After the rivers had thus coursed across the broad deposits of sand, which are inferred to have covered so large a part of Sweden, a movement of subsidence ensued, and the Mälar basin became converted into a shallow sea. During this period of depression, the fine sand, which was unprotected by the coarse gravel and shingle of the river-beds, was washed away, and thus the åsar were formed. As the downward movement continued, stratified clay, with Arctic shells, was deposited all round the åsar. By and by the climate became milder, and the present Baltic fauna succeeded the Arctic one. The land began to rise again, and the åsar, being brought nearer to the surface of the sea, formed long shoals or banks, exposed to the action of the waves, which reassorted their outer portions, adding new layers of sand, interstratified with shell marl. The åsar of the lowlands thus became cloaked in a post-glacial covering; to which, and not to the åsar, properly belong those shells of recent Baltic species, which are got near the surface of the ridges.

Mr. Törnebohm's objections to the marine origin of the åsar are: the great length of these remarkable ridges; their common occurrence in narrow valleys; their river-like ramifications; and the fact that they are met with at greater elevations than any undoubted marine drift-deposits. The highest shell-deposits yet seen in Scandinavia are situated not more than 600 feet above the sea-level, and he thinks it unlikely that the sea ever reached a greater height upon the land. The åsar, however, are not limited to that height, for he has traced well-marked åsar up to 1000 feet, and in the mountainous valleys of the north even up to elevations of over 2000 feet. Mr. Törnebohm does not disguise from himself that it is difficult to understand how the denuding force acted, which is supposed to have swept away the fine sand and left the coarse gravel. If marine denudation cleared away the sand and thus gave rise to the åsar of the lowlands, how would he explain the formation of those åsar which reach to heights above 600 feet—that being, as he thinks, the greatest elevation in Sweden attained by the sea in late glacial or post-glacial times?

IV.—Notes on Fossil Sponges.

By Harvey B. Holl, M.D., F.G.S.

I. *Introduction.*—It has been said, with some degree of truth, that our knowledge of the lower forms of life has advanced *pari passu* with the improvements in the construction of microscopes; and no doubt very considerable progress has been made in some departments of investigation within the last few years. In the vegetable kingdom more especially has this been the case; and with respect to animals, the structure of the *Protozoa* has been especially elucidated by able observers, the Spongiadæ chiefly by the labours of Dr. Bowerbank.

Among the lower forms of extinct life, progress has necessarily been slower, especially as regards the sponges, for although new forms have been described from time to time, the group collectively has never received that strict treatment of which it seems capable. Much has yet to be done towards the attainment of a better knowledge of their structure, mode of growth, and variation in form within the limits of the species, and not until this has been accomplished can a right understanding of the true affinities of the several members of the group be arrived at, or any successful attempt made at arrangement of the species and genera.

The little interest which appears to attach to the study of fossil sponges may possibly be due, in great measure, to the difficulties which lie in the way of a rigid determination of the species. This is owing to the inconstancy of the characters on which specific distinctions have been based; and consequently an enormous number of species have been created, the described characters of which are, in many cases, equally applicable to other forms, which are, nevertheless, totally distinct. Hence the subject is involved in a confusion which is rendered still more perplexing by the circumstance, that many of the original types on which the descriptions were based can no longer be traced. The means, therefore, of identifying the species is by no means easy, and in some cases it is impossible to identify them. As an example, we may mention the *Spongites clavellatus*, Mantell, from the Chalk, of which there are two distinct forms, the one composed of a network of inosculating fibres, the other constituted entirely of branched and tuberculated spiculæ. The same may be said of the sponges included in the genera *Chenendopora*, D'Orb., *Cupulospongia*, D'Orb., etc., some of which are spicular, and others fibrous, and yet are precisely similar in their general appearance. In all these cases there are no means of clearing up the doubt, except by reference to the original type.

Like their living analogues, the fossil sponges are liable to great variation in form, and other external and obvious characters; and the remarks of Dr. Bowerbank on this subject are equally applicable to the extinct as to the living species.[1] Yet on external characters alone nearly all the generic and specific distinctions of the fossil sponges have been framed, and very slight variation in external configuration, in the disposition of the oscules, or even in the geological position, has been thought sufficient for the creation of distinct species. Nevertheless, if we except the Foraminifera, there is no class of animals in which the outward characters are less stable, and like these, in conformity with the same low state of organization, there are none that have enjoyed longer range in geological time.

The insufficiency of mere external character for the purpose of differentiating the sponges, and the consequent difficulty experienced in framing specific descriptions precise enough for their identifica-

[1] "There is no class of animals in which the form varies to so great an extent (as the living sponges) according to difference of locality or other circumstances; and even where there is a striking normal form, it is rarely thoroughly developed until the animal has reached its full maturity." *Spongiadæ* (Ray Soc.) vol. i. p. 3. "As a generic character, form is inadmissible, inasmuch as each variety of it is found to prevail indiscriminately in genera differing structurally to the greatest possible extent." *Ibid.* p. 156.

tion, has been long felt. This renders it desirable to discover, in the minuter structure, characters of a more permanent nature. With respect to the living sponges this has indeed been done, more or less successfully, by Dr. Bowerbank. He finds "in the skeleton and in the form and disposition of the spicula, characters which, however Protean the form and colour of the sponge may be, can always be recognized with certainty." Can the same means be made available for the extinct species? Obviously there will be many difficulties in the way, for in the latter we have to deal with the skeleton alone, modified by fossilization; whereas in the former all the structures are in a condition admitting of minute investigation. Nevertheless, very commonly enough of the minute structure can be made out in the fossil to render it a most important means of discriminating the species. The external appearance is all but valueless for this purpose.

II. Prior to the time of D'Orbigny, no attempt had been made to systematize the genera established by Lamoureux, Goldfuss, De Blainville, Michelin, Reuss, and others. M. D'Orbigny, however, conceiving that the fossil sponges had, for the most part, an organization entirely distinct from that of the recent species, divided De Blainville's class AMORPHOZOA into two orders, viz., the *horny* and the *stony* sponges. The former contained but a single genus, *Cliona:* the latter he subdivided into five families, based entirely upon external characters, viz., 1. the *Ocellaridæ;* 2. the *Siphonidæ;* 3. the *Lymnoreidæ;* 4. the *Sparsispongidæ;* and 5. the *Amorphospongidæ.* At the same time he proposed many new genera. These were constituted partly of species which had been distributed by his predecessors among genera established on recent forms by Lamarck and Schweigger, and adopted for fossil species by Dr. Goldfuss.

Pictet,[1] and more lately De Fromentel,[2] have followed D'Orbigny in the view which he took respecting the stony character of the skeleton of the fossil sponges. The *Petrospongidæ* of Pictet, and the *Spongitaria* of the French author, correspond to the "*Amorphozoaires à squelette testacé*" of D'Orbigny. M. Etallon also entertains the same view. He includes among the fossil horny sponges none but the *Clionidæ;* and in speaking of the *Petrospongidæ* observes that the skeleton is solid, "like that of the ZOANTHARIA, and formed, doubtless, in the same manner."[3] In fact nearly all authors, with the exception of MM. Capellini and Pagenstecher,[4] appear to entertain similar views respecting the nature of the skeleton in this large group of fossil species.

D'Orbigny[5] and De Fromentel[6] maintained that the fossil sponges had originally a solid unyielding skeleton. This opinion was partly

[1] Paléont., iv. 2nd ed. [2] E'ponges Fossiles, 1859.

[3] Classification des Spongiaires du Haut Jura, and E'tudes Paléont. sur le Haut Jura, p. 139.

[4] Mikroskopische Untersuchungen ueber den innern Bau einiger fossilen Schwamme Z. W. Z., etc.

[5] "Qu'ils n'ont jamais été cornés, mais que leur tissu à toujours été calcaire et pierreuse." Cours Elementaire de Paléontologie, tom. ii. p. 208.

[6] *l. c.*, p. 5.

based on the supposition that they would not otherwise have escaped compression, and partly on the circumstance that Polyzoa, *Serpulæ*, *Ostreidæ*, etc., frequently found attached parasitically to the surface of the sponge have been observed to exhibit the worn appearance produced by the rolling of hard bodies on the sea-bed. Moreover, they say that compressed specimens show more or less distinctly the signs of fracture. But while this may be true of some of those sponges that had a solid siliceous framework, it certainly is not generally the case, and examples of *Hippalimus, Ischadites, Mortieria*, and many other sponges more or less distorted by compression, are sufficiently abundant. That they should not—especially the cup-shaped sponges—be more often compressed than they are may, perhaps, be a matter of surprise. But this is probably due to the circumstance that the fine muddy sediment in which they were entombed had so insinuated itself into the interspaces of the sponge as to afford an equal amount of support on all sides.[1] Moreover, some further explanation will suggest itself when speaking of the sponges of Farringdon, and the manner in which fossilization of the sponge appears to have often taken place.

Whether Polyzoa and other parasites are really more frequent on the fossil than on the recent sponge is a question I am not prepared to answer. But M. De Fromentel is certainly not correct in saying that they never occur upon recent sponges; and very frequently the adhesion of the parasite to the fossil sponge is more apparent than real, being produced solely by the cementing influence of fossilization, and by the nature of the matrix in which they are embedded. In any case, unless the Polyzoa grew upon dead individuals, the nature of the skeleton could have had no influence upon the parasite, as, whatever it may have been, it was equally invested by the sarcode of the animal. That the Serpulæ and Ostreidæ sometimes became attached to the sponge while living is apparent from their having become partially embedded in the sponge tissue which has grown over them; but it is so also with recent sponges: and as regards the worn appearance of the parasites and other foreign bodies occasionally found attached to the sponge, it is quite possible that they may have undergone attrition before they became adherent; and, moreover, the fossil itself may have been derived from pre-existing deposits, as were the Oolitic forms found in the gravels of Farringdon.

But there is, in fact, no real ground for assuming with D'Orbigny and others, that the skeleton of the fossil sponges was necessarily

[1] The compression often observed in fossils, especially those of the older rocks, is probably due to the squeezing to which they have been subjected in the change of position and contortion of the beds in which they occur, rather than to the dead weight of the superimposed sediment. It is now well known that Starfish and other soft animals, even at the great depths of mid-ocean, are not compressed, owing to the pressure being applied equally on all parts. Prof. Sars dredged sponges, actinozoa, true molluscs and worms at a depth of 300 fathoms; and the Swedish deep-sea dredgings, in the expedition to Spitzbergen, brought up crustacea, mollusca, and annelids, at depths of from 6000 to 8400 feet. Quoted in *Intellectual Observer* for December, 1866, p. 400, from *Annals of Nat. History*.

always solid and resisting, like that of the recent *Dactylocalyx*, Stutch., the *Farrea* of Bowerb., etc. Many of the siliceous sponges no doubt were so; but as regards the calcareous ones it may be observed that among recent species, according to Bowerbank, "Carbonate of lime, as an element of the skeleton, is known only in the form of spicula."[1] In some cases, as will be shown hereafter, the fibres or twigs were originally complex, formed of bundles of spicula, like the twigs in many of the recent species, and were afterwards consolidated more or less completely by the fossilizing process. But there is no evidence that in others it may not have been keratose, either with or without the accessory spicula. Some of our recent horny sponges are not less resistant than the solid siliceous fibrous species, and are certainly less friable. In the fossil, however, the horny fibre is replaced by silica, lime, or iron. That the tissue in the fossil is not identical with that of the original sponge may be inferred from the circumstance that we commonly find all the sponges from one locality, or one deposit, in the same mineral condition. Thus, all those from the Carboniferous Limestone of the Great Orme's Head are silicified; but so also are the associated Zoophytes, Conchifera, and Gasteropods, etc. All the sponges from the Farringdon Green-sand are calcareous, while those of Warminster are all siliceous. The sponges of the *English* Oolite are all calcareous: those of the Chalk are either silicified, or else in the state of moulds or casts, the walls of which are stained with peroxide of iron.[2]

It has been thought that the iron-staining of the moulds and their refilling with pyrites renders it probable that in the original sponge the fibre was keratose. That in the horny sponges, pyritous casts may be more frequent than in the others is highly probable, but the amount of sulphur in the keratose is far too small to enter into combination with all the iron in the cast in accordance with the theory implied; and assuming that the original skeleton of the sponge was keratose, there is no reason to suppose that the mould would not be refilled in harmony with a general law, *i.e.*, the cast was siliceous when deposited from water holding in solution silica rendered soluble by the presence of lime and alkalies; calcareous from waters holding lime in solution by the aid of an excess of carbonic acid; iron in other cases, and even bisulphuret of lead has been found replacing carbonaceous matter in the plant remains of the Lias of Dunraven.[3] The manner in which the mould is refilled with silica was precisely similar to that by which it is made to replace the carbonate of lime in the tests of the Mountain limestone mollusca of the Great Orme's Head, the Portland rocks of Tisbury, or the Green-sand of Blackdown. The Ostreidæ and Serpulæ, and other parasites

[1] *l. c.* p. 154.

[2] Both *Ischadites* and *Ptylospongia* occurred to Eichwald sometimes calcified, and sometimes converted into bisulphuret of iron, more or less peroxidized. His *Manon deforme*, from Gherikoff, was silicified, while the examples of the same species from the environs of Poulkowa were all calcified. *Lethæa Rossica*, p. 339. *Ischadites Kœnigii* occurs in our British Upper Silurian rocks, both as a calcareous and as a pyritized fossil.

[3] De la Beche, Mem. Geol. Surv., vol. i., p. 273.

attached to the surface of the Warminster sponges are frequently, like the sponge tissue, in the condition of siliceous casts. As shown by Liebig,[1] silica when long in contact with lime in alkaline solutions becomes soluble, and hence it is that we so often find the sponges of the Chalk encased with silex, or with the interstices filled with a more or less porous mass of the same material, which is altogether adventitious to the sponge tissue. In a similar manner the mould may be refilled with carbonate of lime. On the other hand, an originally calcareous sponge may become converted into a siliceous fossil, as we see in the case of the mollusca of the Great Orme's Head and elsewhere, and that an interchange of this kind has actually taken place seems necessary to explain the fact, that siliceous and calcareous sponges are not usually found associated in the same spot.

That the calcareous sponges, those of the English Oolite for instance, are merely casts of the original structure, may be shown in another way. If then sections of the fibres be made sufficiently translucent for the employment of a quarter-inch power of the microscope, it will be seen that the fibre has often the asbestiform structure, radiating at right angles from a central axis, peculiarly a mineral arrangement, and especially of carbonate of lime. The structure of true sponge fibre on the contrary is concentric. The preservation of the sponge, therefore, in its fossil state, depends very much on the nature of the sediment in which it is embedded, and on the mode of its entombment. Hence they are met with but rarely in stiff argillaceous deposits; and although abundant in Mesozoic times, they are absent from all the clayey members of the series, such as the clays of the Lias, and the Oxford and Kimmeridge Clays; yet they occur in continental beds of corresponding ages, but differing in lithological character. At the same time it is possible that the muddy waters of the seas in which these deposits were thrown down may have been ill adapted to the well-being of the sponge, nevertheless they are met with in the Lingula Flags, and in the Upper Silurian Shales.

The condition of the sponges of the gravel pits of Farringdon is remarkable, and may perhaps tend to throw some light on the mode in which fossilization of the sponge takes place in calcareous and such sandy deposits as contain lime; and help to explain, in some manner, the absence of compression in the fossil. Every twig of the sponge presenting a free surface throughout its entire thickness, is invested by a thin coating of minute dog-tooth crystals of carbonate of lime, forming a complete crust over the fibre, much in the same manner as moss, etc., is encrusted by a calcareous spring. These crystals seldom exceed $\frac{1}{750}$ of an inch in height, the average being about $\frac{1}{1000}$ of an inch, or even less; and on their surface they are slightly tinged by peroxide of iron. All the other fossils of the same locality are similarly coated with these minute crystals, even to the interior of the cells of the Polyzoa. When slightly acted upon by dilute acids, the crystalline layer is removed, and the cast of the sponge-fibre exposed; but if the action of the acid be con-

[1] "Lectures on Chemistry," p. 491.

tinued, the whole is dissolved usually without leaving any trace of siliceous spicula.

The sand and gravel in which these fossils are embedded are loosely cemented by carbonate of lime, and it is by no means certain at what period after the sponges were entombed this coating of crystals was deposited upon them. But it is quite possible that something similar to what has taken place in these Farringdon fossils may occasionally occur in other cases as a preliminary to fossilization, in consequence of the sponge, deprived of its sarcode, having long soaked in water charged with carbonate of lime.

The ordinary mode in which fossilization takes place, however, is in one of the two following ways: either the sponge, after the destruction of its sarcode, becomes infiltrated by fine sediment which completely fills up the interstices, and forms, as it were, a mould of the sponge skeleton in which the fossilizing process takes place; or the sponge is simply buried in the deposit, which forms a nidus about it, filling perhaps the tubules and oscular passages, or even the superficial parts of the tissue, but leaving the latter for the most part open and pervious, into which mineral matter is carried in solution, and there deposited. The result of this may be, either to fill up the interspaces entirely, or merely to encrust and consolidate the fibres as in the sponges of the gravels of Farringdon; but in either case there is formed around the fibre or twig, a mould, in which the fossilizing process takes place, which is the same precisely as that which is known to take place in fossils generally, viz., the removal of the original material of the skeleton, and its replacement by another. These changes are greater and more complete in proportion to the antiquity of the deposit in which the fossil occurs.

(*To be concluded in our next number.*)

V.—On Certain Lithodomous Perforations in Derbyshire.[1]

By the Rev. T. G. Bonney, M.A., F.G.S.

In the Geological Magazine for 1870 (Vol. VII., p. 267), I published a brief account of some burrows in Derbyshire; one group of which, at the bottom of Miller's Dale, and on a scarp of rock which was probably artificial, appeared to me wholly irreconcilable with the theory which attributes them to the action of *Pholades*. This conclusion was questioned by Mr. E. Brown (Geol. Mag., Vol. VII., p. 585), who had visited the spot, and, failing to find the burrows in question, was of opinion that I had mistaken a bed of toadstone in the valley, for "limestone, and the vesicular cavities therein for the borings of animals." Fortunately, in expectation of some controversy, I had carried away a specimen, which sufficed to demonstrate (Geol. Mag., Vol. VIII., p. 40) that I really knew limestone from basalt. Wishing, however, to see whether by some inadvertence I had not quite clearly described the locality, or if the rock had been defaced after my visit, I returned thither, in the Easter vacation of the present year, with the following result:

[1] Read before the Cambridge Philosophical Society, April 29, 1872.