PHILOSOPHICAL TRANSACTIONS.

I. *Researches on the Foraminifera.*

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PART III.

ON THE GENERA PENEROPLIS, OPERCULINA, AND AMPHISTEGINA.

119. In my preceding memoirs, I have shown that two very dissimilar types of structure present themselves among Foraminifera; one characterized by its simplicity, the other by its complexity. In the former, of which *Orbitolites*, *Orbiculina*, and *Alveolina* are typical examples, the calcareous skeleton does not present any definite indications of organization, but seems to have been formed by the simple calcification of a portion of the homogeneous sarcode-body of the animal; that sarcode-body is but very imperfectly divided into segments, the communications between the cavities occupied by these segments being very free and irregular; the form of the segments themselves, and the mode of their connexion, are alike inconstant; and even the plan of growth, on which the character of the organism as a whole depends, though preserving a general uniformity, is by no means invariably maintained. In the latter, to which *Cycloclypeus* and *Heterostegina* belong, we find the calcareous skeleton presenting a very definite and elaborate organization; the several segments of the body are so completely separated from each other, that they remain connected only by delicate threads of sarcode; each segment thus isolated has its own proper calcareous envelope, which seems to be moulded (as it were) upon it, and this envelope or shell is perforated with minute parallel tubuli, closely resembling those of dentine except in the absence of bifurcation or ramification; the partition-walls between adjacent segments are consequently double, and are strengthened by an intermediate calcareous deposit, which is traversed by a system of inosculating passages that seems properly to belong to it. The form of the segments, their mode of communication, and consequently the general plan of growth, have a very considerable degree of constancy; and altogether the tendency is strongly manifested in

this type, to the greater individualization of the parts of the composite body, which in the preceding must be looked upon rather as constituting one aggregate whole.

120. I purpose in the present memoir to carry on this contrast, by presenting a detailed comparison of the structure of two generic forms, which, whilst they so far agree in general plan of growth as not only to have been ranked by M. D'ORBIGNY side by side in his order *Hélicostègues*, but to have been placed by other systematists in close apposition, differ in the most marked manner as to all the particulars just enumerated. Both these types are of peculiar interest:—the first, *Peneroplis*, on account of the very wide range of variation it presents, which has led to the establishment of three *genera*, apparently distinguishable by well-marked differences in conformation, upon what I feel satisfied will prove to be but individual modifications of one and the same *specific type*;—the second, *Operculina*, as being the nearest existing representative of *Nummulites*, and consequently as affording not merely the key to the elucidation of the structure, but also the basis for the determination of the value of the reputed species, of that genus, by the study of the range of variation which it presents; this range being, though more restricted than in the preceding case, still quite sufficient to justify a large multiplication of species, in the estimation of those who do not practise that extended method of comparative inquiry, on the importance of which I have dwelt in a former Memoir (¶ 74). With the latter of these genera, as also with *Nummulites*, I shall prove that the genus *Amphistegina* is closely allied; although M. D'ORBIGNY, misled by the marked want of symmetry and by the alternation in the disposition of the chambers, which are exhibited by certain forms of that type, has placed it in a different order, *Entomostègues*. For I shall have to show that a gradational variety in this respect, ending in complete symmetry, may coincide with such a uniformity in general structure, that even a very decided departure from symmetry must be regarded as a character of little value in classification, compared with agreement in the organization of the shell and in those peculiarities in the conformation of the animal which are indicated by it; and further, that a most marked difference in degree of organization exists between two species of *Amphistegina*, which so closely resemble each other externally that the young of one may easily be mistaken for the adult of the other.

Genus PENEROPLIS.

121. *History.*—The genus *Peneroplis* was first instituted by MONTFORT* to distinguish a peculiar type of minute polythalamous shells, which had been previously described and figured by FICHTEL and MOLL†, and had been ranged by them with numerous others under the comprehensive designation *Nautilus*; and MONTFORT correctly indicates its distinctive character, as "bouche de toute la longueur de la base, et percée sérialement par une file des pores," though he seems to have very erroneously interpreted the signi-

* BUFFON de SONNINI, 1802–1805; Mollusques, tome iv. p. 1. pl. 42; and Conchyliologie Systématique, 1808, p. 258.

† Testacea Microscopica, Vindob. 1798–1803, p. 91. tab. 16. figs. *a, i.*

fication of those pores. For he goes on to state, "Cette coquille est encore pellucide, et permet de lire au travers de son têt la série et la disposition des nombreuses cellules de chaque concameration; ces cellules deviennent plus grandes à mesure que la coquille prend plus d'accroissement. Il est probable que leur nombre repond à celui des animaux qui les habitent, et qui les constituent simultanément pour former un nouveau rang." This subdivision of the principal chambers into cells, each occupied by a separate animal, exists only in the imagination of MONTFORT, who seems to have been misled by the peculiar markings of the surface of the shell, which, as will be presently seen, are merely superficial. LAMARCK, not adopting MONTFORT'S genus, referred the *Nautilus planatus* of FICHTEL and MOLL to the genus *Cristellaria*, with which it has no relationship whatever; and having copied their figures into the 'Encyclopédie Méthodique*,' he designated one set of forms as *C. planata*, and another as *C. dilatata*, subsequently reuniting them, however, under a new specific name, *C. squammula*†. The genus *Peneroplis* has been recognized by BLAINVILLE‡ and by EHRENBERG§; and D'ORBIGNY has applied this name, in his various writings on Foraminifera, to the form described by FICHTEL and MOLL, whilst he has created a new generic term, *Dendritina*, for a series of closely allied forms, in which there is a single large dendritic aperture instead of a linear series of separate apertures. The distinctive characters of these two genera, as last given by him ||, are as follows:—"*Peneroplis*; coquille nautiloïde comprimée, pourvue de nombreuses ouvertures sur une seule ligne à la dernière loge seulement. Cavité simple:—*Dendritina*; ce sont des *Peneroplis* dont les ouvertures anastomosées forment une dendrite." In addition to these, I shall cite his definition of another genus, established by LAMARCK in 1801, which, as I shall presently show, consists, like *Dendritina*, of mere varieties of *Peneroplis*:—"*Spirolina*; coquille nautiloïde dans le jeune âge, projetée en crosse dans l'âge adulte."

122. The genus *Peneroplis* is very widely diffused through warmer latitudes; indeed few collections of Foraminifera from sands or dredgings taken from the Mediterranean, the Ægean Archipelago, the Red Sea, the East or West Indies, the Philippine seas, or the shores of Australia or the Polynesian Islands, will fail to present numerous examples of it. A few specimens have been found on British coasts; but it is surmised by Professor WILLIAMSON that these have been brought by the Gulf-stream from the West Indian Seas. "Amongst the multitude of West Indian seeds and other light objects thus thrown upon our north-western shores, it was to be expected that some of the tropical Foraminifera would be entangled; and such may have been the case with the species under consideration¶." The finest examples I have met with were contained in

* Tab. 467, figs. 1, *a*, *b*, *c*, 2; *a*, *b*, *c*.

† Animaux sans Vertèbres, tom. vii. p. 607.

‡ Malacologie, p. 372.

§ "Tabellarische Charakteristik der Bryozoën-Classe und sämmtlicher Familien und Gattungen der Polythalamien," in Berlin Transactions, 1838.

|| Cours Élémentaire de Paléontologie, 1849, tom. ii. p. 198.

¶ On the Recent Foraminifera of Great Britain, published by the Ray Society, 1858, p. 46.

Mr. CUMING'S Philippine Collection; whilst the most numerous were kindly furnished me by Mr. J. GWYN JEFFERYS from his dredgings in the Gulf of Genoa. We shall hereafter find that, as in the case of *Orbitolites*, particular varieties of conformation prevail, though by no means exclusively, in particular localities.

123. *External Characters.*—The ordinary form of the shell of *Peneroplis* (of which an ideal representation is given in Plate I. fig. 2) is an extremely flat spire of about two turns and a half, opening out rapidly in its last half turn (Plate II. fig. 1). In the young shell, each whorl is merely adherent to the preceding, so that the first-formed portion is not concealed by the subsequent growth; but it very commonly happens that the last whorl spreads itself out to such a degree as partially to invest the preceding (Plate II. figs. 1, 3), the extension towards the centre, however, seldom reaching so far as to conceal the original umbilicus. Although this lateral extension is sometimes confined to the inner margin of the spire, as is seen in fig. 1, yet it often occurs along the outer margin also, as is seen in fig. 3; being usually limited, however, to the last four or five chambers. But sometimes, instead of opening out and partially investing the previous whorls, the spire is prolonged in a straight line, and several of its successive chambers present little or no progressive increase in size (Plate II. fig. 5); though even in this variety the last four or five chambers are often seen to spread themselves out rather suddenly, so as to extend along the inner margin of the straight portion. Between these different extremes of conformation, every intermediate gradation presents itself.

124. The surface of the shell is very strongly marked by depressed bands, which indicate the place of the septa between the chambers; and between these septal bands the walls of the chambers rise in flattened arches. In a direction transverse to the septal bands, we almost uniformly observe a strongly-marked striation; the striæ running parallel at tolerably regular intervals, which average about $\frac{1}{1400}$th of an inch, from one septal band to another. This striation, which imparts a very characteristic physiognomy to these minute shells, seems due to a sort of plication or ridge-and-furrow arrangement of the shelly wall (Plate II. fig. 20), which may not improbably have the effect of imparting to it increased strength. The plication generally disappears at the junction of the walls of the chambers with the septa; and consequently we do not usually see it at the mouth when the shell is viewed endways. Sometimes, however, it is continued on to the septum itself; and its character is then extremely well displayed, as in Plate II. fig. 15, which, however, represents not the typical form, but one of the varieties to be hereafter noticed. On the prominences of the plicæ, there are frequently to be seen rows of extremely minute puncta (fig. 20); these, however, are not the apertures of passages through the shell, as might not unnaturally be supposed; but are, like the punctations of *Orbiculina* (¶ 88), mere depressions of its surface,—as I have ascertained by the careful examination of very thin sections. It is remarkable that the plication of the shell is sometimes wanting, though the punctations may still present themselves in rows, as shown in fig. 23; whilst in other cases, not only are the plicæ deficient, but the punctations are distributed uniformly over the entire surface, as shown in fig. 24. That

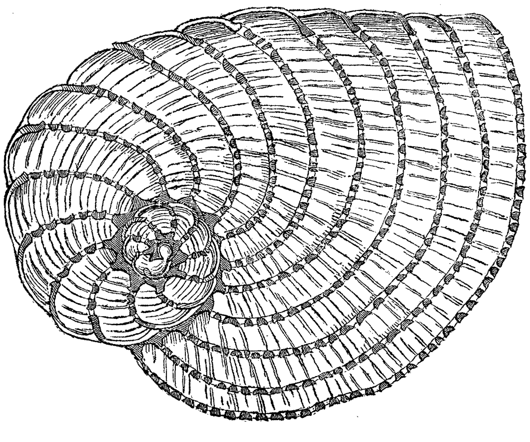
these variations are not indicative of any specific difference, is at once proved by the fact that the shells which exhibit them in one part, present the ordinary character of surface in another. In Plate II. fig. 22 is shown a case in which similar punctations present themselves on the septum closing the mouth of the shell of a *Dendritina*, which, as will presently appear, is only a modified *Peneroplis*.

125. The septum which closes the mouth of the shell is perforated by numerous isolated pores, arranged in a single linear series (Plate I. fig. 2, Plate II. fig. 1); the number of these pores depends upon the length of the septal plane (a very convenient term which I adopt from Professor WILLIAMSON), and thus it usually increases with the age of the individual, each chamber opening externally by a larger number of pores than did that which preceded it. The typical form of these pores seems to be circular, though they are apt to present various departures from that shape; they usually lie in a sort of furrow, formed by the projection of the lateral borders of the mouth somewhat beyond the septum; and, as in *Orbitolites* and *Orbiculina*, each one is surrounded by a prominent annulus of shell.

126. The texture of the shell very closely resembles that of *Orbitolites* and *Orbiculina*, but is somewhat more porcellanous. As in those genera, the shell presents an opaque white hue, when it is viewed by light reflected from its surface; whilst thin sections examined by transmitted light are of a brownish yellow or dark amber colour. Its substance is apparently quite homogeneous, no other trace of structure presenting itself than the plications and punctations already referred to; and its texture is not nearly so firm as that of those Foraminiferous shells which possess a minutely-tubular organization.

127. On examining a thin section of a typical *Peneroplis*, taken through the median plane between the lateral surfaces (Fig. I.), the central chamber is seen to have the

Fig. I.



Section of *Peneroplis*, parallel to its surface.

globose form which has been shown to characterize the primordial segment of the Foraminifera already described; from this first chamber *a single passage* leads to the second,

which communicates in like manner by a single passage with the third, as does the third with the fourth; the fourth chamber, however, communicates by *two passages* with the fifth, as does the fifth with the sixth, and the sixth with the seventh. In the septum between the seventh and eighth, with which the second whorl may be considered as commencing, there are *three* apertures; and this number continues for the four consecutive partitions which divide the chambers forming the next half-convolution. Then, however, commences a very remarkable increase; for whilst in each of the next two partitions there are *four* passages, the numbers in the four succeeding partitions which divide the chambers completing the second turn are respectively 6, 9, 11, and 14; whilst in the last eight partitions which divide the chambers of the outer half-whorl, the numbers of the apertures are respectively 14, 20, 26, 28, 30, 35, 44, and 48. The average distance of the apertures from each other remains nearly the same throughout; so that their number pretty closely corresponds with, and may be taken to represent, the length of the septal plane which they traverse in each case; and it is not a little remarkable, that whilst this number should only increase from 1 to 4 in the first convolution and a half, it should so rapidly augment from 4 to 48 in the last half-convolution.

128. As I have not been fortunate enough to obtain any other than dried specimens of this organism, I have not had the opportunity of examining the structure and arrangement of its soft parts. Such an opportunity, however, has presented itself to Professor EHRENBERG, who collected living specimens in his expedition to the Red Sea; and by treating these with dilute acid, he has freed the animal body from its enclosing shell, precisely as I was able to do in the case of *Orbitolites*. The figure* which he has given of the animal corresponds in every important particular with what an examination of the shell would lead me to expect; for it represents a series of segments of a generally-homogeneous substance, corresponding in form, dimensions, and connexions with the successive chambers of Fig. I. The only departure that I can discover from what I should myself have anticipated, lies in this—that the successive segments are connected along the inner margin of the convolutions by a band much broader and thicker than the threads which pass between other parts of the segments; so that this band would seem to establish a principal connexion, to which the other threads might be considered as secondary. Now after a very careful examination both of the septal planes of numerous specimens, and of sections taken in the direction of Fig. I, I feel myself justified in the positive assertion that no such principal aperture exists at the inner margin of each septum, as would be required to give passage to such a band as is figured by Professor EHRENBERG. Consequently I can only account for this feature in his delineation of the animal (the idea of a difference in the conformation of the shell being negatived by the precise correspondence between his figures of it and my own, as well as by my familiarity with the Red Sea type of *Peneroplis*), by supposing that, like some of his other figures, it rather represents his *idea* of the structure of the animal, than what he actually saw in

* Abhandl. der Konigl. Akad. der Wissenschaft. zu Berlin, 1838. Physik, taf. 2, fig. 1.

its body, this principal band being apparently regarded by him as an intestinal canal, by which he supposed all the segments to be connected together.—Professor EHRENBERG's figure represents a marking-out of spherules in the midst of the otherwise homogeneous substance of the body, closely corresponding to those which I have described in the animal of *Orbitolites* (¶ 43); and it also shows the skeletons of various Diatomaceæ imbedded in the substance of the four outer segments, as I have myself found them in *Orbitolites* (¶ 34). Consequently I can have no hesitation in the belief that the general structure and mode of life of these two forms are analogous; and that there does not exist in *Peneroplis*, any more than in *Orbitolites*, that hypothetical organization which Professor EHRENBERG has attributed to both.

129. *Monstrosity.*—The only example of monstrosity which I have met with in this type, is obviously analogous to the "monstrosities by excess" which I have described as not unfrequent in *Orbitolites*; consisting (at least apparently) in the formation of a secondary body by outgrowth or gemmation from the first. This secondary body does not seem, however, to have its origin in the primordial segment, to which similar outgrowths may always be traced in *Orbitolites* (¶ 62).

130. *Affinities.*—As regards its general organization and plan of growth, it seems clear that *Peneroplis* bears a very near approximation to that form of *Orbiculina* in which the later increase takes place like the earlier upon the spiral type (¶ 87), and in which there is but a single plane of chambers with a single row of marginal pores (¶ 90): the only essential difference, in fact, consisting in this, that each successive increment is formed in the case of *Peneroplis* by a continuous segment of sarcode, occupying an undivided chamber of the shell; whilst in the case of *Orbiculina* each segment is subdivided into sub-segments strung like the beads of a necklace on a continuous stolon of sarcode, the chamber being correspondingly subdivided by transverse partitions having a continuous passage through all. The very close alliance of the two forms is shown by the fact, that specimens are occasionally to be met with in collections of *Orbiculinæ*, which, while presenting the general physiognomy of that genus, exhibit the deficiency of transverse partitions which is the distinguishing character of *Peneroplis*; so as to render it uncertain whether such specimens should be considered as *Orbiculinæ* in which (as certainly happens occasionally in *Orbitolites*, ¶ 61) the usual partitions are deficient, or whether they truly belong to *Peneroplis*, their resemblance to *Orbiculina* being superficial only, and their presence among specimens of that genus merely accidental. In either case it is obvious that the affinity between these two types is very close; and in fact young *Orbiculinæ* frequently present such a strong external resemblance to *Peneroplis*, that their true nature cannot be determined without such an examination of their internal structure as will serve to disclose the transverse partitioning of their chambers. It may be fairly inquired whether the peculiar striation of the surface of *Peneroplis*, which so strongly suggests the idea of internal partitioning as to have led MONTFORT to assert its existence, is not really a rudiment of that structure.

131. *Varieties.*—The relationship just indicated being borne in mind, it will scarcely

excite surprise to find that *Peneroplis*, like *Orbiculina*, presents very considerable diversities of conformation. The first and simplest departure from what has been described as its typical character, consists in a duplication of the series of pores in each septum (Plate II. fig. 7 *a*), the spire being at the same time less compressed, so that the septal plane is wider in proportion to its length. Now it is not a little remarkable that this is almost uniformly the case with specimens furnished by particular localities, whilst those obtained from others not very remote exhibit almost as uniformly the extremest elongation and narrowing of the septal plane with only a single row of apertures; and hence it might not unreasonably be maintained that this difference should be accounted of specific value. In reply to this, however, there is not only the analogy of *Orbitolites* and *Orbiculina*, in which an indefinite multiplication in the rows of marginal pores may take place during the growth of the individual, but also the fact that in *Peneroplis* the two forms cannot be distinguished at an early age, either by the shape of the shell or by the disposition of the pores, which are often arranged neither in a single nor in a double row, but on a sort of mixture of both plans, as shown in Plate II. figs. 9 and 10; whilst among the more advanced examples of each type, it is not at all uncommon to meet with individuals which present a combination of the characters of both, the septal plane having a single row of pores in one part of its length with a double row in another. Sometimes, moreover, in one of the less compressed forms of the shell, although there is but a single row of pores, it is obvious from the elongated shape of these that they indicate a tendency to duplication (fig. 8). Moreover we find in the variety with a complete double row the same disposition as in the ordinary *Peneroplis* to the substitution of the rectilineal for the spiral mode of growth, as we see in fig. 7. Hence I consider that it may be unhesitatingly asserted that the duplication of the row of pores, and the increased turgidity of the spire which it accompanies, are but features of individual variation, and cannot be admitted to rank as specific differences. And in this view I am glad to find myself borne out by Professor WILLIAMSON, who defines *Peneroplis**, not (like M. D'ORBIGNY) as having only a single row of apertures, but as having "septal orifices scattered over the long narrow septal plane;" whilst his figure of *Peneroplis planatus* shows these orifices arranged for the most part in a double row, one portion having them even more multiplied.

132. What is the relationship to the typical *Peneroplis*, however, of that group of forms to which D'ORBIGNY has given the generic designation *Dendritina*, is a question of more difficulty. These are characterized, as we have seen, by the possession of a single large aperture sending out dendritic ramifications in each septum (Plate I. fig. 1, Plate II. figs. 12, 13); but this is by no means the whole of their differentiation. For the spire, instead of being compressed, is very turgid; and its successive whorls not merely surround but also invest those which have preceded them; so that what may be appropriately termed *alar prolongations* (*al*, figs. 12 *a*, 12 *b*, Plate II.) of the chambers of even the last whorl often extend nearly to the umbilicus. The geographical distribution

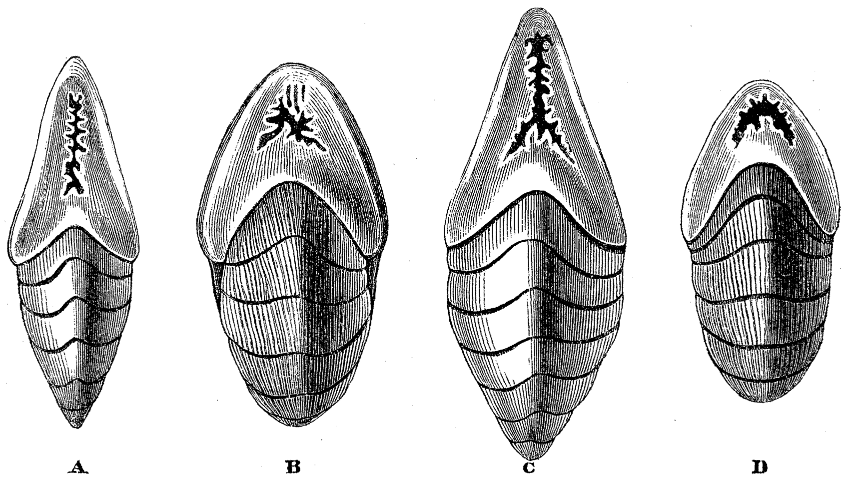
* The Recent Foraminifera of Great Britain, p. 44.

of *Dendritina*, moreover, is peculiar; for, so far as I am aware, this type is restricted to the tropical ocean. I have not met with it in dredgings from any part of the Mediterranean or the Red Sea, where *Peneroplis* abounds; while the largest specimens I have seen are those contained in Mr. CUMING's Philippine explorations, some of these measuring ·078 inch in diameter, and ·030 in thickness or breadth. To such as content themselves with glancing at strongly-marked examples of this type, the propriety of its generic, or at any rate of its specific separation from *Peneroplis*, would seem indubitable. Nevertheless I think that I shall be able to show adequate grounds for the belief, that the two forms cannot be separated by any definite line of demarcation; and that they must therefore be ranked as belonging not merely to the same genus, but even to the same species.

133. In the first place I would refer to the fact that the peculiar plication and punctation of the surface of the shell, which are such marked features in the physiognomy of *Peneroplis*, are repeated in *Dendritina* (Plate II. figs. 21, 22) in a manner so precisely similar, as strongly to impress every one who has his attention directed to the aspects of these two forms respectively, with the idea of their very close relationship.

134. Secondly, the differences of general configuration between *Peneroplis* and *Dendritina* are differences of *degree*, and present themselves in very variable amount in different individuals. For, starting from those forms of *Peneroplis* in which the spire is least compressed, the transition is easy to those *Dendritinæ* whose spire is least turgid, and whose septal plane is not broader in proportion to its length than it often is in *Peneroplis*. From the most compressed forms of *Dendritina* to those which have the most turgid spires and the widest septal planes, the gradation is insensible, scarcely any two individuals according in their proportions; thus we find that whilst the septal plane is sagittate in some (Fig. II. A, C), it tends to become reniform in others (B, D), the

Fig. II.



Front views of four specimens of *Dendritina*.

margin of the spire, which is almost carinated in the first case, becoming obtuse and even cresentic in the second. Again, the extent of the investment of the earlier whorls

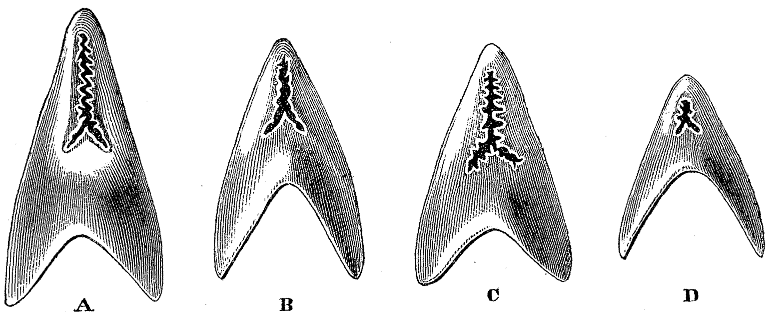
by the later, varies as much as the degree of turgidity; for whilst in some of the most compressed forms, as in *Peneroplis*, each whorl does little more than apply itself to the margin of the preceding (Fig. III. A, C), the more turgid the spire becomes, the more completely (generally speaking) does it embrace the preceding, the alar prolongations of the chambers thus coming to bear a large proportion to their principal cavity (Fig. III. B, D).

135. Thirdly, we observe in *Dendritina* precisely the same tendency to rectilineal extension in the later period of growth, as in *Peneroplis*; for although a distinct generic term *Spirolina* has been given to the form presenting this modification, I think it must be apparent to every one that the example delineated in Plate II. fig. 11, bears just the same relation to the typical *Dendritina*, that those shown in figs. 5, 7 bear to the typical *Peneroplis*. The transition from *Dendritina* to *Spirolina* is well seen in figs. 12, 13; in the first of which we see the last whorl apparently about to disengage itself from the earlier ones, whilst in the second that disengagement has been completed. I cannot conceive that any one could refuse to regard either of these specimens as a *Dendritina*; and yet it is obvious that their continued increase upon the plan which has already manifested itself in the formation of the later chambers, would convert them into *Spirolinæ*. Such continued increase has obviously taken place in the specimen represented in fig. 11, which, up to the time of the substitution of the rectilineal for the spiral mode of growth, has all the appearance of an ordinary *Dendritina*.

136. Still it may be said that, notwithstanding all these points of resemblance, the difference between *Peneroplis* and *Dendritina* is clearly marked out by the difference in the modes of communication between the chambers of the two types; and that such a difference is sufficiently important to constitute a valid generic character. I freely admit that this would be the case, if the difference were constantly to present itself between all the individuals of the same type, as it does between their characteristic examples (Plate I. figs. 1, 2); but the fact is far otherwise. We have seen that among those which would be unhesitatingly ranked under the designation *Peneroplis*, there is not only a tendency to multiplication of the rows of separate pores, but also an occasional fusion of two or more pores, so as to form a single large pore of irregular shape. On the other hand, among the unquestioned *Dendritinæ*, we observe not merely that the form of the single large dendritic aperture is extremely variable, but that it is frequently so simple as to suggest the idea of having been formed by the coalescence of a linear series of pores. The most characteristic forms of the dendritic aperture that I have met with, are shown in Plate II. figs. 12 *a*, 13 *a*; two examples of a remarkable departure from this have just been seen in Fig. II. B, D, where the proportions of the aperture are altogether reversed, its breadth being much greater than its length, and its central part being enlarged at the expense of its ramifications; while through such an aperture as that represented in Plate II. fig. 22, we are conducted back to the ordinary type, though its form is much simplified. On the other hand, in Fig. II. A, C, we have marked examples of a narrowing and elongation of the aperture, with such a reduction

of its dendritic ramifications, that it comes to present little more than a linear fissure. From a comparison of these cases, it will be seen that the form of the aperture bears a pretty constant relation to that of the septal plane; the broadest apertures presenting themselves in the individuals which have the most turgid spire, and the narrowest in those whose spire is most compressed; whilst the proportionate development of the two principal alar prolongations seems related to the degree of that alar extension of the chambers over the whorl they enclose, of which I have already spoken. But the most satisfactory proof of the wide extent of range of variation in the form of the aperture in *Dendritina*, is afforded by a comparative examination of the apertures connecting different chambers of the same individual. Thus in the interior of the very shell that presented the peculiarly characteristic example, Plate II. fig. 12 *a*, we find a form, *b*, closely corresponding to that shown in Fig. II. c; and in four septa of the inner part of another shell, we have the simple forms of aperture represented in Fig. III. A, B, C, D.

Fig. III.



Septal planes and apertures from different parts of the same specimen of *Dendritina*.

137. But further, not only do we thus meet with examples of each type which present more or less of approximation towards the other, but we also not unfrequently encounter individuals in which the characters of the two types are so blended that it is difficult, if not impossible, to say to which they should be referred. Thus in Plate II. fig. 8, we have a young specimen with a linear series of apertures, the marked elongation of which shows each to be formed by the fusion of two, whilst there is an additional pair precisely in the situation of the alar prolongations in fig. 12 *b*; and it is obvious that a longitudinal coalescence of these pores would produce an aperture exactly resembling that of fig. 12 *b*. Again, in another young specimen shown in Plate II. fig. 16, a partial fusion of the separate pores into a single dendritic aperture has actually taken place (fig. 16 *a*), whilst another broad aperture is seen just below this. In fig. 10 we see numerous pores, some small and rounded, others large and irregular, each of the latter being obviously formed by the coalescence of two or three of the separate pores; and it is evident that a closer approximation of the whole would produce a single large dendritic aperture. Other varieties of the same kind are presented in figs. 9 and 14. But a yet more remarkable example is shown in fig. 15; for here the coalescence has pro-

ceeded so far as to produce a number of separate branching apertures, and nothing is wanting but the removal of the line of shell which passes down the middle of the septum, to unite these into the most characteristic form of the single ramifying orifice. This individual, like the one represented in fig. 6, was already beginning to assume the *Spirolina* form, the rounded shape of the mouth showing that the spire has detached itself completely from the previously-formed convolutions: in figs. 4 and 11 *a* are shown the mouths of more advanced examples of the same type, which present such a combination of the large dendritic aperture of *Dendritina* with the isolated pores of *Peneroplis*, as to complete (in my opinion) the proof that no valid distinction can be drawn between these two types, either from the number, the isolation, the position, or the shape of the apertures in the septa. This conclusion will probably become less surprising than it may at first sight appear to such as are accustomed to the study of the more constant characters presented by the shells of Mollusca, when it is borne in mind that the apertures seem to have no other function than to give passage to threads of sarcode; and that it is the general character of the Rhizopod type, for such extensions of the substance of the body to be entirely destitute of constancy either as to position or number.

138. If the foregoing conclusion be admitted, it follows that not merely must the genera *Dendritina* and *Spirolina* be relinquished, but that both these forms must be regarded as mere varieties of *Peneroplis planatus*. From the circumstance that the *Dendritina*-type is found only in tropical seas, and that it attains a far larger size than the ordinary *Peneroplis*-type, whilst the latter seems to be almost starved out (as it were) in the Mediterranean,—presenting itself there under its humblest form, and scarcely extending itself at all into northern seas,—I am disposed to think that temperature has a considerable influence in producing these varieties. I should be far, however, from attributing the entire result to this agency alone, since we find *Peneroplis* presenting itself abundantly in tropical seas, along with *Dendritina*. But as it is in the Mediterranean forms that we meet with the extreme of flattening and with the most uniform singleness of the row of pores, whilst it is among the tropical forms that we find *Peneroplis* not merely attaining its greatest dimensions, but also presenting the closest approximation to *Dendritina* in the turgidity of its spire and in the arrangement of its septal apertures, it seems obvious that the development of this type of structure is favoured by a constantly high temperature; and further, that *Dendritina* may be regarded as the highest form, towards which *Peneroplis* tends in proportion as it is subjected to that influence.—As I have not had the opportunity of examining the fossil forms of this type, I am as yet unable to say how far the foregoing conclusions will be borne out by the phenomena which they present.

Genus OPERCULINA.

139. The collection of Mr. CUMING contains a large number of Nautiloid Foraminifera, differing considerably from one another not only in size and proportions, but also

in general aspect and particular features, yet having so many structural characters in common as to be obviously referrible to the same generic type. This type I shall designate, provisionally at least, as *Operculina*; since, although it does not correspond with the definition of this genus as given by its founder M. D'ORBIGNY, it is obviously related most closely to the fossil forms which have been described under that designation by M. D'ORBIGNY himself, as well as by MM. D'ARCHIAC and HAIME, and to the recent type described as *Operculina* by Mr. CARTER.

140. *History.*—The genus *Operculina* was created by M. D'ORBIGNY in 1825, for the reception of a group of Foraminifera bearing a strong general resemblance to *Nummulites*, but considered by him as differing from it in the extreme compression of its discoidal shell, in the smaller number of its whorls, in the non-investment of the earlier whorls by the later, so that the former remain apparent on both sides through the whole of life, and also in the form of the aperture, which is a transverse slit in *Nummulites*, but triangular in *Operculina*. The following is the definition of this genus given by him in his 'Foraminifères Fossiles de Vienne' (p. 117):—"Coquille libre, équilaterale, ovale ou discoidale, très comprimée, formée d'une spire non embrassante, régulière, également apparent de chaque côté, à tours contigus, et croisant très rapidement. Loges nombreuses, étroites, la dernière formant saillie de toute la largeur de la spire, à tous les âges percée d'une ouverture visible triangulaire, contre le retour de la spire." In his 'Cours Élémentaire de Paléontologie' (tom. ii. p. 197), he defines the genus by the following characters alone:—"Coquille comprimée à tours apparents, pourvue d'une ouverture triangulaire contre le retour de la spire." I think it necessary also to quote from the same work M. D'ORBIGNY'S definitions of three other genera nearly allied to *Operculina*; since, as will presently appear, the characters which he assigns to them are based on an entirely wrong idea of the distinctive features presented by their respective types.—*Nonionina.* "Coquille nautiloïde, pourvue d'une seule ouverture en fente transversale, non masquée, placée contre le retour de la spire."—*Nummulites.* "Coquille lenticulaire à tours embrassants, pourvue d'une ouverture en fente transversale, souvent masquée, contre le retour de la spire."—*Assilina.* "Ce sont des *Nummulites* dont les tours de la spire, ne rejoignant pas le centre, sont tous plus ou moins apparents." In the admirable Monograph of MM. D'ARCHIAC and HAIME*, the genus *Nummulites* is defined as follows:—"Coquille libre, symmétrique, orbiculaire, plane, discoïde, lenticulaire ou subglobuleuse, composée d'une lame calcaire pliée et enroulée suivant un même plan, criblée de pores ou canaux de trois grandeurs différentes, à tours plus ou moins serrés, plus ou moins embrassants, quelquefois simplement juxtaposés. Dans le jeune âge, le dernier est saillant; plus tard, les tours se rapprochent de telle sorte qu'à l'état adulte le dernier paraît se souder tout à fait à l'avant dernier. Canal spiral divisé par des cloisons transverses, plus ou moins nombreuses, percées à leur base, contre le retour de la spire, d'une ouverture linéaire transverse. Ces derniers caractères semblent s'être atténués vers la fin de la vie de l'animal" (p. 70). The genus *Nonionina* is said by these

* Description des Animaux Fossiles du Groupe Nummulitique de l'Inde. Paris, 1853.

authors to differ from *Nummulites* in respect of its flatter form, the comparative shortness of its spire, the smaller number of chambers, and the non-embrace of its convolutions; as also in absence of that narrowing of the later convolutions which leads to the entire closure of the spire in *Nummulites.* The genus *Operculina* is said (*loc. cit.*) to be distinguished from *Nummulites* only by the depression of its form, the small number of its convolutions, and the rapid increase in breadth of the last whorl, which seems constantly to remain open. The genus *Assilina*, having no sufficiently distinctive characters, must (according to these able investigators) be merged in *Nummulites.*—It is obvious, from these remarks, that MM. D'ARCHIAC and HAIME had fully recognized the two fundamental errors of M. D'ORBIGNY'S definition of *Operculina*; viz. his statement that the convolutions are non-embracing, and his description of the form of the aperture as triangular. And although Mr. CARTER* does not allude to the discrepancy between the structure of the recent type described by him and the generic definition of M. D'ORBIGNY, yet it is evident that in assigning to it the designation *Operculina* he was guided rather by its general resemblance to the fossils on which that generic name had been conferred, than by the conformity of its structure to M. D'ORBIGNY'S definition. The errors of that definition are easily accounted for; since it is only by such an examination of thin transverse sections as M. D'ORBIGNY (I have reason to believe) never made, that the fact of the earlier whorls being really embraced by the later, notwithstanding the apparent freedom of the latter, can be substantiated; and the determination of the form of the aperture is very likely to be erroneously made, when the examination is limited to fossil specimens, in which it is frequently but very indistinctly traceable.

141. The minute structure of this type has been already investigated by two excellent observers. Under the designation of "an undescribed species of *Nonionina*," Professor WILLIAMSON† has given an account of the structure of a shell abounding in the Manilla sand, which, not merely from his figures and descriptions, but from a comparison of the specimens which he has kindly enabled me to make, I know to be one of the smaller forms of the Philippine *Operculina*. Mr. H. J. CARTER‡ has still more minutely described the organization of an *Operculina* which he obtained in great abundance on the south-east coast of Arabia, the shells coming up attached to the grease of the sounding lead from sandy bottoms of between ten and twenty fathoms depth; and of the identity of this with a larger form of Philippine *Operculina* I am enabled to speak, from comparison of specimens which Mr. CARTER has obligingly transmitted to me. I find the description of each to be in the main correct so far as it goes, but to be defective in some essential particulars. Thus Professor WILLIAMSON does not notice the canal-system except in the marginal cord; and Mr. CARTER, though he has more fully described the canal-system, has not only missed one important part of it, but has misapprehended the structure of the marginal cord. The investigations of each, moreover, have been limited

* Annals and Magazine of Natural History, Sept. 1852.

† Transactions of Microscopical Society, First Series, vol. iii. p. 112.

‡ Annals and Magazine of Natural History, Sept. 1852.

to one particular form of this protean type; and neither seems in the least degree aware of its extraordinary tendency to variation. The rich store of material placed at my disposal by Mr. CUMING has not only enabled me to prosecute my inquiries into the minute structure of this organism upon specimens of unparalleled size and degree of development, but has also enabled me to bring together a great body of data for comparison as to the extent of variation which it may undergo, alike in external conformation and in internal organization. And as the information hence obtained has a most important bearing upon the study of the closely-allied genus *Nummulites*, I venture to think that, notwithstanding all which has been done by Professor WILLIAMSON and Mr. CARTER, it is desirable that I should give a detailed account of my own investigations into the structure of *Operculina*, as well as a summary of the results of my comparison of its multiform varieties. It will be advantageous in the first place to examine into what appears to be the characteristic structure of the type, and then to inquire into the degree of modification to which this may be subject on each point.

142. *External characters.*—A large proportion of Mr. CUMING's specimens accord in their general aspect with the one represented in Plate III. fig. 7, which is closely conformable to Mr. CARTER's type of *Operculina Arabica*, except in its somewhat larger dimensions. It is a compressed spiral of about ·25 inch in diameter, and about ·015 inch in thickness, consisting of between three and four convolutions gradually increasing in breadth; these are in general nearly flat, but are sometimes a little arched between their inner and outer margins, sometimes depressed so as to present a slight concavity, especially near the outer margin of the last whorl. The chambers are about seventy-five in number, commencing from a primordial spheroidal cell and progressively increasing in dimensions with the widening of the spire; their septa have for the most part a radial direction, but they bend backwards near the outer margin of each whorl; and they are marked externally by bands which are distinguished by their semitransparent aspect from the dull brownish hue of the general surface. These septal bands are commonly on the same plane with the intervening portions of the shell; but sometimes the walls of the chambers are a little arched between the septa that bound them, so that the septal bands are slightly furrowed; whilst the walls of the chambers are sometimes a little depressed, so that the septal bands are prominent; and such varieties may present themselves in different parts of one and the same shell. Not unfrequently the whole surface is seen to be marked by very minute punctations; but more commonly they are larger and fewer in number, and are often arranged in pretty regular lines parallel to the septal bands,—one, two, or three rows of such punctations being seen on the wall of each chamber (Plate V. fig. 7); these punctations, when sufficiently magnified, are found to be spots of semitransparent shell-substance resembling that of the septal bands; and, as in the case of these, their surface is sometimes on the same plane with that of the general surface of the shell, sometimes a little elevated so as to form papillæ, and sometimes a little depressed into minute fossæ (fig. 8). These punctations often present themselves abundantly on some parts of the surface, whilst they are entirely absent from others. Sometimes, instead of a limited number of comparatively large and

regularly arranged punctations, we find a vast number of very minute papillæ, scattered without order over the entire surface of the chambers (fig. 6); these, again, may be absent from some parts of a shell, over other portions of which they are abundantly distributed. There is commonly a large semitransparent tubercle at the umbilicus, and smaller tubercles are often seen along the septal bands, especially of the earlier whorls: the umbilical and the septal tubercles are well seen in Plate III. fig. 6, and (less characteristically) in several other figures of the same Plate; and the septal tubercles are shown on a much larger scale in Plate V. fig. 11. Not unfrequently, however, the umbilicus is depressed, instead of being elevated into a tubercle; and the moniliform tubercles along the septal bands are wanting.

143. The departures from this typical form, however, are very wide. A glance at any considerable aggregation of specimens reveals to us an extraordinary variety of size and shape; and our attention is specially attracted by a series of which an example is represented in Plate III. fig. 9, which are not merely distinguished by a size greatly above the average—their long diameter reaching nearly ·4 inch,—but also by the extraordinary flattening of the later convolutions, and the rapidity with which the spire opens out. The approximation between the two lateral walls of the chambers is here so close, that not only are the septal bands rendered very prominent by the depression of the outer surface between them, but even the outer marginal band stands up as a ridge, from which the walls of the chambers slope down. In fact, an examination of this form leaves the observer impressed with surprise that any room can be left for the animal, the segments of which must be extraordinarily attenuated, losing in thickness what they gain in area. Now a careful comparison of this form with the ordinary type, not only makes it obvious that the former differs from the latter in no other particular than this attenuation, which (as already pointed out in the cases of *Heterostegina* and *Peneroplis*) is a common feature of the later growths in Foraminifera, but also that the attenuation takes place in such different degrees in different individuals, that any attempt to use it as a differential character is completely baffled by the continuous gradation of forms that is presented, between the one which has been assumed as the typical, and such as most widely depart from it in this particular.

144. The collection of Mr. Cuming also includes, however, a considerable proportion of comparatively small specimens, ranging from ·08 to ·20 inch in diameter, which present a very different configuration. In the smallest of these, represented in Plate III. fig. 1, the spire, instead of being flat or even somewhat hollowed, is arched from its inner to its outer margin, so that the breadth of the septal plane is equal to its length, or nearly so; and the like is seen in the somewhat larger specimens of which fig. 2 is an example. This variety of conformation, however, being limited to shells whose earlier period of growth is evinced by their smaller number of convolutions and of chambers, and being seen, moreover, in the earlier whorls of those which afterwards present the greatest flattening, may safely, I think, be regarded as a character of age. It will be recollected that the young of the flattened *Peneroplis* more resembles *Dendritina* in the comparative turgidity of its spire; but I do not find that *Operculina* ever continues long

to increase upon such a plan; for the compression of the spire always shows itself in the third whorl, if it has not previously done so, and is accompanied with a corresponding augmentation of its breadth, so that the septal plane becomes narrowed and elongated, as is seen in comparing fig. 4 with fig. 3. That no basis for specific distinction is afforded by the most marked differences in the form of the spire, as shown in the proportions of the septal plane (A, B, C, D), will be made evident by the examination of such a transverse section as is shown in Fig. V. (p. 21); in which it will be observed that differences equal to those presented by the most compressed and the most turgid forms of the spire, are exhibited by the successive convolutions of one and the same individual.

145. Another marked feature of difference among the specimens of this collection, is the depression or elevation of the central region relatively to the peripheral. In what I have assumed as the typical form, the central region presents the same general level with the rest, though the umbilicus itself is often marked by a prominent tubercle. In such forms as are represented in Plate III. figs. 1 and 2, the umbilical region is rather depressed than elevated; and this depression is often observed in older specimens whose early growth has taken place on this type. But there is a group of specimens, of which three successive ages are represented in Plate III. figs. 3, 4, 5, 8, that have the whole central region so exceedingly prominent as to form a cone, whose apex is marked either by one large tubercle, or by a cluster of smaller ones; and this conformation gives so peculiar a physiognomy to the shells which present it, that few systematists would hesitate in placing them apart as specifically different from the rest. On a careful comparison of a large number of individuals, however, it becomes apparent that this difference, like the preceding, is gradational; every degree of prominence being traceable from the individuals which have the umbilicus marked only by a tubercle, as in fig. 7, through those in which the region generally is slightly elevated, as in fig. 8, to those in which it presents the most marked projection, as in figs. 3–5. We shall presently find (¶ 153) that this difference depends mainly on the degree in which the investing layer, prolonged from the later convolutions over the surface of the earlier, is separated from that surface by the extension of the alar prolongations of the chambers of the investing whorls; as to which point there is a most remarkable diversity, not only among different individuals, but between the several convolutions of the same individual.

146. A fourth very obvious character of differentiation among the individuals of this collection, consists in the presence or absence of tubercles on the septal bands. In what I have described as the typical form (Plate III. fig. 7), there are no considerable prominences over the greater part of the surface; the septal bands are generally smooth and continuous; and it is only in the central region that we observe any departure from this uniformity, the umbilicus being occupied by a small tubercle, and the smooth septal bands being replaced in the first whorl by moniliform rows of little tubercles. In other instances, however, we find not only the central tubercle, but the rows of tubercles marking the septa, much larger and more prominent; and this marking-out of the septal bands by elevated tubercles is not limited to the first whorl, but extends to the second, and even to the third, as is well shown in fig. 6. The specimens whose central region is

very prominent (Plate III. figs. 3, 4, 5), usually show this feature in the most decided manner; but it is occasionally presented also in no less a degree by those whose umbilicus is flat or even depressed. The most remarkable departure from the ordinary type is seen in a small group of specimens in which the tubercles are not only extremely large and prominent (Plate IV. fig. 6), but are distinguished by their opaque whiteness (Plate V. fig. 12), which contrasts strongly with the semi-transparency ordinarily characterizing these prominences. But even this character has no diagnostic value; for a specimen which has the tubercles opaque in one part may have them semi-transparent in another; and as to the size of the tubercles, their degree of prominence, and the proportion of the entire spire over the septa of which they occur, there is every degree of variety. In one of my largest and flattest specimens, the central region is strongly tuberculated, but the tubercles almost suddenly cease when the spire begins to open out, and the septal bands are thenceforth as smooth as in the ordinary type.

147. A less obvious but still very decided feature of individual difference, consists in the presence or absence of papillary elevations *between* the septal bands. I have already spoken (¶ 142) of the frequent existence of symmetrically arranged spots, sometimes slightly depressed, but more commonly elevated, that are distinguished from the rest by the semitransparency of their shell; these spots are sometimes considerably enlarged, and their elevation increased, so that they become prominent papillæ, closely resembling the tubercles upon the septal bands. Their size and disposition vary considerably. Sometimes they are small, numerous, and scattered without any definite arrangement over the entire surface of the wall of the chamber, whilst in other cases they are considerably larger, and form single, double, or even triple rows between the septal bands (Plate V. fig. 10). Another remarkable variety of external aspect is produced by the elevation of the general surface into rounded eminences closely abutting on one another (like the pustules of the skin in a case of confluent small-pox), and distinguished from the preceding by the absence of any peculiarity in the texture of the shell. That these and other analogous variations of surface-marking have no value as differential characters, is at once demonstrated, not merely by their gradational approximation in different individuals, but by the fact that they are presented in very different degrees on different parts of the surface of the very same shell; the chambers of one part of the spire being strongly marked by certain of these peculiarities, whilst those of another may only present indications of them, and those of a third may be perfectly smooth.

148. The collection of Mr. Cuming, however, contains a group of forms which are at once distinguished from the rest by their general physiognomy (Plate III. figs. 11, 12), and which, when their characters are examined in detail, appear to be separated from them by well-marked differences. Their aspect is much more lustrous, and their hue much whiter, varied, however, by a tinge of green diffused in irregular patches; the spire does not in the largest specimens make above three turns, and it begins to open out sooner than in the type already described; the septa are usually considerably more convex anteriorly, and are also rather more distant from each other, so that the interval between them is greater in proportion to the breadth of the spire, the shape of the

chambers being thus modified, and the number of chambers in each whorl being diminished; the septal bands, not merely of the earlier whorls, but even of the last-formed portion of the shell, are raised into prominent tubercles; and multiple rows of large tubercles are seen between the septal bands. It is to this multiplication of smooth tubercles composed of a variety of shell-substance which reflects light much more strongly than the rest, that the more glistening aspect of this type is chiefly due; and I have not met in it with any instances of that general brownish coloration of the surface which is the ordinary characteristic of the other. The most constant and remarkable distinctive feature of this type, however, is the presence of a large hemispherical cluster of semitransparent tubercles in the centre of the spire (Plate III. fig. 10).

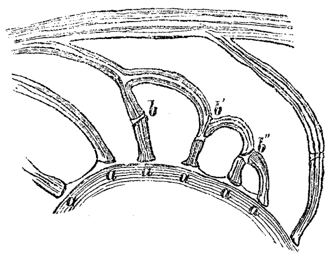
149. Having had no difficulty in setting apart a large number of specimens agreeing very closely with each other, and differing from the rest, in all the foregoing characters, I should have arrived at the unhesitating conclusion that this type deserves to take rank as a species of *Operculina* distinct from the preceding, were it not for the circumstance that every here and there I met with an example in which the differential characters were less strongly marked than usual. Thus in some individuals which preserve the general proportions of the spire, the green coloration is wanting, the large central cluster of tubercles is replaced by a single tubercle of extraordinary size, the septal bands of the neighbourhood are not more tuberculated than in many examples of the ordinary type, and the rows of tubercles over the chambers are either wanting altogether, or are not more prominent than in many individuals of the preceding type. This evidence of the negative value to be attached to the number or prominence of the tubercles as a specific character, is confirmed by a curious fact of an opposite nature; namely, that in certain individuals we find them developed to an extraordinary and obviously abnormal degree (Plate V. fig. 9).—From the difficulty of deciding to which type particular specimens are to be referred, I had been almost led to adopt the conclusion of the specific identity of this with the ordinary form; when Dr. GOULD, of Boston (N. E.), kindly placed in my hands some *Operculinæ*, which had been collected on the coast of Japan by the recent American expedition to that country. These specimens combined in so remarkable a manner the most distinctive features of the two types, —namely, the general form and proportions of the one, with the umbilical hemispheric cluster of tubercles and the general abundance of tubercular elevations characteristic of the other,—as to remove all doubt from my mind with regard to their specific identity.

150. *Internal Structure.*—The study of the internal organization of *Operculina* may be prosecuted in two modes;—by the examination, under sufficient magnifying powers, of thin transparent sections taken in different directions;—and by viewing under a low power, as opaque objects, fragments obtained by breaking the shell, especially (as Mr. CARTER was the first to suggest) after these have been allowed to absorb carmine or indigo by being placed upon water in which either of these colours has been rubbed up. By the former method alone can certain minutiæ of structure be detected; but the latter is extremely serviceable (as I found in my study of *Nummulites*, op. cit.) in enabling the observer to trace out the relations of various parts, which sections exhibit to him

disconnected from one another. In Plate I. fig. 3, an attempt is made to bring together in an ideal representation the most important features of the internal structure of *Operculina*, as disclosed by these two methods of examination; the warranty for all its details being supplied by the delineations of the separate parts that are given in other figures, which are all taken from preparations in my possession.

151. Owing to the circumstance that large specimens of *Operculina* are rarely if ever quite flat, it is next to impossible to make a section through the median plane that shall traverse all the whorls to the central cell; a sufficiently near approach to this, however, has been made in the section represented in Plate VI. fig. 3, and Plate IV. fig. 10, to bring into view the general disposition of the chambers. This is much less regular than would be supposed from a superficial examination of the exterior. For while there is a certain general average in the proportion which their long diameter (that is, the breadth of the whorl) bears to the short (or distance between the septa), which may be stated as about $4\frac{1}{2}$ to 1, this is by no means constantly maintained, the long diameter being sometimes as much as 7 times, and sometimes no more than $2\frac{1}{2}$ times, the short. The ordinary course of the septa, too, is often strangely departed from, as is seen in Plate VI. fig. 3. There are few individuals which do not present—besides abnormal sinuosities, greater or less in degree—very marked irregularities in the conformation of the chambers, analogous to those which I have described in *Nummulites* *. Frequently a septum, instead of passing continuously from the inner to the outer margin of the whorl, stops short without reaching the latter, and bends backwards to join the last-formed septum; and sometimes a second septum unites itself to the first in the same manner, as shown at *a*, Plate VI. fig. 3. The abortion is often still more marked; thus at *b* we see three septa thus interrupted, of which two do not traverse half the distance, and the third not a quarter, thus dividing the space between two complete septa into four small chambers along the inner margin, and one large irregular chamber extending to the outer. Another case of the same kind is seen in an earlier part of the same whorl; and in Fig. IV. an additional illustration on a larger scale is given of the like irregularity, for

Fig. IV.



Irregular disposition of septa in *Operculina*:—*a, a, a,* normal apertures at inner margin of spire; *b, b′, b″*, apertures of communication between abnormally divided chambers.

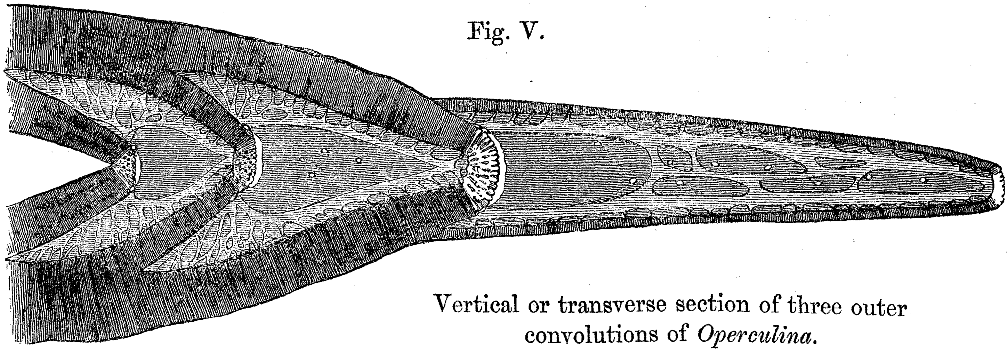
the purpose of showing the arrangement of the communicating passages. Generally speaking, the more nearly we approach the centre of the spire, the more regularly do we find the septa disposed, until we come into close proximity with the central cell.

* Quarterly Journal of the Geological Society, vol. vi. 1850, p. 23.

In Plate IV. fig. 5 we have an illustration of what may be considered the normal mode of commencement of the spire; from which it will be seen that it originates, as in Foraminifera generally, in a spheroidal cell, from which others are successively developed around it, the earlier chambers having no very definite shape, but those which succeed them gradually coming to assume the characteristic form and proportions. The like is shown in vertical section in Fig. VII. B.

152. Each chamber communicates with the neighbouring chamber on either side, by a long narrow crescentic fissure left by the non-adhesion of the septum to the outer margin of the preceding whorl (Plate I. fig. 3). This fissure (Figs. IV., VI. *a*, *a*, *a*) is frequently not to be seen in such a section as is represented in Plate VI. fig. 3, owing to the circumstance that this does not happen to pass through the plane in which it lies; and it is best brought into view either by making thin transverse sections (as Fig. V.), or

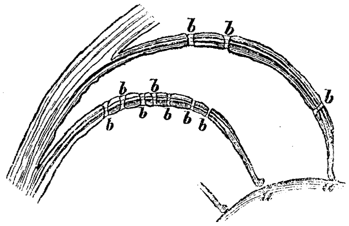
Fig. V.



Vertical or transverse section of three outer convolutions of *Operculina*.

by breaking a specimen transversely and examining its fractured edges, by which such views will be obtained as are presented in Fig. VIII. (p. 26) A, B, C, D. Besides this principal aperture, we observe in the septa, especially of the larger chambers, a variable number of secondary pores (Plate I. fig. 3 *e*), generally circular, and of comparatively small size; these are dispersed without any regularity, as is shown in Figs. V., VI., VIII. They may or may not be brought into view in a horizontal section, according as its plane does or does not happen to pass through them; but when they are thus traversed (Fig. VI. *b*, *b*, *b*), it is seen that these secondary pores, like the principal aperture, establish a direct communication between adjacent chambers*. In the irregular formation repre-

Fig. VI.



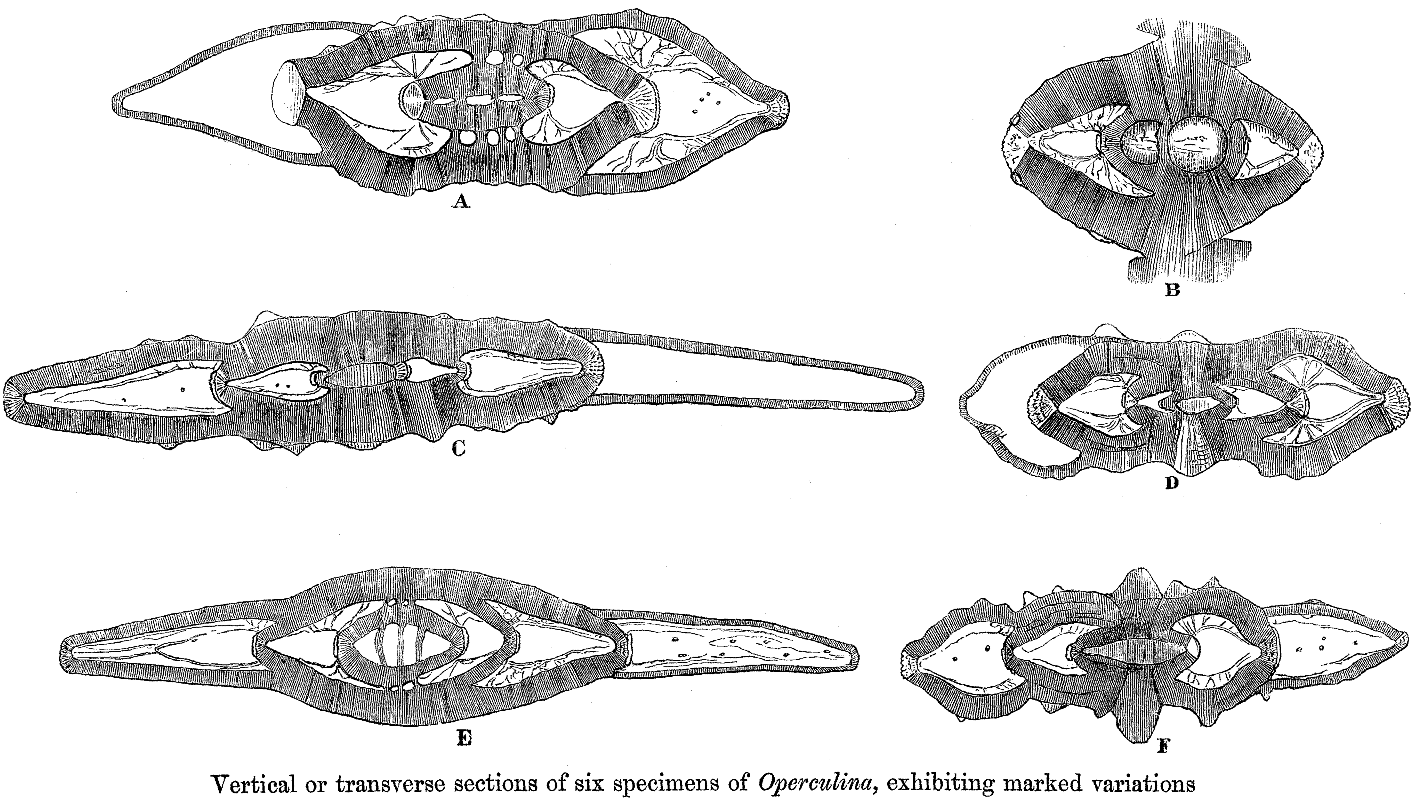
Section of two septa of *Operculina* through the median plane, showing the secondary pores, *b*, *b*, *b*, in addition to the principal orifices, *a*, *a*, at the inner margin of the spire.

* These secondary pores were first observed by me in *Nummulites lævigata* (*op. cit.* p. 24); I then believed, however, that they do not pass through both layers of the septa, but only establish a communica-

sented in Fig. IV., these secondary pores (b', b'', b''') present a disposition which would seem to indicate that they are scarcely less important for the maintenance of the communication between the chambers, than is the principal aperture itself; and it is curious to observe how exactly they repeat at b' and b'' that mode of communication—between *two* segments on the inner side and *one* on the outer—which is so characteristic of *Orbitolites* (¶ 17) and *Orbiculina.* Each septum, as in *Cycloclypeus* and *Nummulites*, is composed of two layers (Plate I. fig. 3 *d*, *d*), each being the proper wall of one of the chambers which it separates; these layers are commonly in close apposition with each other; but they separate at certain spots, to give passage to the very curious system of interseptal canals to be presently described.

153. A comparison of numerous vertical sections brings into view a most remarkable variety in the form and disposition of the chambers, not merely in different individuals, but in different parts of the same individual. Commencing with one of the flattest variety, Fig. VII. c, we observe that the breadth of the septal plane is very small in comparison with its length; and that although the spiral lamina of each whorl except the last obviously extends itself over that of the preceding whorls, the cavity of the cham-

Fig. VII.



Vertical or transverse sections of six specimens of *Operculina*, exhibiting marked variations in the form and proportions of the convolutions.

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tion between the chambers and the interseptal passages. In this idea I am now satisfied, by the examination of *Operculina*, that I was in error; and I am disposed to regard these secondary pores of *Nummulites* and *Operculina* as representing the multiple communications between the chambers of *Peneroplis* (¶ 127).

bers is not so extended, those of each whorl being bounded internally by the external margin of the preceding. Passing from this, however, to forms which are slightly elevated in the centre (Fig. VII. E), we find not only that the breadth of the septal plane is increased, but that the cavity of each chamber is extended into two *alæ*, which are more or less prolonged over the enclosed whorls; so that the spiral lamina of the investing whorl is kept by their interposition from coalescing with that which it embraces, except in the central region. The degree of this extension, however, varies in different convolutions; the alæ being usually smaller in the chambers of each consecutive whorl, and being absent altogether from those of the last,—a transition well shown in Fig. V., which also exhibits the marked variation in the general proportions of the chambers that may present itself between the inner and the outer whorls. In forms which are distinguished by a yet more turgid spire, the proportions of the chambers are very considerably modified; but among these there is a very considerable difference in the degree in which the chambers of the later whorls are prolonged over the earlier; thus in Fig. VII. A, whose centre is on a level with the rest of the spire, we see the alæ prolonged so as quite to reach that region; whilst in D and F, which have the central region depressed, though the general proportions of the chambers correspond with those of the preceding, the alæ are so little extended that the spiral laminæ of the successive whorls coalesce not only at the centre, but at some distance around it. After an attentive examination and comparison of a great number of vertical sections, I feel justified in affirming that no importance can be attached either to the form and proportions of the chambers, whether shown in the relative length and breadth of the septal plane, or in the degree in which their alæ are prolonged over the enclosed whorls, as furnishing characters of specific difference; seeing that it is not only found to vary gradationally when a sufficiently large series of specimens is compared, but that it is often equally inconstant in different parts of the same individual.

154. The spiral lamina, in typical specimens, is much thicker in the inner than in the outer convolutions, that of the last whorl being always comparatively thin (Fig. V.); and a careful examination of transparent vertical sections makes it apparent, that the greater thickness of the spiral lamina of the earlier whorls is partly due to the prolongation of that of the later whorls over them, and to its coalescence with them. I have not been able to satisfy myself that the spiral lamina of the last whorl is thus extended over the preceding whorls; and it has rather appeared to me to be merely applied to the margin of that which it surrounds. The difficulty of certainly determining this point, chiefly arises from the circumstance that the spiral lamina of the last whorl is reduced in thickness in proportion to its extension, as if in consequence of a limitation of the amount of calcareous matter employed in its formation. The spiral lamina is made up of a variable number of lamellæ of a minutely tubular substance (Plate IV. fig. 9), so exactly corresponding with that which I have already described in *Nummulites* (*loc. cit.*) and in *Cycloclypeus*, that any detailed description of it is unnecessary. I have to add, however, that in examining extremely thin transverse sections of this tubular shell-substance with a sufficiently high magnifying power, I have been able to perceive that the

orifices of the tubuli are separated by a very delicate areolation (fig. 9 *b*), as if the whole substance were composed of an aggregation of prisms with a tubulus in the centre of each. And this circumstance appears to me to afford the explanation of an observation which I have elsewhere recorded in regard to certain fossil specimens of *Nummulites* (*loc. cit.*),—namely, that where the characteristic tubular structure is wanting, an appearance of prismatic structure is occasionally presented*; for it is not by any means difficult to conceive that the same molecular change which obliterates the one feature, should bring the other into increased distinctness. The size of the tubuli of *Operculina* is much greater at and near the inner surface of the walls of the chambers, than it is at a little distance from them, as will be seen by comparing figs. 1 and 3 of Plate IV. with figs. 2 and 4; so that when a thin lamina from the innermost part of the wall is examined under a high magnifying power, the tubes are seen almost to fill the areolæ, as is shown in Plate IV. fig. 9 *a*, which is drawn on the same scale as *b*.

155. As is *Nummulites* and *Cycloclypeus*, the shell-substance over the septa is not penetrated by tubuli, and is consequently far more transparent than the rest; and it is in consequence of this difference in texture, that the septal bands are so strongly marked on the external surface, as well as in sections parallel to it (Plate IV. figs. 10, 11; Plate VI. figs. 1, 2). The same is true, also, of the substance of the tubercles, whether occurring as elevations of the septal bands, or upon intermediate parts of the spiral lamina. In the latter case, the tubercles are seated upon inverted cones of the like substance, which do not usually reach down to the inner lamina, so that the internal surface presents the orifices of the tubuli regularly disposed over the interior of the chambers (as seen in Plate IV. figs. 1, 3), even where sections passing at a little distance from these show rounded or elongated spots of transparent substance (figs. 2, 4), around which the tubuli are crowded together, as if they had been displaced by its interposition. Such spots occasionally present themselves in the ordinary type of *Operculina*, as seen in Plate IV. fig. 10; but it is of course in sections of the strongly-tuberculated variety that we find them most marked, and this especially in the investing layers of the central region, where, from the size and approximation of the tubercles, the spaces between them are rendered almost opaque by the crowding together of the tubuli (Plate IV. fig. 11). The tubuli are generally seen, moreover, to be somewhat more crowded in the neighbourhood of the septal bands.—The greatest local development of the non-tubular substance is seen in those varieties which have a large elevated tubercle in the centre (Plate III. figs. 3–5); a section of such a variety has been shown in Fig. VII. D, where it is seen that this tubercle springs from the spiral lamina of the

* As MM. D'ARCHIAC and HAIME, in referring to my statement as to the appearance of prismatic structure in *Nummulites*, would appear to entertain some doubt as to the correctness of my observation (see p. 61 of their Monograph), I think it right not merely to say that fig. 12, Pl. IV. of my Memoir on Nummulites is a most exact representation of a section still in my possession, but also to mention that the vertical fracture of well-preserved specimens of *N. lævigata* often presents an edge so strongly resembling that of the prismatic shell-substance of *Pinna* when fractured in the same direction (though on a much smaller scale), as to have led experienced microscopic observers to a belief in their similarity, before my discovery of the minutely tubular structure of *Nummulites*.

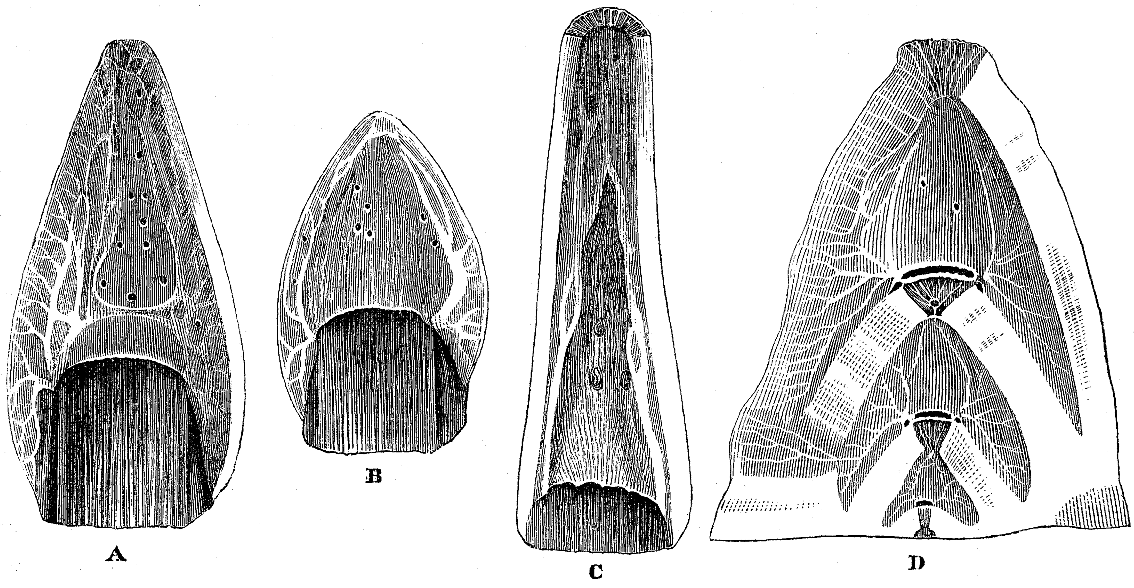
innermost convolution, but that it increases in diameter as it is built upon (so to speak) by each of the whorls by which this is subsequently invested.

156. The texture of the shell-substance which bounds the chambers at the outer margin of each whorl, however, presents a marked departure from that of the spiral lamina; a difference analogous to that which was first indicated by me in *Nummulites* (*loc. cit.*), and which has been found by MM. D'ARCHIAC and HAIME to present itself so constantly in that genus, that they give to this marginal portion the special designation "bourrelet." Mr. CARTER has already recognized in *Operculina* the speciality in the structure of this part of the shell; but he has fallen into what I believe to be an error in his interpretation of that structure, describing it as made up of an aggregation of fusiform spicules, and hence designating it as "the spicular cord." Now I am very familiar with the appearance which has led him to take this view of its nature, since it is one which is commonly presented by thin sections that pass either through the median plane or parallel to it, as shown in Plate IV. fig. 13; but this is only one out of many aspects which are presented by sections taken in various directions; and a comparison of the whole seems to me to lead to quite a different conclusion,—namely, that the supposed spicular composition of this "marginal cord" (as it may be appropriately termed) is due to the peculiar manner in which the homogeneous substance of which it is composed is traversed by the set of canals that are correctly described by Mr. CARTER as forming the "marginal plexus." For if the section should happen to traverse a portion of this plexus in which the canals form a tolerably regular network of elongated meshes in one plane, the appearance delineated in fig. 13 is presented; but just as often a less complete layer of the network is traversed by the section, and the form of the meshes is very inconstant, so that the appearance presented is rather that shown in fig. 14. Moreover the appearances exhibited by transverse sections of this marginal cord, highly magnified (figs. 15, 16), do not at all confirm the idea of a spicular arrangement, but are altogether conformable to the view I have expressed; the most complete confirmation to which is afforded by tangential sections, of which a very successful example,—giving a beautiful view, not only of the canal-system of the "marginal cord," but also of its communications with that of the septa, and of its relations with the two principal spiral canals to be presently described,—is represented in Plate IV. fig. 12. In this it is clearly seen how irregular is the disposition of the inosculating passages, whilst there is not a trace of the spicular structure, which ought, if it existed, to be as well brought into view in a section taken in this direction, as it is in the one shown in fig. 13, which is taken in a plane at right angles to it. The "marginal cord" is traversed on its external surface by longitudinal furrows, which are sometimes very shallow (fig. 15), but sometimes dip down deeply like those between the convolutions of the brain, as shown in fig. 16. These furrows usually form a kind of network with fusiform interstices (Plate V. fig. 5), whilst in other cases they run parallel to each other and inosculate more rarely (fig. 4). From the correspondence between their arrangement and that of the passages in the interior, I am inclined to think that they belong to the same system with these, being, in fact, canals not covered in by shell-substance, that communicate

with the plexus within by inosculating branches, whose apertures may sometimes be detected in the bottom of the furrows. This furrowed surface of the marginal band, and the existence upon it of apertures communicating with a set of canals in its substance, were specially pointed out by me in *Nummulites* (*loc. cit.*), although the changes produced by fossilization prevent the full extent of the "marginal plexus" from being traced out in that genus. The general relation of the marginal cord (*a a*) to the two spiral laminæ (*b*, *b*) with which it unites itself to form the boundary of the chambers, as seen in Plate IV. figs. 15, 16, is precisely the same in *Operculina* as in *Nummulites*.

157. The "marginal plexus" of canals communicates freely with the system of "interseptal canals," which are disposed between the two layers of the septa, as I have described in *Nummulites* and in *Cycloclypeus*, and the existence of which in *Operculina* has been already indicated by Mr. CARTER. The distribution of these is well seen, not only in vertical sections which have happened to traverse the septa, as in Figs. V., VII., and in Plate IV. fig. 8, but also in specimens laid open by fracture in the same direction, especially after the canals have been more distinctly marked out by the imbibition of a colouring liquid (Fig. VIII., and fig. 2, Plate V.). It will be seen from these delineations, all of which are faithfully copied from specimens in my possession, that the distribution of the interseptal canals, whilst presenting a certain general uniformity of plan, is by no means constant in detail. In Figs. VII. A, and VIII. D, we see two principal trunks passing from the two angles of the fissure at the interior edge of each septum, towards the marginal band at its exterior (as in fig. 2 *d*, Plate VI.), and sending out branches which ramify over the part of the septum that joins the spiral lamina (Fig. VIII. D), leaving the intervening portion untraversed; and this is the only arrangement which has been described by Mr. CARTER. But on looking at the other figures, it

Fig. VIII.



Septal planes of four specimens of *Operculina*, showing varieties in the disposition of the interseptal canals.

will be seen that much variety presents itself; thus in Fig. VIII. A (as in fig. 2, Plate V.) we observe two or more such trunks proceeding from each angle of the fissure, those of the same side frequently inosculating with each other; in Fig. VIII. C (as in fig. 8, Plate IV.) the two principal trunks on the opposite sides inosculate as they approach one another in their course towards the outer margin of the septum; and in Fig. V. (page 21) this inosculation is seen to take place much nearer the inner margin of the septum of the last whorl, so that the greater part of the septal plane is occupied by the plexus formed by their interlacement. The interseptal canals of one septum are occasionally, if not invariably, connected with those of another by loops formed between the ramifications of those canals which extend along the alar prolongations of the septa towards the centre of the shell; such inosculating loops are seen at the centre of fig. 6, Plate VI. Moreover, branches of the same system are generally found to penetrate the non-tubular shell-substance whenever it accumulates in any quantity; these branches are at once distinguished from the ordinary tubuli by their much larger size, their diameter being commonly about $\frac{1}{5000}$th of an inch.

158. The branches of the interseptal canals which proceed towards the spiral laminæ are sometimes continued onwards in the non-tubular shell-substance that constitutes the septal bands; and they are also frequently seen to diverge from the septa over the walls of the chambers,—still, however, being usually invested by a layer of transparent shell-substance, as is well shown at *e*, fig. 2, Plate VI. This arrangement, again, corresponds with what I have described and figured in *Nummulites*; but I have not been able to detect in *Operculina* the apertures by which in *Nummulites* these canals communicate with the cavity of the chamber, a circumstance which may perhaps be attributed to the relatively smaller size of these passages in *Operculina*, and the consequent facility with which their apertures may be confounded with those of the ordinary tubuli. In fig. 2, Plate VI. is represented an appearance of areolation I have several times met with in the walls of the chambers,—though usually less conspicuously than in this instance,—which has made me suspect that the ramifications of the interseptal canals sometimes (if not as a regular rule) form a network in the spiral lamina over the entire surface of the chambers.

159. The interseptal system of each whorl is connected with the marginal plexus of the preceding by a very remarkable arrangement, which seems to have altogether escaped Mr. CARTER's notice. At each junction of the marginal cord with the tubular substance of the spiral lamina, the orifice of a large canal (Plate IV. fig. 15 *c*, *c*) may be seen in a vertical section which divides this canal transversely; and either of these canals may be clearly traced, in sections parallel to the surface, which have happened to pass through its plane, as at *d*, *d*, fig. 10, Plate IV., *b*, *b*, fig. 1, Plate VI., and very conspicuously in fig. 5, Plate IV., in which, by a fortunate accident, one of the spiral canals has been laid open in its entire course through the inner whorls, and can be traced nearly to the central cell. In the tangential section, fig. 7, Plate IV., the two canals can be seen running on the outside of what may be called the *nucleus*, consisting of the central cell and of the chambers immediately surrounding it. The mode in which

the interseptal passages branch off from these two spiral canals, is well seen in fig. 1, Plate VI., and also in fig. 10, Plate IV.; and this arrangement is shown in fig. 5, Plate IV. to extend to the septa between the chambers of the innermost convolution. The relations of the different parts of the system are brought extremely well into view in fig. 12, Plate IV., which represents a tangential section of a young shell, the rapid curve of whose spire causes the planes of even the contiguous septa to vary greatly in their direction. The spiral canals, though only running along the angles of the marginal cord, pretty obviously communicate with the plexus of passages which it contains; and thus the interseptal system of one whorl is brought into direct connexion with that of the preceding. It is to be remembered, however, that independently of such connexion, the spiral mode of growth of itself brings about a continuity of the canal-system throughout, by means of the marginal plexus; the consecutive whorls not being added one to another like the successive annuli of *Cycloclypeus*, each of which is (so to speak) *closed* or complete in itself; but being formed by the prolongation of the spiral lamina and of the marginal cord, which may be considered as always *open* to indefinite extension.

160. In regard to the uses of this canal-system, I have not at present anything to add to what I have already stated when describing its distribution in *Cycloclypeus* (¶ 107): I shall have the opportunity, however, of discussing them more fully in a subsequent Memoir upon forms in which this system is still more remarkably developed.

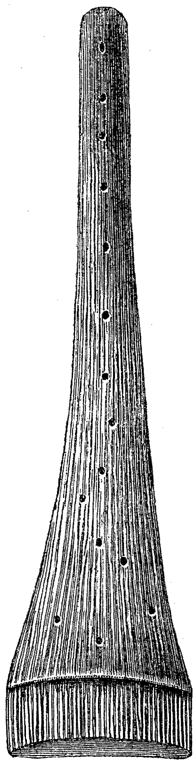
161. I have attempted to determine by a re-examination of my preparations of *Nummulites*, with the additional light afforded by the structure of *Operculina*, whether an arrangement of the canal-system prevails in the former at all comparable to that which I have shown to exist in the latter. In those which have undergone the ordinary fossilizing process, it is difficult to discover more than vague indications of its existence. But the peculiar process of silicification of *Foraminifera*, to which attention has been recently drawn by Professor EHRENBERG *, has afforded an unexpected verification of the anticipations which the similarity of these two genera in other points of structure had led me to form as to this. For by the infiltration of silex tinged with silicate of iron into the cavities of Foraminifera, whilst their calcareous shells have undergone decomposition and removal, a most perfect series of *casts* are presented, not merely of the chambers, but of the canal-system where this exists. And in his figure of such a cast of *Nummulites striata* (taf. 5. fig. 2), Professor EHRENBERG has given a most beautiful representation of the canal-system of the marginal cord, and of its communications with the interseptal canals, so closely corresponding with that which, long before the publication of his memoir, I had worked out in *Operculina*, that no doubt can fairly remain as to the essential similarity between these two types in this important feature of their organization †.

* Über den Grünsand und seine Erläuterung des organischen Lebens. Aus den Abhaldlungen der Königl. Akademie der Wissenschaften zu Berlin, 1855.

† I may here remark upon the confirmation afforded by other parts of this most valuable memoir to the results of my researches upon *Orbitolites* and *Cycloclypeus*; the various figures given by Professor EHRENBERG

162. Hence it would appear that there is no other essential difference between *Operculina* and *Nummulites**, than that which consists in the closing in of the spire, affirmed by MM. D'ARCHIAC and HAIME to be a constant character of the latter, whilst in the former the spire seems ordinarily to open out so long as it continues to increase. But even this is not an invariable difference; for I have met with several specimens of *Operculina*, in which the spire closes in by a somewhat abrupt inflexion of the marginal cord, so as to produce a rapid diminution in the size of the last four or five chambers, ending (as it would appear) in a complete cessation of growth. Examples of this kind are represented in fig. 8, Plate III. and fig. 3, Plate V.; and in Fig. IX. is shown the closing septum of one of these specimens upon a more enlarged scale. Looking, however, to the circumstance that these specimens bear but a very small proportion to those which exhibit no such tendency, and also to the fact that some of the specimens in which this closing-in is seen are very far from having attained their full growth, I am disposed to regard it as an abnormal, or at least as only an occasional occurrence in *Operculina*; and I must confess that, notwithstanding the positive assertion of MM. D'ARCHIAC and HAIME, I still entertain doubts as to whether it is to be accounted as a uniform characteristic of *Nummulites*. At any rate, the occasional occurrence of this condition in *Operculina* deprives the character of that constancy which is requisite to make it good for generic differentiation; and if *Operculina* and *Nummulites* are to be retained as separate genera, I cannot perceive by what features they are to be distinguished, save by the marked compression in form, the limited number of convolutions, and the external display of the whole spire, which are the obvious though not very important characteristics of the former.

Fig. IX.



Front view of the septal plane closing in the last chamber of *Operculina*.

163. It only now remains to speak of certain appearances indicative of *reparation after injuries*, which throw some light upon the physiology of this type of organization. Specimens are not unfrequently met with, exhibiting such irregularities as are delineated in fig. 1, Plate V.; and we can scarcely, I think, be wrong in concluding that these irregularities have commonly been produced by fracture. A portion of the outer part of the spire being broken off, the wound heals by the formation of new shell at the margin; but in its further progress the spire often shows the effect

in his Fourth Plate, of the chambers and passages in different species of an organism which he designates *Orbitoides*, being in the closest conformity with my representations of the corresponding parts of these two genera, between which the form described by Professor EHRENBERG seems to be a connecting link.

* I have already (¶ 104, *note*, Philosophical Transactions, 1856, p. 558) corrected the mistake into which I fell, when treating of the structure of *Nummulites*, in regarding the non-tubular *columns* of the fossil shell as having been *passages* subsequently filled up.

of the injury, in a narrowing of that part of the convolution which succeeds it, the new chambers being formed as it were on the contracted basis to which their predecessors have been reduced. A very remarkable feature in all these reparations is *the continuation of the marginal cord along the fractured edge.* It might have been supposed that the wound would have been healed with some rude exudation, which would have given rise to an amorphous shell-structure; but instead of this, we find the reparation chiefly effected by a new production (probably by extension from the old) of that portion which gives the most evidence in its canalicular structure of being intimately connected with the vital changes taking place in the organism. This phenomenon is beautifully displayed in the specimen represented in fig. 4, Plate VI., which exhibits another remarkable feature, for which it is difficult to account,—a reversal in the direction of growth which has taken place after the fracture. Although the specimen is unfortunately not complete, there can be (I think) no reasonable doubt that its convolutions must have taken the course indicated by the dotted lines; and it would seem that after the first two convolutions had been formed, the spire had been broken across, almost through its centre. It will be at once seen, by comparing the direction of the septa of the second convolution with that of all those which surround it, that the latter have been reversed; and although the part in which the reversal actually took place is unfortunately wanting, yet there can be little doubt that it was made as indicated in the figure (*a*). But the most curious feature in the specimen is this,—that the extension (*ac*) of the marginal cord which has closed in the fractured portion has obviously proceeded not from the later (*b*), but from the earlier (*c*) of the two fractured extremities of the second convolution; and it is in this *backward* growth that the reversal would appear to have originated. A somewhat similar retrograde increase has been already noticed among the modes in which *Orbitolites* is occasionally repaired (¶ 39); and it obviously shows that every portion of the organism is equally capable of extending itself when left free to do so. It is worthy of remark, that the growth of this specimen subsequently to the injury, has taken place more after the plan of *Nummulites* than on the ordinary plan of *Operculina*; the convolutions being more numerous than usual, and their rate of increase slow. There is evidence, however, in the presence of a small fragment of the final whorl, that it underwent the thinning-out which is characteristic of its type. Notwithstanding the great number of specimens which I have examined, I have not met with one that presented any such departure from the normal type of growth as would deserve to be termed a *monstrosity*; so that it would seem as if such aberrations were more frequent in the *cyclical* than in the *helical* type.

Genus AMPHISTEGINA.

164. *History.*—This genus was first constituted by M. D'ORBIGNY in 1825, for the reception of a type of Foraminiferous shells which does not seem to have been previously noticed by those who have given their attention to this group, in consequence, it may be, of its limitation to the seas of warm latitudes. Notwithstanding the very close relationship which, as I shall presently show, it bears to *Nummulites* and other Nautiloid

forms of the order *Hélicostègues*, it was considered by M. D'ORBIGNY to depart from them in a character which he regarded of such fundamental importance as to serve as the basis of a distinct Order, that of *Entomostègues*; of which the following is his most recent definition*:—"Animal composé de segments alternes, formant une spirale. Coquille composée de loges empilées ou superposées sur deux axes alternant entre elles, et s'enroulant en spirale." The mode of increase of these shells, he elsewhere says†, presents a singular mixture of that of the *Enallostègues* with alternating chambers, and of the spiral involution of the *Hélicostègues*. I have already had occasion (¶ 111) to point out, that in placing *Heterostegina* in this order, M. D'ORBIGNY has misconceived the structure of that genus; and I shall now have occasion to show that he has fallen into an equally grave error in regard to *Amphistegina*. His definitions of that genus in the 'Foraminifères Fossiles de Vienne' and in the 'Cours Élémentaire de Paléontologie,' are by no means accordant with each other: I take the last as the most authoritative.—"Coquille déprimée a spire embrassante, pourvue de loges alternes d'une coté et non de l'autre, séparées, intérieurement, par des cloisons longitudinales‡."

165. The only inquiry yet made, so far as I am aware, into the minute structure of the shells of this type, is that of Professor W. C. WILLIAMSON, in the memoir § to which I have already had such frequent occasion to refer. His investigations were made on small specimens of the *Amphistegina gibbosa*, a species which seems to be pretty generally diffused through the tropical ocean, and which has been recently dredged up in great abundance by Mr. McANDREW in the neighbourhood of Teneriffe. Professor WILLIAMSON showed by means of horizontal and vertical sections that *Amphistegina* has the general structure of *Nummulites*, but with this marked difference (as he considered), that the shell is *inequilateral*; the spire making its convolutions obliquely instead of revolving in the same plane (in other words, being *turbinoid* instead of *nautiloid*), and the alar prolongations of the chambers being much larger, and extending further, on one side than on the other. He did not detect any indications of a canal-system in this shell; nor does he mention that division of the septa into two laminæ, one belonging to each of the contiguous chambers, which usually goes along with the other characters of this type.

166. *Organization.*—My own inquiries have been chiefly made upon a set of specimens contained in Mr. CUMING's Philippine Collection, which present this type in a condition of far higher development than it has been elsewhere seen to attain; but I have also had the advantage of examining large numbers of specimens from New Holland, Teneriffe, and various parts of the Indian Ocean, as well as (through the kindness of Mr. W. K. PARKER) numerous fossil specimens from tertiary deposits in different parts of the globe. Of these last, nearly all seem to belong to the same species, *A. gibbosa*, as that described by Professor WILLIAMSON; and it is remarkable, that whilst the average dia-

* Cours Élémentaire de Paléontologie et de Géologie, tom. ii. p. 201.

† Foraminifères Fossiles de Vienne, p. 199. ‡ *Op. cit.* p. 201.

§ "On the Minute Structure of the Calcareous Shells of some Recent Species of Foraminifera," in Transactions of Microscopical Society, First Series, vol. iii. p. 105.

meter of the recent specimens does not elsewhere exceed ·065 inch, it attains in some of the Philippine examples as much as ·115 inch, thus equalling that of the largest fossil specimens which have come under my notice. The general correctness of Professor Williamson's description of this species I can fully confirm; but the comparison of a large number of sections leads me to the unhesitating conclusion that the inequilaterality which has been considered the distinctive character of this type is so inconstant, as to forbid our assigning any value to it as a *generic*, still less as an *ordinal* character. It is often very strongly marked in the fossil *Amphisteginæ* of the Vienna and St. Domingo tertiaries; but it is as frequently absent altogether, the shell being perfectly equilateral; and between these two extremes of form we find every intermediate gradation. So it frequently presents itself among the small specimens of *Amphistegina gibbosa* which are common in tropical seas, and I have met with specimens exhibiting as great a want of symmetry as the one of which Professor Williamson has delineated a section; yet on the whole, I should say, that in the great bulk of the smaller specimens which have passed under my notice, the want of symmetry is but slight; whilst perfect equilaterality both of external form and of internal arrangement not unfrequently occurs; and in those large specimens from the Philippines which present this type in its highest development, there is little or no departure from exact symmetry.—But further, Mr. Cuming's collection furnishes numerous examples of a remarkable species whose general conformity of structure to *Amphistegina gibbosa* seems to leave no doubt of its near relationship to it (the resemblance of its younger specimens to that specific type being so close as to have led me in the first instance to a belief in the specific identity of the two), and yet the most exact symmetry here presents itself as the rule, departures from it being exceptional, and never proceeding to any considerable extent. It may be considered, therefore, as satisfactorily established, that want of lateral symmetry is not to be held as an essential character of the shells of this genus, although more frequently occurring in it than in *Nummulites* or *Operculina*, to which, as I shall now show, this type bears an extremely close relationship.

167. The species to which I have just referred being hitherto undescribed, I shall designate it *A. Cumingii*. In its young state it is lenticular in form (Plate V. figs. 13, 14), and is only distinguishable from the symmetrical variety of *A. gibbosa* by the smaller number and greater angular distance of the septal bands which radiate from the centre and suddenly turn backwards as they approach the margin. (The radiating portions of these septal bands, as will presently appear, mark the direction of the portions of the septa that intervene between the alar prolongations of the chambers; whilst the recurrent portions mark the direction of the portions of septa that separate the principal cavities of the chambers.) As the *A. Cumingii* advances in life, however, a marked change presents itself in its form, corresponding to that which I have shown to occur in *Heterostegina*, *Peneroplis*, and *Operculina*; for the spire, after about its fourth turn, begins to flatten itself out, and separates itself henceforth from the central portion of the shell, to which it affords a very partial investment (figs. 15–17), the spiral lamina

being still continued over it, but the cavity of the chambers being limited to the peripheral portion of the whorl. Thus the form of the shell is so completely altered, that it would not be recognized as the same if the successive stages of this alteration could not be traced, especially as the characteristic radiating lines are no longer to be seen on the prominent centre. Its diameter undergoes an extraordinary increase; the specimen from which fig. 17 was taken measuring no less than ·30 inch by ·25 inch.

168. The organization of the interior of the shell, as displayed by sections passing either through the median plane or parallel to it (Plate VI. fig. 6), and by sections taken perpendicularly to the median plane, or vertically (Plate VI. fig. 5), is closely conformable to that of *Operculina*; the chief difference arising out of the extension of the alar prolongations of the chambers of each successive whorl, and of their dividing septa, over the entire surface of the penultimate whorl, except at the centre of the spire, which is commonly occupied by a solid pillar of non-tubular substance, having the general shape of a double cone, whose apex is in the primordial cell, and whose base is on the most prominent part of each surface. As it is very seldom that the successive whorls lie precisely on the same level, a section which traverses the outer convolutions in the median plane will pass above or below the plane of the inner whorls; and it will thus, in traversing the surfaces of these, bring into view the centripetal prolongations of the septa intervening between the alar prolongations of the chambers of the whorls which invest them, as is shown in the central portions of fig. 6. These centripetal prolongations are composed of non-tubular shell-substance, and the portion of the spiral lamina above them is also non-tubular; and thus it is that their position is marked on the exterior by radiating bands, which never rise in *A. Cumingii* into tubercles or ridges, though they sometimes become thus elevated in *A. gibbosa*. These septal bands are, generally speaking, those of the last-formed whorl alone, those of all the preceding whorls being concealed by the investment they have received; but in unsymmetrical specimens (as often happens in *A. gibbosa*, and occasionally in *A. Cumingii*), the alar prolongations do not extend to the centre of the flatter side; so that the septal bands which radiate from the centre are those of the penultimate whorl, and are interrupted as they approach the margin by a new series belonging to the last-formed convolution. The reason of the obliteration of the septal bands on the prominent portion of the shell in advanced specimens of *A. Cumingii* is at once explained when we look at fig. 5; for as the last whorl extends itself peripherally, the alar prolongations of its chambers and therefore of its septa are withdrawn from the central region, and thus no new septal bands will be formed; whilst the continuation of the thick spiral lamina over the whole surface of the penultimate whorl prevents *its* septal bands from displaying themselves. In this respect there is a marked contrast between *A. Cumingii* and *A. gibbosa*; for on the surface of the oldest specimens of the latter we see not only the numerous septal bands of the outer whorl, but indications of those of the penultimate whorl, which show themselves as imperfect or broken lines between the complete radiating bands. This is probably due to that elevation of the septal bands of which mention has

already been made, which causes them to unite at intervals with the spiral lamina that is subsequently formed over them; so that they are marked on its external surface by the non-tubularity of its substance in those parts which immediately overlie them.

169. Allowance being made for the differences arising out of this diversity in their plan of conformation, we find an extraordinary resemblance in the general organization of *Amphistegina Cumingii* to that of the *Operculina* already described, as will be apparent from a comparison of figs. 5, 6, Plate VI. to figs. 8, 10, Plate IV. of *Operculina*. Hence it will be quite unnecessary to enter into any minute description of its structure. In regard to the mode of communication between the chambers,—by one principal orifice in the form of a narrow slit along the inner margin of each septum, with a variable number of secondary apertures irregularly disposed in different parts of the septal plane,—there is an absolute identity with *Operculina*; as there is also in the distribution of the interseptal passages between the two layers which each septum here unmistakeably exhibits. The marginal cord, likewise, exhibits the same peculiarity of organization as in *Operculina*; being channeled out by freely inosculating passages which communicate with those of the interseptal system (Plate VI. fig. 6). This marginal system of passages is even more developed than in *Operculina*; and a study of its distribution will, I think, remove all doubt as to the correctness of my interpretation of the appearances often presented by sections of the marginal cord in that genus (¶ 156). There is this difference, however, in the relation of the interseptal to the marginal system of canals in these two types,—that the interseptal canals of *Amphistegina* appear to take their origin directly from some of the large superficial passages of the marginal cord on which the septum abuts, instead of branching from a pair of regular spiral canals as in *Operculina*, no distinct evidence of such canals having here presented itself to me.

170. The relationship of *Amphistegina Cumingii* to those forms of *Nummulites* in which the alar prolongations of the chambers of each whorl are continued, with centripetal prolongations of the septa, over the whole surface of the penultimate whorl, is obviously extremely close; in fact, I can discern no distinguishing character between these two types, except that which is afforded by the tendency of the last turn of the spire of *Amphistegina* to open out, whilst that of *Nummulites* closes in. The double-coned axis of non-tubular substance would seem to be a distinctive character of *Amphistegina*; but I am not inclined to lay much stress upon it, as it presents itself in very different proportions in different individuals.

171. Whilst the type which I have now been describing is thus closely related to the highest because most specialized forms of Foraminiferous organization, it is singular that the smaller species to which I have referred under the name of *A. gibbosa* should present such a marked inferiority of conformation. Its spiral lamina is as minutely tubular as that of its congener; but I have not been able to detect the least trace of a system of interseptal canals; and it is especially to be noticed, that the marginal cord, which exhibits such a high development of the canal-system in *A. Cumingii*, consists in *A. gibbosa* of homogeneous non-tubular shell-substance, without any vestige of canals,

though traversed here and there by a stray tubulus resembling the straight parallel tubuli of the spiral lamina. I am inclined to attribute this difference in part to the smaller scale of the last-named species, which prevents any part of its shell from being far removed from the contact of sarcode; the absence of a canal-system being analogous, under this point of view, to the absence of Haversian canals in laminæ of bone which are thin enough to draw their nourishment directly from the nearest vascular surface. The smaller species may thus be considered as—so to speak—a degraded form of the larger; the other differences in its structure being of very subordinate value. These differences, however, serve for its recognition by external characters; for whilst the number of radiating septal bands to be seen in *A. Cumingii* is never much greater than twenty, and in young specimens does not reach half that amount, that of the radiating septal bands in *A. gibbosa* commonly exceeds thirty; besides which, the backward turn which these bands take, when they have passed the margin of the penultimate whorl, is far more striking in the last-named species than in that which I have been specially describing. The granular character of the surface in the neighbourhood of the mouth, which seems due (as Professor WILLIAMSON has pointed out) to a secondary deposit of minute papillæ of non-tubular shell-substance, is another distinguishing feature of *A. gibbosa.* To this species I am disposed to refer all the three fossil forms of *Amphistegina* that are described by M. D'ORBIGNY* under the names of *A. Hauerina*, *A. mamillata*, and *A. rugosa*, since these differ no more from each other than do the recent examples of the species,—their chief distinctions being based on the degree of their departure from bilateral symmetry, and on the limitation of the alar prolongations on the flatter side to the marginal portion of the included whorl; characters, which I have shown to possess no constancy, and to be therefore quite valueless for systematic purposes. I have examined several large *Amphisteginæ* from the miocene of St. Domingo, which seem to conform to the same type; but in consequence of the alterations brought about by fossilization, I have not been able to determine satisfactorily whether the apparent absence of a canal-system indicates that it had no existence in the recent organism; so that the identification of the species must rest on the less satisfactory characters furnished by the number and direction of the septal bands.

* Foraminifères Fossiles de Vienne, pp. 207–209.

Explanation of the Plates.

PLATE I.

Fig. 1. Ideal figure of *Dendritina*, partly laid open, so as to show the arrangement of its chambers, the nature of their communications by a single fissure of irregular form (simpler in the earlier whorls, but more complex in the later), the overlapping of the earlier whorls by the alar prolongations of the chambers of the later, and the manner in which the last turn of the spire tends to detach itself from the earlier convolutions.

Fig. 2. Ideal figure of *Peneroplis*, partly laid open, so as to show the arrangement of its chambers, the nature of their communication by isolated pores, which are arranged in a single row in the later whorls, but frequently form a double row in the earlier, the rapid increase in the breadth of the spire coincident with its very extraordinary flattening in the last convolution, and the very slight degree in which the earlier whorls are covered in by the later.

Fig. 3. Ideal figure of *Operculina*, laid open to show the details of its structure:— *a a a*, marginal band (the "spicular cord" of Mr. Carter, the "bourrelet" of MM. d'Archiac and Haime), divided transversely at a', so as to show the orifices of its canals, the distribution of which is seen at $a''a''$ in a tangential section of the band, and at $a'''a'''$ in a section through the median plane; *b*, *b*, *b*, external surface of the chambers, marked out by the septal bands; *c*, *c*, *c*, interior of the chambers of the outer whorl, the alar prolongations of which extend, as shown at c', c', over the surface of the interior whorl, reaching nearly to the centre of the spire; the chambers are separated by the septa *d*, *d*, *d*, formed by the union of two layers of shell, one belonging to each chamber, and having spaces between them in which lie the interseptal canals, whose smaller branches are seen irregularly divided in the septa d', d', whilst in the septum d'' one of the principal trunks is laid open through its whole length; at the approach of each septum to the marginal cord of the preceding whorl is seen the fissure which forms the principal connexion between the chambers; at *e*, *e* are seen the secondary orifices of communication, and in the same septa is shown the distribution of the interseptal system of canals, branching from *f*, *f*, the two spiral canals; and at *g*, *g* are seen the conoidal columns of translucent shell-substance, forming tubercular projections on the surface, which frequently overlie the septa, and are penetrated by branches of the interseptal system of vessels.

PLATE II.

Fig. 1. Side view of a characteristic specimen of *Peneroplis*:—1 *a*, front view, or septal plane, of the same, showing its single row of isolated pores:—40 diam.

Fig. 2. Front view of a young specimen, intermediate in its characters between *Peneroplis* and *Dendritina*:—40 diam.

Fig. 3. Side view of a specimen of *Peneroplis*, of which the later chambers are widely extending themselves laterally:—40 diam.

Fig. 4. Septal plane of cylindrical prolongation of *Spirolina* (see fig. 11), showing transition between the isolated pores of *Peneroplis* and the coalesced fissures of *Dendritina*:—40 diam.

Fig. 5. Side view of a specimen of *Peneroplis*, of which the later chambers are extending themselves longitudinally:—40 diam.

Fig. 6. Front view of a young specimen, intermediate in its characters between *Peneroplis* and *Dendritina*:—40 diam.

Fig. 7. Side view of a specimen of *Peneroplis*, of which the later chambers are extending themselves longitudinally, and of which the spire is more turgid, and the pores arranged in a double row, as shown at 7 *a*:—40 diam.

Figs. 8, 9, 10. Front views of young specimens of *Peneroplis*, showing various departures from the normal type in the form of the septal plane and the disposition of the apertures:—40 diam.

Fig. 11. Side view of *Spirolina*, which bears the like relation to the *Dendritina*-type shown in figs. 12 and 13, that the specimens represented in figs. 5 and 7 bear to the ordinary *Peneroplis*-type; the septal plane of its cylindrical extension, with apertures of intermediate form between those of *Peneroplis* and of *Dendritina*, is shown at 11 *a*:—40 diam.

Fig. 12. Side view of a typical specimen of *Dendritina*:—at 12 *a* is shown the septal plane and single large dendritic orifice of its last chamber, and at 12 *b* the same, from the preceding whorl; *al*, *al*, alar prolongations of the chambers, which bear a much larger proportion to the principal cavity in the middle than in the later part of the growth:—40 diam.

Fig. 13. Side view of a specimen of *Dendritina* tending towards the *Spirolina*-type, the last turn of the spire having already detached itself, and the last chamber having completely lost its alar prolongations, as seen at 13 *a*:—40 diam.

Fig. 14. Front view of a young specimen of *Peneroplis*, presenting a very marked departure from the ordinary type in the form of its septal plane and the disposition of its apertures:—40 diam.

Fig. 15. Septal plane of a specimen resembling in general form that represented in fig. 13, but showing a want of coalescence of the fissures of which the dendritic orifice is made up: the ridge-and-furrow arrangement of the walls of

the chambers is here prolonged in an unusual manner over the borders of the septal plane:—100 diam.

Figs. 16, 17, 18, 19. Side and front views of young specimens of *Peneroplis*, showing various departures from the normal type in the form of the septal plane and in the disposition of the apertures:—40 diam. (See also figs. 2, 6, 8, 9, 10, 14.)

Fig. 20. Portion of the ordinary surface of *Peneroplis* more highly magnified, showing its ridge-and-furrow plication, and its rows of minute punctations:—100 diam.

Fig. 21. Portion of the ordinary surface of *Dendritina*, showing precisely similar characters:—100 diam.

Fig. 22. Septal plane of a specimen of *Dendritina*, showing the punctations continued over its surface:—100 diam.

Fig. 23. Portion of the surface of a specimen of *Peneroplis*, on which the plications had become obsolete, but the punctations are still arranged in rows corresponding to them in distance:—100 diam.

Fig. 24. Portion of the surface of a specimen of *Peneroplis*, over which the punctations are scattered without definite arrangement:—100 diam.

PLATE III.

Figs. 1–9. Side and front views of specimens of *Operculina* at various ages, showing differences in the form and proportions of the spire, in the surface-markings, and in the number and arrangement of the tubercles marking the septal bands:—10 diam.

Fig. 10. Hemispherical cluster of tubercles occupying the umbilicus of the variety of *Operculina* represented in figs. 11, 12:—25 diam.

Figs. 11, 12. Side and front views of young and mature specimens of peculiar variety of *Operculina*, characterized by the rapid opening-out of the spire, and by the extraordinary development of tubercles, not only along, but also between the septal bands:—10 diam.

PLATE IV.

Fig. 1. Part of the internal surface of one of the chambers of an *Operculina* that presented large tubercles on its exterior, showing the uniform distribution of the tubuli except along the septal bands, and the comparatively large size of their orifices:—120 diam.

Fig. 2. Section through the wall of a contiguous chamber of the same, showing the partial deficiency of tubuli in certain spots, with their crowding together in

the neighbourhood of these, and the diminution in the size of the tubuli as they pass towards the outer surface:—120 diam.

Fig. 3. Part of the internal surface from another *Operculina*, presenting smaller and more numerous tubercles on its exterior:—120 diam.

Fig. 4. Section through the wall of a contiguous chamber of the same:—120 diam.

Fig. 5. Section through the median plane of the earlier convolutions of an *Operculina*, showing the spheroidal form of the primordial chamber, the irregular forms of the chambers that immediately succeed it, and one of the spiral canals, which may be traced in the marginal cord almost to the centre of the spire:—75 diam.

Fig. 6. Portion of the external surface of an *Operculina*, of which the tubercles were particularly prominent:—75 diam.

Fig. 7. Vertical section of the inner convolutions of an *Operculina*, which has happened to pass close to the primordial chamber and the one that springs from it, and which shows at *a* the two spiral canals running along their exterior:—100 diam.

Fig. 8. Vertical section of a typical *Operculina*, passing through nearly the centre of the spire; showing at *a*, *a* the spiral lamina of the second whorl, separated from that of the whorl which it invests by the alar prolongations of the chambers of the latter, which extend nearly to the centre of the spire; *b*, the spiral lamina of the last convolution, thinned away in proportion to its extension, and coalescing with that of the preceding convolution near the margin of the latter, the alar prolongations of the outer chambers being comparatively small; *c*, septum between contiguous chambers, traversed by the interseptal system of canals; *d*, *d*, marginal cord divided transversely (see figs. 15, 16); *e*, *e*, fissure of communication between contiguous chambers; *f*, *f*, spiral canals divided transversely:—40 diam.

Fig. 9. Very thin section of a lamina of the tubular shell-substance of *Operculina*, magnified 120 diameters, cutting the tubuli transversely, and showing a delicate areolation between them; *b*, prismatic appearance of a portion of the same, magnified 250 diameters; *a*, another portion, magnified 250 diameters, showing the comparatively large size of its tubuli close to the internal surface.

Fig. 10. Portion of a section of a typical *Operculina* (see Plate VI. fig. 3), taken through the median plane:—*a*, *a*, marginal cord traversed by canal-system; *b*, *b*, walls of the chambers, composed of minutely-tubular substance; *c*, septal bands with their lateral branches, composed of transparent non-tubular shell-substance; *d*, *d*, one of the spiral canals:—50 diam.

Fig. 11. Portion of a similar section of a tuberculated specimen of *Operculina*, showing the clear spaces left by the absence of tubuli in the spots beneath the tubercles, and the semi-opacity produced by the crowding together of the tubuli elsewhere:—50 diam.

Fig. 12. Portion of a vertical section passing tangentially along the exterior of the inner-

most convolution of a young *Operculina*, and affording a most advantageous display of its canal-system:—*a a*, marginal cord of the inner convolution; *b b*, *b b*, spiral lamina of the outer convolution; *c c*, *c c*, spiral canals; *d d*, *d d*, origins of the interseptal canals from the spiral canals; *e*, *e*, *e*, projection of the septal bands of non-tubular shell-substance into ridges on the surface:—120 diam.

Fig. 13. Portion of the marginal cord, *a*, *a*, of *Operculina*, as seen in a section passing through the median plane, showing the fusiform spaces formed by the inosculation of the canals:—120 diam.

Fig. 14. Another portion, showing more elongated and less regular spaces:—120 diam.

Fig. 15. Transverse section of the marginal cord, *aa*, as seen in a vertical section of *Operculina* (fig. 8), showing its slightly furrowed external surface, the canal-system which traverses its interior, its junction with the ordinary tubular substance, *b b*, of the spiral lamina, and the spiral canals, *c c*:—120 diam.

Fig. 16. A similar section from another specimen, showing deep furrows upon the external surface of the marginal cord:—120 diam.

PLATE V.

Fig. 1. Side view of an *Operculina*, of which a portion of the last whorl has apparently been broken off, and the injury repaired by the continuation of the marginal cord along the line of fracture:—10 diam.

Fig. 2. Portion of the outermost and penultimate convolutions of *Operculina*, laid open by vertical fracture:—*a*, external surface of marginal cord of the convolution inclosed by them; *a'*, *a'*, transverse sections of the marginal cord in the outer convolutions; *b b*, the two marginal canals, whose transverse sections, *b' b'*, are seen in the penultimate convolution; *c*, septum between the contiguous chambers of the penultimate convolution; *c'*, the same in the outer convolution; *d d*, origins of interseptal system of canals; *e*, *e*, fissures of communication between contiguous chambers; *f*, secondary pores; *g g*, thick spiral lamina of tubular substance, formed by the coalescence of that *g' g'* of the last whorl over that of the penultimate whorl:—75 diam.

Fig. 3. Side view of an *Operculina*, of which the last whorl has closed in by a gradual diminution in the size of its chambers:—10 diam..

Figs. 4, 5. External surface of marginal cord, *a a*, showing two modes of disposition of its furrows, in which are seen the orifices of some of the canals; at *a'a'* the cord is seen in transverse section; and at *b b* is shown its junction with the spiral lamina:—75 diam.

Figs. 6 to 8, 10 to 12. Varieties in the superficial characters of *Operculina*:—40 diam.

Fig. 9. Young specimen of the tuberculated variety of *Operculina*, showing an extraordinary development of the central clusters of tubercles:—10 diam.

Figs. 13 to 17. Successive stages of growth of *Amphistegina Cumingii*:—10 diam.

PLATE VI.

Fig. 1. Section of a portion of the outer whorl of *Operculina*, parallel to the surface, showing a marked irregularity in the disposition of the septa:—*a a*, marginal cord; *b b* one of the spiral canals; *c*, *c*, septal bands of transparent shell-substance; *d*, tubular shell-substance of spiral lamina forming the walls of the chambers; *e*, *e*, prolongations of interseptal canals in spiral lamina:—100 diam.

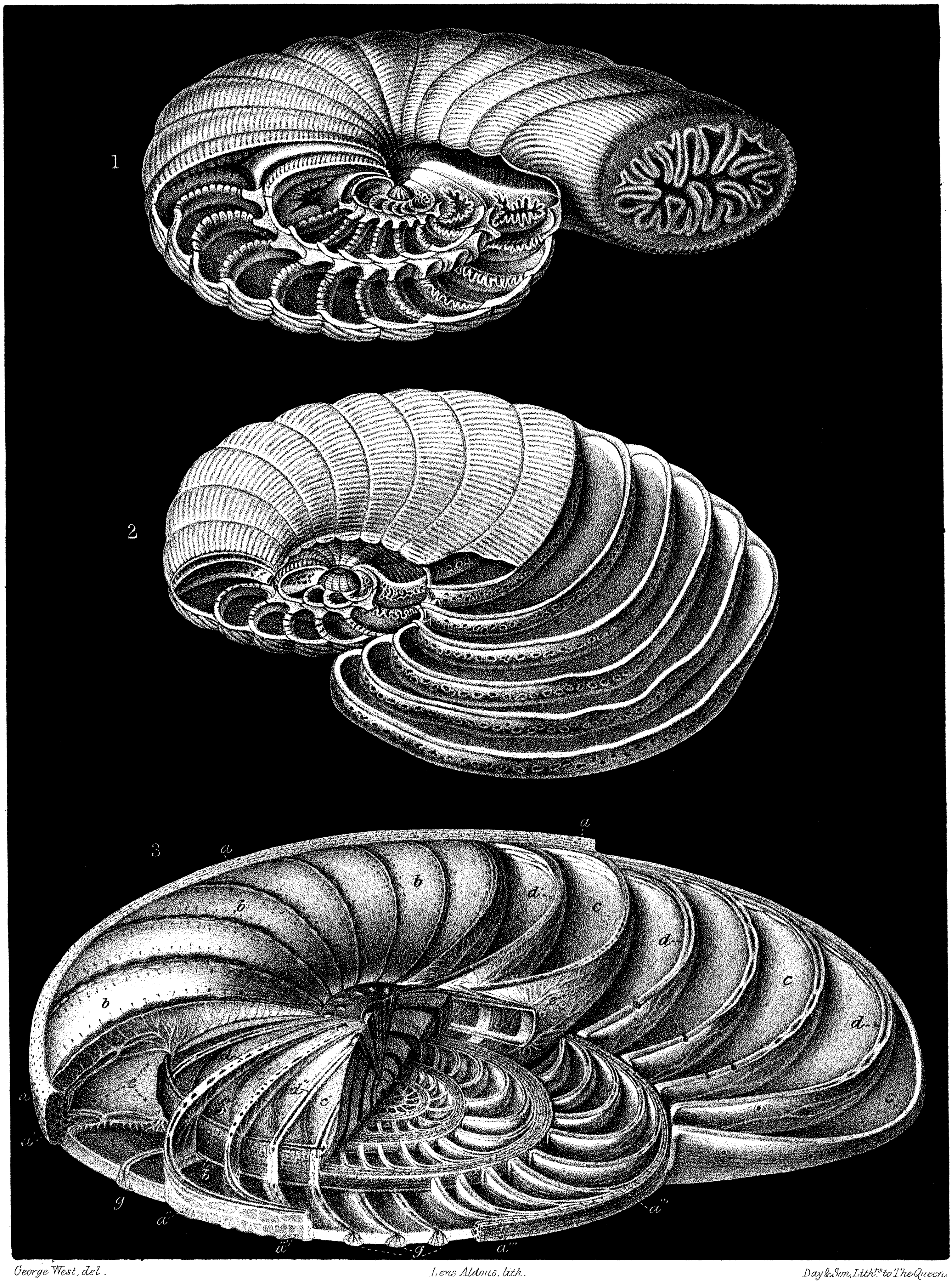
Fig. 2. Similar section from another specimen, showing an appearance of reticulation in the spiral lamina:—*a a*, marginal cord; *c*, septal band; *d*, one of the interseptal canals communicating with canal-system of marginal cord; *e*, prolongation of interseptal canals in spiral lamina:—100 diam.

Fig. 3. Section of *Operculina*, traversing its median plane except in its central portion, and showing, especially at *a* and *b*, great irregularities in the disposition of its chambers:—12 diam.

Fig. 4. Portion of a specimen of *Operculina*, which seems to have undergone fracture at an early age, and to have thenceforth grown in a reversed direction, as will be seen on comparing the direction of the septa in the whorls *a* and *b*; the marginal cord appears to have been continued from *c* to *a* along the line of fracture, and thence to have grown onwards to *b*:—50 diam.

Fig. 5. Vertical section of *Amphistegina Cumingii*, showing its conformity in all essential respects to the type of *Operculina*, and the differences produced by the smaller size of its chambers in proportion to the thickness of its spiral lamina:—50 diam.

Fig. 6. Portion of section of *Amphistegina Cumingii*, traversing its outer whorls in the median plane, but passing along the surface of its inner convolutions, so as to bring into view the alar prolongations of the septa in their passage towards the centre, and the occasional inosculation of their canal-systems by loops in that region:—50 diam.



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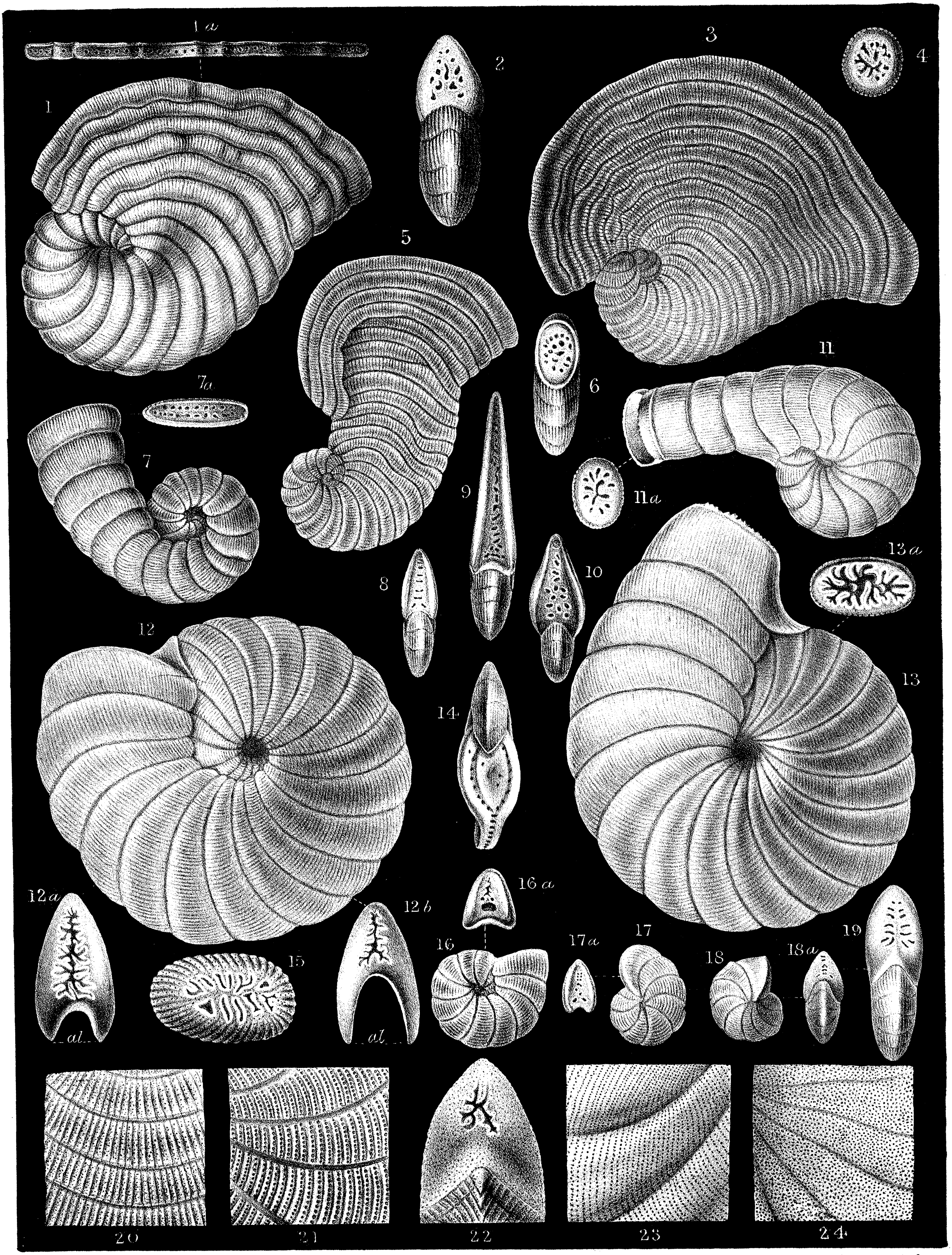

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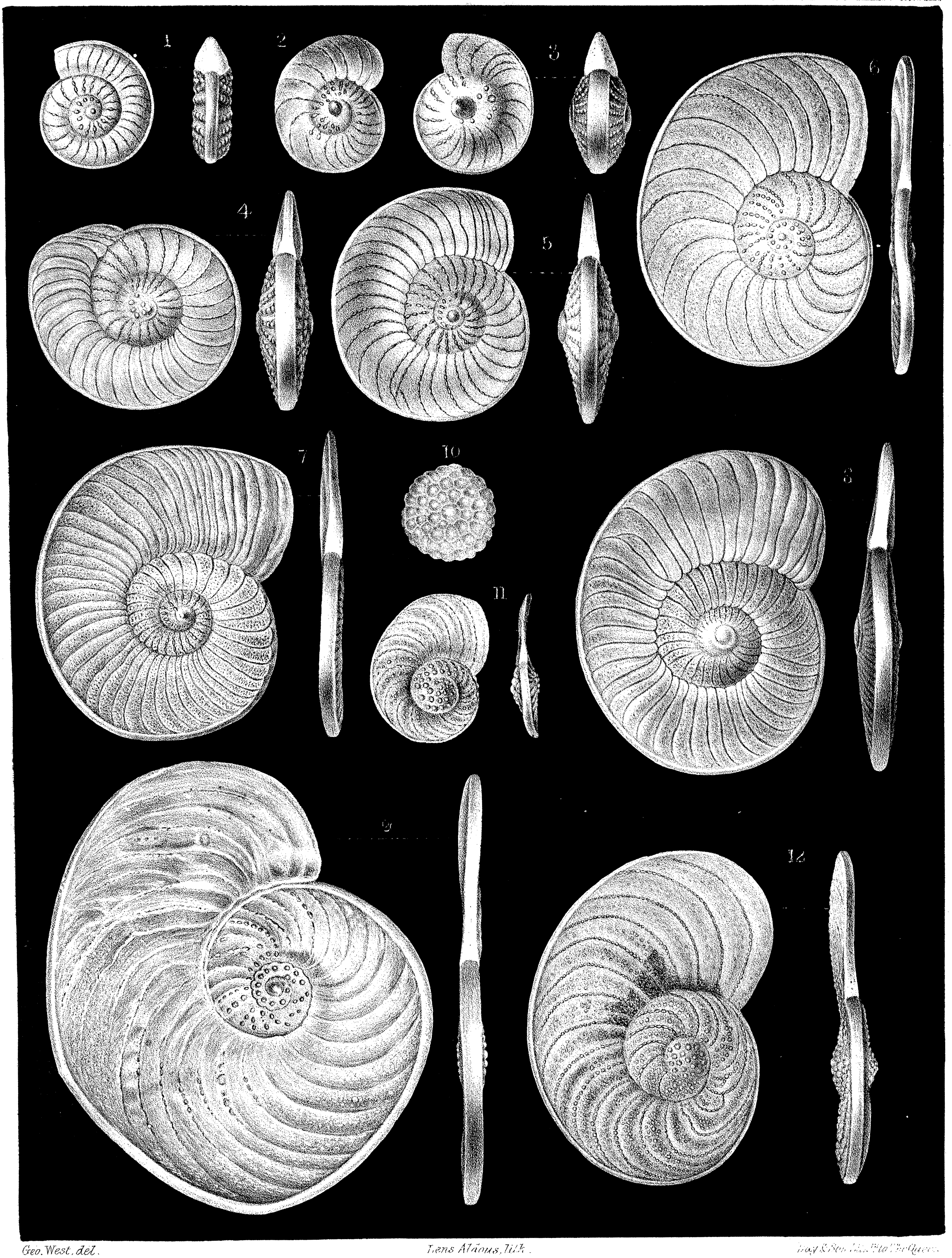

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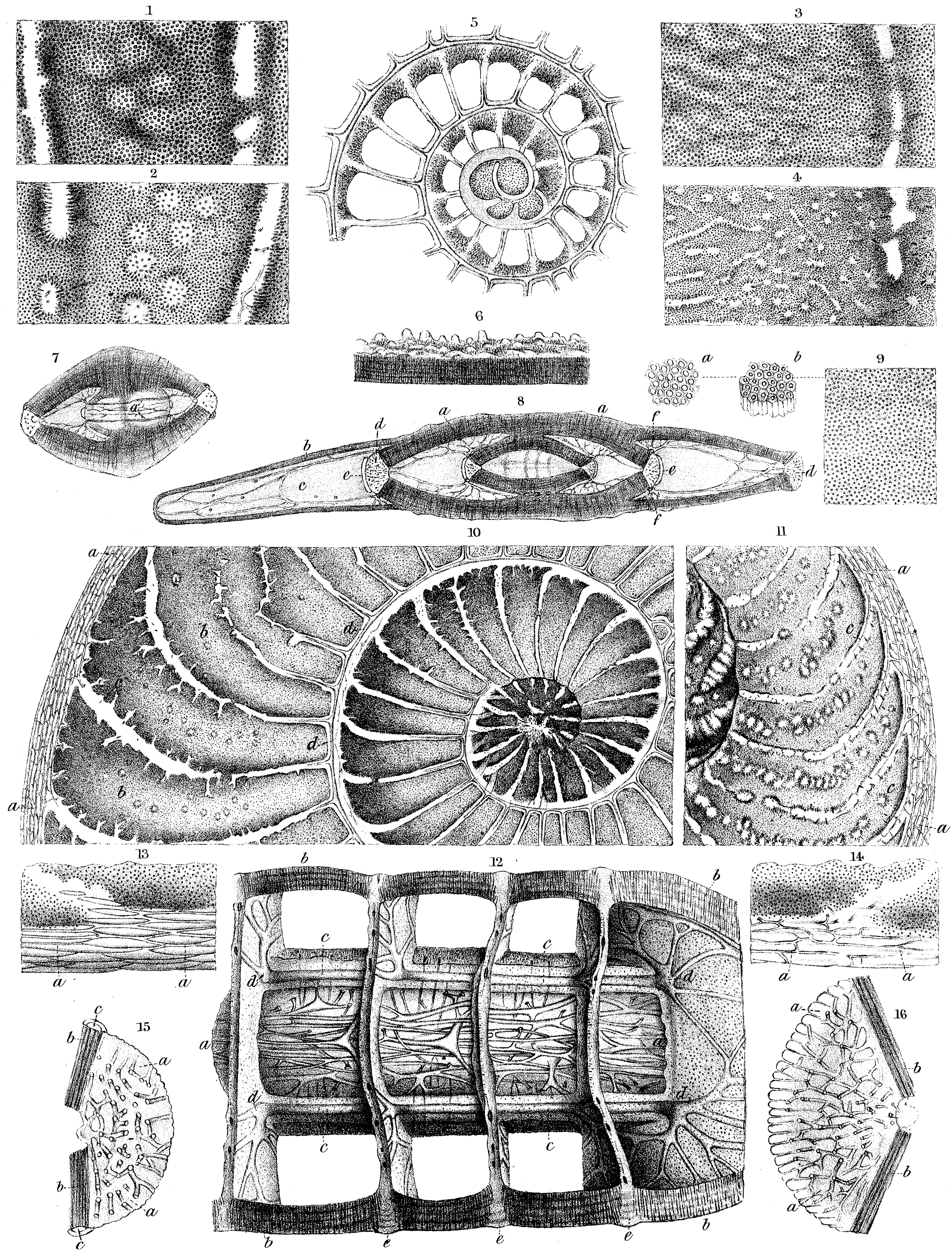

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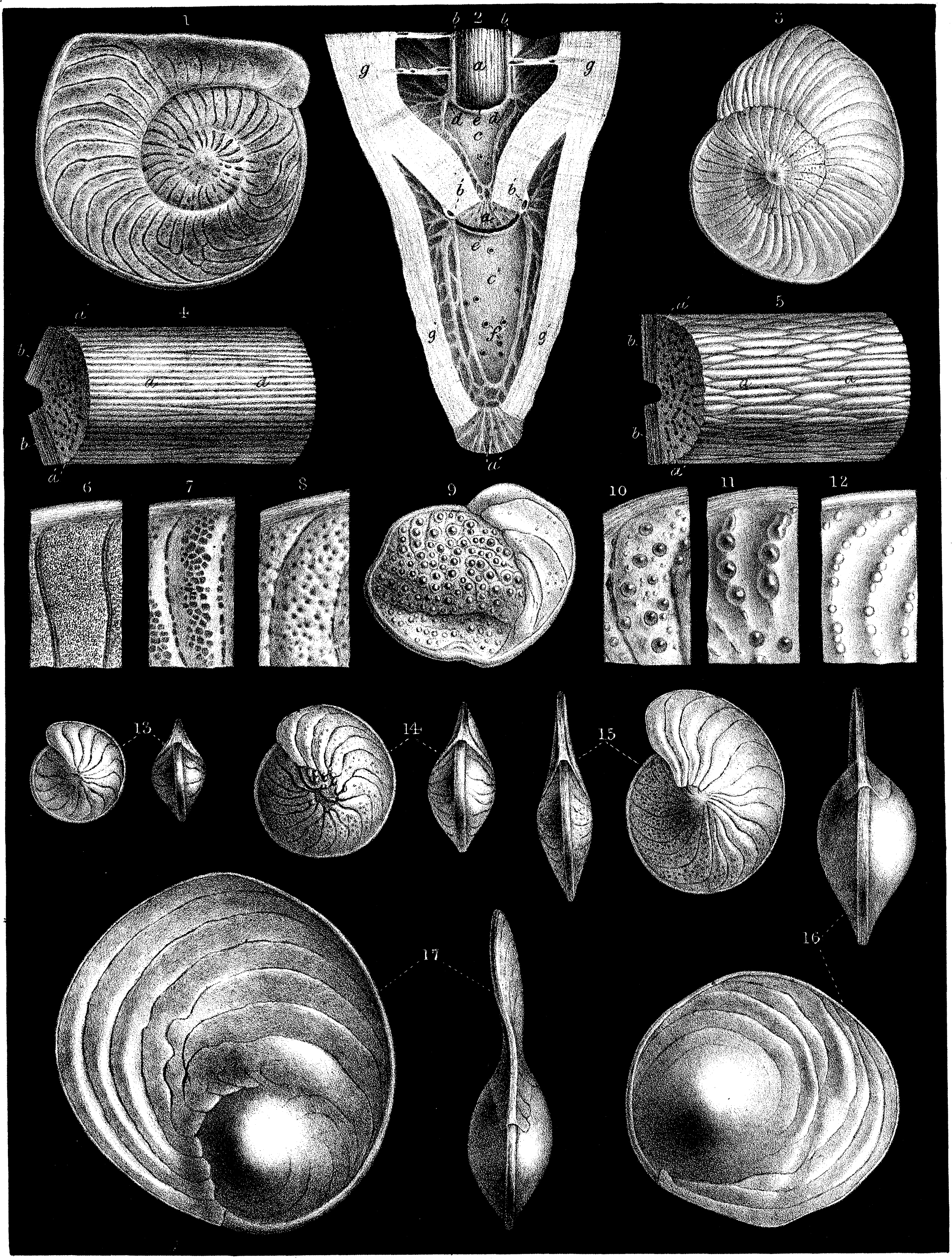

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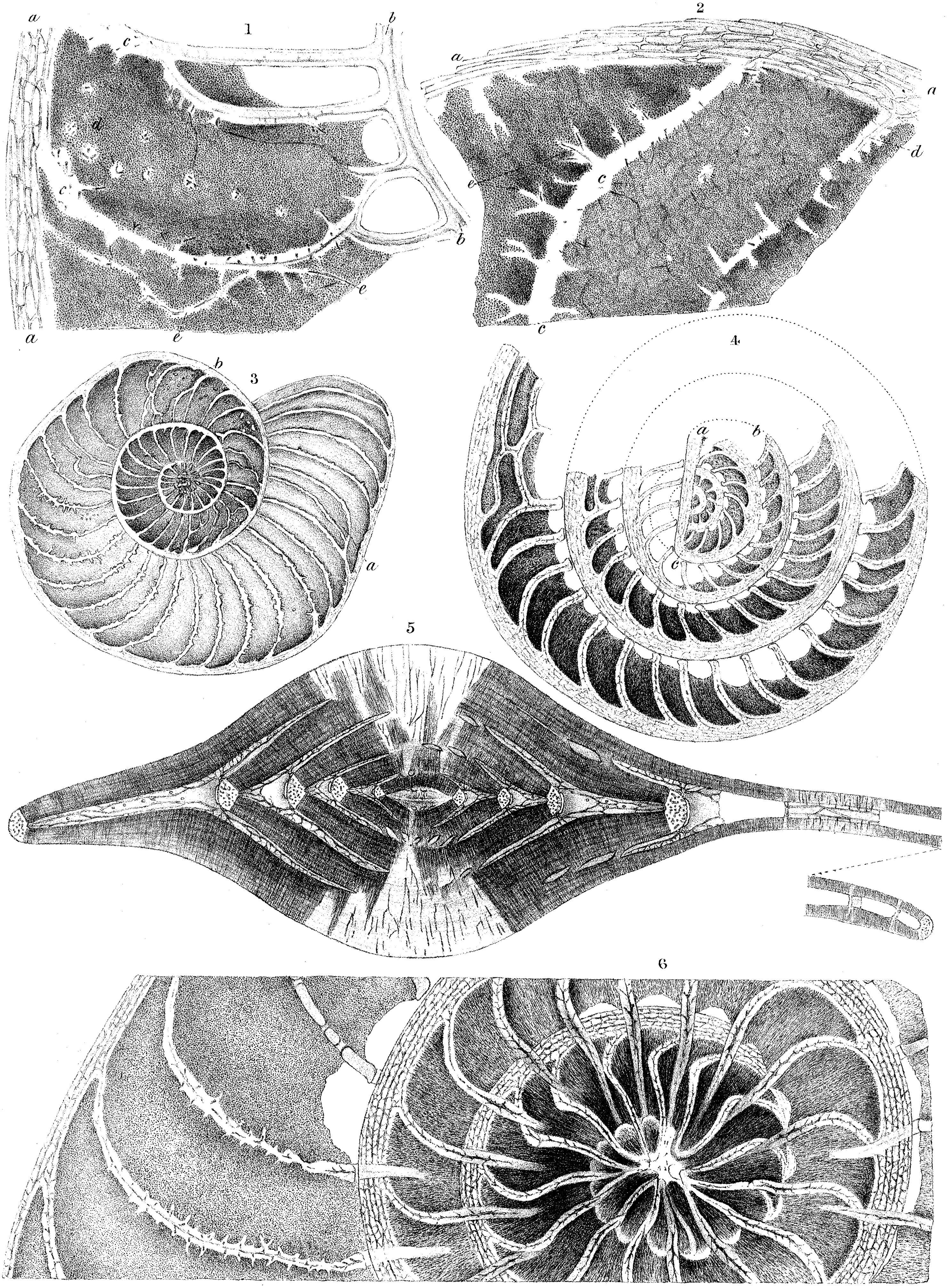

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