber; for with the two or three preceding ones, it is almost always broken or absent. All I can state in connection with this is, that there are always more or less vessels of the marginal plexus cut through or broken in a transverse section or fracture of the spicular cord, and frequently a large one close to its apex, which, after the shell has been filled with a solution of carmine and then laid in pure water, purges it almost completely from the colouring matter with which it had been filled;—a broken interseptal vessel will also do this. Hence it is not impossible, that a natural opening of the

kind may exist at the termination of the spicular cord, for this purpose; but, then, it has nothing to do with the spicular cord itself, of the natural termination and uses of which I am equally ignorant. It should here also be mentioned, that when a thoroughly empty shell, which may be known by its pearly whiteness, is gently laid on the surface of a solution of carmine, so as to float there, the latter is seen, first to colour the margin, then the interseptal vessels become filled, and lastly the *walls* of the chambers; none of the semitransparent parts of the shell become coloured. This will take place sometimes in a few hours, but with some shells it requires a day or two for its completion. By keeping one side of the shell dry the air is enabled to pass out of it, while the solution enters the depending side, and in this way the whole of the hollow structure of the shell becomes coloured. When the shell is washed and dried in this state, the carmine is seen to be chiefly in the interseptal vessels, and this is perhaps the best way of tracing out the terminations, or rather origins, of the *ramusculi*. On the other hand, when the shell is placed in pure water and watched with a magnifying glass, a stream of carmine particles will be seen slowly issuing from the vessels of the marginal plexus, at the broken end of the spicular cord, or from any other part of the large whorls, where an interseptal vessel may have been broken; and after a time, according with that which the shell has taken to imbibe the colouring matter, it will become perfectly white again. Whether this be owing to the watery distension of the gummy fluid suspending the carmine, or a natural consequence of the structure of the shell itself, further observation must determine. The fact of the carmine accumulating at the orifices of the *ramusculi*, as it would in a filter, seems also, with what has just been stated, to point out the course of circulation in them; and if we may be allowed to carry out the analogy still further, which is now seen to exist so strikingly between Foraminifera and Porifera, we might compare the interseptal circulation in the former to the aqueous circulation in the latter, and thence might infer, that the water entered by the *ramusculi* or small pores, and came out by the larger ones, gathered together into one vessel, opening in its natural state at the end of the spicular cord; but, until a perfect specimen be obtained to determine this, all must of course remain conjectural.

Growth.—From what I have stated respecting the existence of a substance, resembling the cuticle of shells, over the external surface of *Operculina Arabica*, and the presence of innumerable puncta, which appear to be connected by tubular communications with the chambers beneath, it is not unreasonable to infer, that by this arrangement successive additions may be made to

the external surface of the shell, and the laminated structure, which it presents on a vertical section, thus formed; while the addition of chambers would appear to commence from the opening in the septum close to the preceding whorl, and an interseptal vessel, arising as before described from its marginal plexus, to extend outwards, on either side, *pari passu* with the chambers to the circumference, which it may fall short of or not, as already stated. Again, it would appear that this addition does not take place singly, but that there are always two or more chambers (fig. 8 *b, b, b*) in process of formation, the last being the smallest, and that, one after another, they gradually reach the margin. I have come to this opinion, not from the recent specimens of *Operculina* in my possession, in which, as before stated, all the last-formed chambers are broken, but from having observed the ochraceous casts of microscopic nautiloid species of Foraminifera which have been fossilized, to present this form, when dissolved out from their matrix.

Analogy to Porifera.—When Dujardin, guided by the suggestion of Bory St. Vincent, was struck with the analogy which exists between the filamentous prolongations of Foraminifera and those of the *Amœba* or *Proteus*, he could have little thought, that however nearly the latter might be allied to the Sponges, the former would be found so similar to them in their compact structures. Who, indeed, looking at the nautiloid form of a foraminiferous shell and an amorphous piece of sponge, would say, that they bore the least resemblance to each other? Yet they are, as we have seen, most intimately allied, both in their fleshy and their compact structures. It must be now generally allowed, that the rhizopodous nature of Foraminifera is identical with that of the *Amœba* or *Proteus*, and through the latter with the sponge-cell; and in addition to this, we have the former, at least the genus *Operculina*, still more nearly allying Foraminifera to the Sponges, by possessing a spicular structure, if not a circulating system also, like that of sponges. It is curious too, that without any reference to the use of the pores in these two orders of animals, they should have received names of the same signification, as if the intimate relationship which is now found to exist between them was instinctively anticipated, before it was proved by demonstration. The genus of Porifera to which *Operculina* comes nearest is, of course, the calci-sponges, that called *Grantia*, after their distinguished discoverer Dr. Grant; and of this genus, it would seem to approach nearest to the tubular species, which have but one vent.

Structure of the Shell of Operculina compared with Nummulites.—It will be very gratifying to those whose investigations of the structure of Nummulites must have been attended with so much

labour, difficulty and doubt, to see, how satisfactory the examination of a recent foraminiferous shell, so nearly allied to *Nummulites* as that of *Operculina*, confirms and elucidates their observations. The vertical tubes passing from the surface of the shell to the interior of the chambers (see Dr. Carpenter's illustrations, fig. 15, *loc. cit.*); the intercameral communication (*id.* fig. 7 *b*); the linear markings or grooves immediately under the latter (*id.* fig. 7 *c*), which appear to have been produced by the previous existence of a spicular cord in this position; and the radiating lines (*id.* fig. 15 *b*, *b*), caused by the arrangement of the spicula in horizontal layers inclined towards the apex of the cord, with the sloping papillary tubes on each side of it.—The "minute apertures" (*id.* fig. 7 *a*), which only penetrate *one* layer of the septum, and others which open on the internal surface of the walls, are probably the orifices of the *ramusculi* of the interseptal vessels which go in this direction.—And the "perforations of considerable size, which pass directly downwards from the exterior through the superposed investing layers of the successive whorls" "until they reach the floor of the chambers of the central plane which they do not penetrate" (*id.* fig. 8 *a*);—the vertical interseptal vessels, or an enlargement and union into one tube of the *ramusculi*, which pass upwards and downwards from the horizontal interseptal vessels as seen in *Operculina*.

The latter, that is, the union of the vertical with the horizontal interseptal vessels, I have been able to make out in some specimens of *Nummulites acuta*, Sow. (Geol. Trans. 2nd Ser. vol. v. pl. 24. fig. 15), which have had their cavities thoroughly infiltrated with ochraceous oxide of iron; as well as everything else mentioned by Dr. Carpenter; and with the exception of the spicula themselves, everything that I have seen in *Operculina*. MM. Joly and Leymerie seem to me to have described one thing and to have figured another. They describe the papillary tubes, and seem, from the distance between them, to figure the orifices of the vertical interseptal vessels (pl. 11. *op. cit.*), which Dr. Carpenter has particularly described.

The columns represented by Sowerby in *Lycophrys ephippium* (Geol. Trans. *loc. cit.* fig. 15), and to which Dr. Carpenter has alluded (*loc. cit.* p. 26), appear, to me, to be made up of the papillary tubes which descend from chamber to chamber (fig. 9 *g*, *g*), and which in purely calcareous fossils are filled with a white opake matter, but in those infiltrated with oxide of iron, with ochraceous matter; while the intervening parts are composed of the septal substance, through which the interseptal vessels pass to the surface and margin in *Orbitoides* as well as in *Nummulites*.

The same system of circulation would also appear to be car-

ried on in *Orbitolites*, where the mass is made up of spheroid or ovoidal cells: for if the nearly flat Indian species, which has a papillary eminence in the centre of the convex side, be rubbed down, the latter presents a ramification of transparent substance like that filling the septal spaces of *Nummulites* and *Orbitoides*; which, radiating upwards and outwards from this eminence, passes into the general structure of the shell.

The transitionary forms of the chambers in *Operculina*, through *Nummulites* and *Orbitoides* to *Orbitolites*, would, when viewed in a vertical section, appear to be thus:—In *Operculina* there is a single plane of spear-head shaped chambers; in *Nummulites* a central plane of conical chambers with layers of compressed ones above and below it; in *Orbitoides*, a central plane of quadrangular chambers with numerous layers of compressed ones above and below it; and in *Orbitolites*, a mass of circular or ovoidal cells more or less definitely arranged. Hence, if these be their respective peculiarities, *Orbitoides Mantelli* will, from Dr. Carpenter's illustration (fig. 31, *loc. cit.*), belong to the latter, and would therefore be now more properly named *Orbitolites Mantelli*.

One other observation I would here make with reference to geology, viz. the natural union which now seems to be pointed out between the Chalk and the Nummulitic series, by the great prevalence of the same class of animal remains in each—that is to say, the abundance of flints which indicate the previous existence of *siliceous sponges* in the former, and the myriads of Foraminifera which are closely allied to the *calci-sponges* in the latter.

Bombay, May 12, 1852.

EXPLANATION OF PLATE IV.

Fig. 1. *Operculina Arabica*, natural size.

Fig. 2. Large and small papillæ on the external surface of the shell, highly magnified.

Fig. 3. Vertical section of the shell over the chambers, highly magnified, showing:—*a*, *a*, large papillæ; *b*, *b*, small ditto; *c*, *c*, horizontal lines indicative of the layers of the shell; *d*, *d*, vertical tubes.

Fig. 4. Spicula *in situ*, highly magnified.

Fig. 5. Diagram of horizontal section of three large chambers of the shell, showing the interseptal vascular system and spicular cord: *a*, *a*, *a*, chambers; *b*, *b*, *b*, septa; *c*, *c*, *c*, interseptal vessels; *d*, *d*, *d*, *ramusculi* coming to the surface of the shell; *e*, *e*, *e*, *e*, ditto, going to the walls of the shell, &c. through the septa, the dotted lines indicating those branching out into the former; *f*, *f*, *f*, marginal plexus; *g*, *g*, *g*, *ramusculi* of margin; *h*, *h*, spicular cord; *i*, half-formed septum with termination of interseptal vessel.

Fig. 6. Diagram of vertical section of the shell to show the form of the spicular cord: *a*, margin or free surface of spicular cord; *b*, vertical

or papillary tubes, here sloping outwards on each side the cord; *c*, truncated vessels of the marginal plexus; *d*, *d*, small channels of intercameral communication; *e*, grand semilunar or crescentic channel of ditto; *f*, septum.

Fig. 7. Diagram of vertical section to show the situation of the interseptal vessels: *a*, *a*, interseptal vessels; *b*, septum; *c*, grand channel of intercameral communication; *d*, part of spicular cord.

Fig. 8. Enlarged view of first-formed chambers of *Operculina Arabica*: *a*, central cell or chamber; *b*, *b*, *b*, probable forms of last chambers in process of development.

Fig. 9. Diagram of vertical section of *Nummulites acuta*, Sow.: *a*, spicular cord?; *b*, truncated vessels of marginal plexus; *c*, *c*, chambers of central plane; *d*, *d*, vertical interseptal vessels (the "perforations," &c. of Dr. Carpenter); *e*, *e*, horizontal interseptal vessels; *f*, *f*, *f*, chambers on each side the central plane; *g*, *g*, *g*, *g*, vertical tubes.

XVI.—*On some genera of the* Icacinaceæ. By John Miers, Esq., F.R.S., F.L.S.

[Continued from p. 119.]

Emmotum.

This neglected genus was proposed by Desvaux in 1825 upon a plant from Guiana. By Endlicher it was referred to *Leretia* of the 'Flora Fluminensis,' with which it neither accords in the appearance of the leaf nor the mode of its inflorescence: Hamilton's character as given in his 'Prodromus,' notwithstanding its brevity, is sufficiently well marked to show that it does not differ from *Pogopetalum*, founded by Mr. Bentham in 1840; indeed the *Emmotum fagifolium*, Desv., corresponds with *Pogopetalum acutum*, Benth., both from Guiana, so as to leave no doubt of their identity: according therefore to the austere rule of science, the latter name must give way to the former. Mr. Bentham in establishing his genus recorded two species, and has since described two others, and I have now to add a fifth. All the species, which are from Guiana and intertropical Brazil, seem to form good-sized trees, with very thick coriaceous leaves of a peculiar appearance; their inflorescence is in axillary crowded fascicles of rather small flowers, which are distinguished by having petals densely beset on their inner face with long red silky hairs arising from an elevated costal nervure. Their chief peculiarity, however, consists in the unusual structure and singular mode of dehiscence of their anthers, which are formed of two opposite, unilocular, valveless, and separate cells, the pollen being discharged extrorsely through a fissure arising from the secession of the dorsal margin of each boat-shaped cell from the very fleshy connective, features that have hitherto escaped obser-

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