# On Merlia normani, a Sponge with a Siliceous and Calcareous Skeleton.

By

**R. Kirkpatrick.**

With Plates 32–38 and 5 Text-figures.

A good deal of the work in connection with the following investigation was done at the Lister Institute, in the laboratory of Professor E. A. Minchin, and I take this opportunity of thanking him for the continual help and instruction which he very kindly gave me in methods of technique.

Also I would express my sincere thanks to Senhor A. C. Noronha, who accompanied me to Porto Santo to help with dredging for Merlia.

Most of the drawings have been done by Mr. P. Highley, who has put them on stone. The drawings of young stages of Merlia on Pl. 38 and figs. 1–4 on Pl. 36 were done by Miss Rhodes.

In 1908 Canon Norman, who had been working out the Polyzoa of Madeira, sent to the Natural History Museum four small, dried, incrusting calcareous organisms resembling Polyzoa. The crusts were about a square centimetre in area, and a millimetre or less in thickness. They had been detached from a small mass of calcareous conglomerate hooked up by a fisherman from sixty fathoms off Porto Santo island, about twenty miles N.E. of Madeira.

The specimens were covered with a thin yellow pellicle stretching across a white calcareous network, with very minute polygonal meshes, and with small rough tubercles rising from the nodes and pushing up the pellicle. A vertical

section showed a series of vertical tubes divided up by horizontal partitions or tabulæ. The vertical walls were imperforate, but marked with longitudinal vertical sutures extending from the upper surface to the base, one suture being between any two tubercles. The horizontal tabulæ usually had a central hole or slit, but were sometimes imperforate. In the uppermost spaces of this honeycomb-like framework were bundles of slender pin-shaped spicules. In the small fragment that could be spared for the making of preparations I found a "tuning-fork" spicule, seemingly imbedded in one of the tabulæ (Pl. 38, fig. 6).

Apparently the pin-shaped spicules were not present in the particle of Merlia used for decalcification, and I wrongly concluded that these spicules were calcareous and that they had been dissolved in the acid.

I named the incrusting organism Merlia normani, and regarded it as a Pharetronid sponge.[1] (1) Even if I

[1] If it had been lawful to base any opinion at all on the investigation of such scanty material, then the conclusion arrived at was, I think, a legitimate one. "Tuning-fork" spicules with thick, parallel, wide-apart prongs have been found only in Pharetronid sponges. Finding this rare and peculiar form of spicule seemingly imbedded in one of the tabulæ of a mysterious calcareous skeleton unlike that of any known recent organism, it seemed justifiable to conclude that the spicule belonged to the framework, and that therefore the latter had been made by a calcareous sponge. The upper surface of the skeleton of Merlia shows, too, certain resemblances to that of the Pharetronid sponges, Porosphæra and Plectroninia. Further, a Pharetronid —Murrayona phanolepis, Kirkp. ('Proc. Roy. Soc.,' 1910)—has now been found, in which solid skeleton fibres are devoid of an axial core of spicules, and it was on these characters that I founded the subfamily Merlinæ. The spicule, which sent me on the wrong track, was a genuine "tuning-fork" and not a simulacrum made by some boring fungus or Alga, for when I crushed under the cover-slip the fragment of sponge containing the spicule, the latter floated out solid and free into the balsam. At present only three Pharetronid Lithonine sponges are known with a similar kind of tuning-fork, and these have been recorded from the Indian Ocean and Pacific. Off Porto Santo Island, in submarine holes or caves, possibly almost inaccessible to dredges, there must be a Pharetronid sponge. Unfortunately I failed to secure examples, in spite of twelve days' dredging.

had known that the pin-shaped spicules were siliceous—as, indeed, they were—I would have considered them as part of a siliceous sponge growing over a Pharetronid. In January, 1909, mainly with the object of procuring living specimens of Merlia, I spent a winter holiday at Madeira and Porto Santo. After dredging for nine days off the latter island I found the sponge in sixty fathoms off a little rocky islet called Cima, at the S.E. corner of Porto Santo. The living specimens were in the form of little bright vermilion crusts, with a smooth surface. At first, when removed from the water, nothing else was seen excepting the bright smooth patch of colour, but soon the surface sank a little, and the porcelain-white skeleton network with its nodal tubercles became visible, thus enabling Merlia to be distinguished from certain other small red incrusting organisms brought up in the dredge, viz. a red Ectyonine sponge, a polyzoan, a compound ascidian and a coralline alga. It is true these latter all had slightly different shades of red, but Merlia itself varied slightly in this respect. A crust of Merlia broken in half showed the cavities of a calcareous framework filled with orange-coloured jelly.

Specimens were fixed in ·5 per cent. osmic acid in sea-water, washed, stained immediately in Weigert's picrocarmine, and either graded into alcohol or put into glycerine. Others were fixed in Flemming mixture, and others again in absolute alcohol.

When I came to examine the first decalcified sections of the fresh material I was expecting to find a Pharetronid sponge, and great was my surprise on seeing at the surface a siliceous sponge, and below the latter and in continuity with it a series of separate but closely packed parallel moniliform cylinders chiefly made up of large granular cells imbedded in a tough transparent maltha. In specimens decalcified whole the cylinders hang down from the thin surface lamina, the various segments of each cylinder being united by narrow central isthmuses of tissue which had passed through the holes in the centre of the tabulæ. After a long search

among many specimens I failed to find any calcareous spicules, "tuning-fork" or otherwise.

At first sight it seemed that Merlia must be some unknown calcareous organism, viz. Foraminiferan, Pharetronid sponge, Coral or Polyzoan, infested by a remarkable siliceous sponge. Weltner, (2) who had seen some of the fresh specimens and sections, published a short paper entitled "Ist Merlia Normani Kirkp. ein Schwamm?" in which he stated his belief that Merlia was an unknown calcareous organism, and that the siliceous sponge associated with it was merely a "raumparasit" which would probably be discovered sheltering itself in other suitable situations. Later, in a paper on Astrosclera willeyana, Weltner (3) again expressed his opinion that the siliceous sponge had simply incrusted and grown into the calcareous organism. There was, however, an important objection to this theory. When shells on which the Merlia was growing were ground down till the base of the Merlia appeared, the cavities or "crypts"[1] of the calcareous framework were found crammed with the large granular "crypt" cells even five stories down below the surface, and frequently such crypts were roofed over by tabulæ in which the central hole has become reduced to an almost imperceptible slit from 1 to 3 $\mu$ in diameter. À propos of the crypts and the cells inside them, to the question "Whose grave is this?" the answer seemed to be, "'Tis indeed thine, since thou liest in it." I concluded that the cells had been formed in situ and had not grown down from the surface. I named the siliceous sponge Noronha scalariformis, but failed to arrive at any definite opinion concerning the calcareous structure, pointing out, however, its resemblance to certain Palæozoic fossils (Monticulipora sensu lato, Rhaphidopora) and to Heliopora. (4)

Further examination showed that the masses of crypt-tissue were in vital continuity with the sponge at the surface. In some instances bundles of siliceous spicules were found imbedded amongst them. The existence of a sponge with

[1] A name suggested by Prof. E. A. Minchin.

siliceous and calcareous skeleton had seemed to me as improbable as that of a centaur, for no distinction between siliceous and calcareous sponges has been considered so profound as that of the chemical constitution of the skeleton.

After examining about 1000 specimens, and tracing the development of the soft tissues and skeleton at the growing edges, I became convinced that Merlia was, beyond doubt, a sponge with a siliceous and calcareous skeleton (5). The grounds on which this conviction is based are so firm that the final proof, such as would be afforded by seeing an embryo of Merlia settle down and develop the siliceous and calcareous elements, is, in my opinion, no longer necessary. I am having, however, relays of specimens sent from Porto Santo every fortnight, in the hope of discovering when Merlia forms its reproductive cells and embryos, and of thereby being enabled to work out the development.

## Description of Merlia normani.[1]

The great majority of the specimens, of which there are about 1000, were obtained from sixty fathoms off Porto Santo Island. All the specimens from this depth are in the form of small incrustations, on an average about a square centimetre in area and a millimeter or less in thickness. The crusts grow on shells, branches of corallines, Foraminifera, worm-tubes, etc., are bright vermilion in colour, and have a smooth surface. They conform closely to the surface of the objects upon which they grow, creeping round the edges of shells and encircling the branches of corallines (Pl. 32, figs. 1–3). They are flat and thin when spread over the smooth inner surface of a shell, but in other situations they may form slightly thicker convex bosses. Merlia always grows on hard unyielding surfaces, and never on soft objects such as sponges or Ascidians. The Merlia crust is always so intimately united to the surface of foreign objects that it is almost impossible to flake it off without removing some of the

[1] A certain amount of repetition of details given in the introductory account seems unavoidable.

foundation on which it is growing. This close union is one of the characters that has made the problem of Merlia difficult to solve, and has led to false inferences being drawn, as I shall endeavour to explain later.

In addition to the above-mentioned specimens there are two much larger ones requiring special notice. One of these, a fine example forming a large patch over 30 square centimetres in area on a small block of volcanic rock, was hooked up by a fisherman from ninety fathoms off Porto Santo Island (Pl. 32, fig. 4). The specimen was nearly dry when brought to me, but it still retained its red colour. Lastly, in the Seminario Museum at Madeira there is a large fragment of a dead Dendrophyllia covered over a considerable area with a thin crust of Merlia. The coral was hooked up from ninety fathoms off Cape Garajau, Madeira. Pl. 32, figs. 5, 5*a* shows a small piece of incrusted coral, which the authorities of the Seminario Museum kindly allowed me to break off. The Merlia incrusts both the sides and free end of the coral branch. Evidently the sponge flourishes better in ninety fathoms than in sixty, and it may be inferred that the habit of Merlia is always incrusting.

When living specimens are removed from the sea the soft, smooth surface sinks down a little, thus allowing the porcelain-like network, with its minute circular or polygonal meshes and little nodal tubercles, to be seen imbedded in the red flesh. Usually no openings of any kind are to be seen, but in the case of two specimens killed suddenly by dropping alive into Flemming's mixture, several very small circular or oval holes, from 20 to 60 $\mu$ in diameter, were visible (Pl. 32, figs. 7, 8). These two specimens were the best preserved of all, for they were in the expanded condition, and the fixing fluid had penetrated well into the interior.

The thin growing edge of the sponge extends well beyond the edge of the calcareous skeleton in examples in which the crust spreads freely over a surface, but often the growing or creeping edge is dammed up, so to speak, and the sponge and its calcareous skeleton increase in depth at such places.

A living sponge broken in half—i. e. in vertical section—shows (Pl. 32, fig. 10), beneath the soft surface-layer, a more or less regular white calcareous honeycomb, with blocks of reddish orange-coloured jelly filling in the spaces, the appearance being that of pots of jelly superposed one on another in from one to three or four or, rarely, five storeys from edge to centre of the sponge. The blocks often form fairly regular horizontal and vertical rows. Occasionally the uniformity of a vertical row is interrupted by a block of double breadth, and very frequently the regularity of the horizontal rows is broken owing to the blocks of "jelly" being longer or shorter than the average. Pl. 32, fig. 9, shows variation both in the length and (once) in the breadth of the blocks of soft tissue filling in the spaces or crypts in the calcareous skeleton. Pl. 35, fig. 17, shows a section of the skeleton with nearly equal and uniformly arranged compartments. In the youngest specimens, which form little red spots only 2 or 3 mm. in diameter, there are no crypts at all, the calcareous skeleton consisting merely of slender bars of a wide-meshed polygonal network. Also, in the case of specimens which can extend freely over the flat or curved, smooth inner surfaces of old bi-valve shells, there may be only a few crypts in perhaps one or two storeys at the centre of the crust, the rest of the skeleton being composed of deeper or shallower pits, with the floor formed by the surface of the shell.

Not infrequently the sponge grows in depth rather than in extent, and the crypts may then become four, or even five, storeys deep, or rather, it should be said, high, for the growth is from below upwards. In such specimens the storeys may diminish gradually to four, three, two, one, and finally to none at the growing edge.

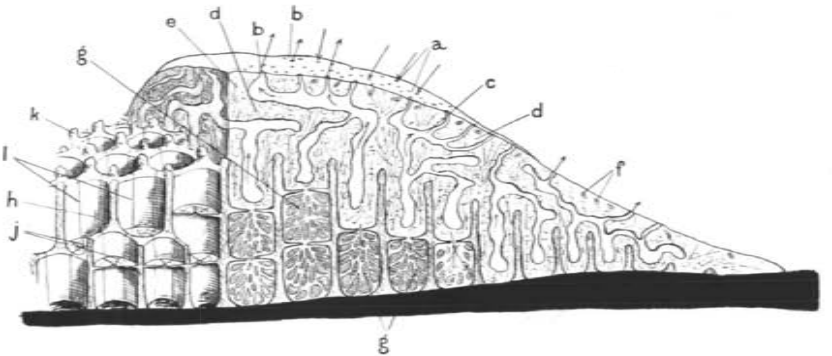
On viewing by powerful reflected light under a low magnification a stained specimen in glycerine, it is possible to see, below the transparent surface, circular masses of flagellated chambers filling in the uppermost spaces of the calcareous framework, and joined to each other by radiating spokes, also composed of masses of flagellated chambers, crossing

over the upper edges of the calcareous walls and between any two tubercles (Pl. 33, fig. 1). The circular masses show a lighter central area, or occasionally two such areas. Further, from one to three nearly vertical bundles of fine needles are present in or above each circular mass. Scattered mostly in or upon the surface of the sponge are very minute, oval siliceous rings. The siliceous spicules are not visible in glycerine preparations, but clearly so in balsam ones. Thin specimens decalcified whole show very clearly the darker node-like circular areas of masses of flagellated chambers joined to each other by five to seven radiating spokes, the blank spaces between the spokes having been occupied by the calcareous tubercles. The under-surface of fairly thick decalcified specimens presents an extraordinary appearance, such as has never been observed before in any sponge. Hanging down from the thin surface-layer of the sponge are closely packed but separate parallel moniliform cylinders. The segments of each cylinder vary in breadth from 75 to 100 $\mu$ (or rarely 150 $\mu$), and in length from 75 to 250 $\mu$. The segments are joined to those above and below by narrow central strands, which had passed through the holes or slits in the tabulæ.

Fig. 9 on Pl. 32 shows a vertical section of a decalcified specimen. The spaces between the cylinders extend from the base of the sponge to the apex of the gaps left by the dissolved tubercles, not taking into account the fine organic basis of the skeleton remaining after decalcification. The upper part of the section, including the ectosome and part of the choanosome, is extremely contracted, but below this the flagellated chambers, bundles of spicules, and the cylindrical masses of large granular cells are to be seen.

Fig. 3 on Pl. 33 shows a decalcified vertical section of one of the two expanded specimens; in the part of the section shown in the figure there happens to be only one mass of crypt cells that had been covered by a tabula. All the other basal extensions of soft tissue had filled in calcareous pits, the floors of which had been formed by the surface of the shell on which the sponge grew (see below, Section 3).

TEXT-FIG. 1.




Diagrammatic plan of **Merlia normani**. Soft tissues removed on the left side of figure. *a*. Incurrent pores. *b*. Oscules. *c*. Excurrent canal. *d*. Flagellated chambers. *e*. Long siliceous spicules( tylostyles). *f*. Clavidises (siliceous microscleres). *g*. Crypt cells (calcocytes) in crypts. *h*. Calcareous skeleton. *j*. Tabulæ (in section). *k*. Nodal tubercles. *l*. Longitudinal sutures.

By macerating specimens in Eau de Javelle the calcareous framework stands out clear (Pl. 32, fig. 6, and Text-fig. 3, see Section 2 *b*).

Having given a general account of the external appearance and coarse anatomy of Merlia, I will now describe the sponge more in detail under the following headings:

(1) The canal system.
(2) The skeleton; (*a*) siliceous, (*b*) calcareous.
(3) The soft tissues and cells.
(4) Young stages of Merlia.
(5) Theory of construction of the calcareous skeleton.
(6) Systematic position of Merlia.
(7) On some resemblances between the calcareous skeleton and certain Palæozoic fossils.
(8) Summary.

## (1) The Canal System: a New Type.

It would have been very difficult to have learned the structure of the canal system from contracted specimens. Under such conditions no surface openings are to be seen, and the upper part of the sponge is squeezed down—like a closed concertina—into the open crypts.[1] Some examples of this very contractile and sensitive sponge, dragged up with a mass of shells and *débris* from sixty fathoms, were resuscitated by trailing them in a bottle in the sea, and then suddenly dropping them into Flemming. In these specimens not only are some of the oscules and pores open, but the whole sponge is expanded and shows wide ectosomal spaces. In contracted specimens the sponge surface almost rests on the calcareous tubercles, but in expanded examples the latter are a considerable distance below.

The larger openings or oscules measure about 60 $\mu$ in

[1] Open crypts—the uppermost spaces in the calcareous skeleton. In the macerated skeleton these spaces are open and not roofed over by tabulæ.

diameter, and the smaller ones or pores about 20–30 $\mu$. Both kinds are oval or circular, and quite flush with the surface.

The pores may form a circle round an oscule (Pl. 32, fig. 7), but sometimes no regular arrangement is perceptible (fig. 8). The regular plan of a central oscule and a ring of pores would seem to conform to the shape of the upper crypts and tubercles, but the reverse is probably the case, the crypts conforming to the arrangement of the canal system, as I hope to make clear later.

Both oscules and pores are provided with a very well-developed sphincter apparatus, consisting of concentric and radial contractile cells for respectively closing and opening the orifices. Some of these cells are remarkable in shape, viz. with long processes which curve round the orifices and which may actually anastomose, thereby becoming porocytes. These cells seem to indicate the mode in which porocytes may have arisen, viz. by the fusion of processes curving round an orifice, and not by the appearance of a hole in the solid body of the cell (Pl. 37, fig. 3).

The incurrent canals pass down and bifurcate, passing right and left (as seen in sections). Some of them present a puzzling appearance, for they are surrounded by flagellated chambers. Sometimes a string or tube of flagellated chambers is seen traversing an open space. The lumen of the tube is the incurrent canal and the open space is an excurrent one, into which the apopyles on the outer surface of the tube open.

Fig. 13, on Pl. 33, which depicts the growing edge of a very young sponge, will show how this arrangement has probably come about. In the youngest stage the canal structure is that of a simple rhagon, i. e. of a gastral cavity with much folded walls, the folds branching out to the periphery. The spaces between and outside the folds constitute the incurrent, and those in the lumen of the folds, channels or canals, the excurrent system.

The incurrent canals pass between the little clusters of flagellated chambers, which clusters at this stage have a

narrow lumen (or excurrent canal). In the course of growth the clusters expand at the same time that their lumen increases, and they encroach on the incurrent spaces, which may now consist of narrow channels or canals completely surrounded by flagellated chambers.

A tube of flagellated chambers may be compared to a hollow central column (say with a "pore" at the summit opening on the roof) supporting a groyned vault, the concave surfaces of which face the interior of the building which leads to a door (oscule).

The excurrent spaces or channels in the upper part of the sponge often form wide pouch-like out-foldings, but those in the deeper parts which are crowded into the uppermost open crypts of the hard skeleton are in the form of narrow canals.

In a section the in- and excurrent canals are easily distinguished by the direction of the apopyles and the collar-cells. A terminal excurrent canal or space opens into the floor of one of the large ectosomal spaces, and the latter open to the exterior by an oscule.

The flagellated chambers possess a remarkable structure not known to occur elsewhere. They are semi-oval or hemispherical, and about 33 $\mu$ in diameter. They are usually closely approximated to each other, being joined—or separated—only by a few connective-tissue cells.

Stretched across the excurrent aspect of each chamber is a membrane with a thin-edged circular apopyle in the centre. Nearly surrounding each apopyle is a single contractile cell which acts as a sphincter muscle. The apopyles vary in diameter from a point up to nearly the width of the flagellated chamber.

The prosopyles consist simply of spaces between the fused rays of the stellate bases of the collar-cells (Pl. 33, fig. 6) —a character recalling the membrana reticularis of Hexactinellida. This stellate arrangement of the cell-plasma is not easy to see, and I am thereby led to believe that this mode of union may possibly occur among other tetraxonid

sponges, especially among those with a eurypylous type of canal system.[1]

The collar-cells vary greatly in appearance according to their state of contraction. Figs. 8–12 on Pl. 33 are drawings of collar-cells on one and the same slide. Some are relatively short and thick, with the collar contracted down and joined to the collars of neighbouring cells, and with a wide opening with polygonal outline. Others are elongated and with separate cylindrical collars. The collar-cells vary in height from 4·5 $\mu$ to 8·5 $\mu$. The usually spheroidal but sometimes hemispherical body is about 3·3 $\mu$ in diameter. The spherical nucleus is at or near the base of the cell. The flagellum passes down through the cell to the nucleus (Pl. 33, fig. 12). The name "hymenopylous"[2] is proposed for the new type of canal system, which seems to be a modification of the eurypylous type.

### (2A) The Siliceous Skeleton.

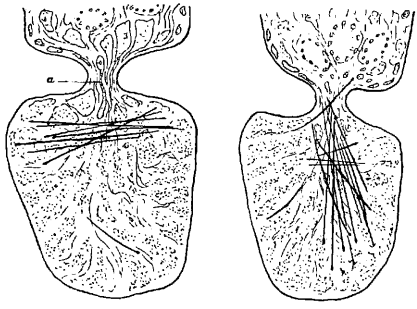
The siliceous skeleton consists mainly of upright bundles of

[1] Fig. 6, Pl. 33, is, I find, slightly diagrammatic in places, but it is sufficiently accurate in places to justify the statement that the collar-cells are joined to each other by stellate basal processes. Further investigations of new, well-fixed material, prepared with a good plasma stain, are desirable. It is not surprising that we have so little knowledge concerning the inter-relations of collar-cells in siliceous sponges. The difference between the tissues of healthy living sponges and dead ones fixed under the best possible conditions must be very great, especially in the matter of contraction. Minchin and Reid have shown ('Proc. Zool. Soc., London,' 1908, p. 674, pl. xxxvii, fig. 24) that in Clathrina contorta the bodies of the collar-cells are separated by delicate extensions of the gelatinous ground-substance of the sponge. Muriel Robertson and Minchin ('Quart. Journ. Micr. Sci.,' November, 1910, p. 621) write that probably the collar-cells are connected across this intervening substance by protoplasmic fibrils, though they have not yet seen such connections. Certainly the manner in which a contracted Ascon with its collar-cells squeezed out among the porocytes expands again with all its collar-cells "dressed" and in line would lead one to suspect that here also there may be a kind of collar-cell membrane, as in Hexactinellids.

[2] *ὑμήν, ένος*, membrane; *πύλη*, gate.

slender tylostyles[1] with pointed ends outwards, along with a few slender rhaphides, which form more or less vertical pillars of support round the large ectosomal spaces and incurrent canals. In contracted sponges one to four of these vertical wisps are drawn down into the upper crypts, but in expanded specimens the wisps are outside the crypts and form supporting pillars to the ectosome and canals (Pl. 32, fig. 10, and Pl. 33, fig. 3). Sometimes a bundle of spicules lies transversely on the floor of an upper open crypt. Only very rarely are spicules of any kind found in the lower crypts, but neverthe-

TEXT-FIG. 2.




Sections of masses of crypt-tissue showing siliceous spicules. *a*. An elongated calcocyte in neck of crypt. Soft crypt-tissue mostly disintegrated owing to insufficient fixation. × 225.

less they do occur there. (The probable reason for this rarity is explained in Section 5).

Numerous microscleres in the form of oval rings—for which I propose the name "clavidiscs"[2]—are scattered about on the surface, and also, but much less abundantly, deeper down.

[1] In the report on the "Discovery" Tetraxonida I have used the term "tyle" in place of "tylostyle," because it was short, and by way of antithesis to "amphityle," but I now return to the commonly used designation "tylostyle."

[2] Clavis, key, referring to the key-hole notches; discus, quoit.

A second kind of microsclere, viz. a very minute, slender, simple sigma is found in fair abundance in the choanosome, especially in the immediate neighbourhood of the flagellated chambers. At one time I thought these spicules were the broken curved ends of rhaphides, but latterly I have seen the little spicules in their scleroblasts.

Rhaphides and trichodragmata constitute a third and fourth kind of microsclere.

The Spicules.—The slender tylostyles (Pl. 35, fig. 1), which are commonly curved at the distal end, though sometimes nearly straight, are about 140 $\mu$ long, 1·8 $\mu$ thick, and with oval heads 5 by 2·2 $\mu$ in length and breadth. The rhaphides (Pl. 35, fig. 2*a*) are about 80 $\mu$ long. They are found separately or mixed in with tylostyles. Trichodragmata (Pl. 35, fig. 2) occur, but are rather rare. In one specimen there are toxa-like spicula with a central kink or bend (Pl. 35, fig. 13), but this is an exceptional feature. The clavidiscs (Pl. 35, figs. 3–9) are about 45 $\mu$ long, 30 $\mu$ broad, and with the rim, which is bevelled inwards to a thin edge, 3 $\mu$ broad. A key-hole shaped sinus or notch is present on the inner margin at each end of the long axis. The axial canal is in the centre of the thickness of the outer edge of the rim. Numerous variations and sports occur, which are interesting because they show the mode of origin of these spicules, viz. from deeply curved rods which have bent round till the ends met and joined. Sometimes the ends cross or do not meet at all, or a transverse bar may cross from side to side (Pl. 35, figs. 7, 8). Fig. 14 shows clavidiscs with a disc-like plate in place of the key-hole sinus. Fig. 7 shows a sigma-shaped spicule which is probably merely a deviation from the ring shape. Again, the key-hole sinuses may be absent from one or both ends. Lastly, the clavidisc may sometimes be in the form, not of a ring, but of a solid disc (not figured).

I had formerly supposed (**6**) that the clavidiscs were related to chelate spicules of Desmacidonidæ, but I now consider their affinities to be with the diancistra of Hamacantha (see Section 6 on the affinities of Merlia). These spicules

are mostly scattered at the surface, in which they lie horizontally.

The oval rings found deeper down in the sponge usually have thinner rims. In one instance six rings followed at equal intervals on one side and five on the other side of the mass of sponge filling an open crypt. Hence I called the upper part of the sponge Noronha scalariformis.

The very fine primitive simple sigmata are commonly found in the neighbourhood of the flagellated chambers.

There seems to be no transition between the sigmata and the clavidiscs. At the same time the clavidiscs probably developed from some such form. In one or two of the myocytes acting as sphincters round the apopyles there seemed to be an appearance of a slender curved axial rod of silex. Possibly the slender sigmata may originally have come into existence owing to the presence of sphincters, which surround not only the pores and oscules, but also the apopyles of the flagellated chambers.

To sum up, normally there are five kinds of spicules in Merlia, viz. tylostyles, long rhaphides, trichodragmata, clavidiscs, and slender sigmata. Rarely thicker sigmata and toxa occur.

Pl. 35, figs. 11–15 show abnormal forms of spicules, all found in one specimen.

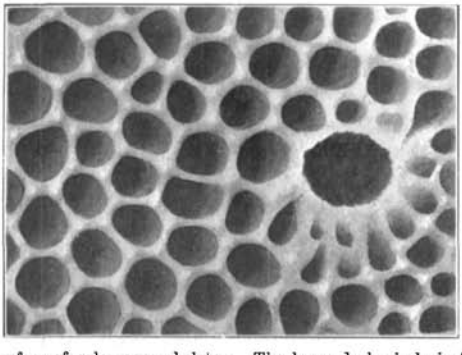
### (2b) The Calcareous Skeleton.

When a living sponge is taken from the water presently the semi-transparent, red, fleshy surface sinks a little, and the porcelain-white calcareous skeleton becomes visible. Under a lens it is possible to see the very minute circular or polygonal meshes of a fine network, and the still more minute tubercles rising from the nodes. In dried specimens the flesh forms merely a thin yellowish pellicle, covering the surface, which has a uniformly granular aspect due to the tubercles below, with here and there a polygonal pattern where the soft tissues have sunk more deeply into the spaces of the skeleton beneath.

For the investigation of the skeleton specimens were macerated in Eau de Javelle, and vertical and horizontal sections ground down, and some examples were incinerated. To the naked eye the surface of a macerated-out skeleton or of a dried specimen like that encrusting the Dendrophyllia (Pl. 32, fig. 5, 5*a*) has a very finely porous appearance, the meshes being barely visible.

The meshes are about ·18 to ·22 mm. in total diameter, i.e. four and a fraction to a millimetre, the actual spaces or holes

TEXT-FIG. 3.



Surface of calcareous skeleton. The large dark circle is the mouth of a worm-tube. × about 40.

being about ·12 to ·15 mm. across, and the walls about ·04 to ·06 mm. thick. The number of tubercles round a mesh varies from four to seven or eight, five or six being the average number. Occasionally two meshes are combined into one larger oval one, with ten to twelve tubercles.

The tubercles are about 75 $\mu$ high and 75 $\mu$ broad at the base, and are covered with very minute sharp-pointed conules about 10 $\mu$ high and 16 $\mu$ broad at the base, but varying both in shape and size. The point of the conule is generally nipple-shaped and may lean over a little to one side. Again the

conules may be rounded at the summit, or more elongated than usual. A little below the surface the uppermost tabulæ are visible, each with a central, circular or oval hole or nearly closed slit (Pl. 35, fig. 16). Sometimes the tabula is merely a rim or ledge round the inner wall of the calcareous tube, and the central hole is correspondingly large; or, again, the tabula may be imperforate. The tabulæ show five or six sutural lines radiating from the central hole or slit to the circumference.

On the surface of the specimen incrusting the Dendrophyllia there are numerous small circular holes due to worm-tubes, and here and there among the ordinary meshes of the Merlia are larger ones nearly ·5 mm. in diameter, with a shallow floor, on which there are radiating ridges and even a central columella-like knob, the whole somewhat resembling a very small coral calycle. The large meshes are here simply due to the effort of the sponge to repair the lesion caused by the presence of the worm-tubes, the openings of which are found just beneath the floors of the supposed calycles.

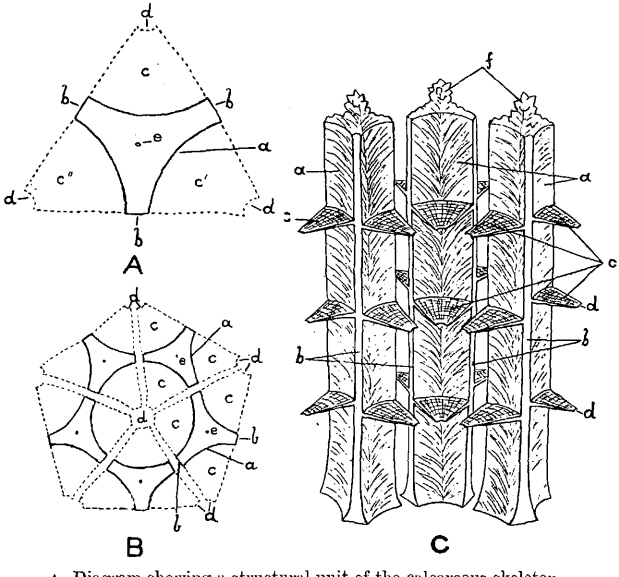
A vertical section of the skeleton shows parallel vertical tubes divided up by tabulæ (Pl. 35, fig. 17). Often the tabulæ form a series of parallel horizontal planes at regular intervals of about ·15 mm., but the regularity is frequently disturbed, as will be obvious from fig. 9 on Pl. 32, showing the soft tissues which filled the crypts.

The magnified surface view of the skeleton (Pl. 35, fig. 16) shows three flanges or wings radiating from the base of each tubercle and meeting opposing flanges from neighbouring tubercles. A sutural line marks the junction of the opposing flanges, and the most prominent radial sutures on the tabulæ are continuous with those between the flanges. A vertical section shows the interflange sutures to be continued as vertical lines down the walls of the tubes from surface to base.

The tabulæ are about ·015 mm. thick. On both surfaces, in addition to the radial sutures there are fine concentric markings confined to those surfaces, the thickness of the tabula being homogeneous. The radial sutures typically

run from the central region to the vertical sutures between the flanges and are continuous with them, though occasionally this arrangement is a little obscured. Fig. 19, Pl. 35, shows a thick ground-down section in balsam as viewed by powerful

TEXT-FIG. 4.




A. Diagram showing a structural unit of the calcareous skeleton. Horizontal section at level of three tabulæ. *a*. Curved surface. *b*. Suture of flange. *c*, *c'*, *c''*. Three segments of tabulæ. *d*. Margin of portion of central hole in tabula. *e*. Central vertical axis below apex of a tubercle. B. Diagram showing five structural units joined to form one tube and tabula, and parts of five other neighbouring tubes and tabulæ. Horizontal section at level of tabulæ. Lettering as before. C. Three structural units in elevation (diagram). Lettering as in A. *f*. Tubercle.

oblique reflected light. The walls of the tubes were here, i. e. at the base of the sponge, very thick, but both the hori-

zontal tabular and vertical (or columnar) sutures were beautifully lighted up.

The disposition of these vertical and horizontal sutures clearly shows how the skeleton has been built up. The structural unit is a broadly based pillar with three vertical longitudinal wings or flanges (which unite with the flanges of three juxtaposed columns), and with three vertical longitudinal curved surfaces or flutings which form a part or segment of the walls of three tubes, and lastly with tiers usually of three horizontal triangular tabular segments in one plane, the number of tiers varying with the number of tabulæ. (See diagrams A, B, C in text.)

It was a surprise to find that there was no continuous floor such as was depicted (in vertical section) in my original figure.(7) The seeming existence of a floor in certain places is apparently due to the section cutting through the thick outspread base of a vertical wall.

It is certain there is no continuous basal lamina at the periphery of thin spreading crusts, but occasionally I have seen what appear to be complete floors at the base of some of the basal crypts. The floor of Merlia is formed by the shells, coralline algæ, Foraminifera, etc., on which the sponge is growing. The vertical walls of the lowest crypts, often thickened and spread out a little at their bases, are intimately fused with the foreign foundation.

Under a fairly high power the skeleton shows a finely fibrillar structure (Pl. 35, figs. 16, 17). When the skeleton is viewed from the surface, the fibrillæ are seen to radiate out from below the base of each tubercle towards the longitudinal sutures, where they meet but do not blend with the fibrillæ of opposite flanges (Pl. 35, fig. 16). Superposed zones of fan-like bands of striæ radiate upwards and outwards from the vertical axes of the columns of the skeleton and pass into the tabulæ and walls of the tubes (Pl. 35, fig. 17).

An English colleague was engaged, at the time this was being written, in the attempt to show that Merlia was a Foraminiferan. He had only a dried skeleton, coming, I

believe, from the West Indies, and two of my specimens of the real Merlia from Porto Santo, on which to base his conclusions. If I had had such scanty material, I also might easily have come to the same conclusion, because Merlia often grows on a spreading crust of Polytrema or other Foraminifera, and the cancellated structure of the latter appears to belong to the Merlia; but having had hundreds of specimens to deal with, I have found Merlia growing on shells, on gneiss, on spreading laminæ of thin incrusting Corallines, etc. Foraminifera with a superficial reticulate pattern with nodal tubercles are not uncommon. Dr. Harmer showed me one he had found among the "Siboga" Polyzoa. Professor Stanley Gardiner collected a similar species incrusting Lithothamnion from Providence Reef. I myself dredged a Carpenteria-like species off Christmas Island. In all these instances the Foraminiferal nature is clearly shown by the finely perforated floor at the base of each mesh. At one time I myself thought Merlia was a Foraminiferan, not only on account of the calcareous skeleton, but also because the masses of crypt-cells (in glycerine) looked like lobose pseudopodia, the maltha in which they were imbedded being invisible.

At the growing edges of the sponge and in whole young specimens there is simply a delicate network of calcareous bars. In the case of young specimens on thin bivalve shells one can often see through the whole structure. The soft sponge tissues cover the calcareous network, which has no basal lamina, and there is no trace of any other organism whatsoever. Even this strong circumstantial evidence in favour of the theory that Merlia is a sponge is unimportant in comparison with the positive evidence afforded by the soft tissues.

The growing edge of the skeleton shows the delicate polygonal network, with half- or open polygons at the edges, and here and there isolated small lumps or even bars (Pl. 38, fig. 5). In the older parts the slender bars of the delicate meshwork have increased in height and the meshes have become pits, and still later tubes with one or more tabulæ.

The growth of the skeleton is much influenced by the conformation of the base. When growing on shells or worm tubes with ridges, the sponge makes squarish oblong meshes with parellel or concentric arrangement (Pl. 35, fig. 20).

This last figure of a specimen macerated in Eau de Javelle shows well also the earliest beginnings of the skeleton before bars or tubercles are formed. Here, in places, little smears of calcareous scales are beautifully distinguished on the reddish surface of the worm-tube. These glistening bands have a crystalline appearance as if a brush dipped in strong solution of sugar had been drawn over the surface and allowed to crystallise. The individual scales have a finely punctate structure, and each one shows a little elevation which corresponds, I believe, to the nucleus of the cell which, made the scale (Pl. 35, fig. 21). Viewed as opaque objects, the fine points and the little nuclear hump in each scale strongly reflect the light. I was unable to detach the glistening scales from the worm-tube so as to examine them by transmitted light under a high power.

The calcareous skeleton of Merlia is formed of calcite. Dr. G. T. Prior found that the specific gravity was 2·65. That of pure calcite is 2·7, the difference being due to a certain amount of organic matter remaining in the Merlia even after being finely ground and macerated. The specific gravity of arragonite is much higher, being 2·9, and, moreover, Meigen's test gave no reaction.

### (3) The Soft Tissues and Cells.

Merlia is semi-transparent, and its tissues are of a soft texture, but, at the same time, rather tough. The bright red colour resides in the granules of certain cells—the amœbocytes. The colouring matter is soluble in alcohol, in which it forms an orange-yellow solution. The cells will be described under the following headings: (A) Collencytes, and ground substance or maltha; (B) gland-cells and cuticle;

(C) canalar epithelium; (D) myocytes; (E) scleroblasts; (F) choanocytes; (G) amœbocytes; (H) tokocytes.

### (A) Collencytes or Connective-Tissue Cells.

The connective-tissue cells or collencytes (Pl. 37, fig. 2) are finely granular with an oval vesicular nucleus devoid of a distinct nucleolus, and with branching processes which anastomose with those of other collencytes to form a network. The ground substance or maltha at first sight seems almost homogeneous, but in good preparations under a high power it shows a very finely fibrillar structure. When bundles of fibrillæ are cut across they form finely granular areas in section (Pl. 34, fig. 4).

### (B) Gland-cells and cuticle.

The sponge surface is often coated over with a very thin layer of structureless cuticle, apparently the product of elongated granular cells vertically orientated just below the surface (Pl. 37, fig. 4). In these cells there is a minute dark body like a nucleolus, but situated just outside the vesicular nucleus.

### (C) Canalar Epithelium.

A remarkable feature of great interest, and, I believe, unique, is the absence of a surface layer of epithelium. In all the best preserved material I found the cells at the surface precisely the same as those in the body of the sponge, i. e. they were branching collencytes well separated from each other by the maltha in which they were embedded. Knowing how difficult it often is to see the outlines of surface epithelial cells, at first I concluded that the cuticle—usually, but not always present—was an epithelial layer. Further, in one or two very contracted specimens, which had not been properly fixed, the collencytes had become so pressed down in the

maltha as to resemble an epithelium when viewed from the surface. In some very thick vertical sections, well preserved and stained, it was possible to see a considerable area of the surface as well as the depth of the sponge, and to note the entire absence of any trace of an epithelium. Accordingly, Merlia in its adult condition affords a confirmation of the theory put forward by Haeckel and confirmed by the embryological researches of Maas, Yves Delage and Minchin, that the sponge is a two-layered organism. Merlia has an "exoderm" and an "endoderm," but no mesoderm.

Although there is no epithelium on the surface of the sponge the canals have an epithelial lining, which apparently consists of cells of the same nature as the collencytes in the maltha, for sometimes a cell on the surface of a canal has branching processes extending back into the maltha.

### (D) The Myocytes.

The myocytes form concentric or radial groups round the incurrent and excurrent orifices. The myocytes have a granular plasma, the granules being coarser than those of the collencytes, and the nucleus is vesicular and without a nucleolus. They vary greatly in shape, but generally have branched prolongations—indeed, they do not differ greatly from the collencytes. Sometimes the branched prolongations surround an orifice and fuse, so that the myocyte becomes a porocyte (Pl. 37, fig. 3). Further, one or more small, curved, fusiform myocytes surround the apopyle of each flagellated chamber.

### (E) Scleroblasts.

The scleroblasts are very finely granular, and with a clear spherical nucleus. Pl. 36, fig. 2 shows these cells both in longitudinal and transverse sections of spicule bundles. Pl. 36, fig. 10 shows a scleroblast of one of the clavidiscs.

### (F) Choanocytes.

(See under "Canal System," Section 1, and Pl. 33, figs. 8–12.)

### (G) Calcigenous Amœbocytes or Calcocytes.

It is to these cells that the extraordinary character of Merlia is due, for they are calcigenous, and it is their function to build the calcareous skeleton.

Quite apart from their lime-forming function, the arrangement of these masses of cells in the form of moniliform cylinders is a very remarkable feature.

Before I had understood the structure of Merlia I called these cells crypt-cells, because many of them are found in spaces of the calcareous skeleton covered over by tabulæ. As I am now practically certain that these cells which fill up the crypts also build those structures, I suggest the designation "calcocyte," which is in keeping with the cytological terms now in use. Since these lime-forming cells of a siliceous sponge constitute a special and unique phenomena, I think they should be distinguished by a separate name from the telmatoblasts, or better, telmatocytes, which form the cement in Pharetron sponges.(8)

The lime-forming cells of Merlia are exceptionally deserving of the designation "amœbocyte," for they exhibit a remarkable variation in shape in accordance with their position in the sponge and the kind of work they have to do. Before settling down to build the skeleton and in places where they are not compressed in an enclosed space they are more or less elongated (Pl. 38, fig. 1). When caught in the isthmus between two crypts they may be vermiform (Pl. 36, fig. 3, and Text-fig. 2). In the crypts, where the cells are pressed against each other, they are massive and cylindrical or pyriform (Pl. 36, figs. 1–4), excepting on the outer surface of the crypt masses, in which situation they become flattened (Pl. 34, fig. 6*a*, and Text-fig. 5). When forming the bars of the young calcareous skeleton or the inner smooth walls of crypts

they form large flat plates with the nuclear region projecting out from the free surface (Pl. 36, figs. 6, 7, 8).

Whatever their disguise, they possess certain common characters which enable them easily to be recognised. They are crammed with large orange-coloured pigment-granules, the colour being retained for a long time in specimens preserved in glycerine or formalin. Further, they have a large, soft, spheroidal or oval, vesicular nucleus and a distinct nucleolus. The granules, which stain easily and deeply, vary apparently according to the state of the metabolism—that is to say, in the early stages in the history of a calcocyte the granules are often of unequal size, but when they are in a position to lay down lime they become more or less uniform.

When the granules are pressed out of a cell and viewed under a high power slightly out of focus they appear as uniformly light discs, and gradually, as they are brought into focus, a dark point appears in the centre surrounded by a light circle; on focussing down further the dark point enlarges till the circle becomes uniformly dark. The appearance of the dark point in the light circle is of some importance, because it is seen all over the surfaces of the calcareous skeleton, where the ends of the fibrillæ give this appearance, and even in the interior of the conules on the tubercles (Pl. 35, fig. 22, and Pl. 36, fig. 9). The granules appear to be the essential calcigenous elements.

Wherever the skeleton is being laid down these granular calcocytes abound, and in decalcified specimens they are found in the closest relation with the organic basis of the dissolved skeleton.

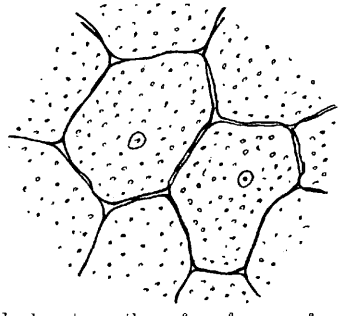
Pl. 34, fig. 3, shows a decalcified tubercle and side of a polygonal mesh with the calcocytes closely applied.

Fig. 1 on Pl. 37, which represents the extreme growing edge of the sponge, is especially interesting, for it shows the calcocytes planning out the first foundations of a polygonal mesh on the surface of the shell on which the Merlia is growing. The calcareous products of calcocytes in this position are flakes or scales (see Section 2B, and Pl. 35, fig. 21).

I believe the whole skeleton to be made of calcified calcocytes. Fig. 22 on Pl. 35 shows a camera lucida drawing by Mr. Highley of a conule, which seems to me to be nothing else than a petrified calcocyte. For the conule fits like a cap on the rounded surface to which it is attached; also the edges of its base are rounded and show a lobose process. Further, there is an appearance of an oval nucleus in the interior, and the fine structure shows the granules each with the dark central point.

In the crypts and on the bars of the polygonal network the

TEXT-FIG. 5.



Flattened calcocytes on the surface of a mass of crypt tissue. × 750.

surface calcocytes are spread out in the form of plates (Pl. 34, fig. 6, and Pl. 36, fig. 1, both in vertical section), and the nucleus forms a little hump-like projection on the surface facing the soft tissues.

The supposed epithelium on the surface of the masses of crypt-cells is composed simply of flattened-out calcocytes of the same nature as the massive cells in the interior of the mass. Fig. 1 on Pl. 36 is drawn from sections made from material in which the fixing fluid did not well penetrate. The large nuclei of the plate-like calcocytes are shrunk and compressed, and cut into vertical sections. Fig. 6 on Pl. 34 shows much better the

vertical sections of the calcocytes on the surface of a crypt; here the nucleus is pressed outwards or away from the skeletal face of the cell to form a little mound on the opposite face. The most difficult part of this investigation was the discovery of the precise nature of the surface of the masses of crypt-tissue. This difficulty was partly due to the slowness with which fixing reagents penetrated into the nearly inaccessible crypts, and partly, I think, to actual variation in the condition of the surface-cells owing to functional causes. Pl. 34, fig. 6, shows a well-fixed Flemming preparation, and Pl. 36, fig. 1, a badly fixed osmic-picro-carmine one. Sometimes flattened surface-calcocytes are very well shown; at other times one can make out only a diffused layer of granules, the boundaries of cells being invisible.

There is a possibility that the large inner cells may be trophic stores, but in my opinion the surface crypt-cells are amoebocytes of the same nature as the inner ones, and also I think they are calcigenous, and not by secretion, but by actual transformation.

Fig. 6 on Pl. 36 shows the calcocytes forming an epithelium-like layer closely moulded to one of the calcareous bars of a polygonal mesh at the growing edge of a crust of Merlia.

The theory that the calcocytes become wholly transformed into calcified lumps or scales is confronted with one difficulty, viz. to account for the fan-like, fibrillar structure of the skeleton. I can only suggest that possibly the fibrillation is a secondary change. A decalcified section of a tubercle (Pl. 34, fig. 3*b*) shows radiating, fibrillar structure apparently corresponding with that of the hard skeleton.

A propos of the calcocytes, it only remains to say that the cylindrical, moniliform masses of these cells are simply basal prolongations of the sponge body in which they have accumulated. The cells are imbedded in the finely fibrillar maltha, just as are the rest of the tissues of the sponge. Occasionally the maltha in the crypts contains collencytes, scleroblasts, and spicules, and, very rarely, undeveloped wedge-shaped

collar-cells, such as occur in the youngest specimen. The reasons for this sharp separation between hypersome and hyposome now seem to me obvious. The calcocytes migrate down and accumulate in the base of the sponge, leaving but little or no room for the other elements, which can only expand upwards. The continued growth of the soft tissues thus separated into upper and lower, or superficial and basal, within the confined space of calcareous pits or tubes which have gradually been forming, leads to an hour-glass constriction and forming of tabulæ, with still more complete separation of the hyper- and hyposomal elements (see Section 5 below).

Often the calcocytes migrate to the periphery of a crypt, leaving the central part of the maltha clear and free of cells, and giving to the mass of cells the appearance of being arranged as a columnar epithelium against the crypt-wall and surrounding a cavity (Pl. 34, fig. 4). Partly for this reason I was led to think that Merlia might be a coral of some sort, since both the hard and soft tissues "conspired" to produce this impression.

### (H) Tokocytes.

At one time I thought that the cylindrical masses of calcocytes in the crypts were gemmule cells, but unless they were capable of dissolving the calcareous skeleton, in which most of them were interred and cut off from the world, it was difficult to understand what could be the object of forming gemmule cells in nearly closed crypts, roofed in by tabulæ with central holes or slits sometimes only from 1 to 3 $\mu$ in diameter.

Just below the choanosome in one section are some granular cells with the nucleus and nucleolus larger even than in the calcocytes (Pl. 34, fig. 8). Such cells may be egg-cells. The specimen from which the section was made was captured in May.

### (4) Young Stage of Merlia.

The youngest example found was in the form of a little red

spot, about 2 mm. in diameter, on the inner surface of a shell. The figure (Pl. 32, fig. 12), magnified twenty-five times linear, shows the delicate polygonal network below the surface of the sponge. There are no crypts at this stage, but simply the slender strands or bars of the wide-meshed network, with small tubercles at the nodes.

A vertical decalcified section, highly magnified (Pl. 38, figs. 1–3), shows a layer of cells all over the sponge at, or rather just below, the surface. The cells have processes which branch dendritically into innumerable slender fibrillæ or filaments. The fibrillæ passing to the surface form a thin, surface feltwork, which shows as a thin line in the section.

Bundles of fibrillæ pass down from the cells of the upper surface, and up from the basal cells. Occasionally the opposing filaments meet and almost form a central, horizontal lamina, especially near the periphery of the sponge, where the upper and lower surfaces are very close together. The waving masses of branched fibrils almost resemble the flames of a conflagration as conventionally depicted.

The calcocytes are elongated, and mostly congregated near the base of the crust and orientated at right angles to the base, like a field of stakes or hop-poles. Many of these cells are embraced between bundles of fibrillæ passing up from the basal branched cells.

The flagellated chambers are not yet formed, but the collar-cells are present as small wedge-shaped cells which here and there show a tendency to be arranged in half circles (as seen in section). Further, some wedged-shaped cells appear to be prolonged at their acute angle into a filament which joins on to a main filament, like the main stalk and secondary stalks of a pinnatifid leaf. Apparently the main stem and lateral stems represent the beginnings of the canal system. I have not been able to determine the nature and relations of these branched filaments; possibly they are the processes of connective-tissue cells.

Scleroblasts and their spicules are abundantly present.

The little grooves or arches at the base of the section are

the gaps left by the dissolved bars of the calcareous skeleton. In this situation a few calcocytes are seen in the walls of the arches.

(5) Theory of Construction of the Calcareous Skeleton.

The skeleton is formed by the granular amœbocytes or calcocytes. The youngest stages of the skeleton (Pl. 35, figs. 20, 21) consist simply of microscopic scales, flakes or lumps laid down on the surface of the shell or other body which Merlia incrusts.

Within the growing edge of a flat, thin, spread-out specimen of the sponge the edge of the skeleton is visible in the form of slender bars forming a polygonal network, the polygons being incomplete at the extreme edge. In a still younger stage, visible only under fairly high powers, the slender bars are no more than smears or streaks of flakes, scales or lumps, somewhat higher at points where the tubercles will be formed. In course of growth the smears become ridges, and the polygonal outlines grow into circular pits with a rim of tubercles, and finally the pits become tubes with tabulæ varying in number from one to five, but commonly with one or two.

I believe that this complicated structure can be accounted for in the following way: Merlia is a thin incrusting siliceous sponge which has acquired the character of forming a calcareous skeleton. This sponge, like many other Tetraxonid sponges, is a modification of the simple "rhagon," i.e. of a thin-walled flattened sack with the choanosomal folds branching out all round. The mode of growth is that of dichotomous branchlets extending out from centre to periphery and possibly anastomosing with or in close juxtaposition to neighbouring branches (see radiating spokes on Pl. 33, fig. 1). At some epoch in its history—a point to be discussed later—the metabolic cells, the amœbocytes, became fed up with carbonate of lime, and either underwent calcification or re-secreted the lime. These cells would necessarily occupy the spaces in the sponge between the choanosomal branches, especially at points of

bifurcation.[1] Accordingly heaps of amœbocytes would accumulate at these points, and would extend along lines at right angles to the choanosomal branches till they met neighbouring ridges, in such a way as to enclose polygonal or circular areas, over the edges of which the choanosomal branches would extend (and between the tubercles or points of greatest heaping). At last the shallow meshes would become pits into which the heavy amœbocytes loaded with calcigenous granules would migrate. The heavy masses of loaded amœbocytes in the pits would tend to stay there, but the choanosome and ectosome would continue their growth in the direction of the surface. A tendency to a cleavage into two zones, hypersome and hyposome, would gradually become accentuated, especially in cases where the sponge can increase considerably in depth.

The result of the pull between opposing forces would be to cause in the little cylinders of soft tissue an hour-glass constriction. The continual growth of cells and tissues in a confined space would fill in the space round the hour-glass neck so that the "glasses" would become two closely approximated cylinders, between which the amœbocytes, or rather, calcocytes, would form a tabula leaving only an isthmus of tissue. Often even this little isthmus is nipped in and finally cut through by the total closure of the tabula, and the calcocytes below become cut off and buried in their crypt.

Obviously with varying factors there will be varying results. With uniform migration of calcocytes over a flat surface there is a tendency to peripheral extension rather than to growth in depth, and a uniform pull between hypersome and hyposome will lead to uniformity in size of crypts and to deposition of tabulæ in horizontal planes, and so on.

[1] The laying down of calcareous bars in the earliest stages before the flagellated chambers are formed would seem at first to furnish an argument against the theory that the form of the calcareous skeleton has been, so to speak, moulded by the choanosome. It must be remembered that siliceous spicules are found, too, in the youngest stage, and these must originally have been developed later than the flagellated chambers. By "choanosome" is here meant chiefly the canal system and flagellated chambers.

A simple model such as a wide india-rubber tube attached at one end and stretched so as to form a "node"—which could be tied with string—may serve to represent hyposome and hypersome. If air be forced in at each end, the two sections will become cylinders tending to approximate at the node. The pumped-in air will represent the growing tissues and cell-masses. Perhaps the rubber tube should be encompassed by a hard cylinder corresponding to the calcareous pit or tube.

Where growing protoplasm surrounds itself with a nearly closed calcareous cell or wall this opposition between the pull of basal inertia and that of centrifugal growth force tends to bring about the formation of a tabula or its equivalent.

In cases where the soft tissues in a tube are lifted bodily up and secrete a new floor at their base the comparison with what takes place in Merlia does not quite hold. The hour-glass-shaped siphonoglyphe of Tubipora and the cystiphragms in certain Monticuliporas appear to be due to special kinds of pulls or strains on the epithelial and other soft tissues.

The varying style of construction of the calcareous skeleton is due, I believe, to the fact that the calcocytes either settle down and deposit heaps of lumps (the conules of the tubercles) or—in the case of crypt-walls and tabulæ—layers of flakes. When crowded in the crypts the actively secreting calcocytes are spread or squeezed out flat and make smooth walls, filling in irregularities between the already formed conules. Sometimes from difficulties of terrain, such as the presence of steep ridges or shells, the little builders form thick conical main pillars conulated from base to summit and with scarcely any flanges or tube-walls.[1]

[1] The researches of Koch and Bourne seem to prove that the skeleton of stony corals is formed as a secretion from calicoblasts. Heider and Maria Ogilvie, on the other hand, have concluded that this skeleton is the product of calcified cells. At present the former theory is in the ascendant. I have given evidence, though not so much as I could have wished, to show that the almost coral-like skeleton of Merlia is built up of calcified cells. The amœbocytes of a sponge are so very different from the epithelial cells of a coral that it is doubtful whether the knowledge of the mode of skeleton formation in Merlia would throw light on the question of stony coral formation.

Porto Santo is a little island about six miles long from east to west, with a small islet, Cima,[1] at its south-east corner, and another, Ilheo de Baixo, at its south-west corner. Baixo, which is a volcanic island, is extremely interesting geologically, for it has beautifully preserved coral reefs sandwiched between layers of basalt. The Madeirans use the coral for lime, and the English name of the island, viz. Lime Island, is of some significance from the point of view of a theory I am about to suggest in explanation of the peculiar feature of Merlia, viz. that this little sponge may have acquired its lime-forming character at the epoch when the coral reefs of Baixo were being formed, that is to say, during the Miocene period.[2]

There would probably have been a larger amount of carbonate of lime in solution and of fine particles of that substance in suspension in the sea-water in that area than at present.

Possibly the metabolic cells of Merlia became fed up (if a vulgar colloquialism may be permitted in the classic pages of this journal) with calcareous matter, and either re-secreted it, or became wholly calcified into lumps or flakes.[3] Nature, always selecting what is helpful for survival, ended in making use of this property to elevate the delicate little crust—so liable to be overlaid by other organisms—and to form shelter-pits for the soft tissues. Support and shelter are two very important factors in sponge economy, as witness the boring sponges, which have acquired the character of working their way into shells and limestone. Merlia constructs its own shelter and supports. Morphologically the calcareous skeleton is wholly on the basal surface of the sponge, and, indeed, outside of it.

[1] Cima above, Baixo (cf. basis) low. The Portuguese refer to a location to the east as cima and one to the west as baixo, because their own mountains are east and their coasts west.

[2] It would be interesting to discover Merlia incrusting the shells, corals, etc., so abundant in these reefs. It seems to me very probable that it will be found there.

[3] Compare Haeckel's theory of the origin of calcareous and siliceous sponges respectively on calcareous and siliceous oozes.

If it be asked why other siliceous sponges, especially those living in coral-reef areas, do not form calcareous skeletons, the reply would be that it is too much to expect to be able to explain why any apparently spontaneous variation takes place in any living organism, because the ultimate molecular and chemical factors elude the power of analysis. As Weismann writes (**12**)—(but à propos of the trophic effect of functional stimulus)—"We are here face to face with the fundamental phenomenon of life, metabolism; and since we do not understand the cause of this, we are not in a position to say why it varies in this way or that according to the stimulus." Possibly the orange-coloured protoplasmic granules of the calcocytes happened to acquire under favourable conditions just that molecular constitution that rendered carbonate of lime attractive, but apparently under penalty of becoming petrified. Later the "penalty" of the individual cells became transformed into an advantage for the common good.

The theory that Merlia constructed its calcareous skeleton in comparatively recent times is rendered plausible by the fact that no fossils, even with a superficial resemblance to the latter, occur till Palæozoic times. In any case the resemblance between Merlia and certain Palæozoic fossils may be purely homœomorphous.

If, as I believe, Merlia is a siliceous sponge[1] which has taken to forming a calcareous skeleton, then this sponge furnishes a good example of the hereditary transmission of an acquired character, and further, a striking instance of the tendency, which Herbert Spencer (**9**) first called attention to, of one part of an organism to increase in size and importance at the expense of the rest.

Weismann gave the name "intra-selection" to this ten-

[1] Whether Merlia acquired its calcigenous properties in Silurian or in Miocene times, it is difficult to regard it as any other than a siliceous sponge related to Desmacellinæ. No spongologist would believe that Merlia got its tylostyles, sigmata, trichodragmata and occasional toxa by a process of convergent evolution.

dency. It is surprising to realise that the extensive crust of Merlia on the Dendrophyllia is the product of a very thin incrusting siliceous sponge, and, again, it is equally surprising to observe the great bulk of the masses of calcocytes in proportion to the rest of the tissues.

The English colleague already mentioned, who is, I believe, publishing a report on the dried calcareous skeleton of an organism which he thinks is Merlia, considers it to be a Foraminiferan. I think the specimen comes from the West Indies. Assuming the skeleton to be that of a Merlia, in which case it will be part of a sponge, the existence of Merlia at Porto Santo may have been due to embryos being carried by the Gulf Stream. On the north shore of the island Columbus collected Entada beans, which led him to speculate on the existence of land beyond the western horizon. The currents which carried the Entada beans might also carry the Merlia embryos which would settle on the first submarine peaks they would come to after their long voyage.

The theory that Merlia is a local survival from the periods when the coral reefs of Ilheo da Baixo were laid down seems to me more probable, however, than that of the West Indian origin of the sponge.

## (6) Systematic Position of Merlia.

The calcareous skeleton may be a character of no great importance from the systematic point of view.

The canal system—in spite of its novel or hymenopylous character—and the siliceous skeleton undoubtedly resemble in many respects the types commonly found in Monaxonellid sponges.

The calcareous skeleton is, I believe, an accidental and acquired character due to the activities of cells usually concerned in the metabolism of food and not occupied with skeletogenous functions, these latter belonging to a wholly different type of cells—the scleroblasts. Merlia, then, is a Monaxonellid

sponge, and further, there need be no hesitation in placing it in the family Haploscleridæ. At one time I had regarded the clavidiscs as modified chelæ, on account of the existence of two minute knobs on one of the "teeth" of a developing form, but it soon became evident that the affinities of these spicules were with the sigmata. If the free ends of the diancistra of Hamacantha were united it would become a clavidisc. Merlia, with its tylote megascleres, its rhaphides, trichodragmata, sigmata and toxa, is nearly related to the Desmacellinæ, a sub-family into which Lundbeck (11) places the three genera, Biemma, Desmacella, and Hamacantha. The scattered vertical tufts visible through the surface of Merlia in whole decalcified specimens somewhat resemble similar tufts at the oscular and poral surfaces of Biemma rosea Fristedt (11). Occasional horizontal bundles of spicules lying on the tabulæ in Merlia might be compared with the deeper-lying spicular network in B. rosea.

The presence, however, of clavidiscs and of a peculiar type of canal system in Merlia necessitate the founding of a new sub-family, viz., Merlinæ, which should be placed next to Desmacellinæ.

It would be an interesting experiment to cultivate Merlia in lime-free sea-water. If the sponge survived such deprivation the calcocytes would probably at first continue to heap up or build a soft skeleton similar in shape to the hard one, but later, being unburdened with lime, would resume their original functions as ordinary amœbocytes.

### (7) On Some Resemblances between the Calcareous Skeleton of Merlia and Certain Palæozoic Organisms.

The calcareous skeleton of Merlia undoubtedly presents striking superficial resemblances to certain Palæozoic fossils, such as certain Monticuliporas, and to Rhaphidopora stromatoporoides from the Devonian of Gerolstein (Pl. 38, figs. 7, 8, 9). In each case there is a surface polygonal

network with tubercles at the nodes, and tabular floors. In Rhaphidopora the tabulæ have a central hole and radial (? sutural) lines. In a former paper on Merlia I pointed out that these resemblances might be merely homœomorphous; at the same time I hoped that Merlia might throw light on the problem of the nature of Monticulipora and kindred organisms that have been placed by various authors in widely different groups; and I was rash enough to state that there was now more evidence in favour of the theory that some Monticulipores were sponges than in that of any other theory concerning the nature of these fossils.

After re-examining the large British Museum collection of fossils, and sections of Monticulipora and allied forms, especially the American series presented by Prof. Ray Bassler, I doubt whether Merlia is going to throw light on the problems concerning the nature of these organisms. It would, indeed, be an astounding paradox to state that some of the Palæozoic so-called Tabulate corals (Nicholson) or Polyzoa (Bassler) might prove to be the product of siliceous sponges, but the theory here put forward concerning the nature of Merlia is just such a paradox. At any rate the fact must be taken into account that it is possible for a siliceous sponge to make a tubular tabulate calcareous skeleton with certain resemblances to some of the Palæozoic Monticuliporas sensu lato. If Merlia had been found fossil, Nicholson would certainly have classed it among the Tabulate corals. Nickles and Bassler would, I think—but I write subject to correction—have placed it among the Polyzoa, possibly in a new sub-order, or in the Trepostomata, though not in the family Monticuliporidæ Nicholson (emend Ulrich) (**10**), seeing that Merlia has no cystiphragms, mesopores, or acanthopores. The zoologist who would propose to classify a recent Merlia among the Foraminifera would naturally place the fossil Merlia in that group. I myself at first described the dried skeleton as that of a Pharetron sponge. Certainly no palæontologist or zoologist would have regarded such fossils or dried recent skeletons as products of siliceous

sponges. Yet in this instance I may say, in view of my own error, that truth is stranger than fiction.

It seems to me unlikely that Merlia could form anything else than a thin crust, i.e. that it, or forms allied to it, could have formed a laminate or branched growth, for instance, but sometimes the living sponge grows over a dead crust of its own kind.

What has happened in one instance may have taken place on other occasions. Amœbocytes of Tetraxonid sponges may have become calcocytes under favourable conditions at any epoch, and these calcocytes may have formed calcareous skeletons, just as Merlia has done.

## (8) Summary.

Merlia is a vermilion coloured incrusting Monaxonellid sponge belonging to a new sub-family—Merlinæ—of the Haplosclerida. Large granular amœbocytes (calcocytes) have constructed a basal calcareous skeleton formed of vertical tubes divided up by horizontal tabulæ. The tubes are built up of columns, each with three vertical wings which unite with wings of neighbouring columns to form tubes. This mode of construction was probably primarily determined by the disposition of the branches of the choanosome which led to the deposition of amœbocytes at the points of bifurcation of the lines of flagellated chambers.

Apparently the calcocytes become wholly transformed into lumps, conules or flakes.

The calcareous skeleton shows certain resemblances, especially at the surface, to certain Palæozoic fossils, classed among "Tabulate corals" or Polyzoa.

There is no dermal epithelium, and the canal system is hymenopylous.

The sponge has been found in 60–90 fathoms off Porto Santo Island and Madeira.

A few more words remain to be said. It has been denied that Merlia is a sponge. I can only say that my opinion

whether right or wrong, is based on the prolonged investigation of abundance of good material, whereas other opinions seem to me to be founded mainly on à priori considerations.

I have examined over 500 specimens of Merlia and have always found the tissues of the sponge in most intimate association[1] with a calcareous structure, which grows as the sponge grows. Granular amœbocytes varying in shape according to circumstances are found everywhere in contact with the skeleton, and apparently in continuity with the organic matrix of the same. Also there is a curious similarity in appearance between the granules of these superficially placed cells and the surface view of the ends of the fibrillæ of the skeleton. The amœbocytes in the upper part of the sponge have the same fundamental characters as those in the interior of the crypts.

Amœbocytes are found deep down in crypts nearly closed over by tabulæ, and it is incredible that these large masses of cells could have worked their way down through the almost closed slits which are found in many tabulæ. Apart from these mechanical difficulties, one cannot imagine, from the point of view of common-sense, why the under surface of a supposed parasitic sponge should send down cylindrical moniliform masses of granular cells into the empty spaces of a foreign organism, thereby carrying out a seemingly useless and exhausting procedure. In young sponges on delicate shells, well stained and perfectly transparent, it can be clearly seen that there is not the least trace of any other organism than the sponge (on the shell). Weltner writes—and not unnaturally—of the calcareous structure as that of an unknown organism in which a sponge has settled. If this be so the said organism has preserved its incognito in a marvellous manner. The theory that Merlia is a sponge that has formed both a siliceous and a calcareous skeleton seems to me the only one possible, and further, the theory that it is a siliceous

[1] Of course, it is usual for a parasite to be closely associated with its host, but I trust that this investigation will make it clear that Merlia is not an instance of an association of this nature.

sponge that has taken to forming carbonate of lime one that is extremely probable.

Personal Note.—The finding of Merlia was associated with a curious incident which I trust may be of sufficient interest to be worth mentioning. I went out dredging daily at Porto Santo in a small whaling boat with Senhor Noronha and a crew of seven men. As day after day passed without result, I reluctantly decided to give up the search and return to Madeira. On the ninth day of dredging I secured as usual several large tubfuls of various specimens, but apparently Merlia was not amongst them. One of the tubs contained coarse sand, and I had told the men to throw it overboard in order to refill with more likely material, such as shells, pieces of rock, etc. I had arranged to leave the island that evening, and shortly after landing from the dredging I sent my luggage down to the beach. While the men were carrying away my boxes I casually picked up a small worm-tube out of the tub of coarse sand which had been brought ashore after all. Great was my pleasure on recognising in the fading light the long-sought-for Merlia. I at once altered my plans and went next morning to the spot whence the sand had been dredged, and secured a number of living specimens of the little sponge.

## Literature.


1. Kirkpatrick, R.—"On Two New Genera of Recent Pharetronid Sponges." 'Ann. Mag. Nat. Hist.,' 1908 (8), ii, p. 503.
2. Weltner, W.—"Ist Merlia normani Kirkp. ein Schwamm?" 'Archiv für Naturg.,' Jahrb. 75, Bd. i, Heft 1, 1909, p. 139.
3. ——— "Ist Astrosclera willeyana Lister eine Spongie?" 'Archiv für Naturg.,' Jahrb. 76, Bd. i, Heft 1, 1910, pp. 128–134.
4. Kirkpatrick, R.—"Notes on Merlia normani Kirkp.," 'Ann. Mag. Nat. Hist.,' 1909 (8), iv, p. 42.
5. ——— "Further Notes on Merlia normani Kirkp.," 'Ann. Mag. Nat. Hist.,' 1910 (8), v, pp. 288–291.
6. ——— "Notes on Merlia normani Kirkp.," 'Ann. Mag. Nat. Hist.,' 1909 (8), iv, p. 47.

7. Kirkpatrick R.—'Ann. Mag. Nat. Hist.,' 1908 (8), ii, p. 503, pl. xv, fig. 14.

8. ——— 'Ann. Mag. Nat. Hist.,' 1908 (8), ii, p. 509.

9. Spencer, Herbert.—"Weismannism Once More," 'Contemporary Review,' reprint, 1894, p. 7.

10. Nickles, J. M., and Bassler, Ray S.—'A Synopsis of American Fossil Bryozoa,' 1900, p. 28.

11. Lundbeck, W.—'The Danish Ingolf-Exp. VI, i, Porifera (1),' 1902, p. 82, pl. xv, figs. 7, 8.

12. Weismann, A.—'The Evolution Theory,' transl. J. A. and M. Thomson, 1904, vol. i, p. 244.

## EXPLANATION OF PLATES 32–38,

Illustrating Mr. R. Kirkpatrick's paper "On Merlia normani: a Sponge with a Siliceous and Calcareous Skeleton."

### PLATE 32.

Fig. 1.—Merlia normani. Piece of shell incrusted with three small specimens. Natural size.

Fig. 2.—Specimen on coralline. Natural size.

Fig. 3.—Specimen on shell. × 3.

Fig. 4.—Specimen on volcanic block. Natural size.

Fig. 5.—Specimen, dried and mostly denuded of soft tissues, incrusting Dendrophyllia. Natural size.

Fig. 5*a*.—Part of same. The larger circular holes are due to presence of worm-tubes. × 5. (See also Text-fig. 3, p. 373).

Fig. 6.—Macerated and incinerated specimen. × 15.

Fig. 7.—Part of surface of sponge showing oscule surrounded by a ring of pores. × 50.

Fig. 8.—Another part of surface showing irregular distribution of pores. × 50.

Fig. 9.—Decalcified thick vertical section of sponge showing several storeys of masses of crypt-cells or calcocytes; sponge much contracted at surface. × 50.

Fig. 10.—Vertical section of well-expanded specimen. *a*. Subdermal spaces. *b*. Flagellated chambers. *c*. Crypt-cells or calcocytes. *d*. Long

siliceous spicules. *e*. Clavidiscs. *f*. Tubercles of calcareous skeleton. *g*. Skeletal wall showing zones of fibrillæ fanning out. × 125.

Fig. 11.—Crypt-cells in glycerine. × 1500.

Fig. 12.—Youngest specimen (A) forming a minute red spot on a shell. × 25.

## PLATE 33.

Fig. 1.—Upper surface of decalcified specimen showing "nodal" masses, *a*, of flagellated chambers joined by radial bands, *b*, of flagellated chambers. *c*. Spaces left by decalcified tubercles. × 100.

Fig. 2.—Under surface of another specimen (decalcified). *a*. Masses of choanosome filling uppermost spaces of calcareous skeleton. *b*. Radial "spokes" joining these masses. *c*. Spaces left by decalcified tubercles. *d*. Crypt cells. × 120.

Fig. 3.—Decalcified vertical section of well-expanded specimen (showing only one mass of crypt-cells). *a*. Subdermal space. *b*. Flagellated chambers. *c*. Soft tissues (in uppermost crypts). *d*. Soft tissues, mostly calcocytes, in a lower crypt. *e*. Bundles of siliceous spicules. *f*. Clavidiscs. *g*. Inhalant pore. × 140.

Fig. 4.—Flagellated chambers. *a*. Apopyle in sphinctrate membrane. *b*. Sphincter "muscle"-cell. × 750.

Fig. 5.—Flagellated chambers. Lateral view. × 750.

Fig. 6.—Flagellated chamber, convex surface, showing prosopyles between stellate bases of collar-cells. × 1600.

Fig. 7.—Section of a flagellated chamber. × 2425.

Figs. 8–11.—Collar-cells in different conditions of contraction, drawn from the same section. × 1800.

Fig. 12.—Collar-cell showing flagellum passing down to nucleus. × 1800.

Fig. 13.—Growing edge of young specimen. *a*. Flagellated chambers. *b*. Radiating tufts of spicules. *c*. Clavidisc. × 175.

## PLATE 34.

Fig. 1.—Section of a small decalcified specimen showing gradual development of calcareous skeleton from edge to centre of the crust (the skeleton being represented by spaces in figure). × 25.

Fig. 2.—Surface of a young specimen. *a*. Oscule. *b*. Pores. × 425.

Fig. 3.—Decalcified tubercle and upper edge of wall of skeleton, showing large granular cells (calcocytes) and radiating fibrillar structure of organic matrix. *a*. Granular cells. *b*. Radiating fibrillæ in body of tubercle. *c*. Flagellated chamber. × 375.

Fig. 4.—Transverse section of mass of crypt-cells (calcocytes). *a*. Fibrillæ of maltha. *b*. The same cut across. × 540. (N.B.—Calcocytes in crypts are, for convenience, termed crypt-cells.)

Fig. 5.—Portion of same. × 2000.

Fig. 6.—Edge of mass of crypt-cells, showing cut edges of surface ones forming a flat epithelium (*a*), with the large oval nucleus forming a hump on inner aspect facing cell-mass. × 1025.

Fig. 7.—A crypt-cell showing spherical nucleus and nucleolus. × 3000.

Fig. 8.—Granular cell in an uppermost or open crypt, with very large nucleus and nucleolus, *a*. ? Tokocyte (egg-cell). × 3000.

## PLATE 35.

Fig. 1.—Tylostyles. × 525.

Fig. 2.—Trichodragma. × 750.

Fig. 2*a*.—Rhaphides. × 750.

Fig. 3.—Clavidisc, most frequent shape. × 750.

Fig. 4.—Broken clavidisc showing axial canal. × 1000.

Fig. 5.—Clavidisc with narrower rim, deeply situated in the sponge. × 750.

Fig. 6.—Developmental form of clavidisc, with ends joined by slender filament. × 750.

Fig. 7.—Incomplete clavidisc, like a sigma. × 750.

Fig. 8.—Clavidisc with crossed ends. × 750.

Fig. 9.—Young twisted form of clavidisc—abnormal. × 750.

Fig. 10.—Very slender, simple sigmata. × 750.

Figs. 11–15.—Abnormal spicules, all from one specimen. Fig. 11, tylostyle with three knobs. Fig. 12, tylostyle with double curve. Fig. 13, toxa-shaped rhaphide. Fig. 14, clavidisc with flat discs in place of keyhole sinuses. Fig. 15, slender sigmata with knobs at each end. All × 750.

Fig. 16.—Calcareous skeleton, surface view, showing surface tabula, with central hole, or slit, which may be quite closed. The tabula show concentric circles and radial sutures radiating from centre to the inter-flange suture. × 130.

Fig. 17.—Vertical section of skeleton, showing several crypts, one series being laid open and two others closed over (by vertical flanges or wings). × 130.

Fig. 18.—Base of skeleton, showing some tabulæ nearly closed, which

roofed over crypts which had been full of calcocytes, later macerated out. × 100.

Fig. 19.—Ground-down basal section with soft tissues remaining. Thick walls of tubes as seen by strong, oblique reflected light, showing well how vertical flanges or wings join to form walls of tubes. *a*. Tabula. × 160.

Fig. 20.—Calcareous skeleton of Merlia on surface of carinate worm-tube, macerated in Eau de Javelle, the youngest parts of skeleton being lumps and scales. × 100.

Fig. 21.—Calcareous scales on surface of worm-tube (see fig. 20) having appearance of calcified flattened cells, with a nuclear hump and granular structure. × 425.

Fig. 22.—A conule at base of tubercle having the appearance of a petrified amœbocyte, fitting cap-like on rounded surface below, with rounded basal rim and lobate basal process, with oval nucleus and granular structure. × 1500.

## PLATE 36.

Fig. 1.—Part of mass of crypt-cells. *a*. An isthmus of tissue. *b*. Flattened crypt-cells in section, much contracted, showing sections of nuclei. *c*. Connective tissue cell. × 1000.

Fig. 2.—Part of sponge tissue at bottom of an upper or open crypt. *a*. Collar-cells. *b*. Longitudinal bundles of spicules with their sclero-blasts. *c*. Transverse section of spicule bundle. × 1500.

Fig. 3.—A neck or isthmus joining upper part of sponge to a mass of crypt-tissue. *a*. Large granular crypt-cells. *b*. Connective-tissue cells (collencytes). × 1500.

Fig. 4.—Large granular crypt-cells. × 1500.

Fig. 5.—Three calcocytes on summit of a tubercle. Slightly separated by pressing down cover-slip; separation indicated by Y line. [Note.—The view is in projection; the cells extend some distance vertically down.] × 2200.

Fig. 6.—Growing edge of skeleton. Calcareous bar covered with layer of calcocytes. × 650.

Fig. 7.—One calcocyte from those depicted in fig. 6, showing granular contents (each granule with dark central spot), large oval nucleus, and the nucleolus. × 4000.

Fig. 8.—Two flattened granular cells. × 2220.

Fig. 9.—Calcareous skeleton, showing granular appearance (due to ends of fibrillæ) at surface, and fibrillar structure in section. × 1800.

Fig. 10.—Clavidisc with its scleroblast. *a*. Nucleus. × 1450.

## PLATE 37.

Fig. 1.—Growing edge of a specimen of Merlia (osmic-picro-carmine preparation in glycerine) showing elongated calcocytes planning out calcareous skeleton on smooth surface of shell. *a.* Calcocytes. *b.* Flagellated chambers and excurrent canal. *c.* Siliceous spicules. *d.* Edge of sponge. *e.* Connective-tissue cells (collencytes). × 750.

Fig. 2.—Collencytes. × 2425.

Fig. 3.—Myocytes arranged radially and concentrically round a pore. × 1450.

Fig. 4.—Gland-cells. × 2425.

## PLATE 38.

Fig. 1.—Vertical section of very young specimen figured on Pl. 32, fig. 13, decalcified. *a.* Spaces left by dissolved skeleton. *b.* Elongated calcocytes. *c.* Connective-tissue cells, with finely and abundantly branched processes. *d.* Young wedge-shaped collar-cells. × 1000.

Fig. 2.—Vertical section of same showing a tylostyle and a bundle of siliceous spicules cut transversely. × 1000.

Fig. 3.—Vertical section of same nearer to edge of sponge than in fig. 1. × 540.

Fig. 4.—Part of a collencyte (mostly cut away) showing many tufts of branching processes. × 1500.

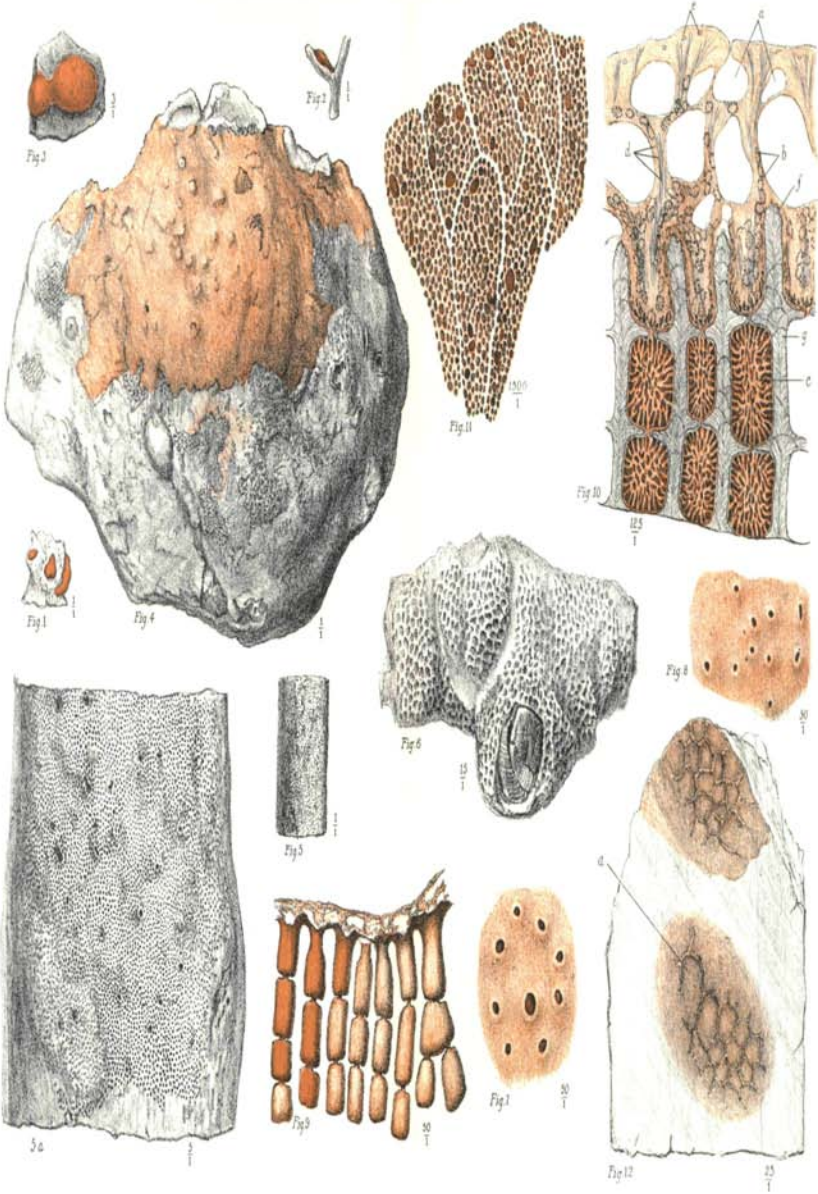
Fig. 5.—Growing edge of a specimen. *a.* Edge of sponge. *b.* Calcareous skeleton. × 120.

Fig. 6.—The tuning-fork spicule from the original dried specimen of Merlia. × 1050.

Fig. 7.—Monticulipora (Heterotrypa) monilformis Nich. (from Devonian of Ontario), surface, showing polygonal network and tubercles. Copied from Nicholson's 'Palæozoic Corals,' "Monticulipora," 1871, pl. i, fig. 1*a*. × 18.

Fig. 8.—Rhaphidopora (Chætetes) stromatoporoides Roemer. Devonian of Gerolstein. "Tangential section" (but ? surface view.—R.K.). From Nicholson and Foord, 'Ann. Mag. Nat. Hist.' (5), xvii, pl. xvi, fig. 5, showing polygonal network, tubercles, and tabulæ, some with central hole and apparently with radial sutural lines. × 20.

Fig. 9.—The same as fig. 8, deeper transverse section. × 20.




Percy Highley, del. et lith.

C. Hodges & Son, imp

MERLIA NORMANI

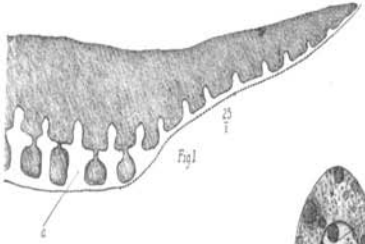

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Fig 1
a


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3000
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Fig 8


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Fig 7
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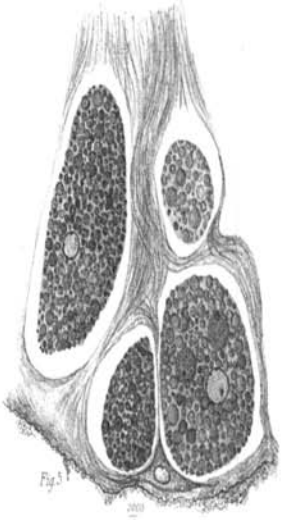
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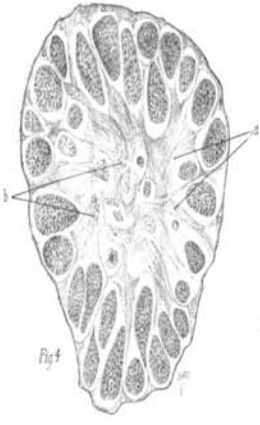
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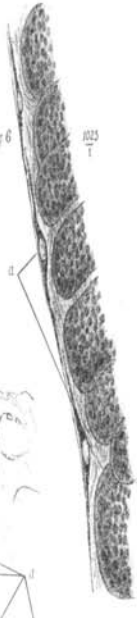
Fig 4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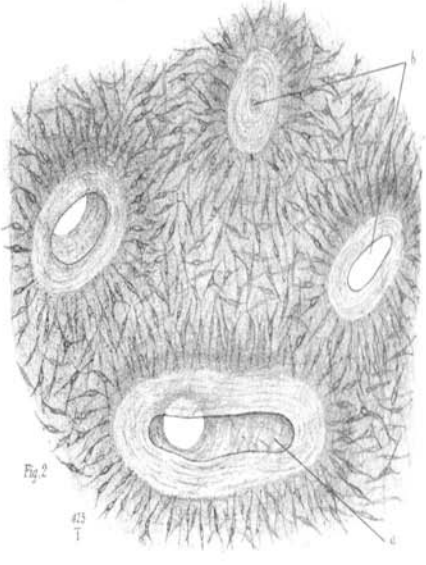
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Fig 2
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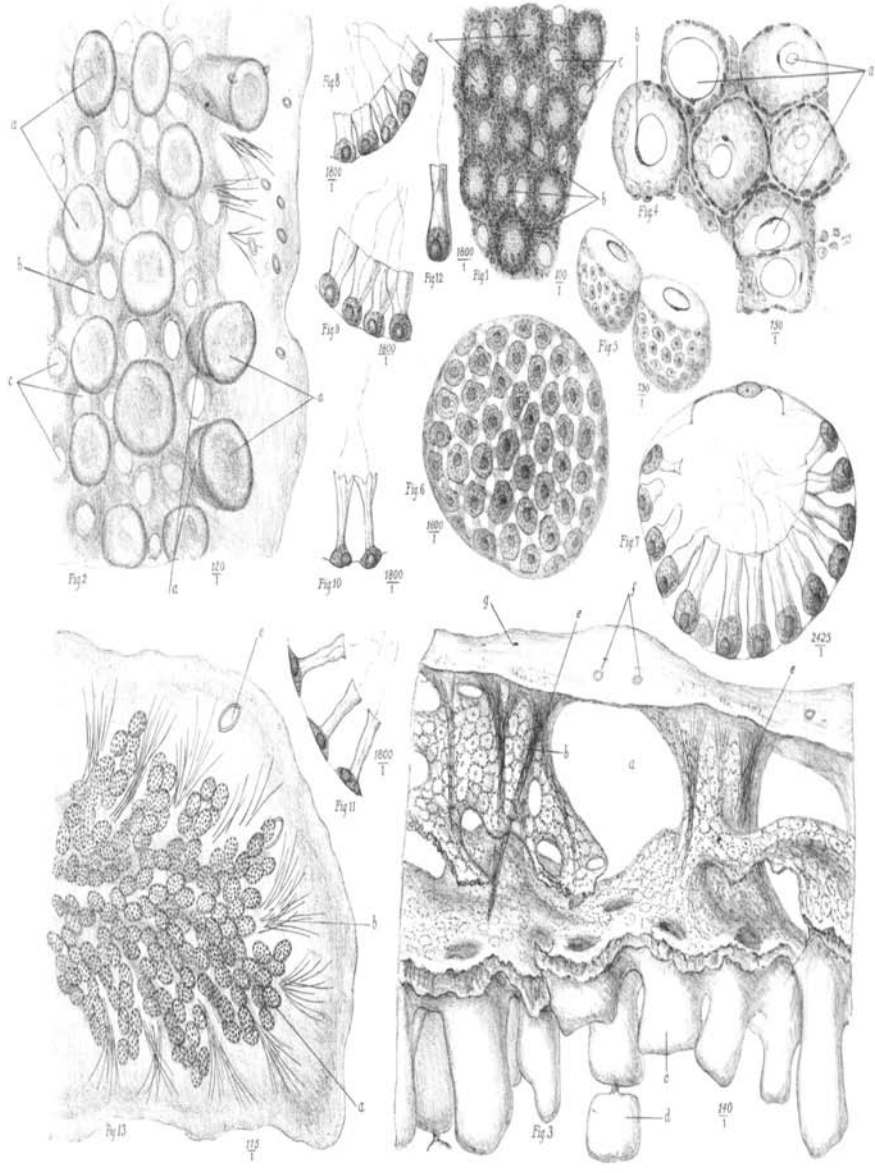
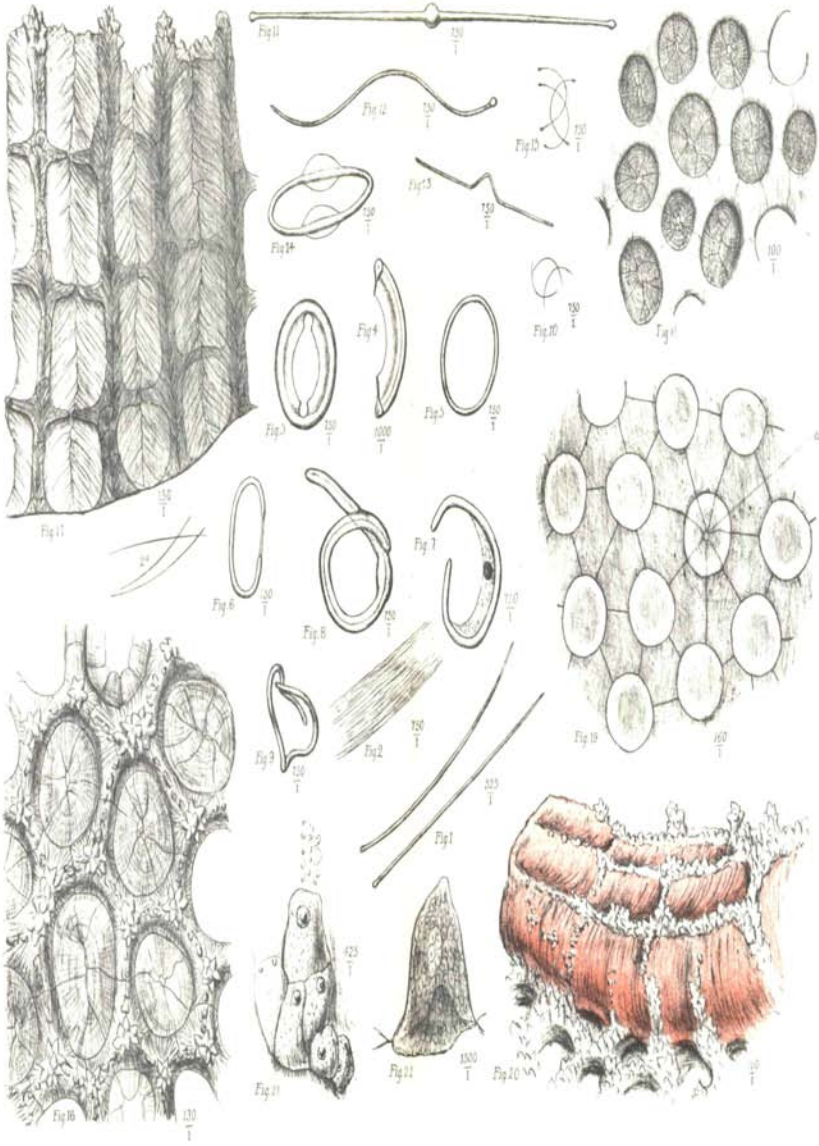



Percy Highley del. et lith.

C. Hodges & Son imp.

MERLIA NORMANI.



Percy Highley del. et lith.

C. Hodgson & Son, imp.

MERLIA NORMANI.


Fig. 10 $\frac{1850}{1}$

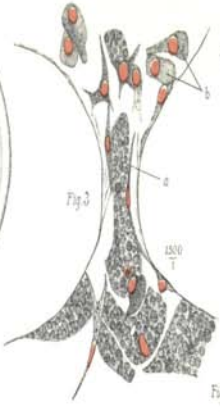


Fig. 3 $\frac{1500}{1}$

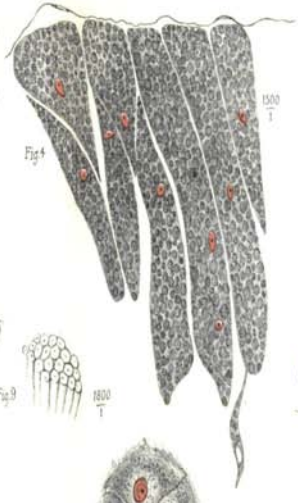


Fig. 4 $\frac{1500}{1}$


Fig. 9 $\frac{1800}{1}$

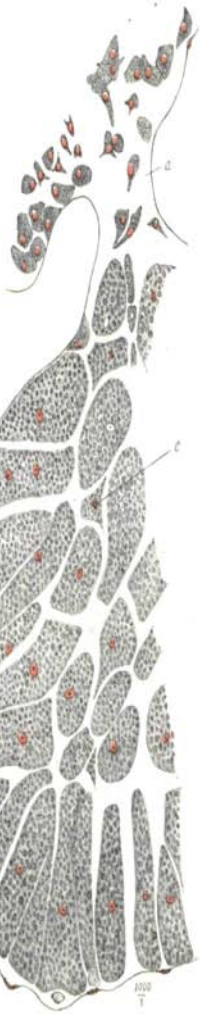


Fig. 1 $\frac{1000}{1}$

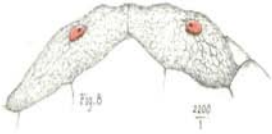


Fig. 8 $\frac{2200}{1}$

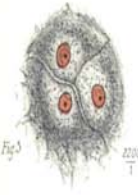


Fig. 5 $\frac{2200}{1}$

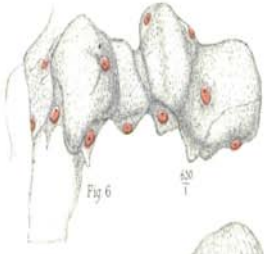


Fig. 6 $\frac{650}{1}$



Fig. 2 $\frac{1500}{1}$

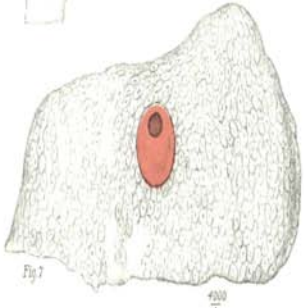


Fig. 7 $\frac{4000}{1}$

Percy Highley, del et. Lith.

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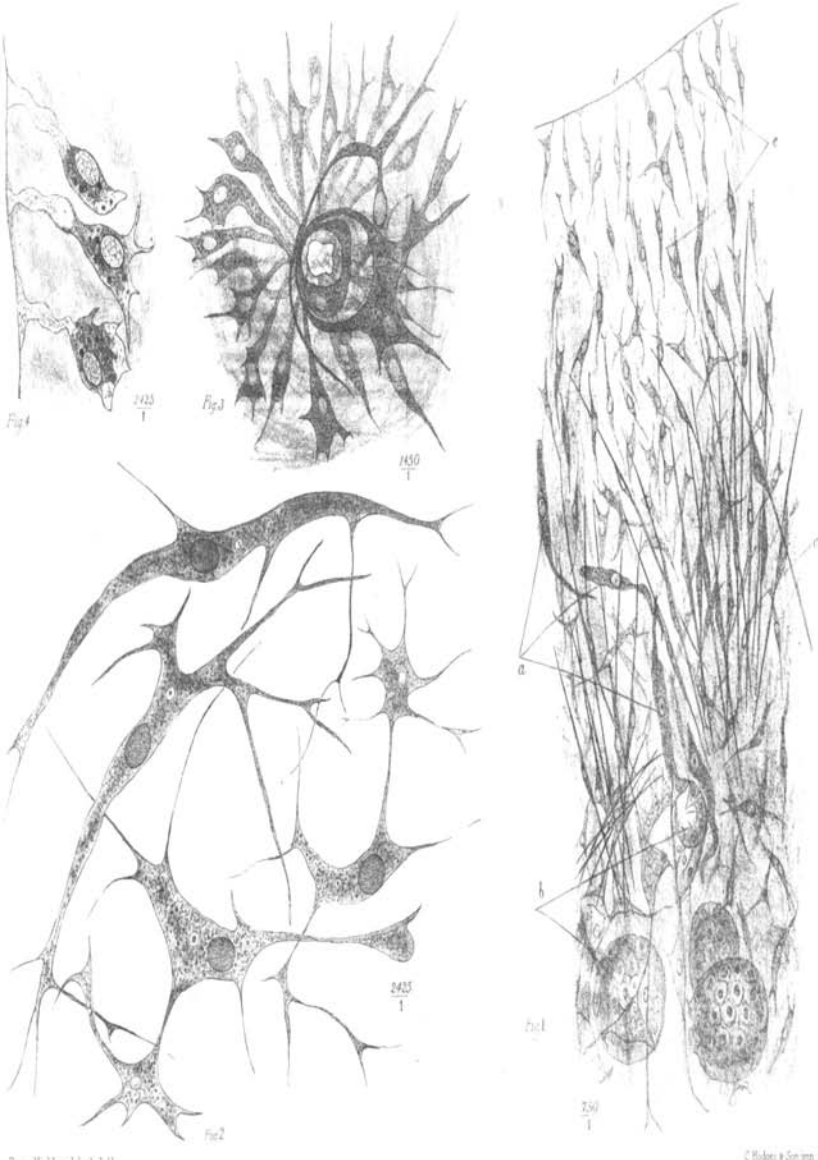
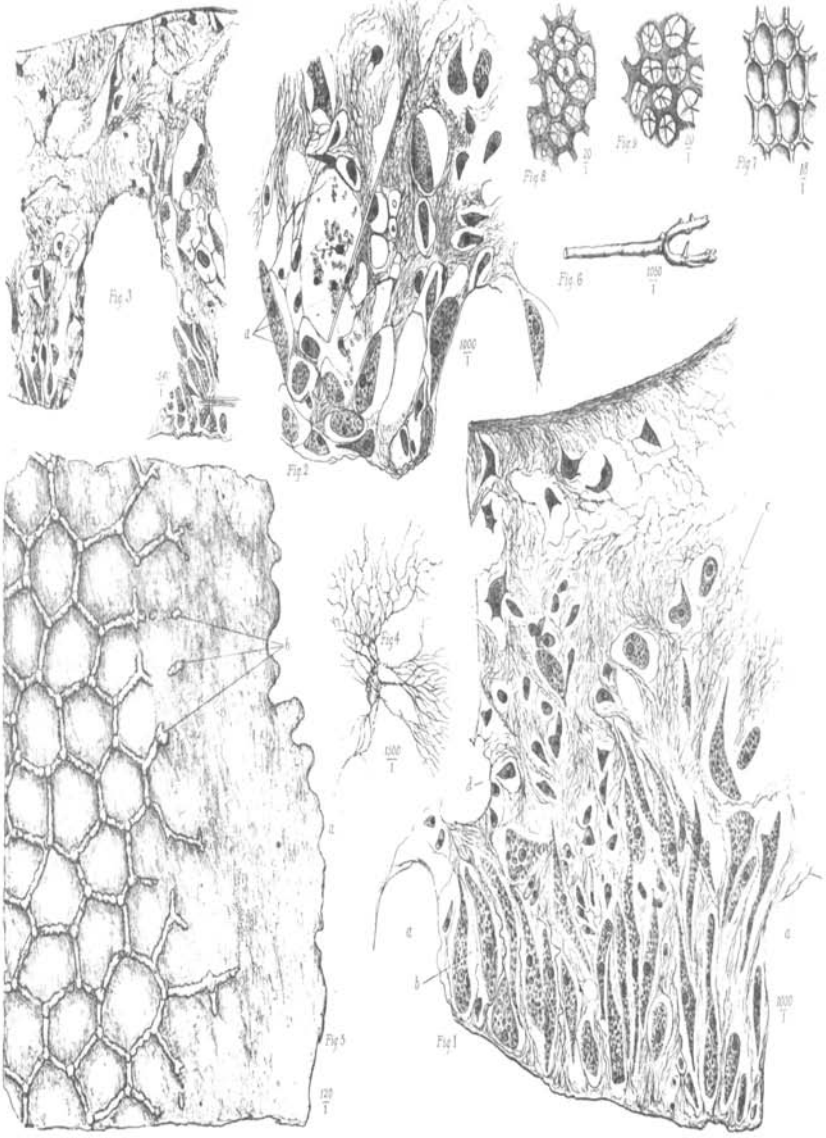



Percy Highley, del. et lith.

C. Hodgson & Son imp.

MERLIA NORMANI.




Percy Highley del. et lith.

C. Hodges a. Son imp.

MERLIA NORMANI.