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HYALOTHRIX, Gray, P. Z. S. 1867, p. 119.

Bark smooth. Polypes oblong when contracted, low. Tentacles 40.

Hyalothrix lusitanica, Gray, *l. c.* 1867, p. 119. B.M.

Type *Hyalonema lusitanicum*, Bocage, P. Z. S. 1864, p. 265, t. 22; 1865, p. 662; Gray, Ann. & Mag. Nat. Hist. 1866, xvii. p. 287; Lovén, Ann. & Mag. N. H. 1868, p. 90.

Var. *spongifera*.

H. lusitanicum, Bocage, Ann. & Mag. Nat. Hist. 1868, ii. p. 36; Bowerbank, P. Z. S. 1867, p. 902.

Hab. Portugal.

P.S. Dr. Perceval Wright, who has just returned from dredging for *Hyalonemata* on the coast of Portugal, informs me (Sept. 14) that he believes the coral (*H. lusitanicum*) grows at the bottom of the sea in deep water, with the free part of the coil sunk in the sand. He also mentioned to me that M. Bocage has some specimens of the sponge that grows on the *H. lusitanicum* with a shallow cavity that is covered with a netted lid formed of spicules, like the lid of *Euplectella*. I do not find any trace of such a lid in the three sponges on the *Hyalonema Sieboldii* in the British Museum; but it seems to exist in some specimens of that sponge, as Dr. Lovén says that Prof. Schultze found "the flattened surface of the smaller and younger specimen (No. 4) covered by a network of spicules similar to that which covers the free end of *Euplectella*." (Ann. & Mag. N. H. 1868, ii. p. 89.)

XXXIII.—*On the Boring of certain Annelids.*

By W. C. M'INTOSH, M.D., F.L.S.*

[Plates XVIII., XIX., XX.]

AT the Meeting of the British Association held at Dundee, my friend Mr. E. Ray Lankester read a very interesting paper on "Lithodomous Annelids," or, rather, on the boring of *Sabella saxicava*, Quatref., and *Leucodore ciliata*, Johnst., chiefly with reference to the latter. In the discussion which followed, Mr. Gwyn Jeffreys and I strongly opposed the theory advocated by the author as to the action of a purely chemical agency in the production of the perforations. I specially mentioned that *Leucodore ciliata* bores in aluminous shale—a fact fatal to the chemical (or acid) theory—and am

* Communicated by the Author, having been read at the Meeting of the British Association at Norwich, Aug. 24, 1868.

now compelled to make a few remarks on the subject at this stage, on account of the publication of the above-mentioned paper in the 'Annals of Natural History' for April of this year (1868). In the latter publication the author states that "Dr. M'Intosh was the only observer at Dundee who expressed a belief that these Annelids perforate rocks other than carbonate of lime. He said he had seen aluminous shale so bored; but I think he had other excavations in mind, such as Annelids will make in the semisolid silt filling cracks in shale, or else that he has since seen reason to change his opinion; for he has not produced any such specimen of shale, although then challenged to do so. I submit that the opinion as to aluminous shale, unsupported by any chemical test or specimen, and confessedly only casually noticed, should not be of any weight in the balance against the facts as to the exclusive erosion of limestone which are above recorded." I had for the time forgotten the subject till I saw this paper (and for the first time its challenge) in the 'Annals;' yet, on referring to my notes on *Leucodore ciliata*, made several years ago, I find that it bores not only in aluminous shale, but in a material, in a chemical sense, even more impenetrable.

Boring and burrowing are very common features in the British Annelida. The majority are fitted chiefly for perforating sand or sandy mud, such as the *Lumbrici*, *Nephtys*, *Nerine*, *Cirratulus*, *Nereis*, *Eteone*, *Glycera*, *Arenicola*, *Scalibregma*, *Ammotrypane*, *Ophelia*, *Travisia*, *Aricia*, *Terebella*, *Sabella*, *Mæa*, and others; and the modes in which they pursue this their daily occupation vary greatly. *Glycera* and *Nephtys* especially disappear with rapidity amongst the sand by boring with their proboscides, the former passing its elongated organ through a considerable space in a single thrust. *Eteone* dashes through the water in ever-varying screw-coils, and carries its snout with equal facility through sand; and the motions of *Ammotrypane aulogaster* are even more vigorous, especially as regards penetration of the latter. The efforts, again, of *Scalibregma*, *Ophelia limacina*, *Travisia*, and *Mæa* are less violent; but they easily penetrate the same semisolid medium. Some, such as *Nereis pelagica* and *Dumerilii*, occasionally occupy galleries in the stems of softened *Laminaria*; while *Hediste* (*Nereis*) *diversicolor* bores in vast numbers in the peat of Perrelle Bay, in Guernsey, and more sparingly in casual pieces of the same material on the eastern shores of North Uist. Several delight to bore in muddy clay, such as *Eunice*, *Lumbrinereis*, and *Notocirrus*. Many species occur in galleries between the layers of shale and sandstone, and in the cracks of granite, gneiss, and other rocks, amidst sandy mud,

as well as elsewhere, such as several of the *Spionidæ*, *Eunice*, *Lysidice*, *Trophonia*, *Syllis armillaris*, *Psamathe fusca*, *Castalia punctata*, *Eulalia*, *Thelepus* (*Venusia*), and *Aphlebina*. Of these, *Lysidice* is often found under the calcareous spreading base of *Corallina officinalis* along with *Leucodore*, under the large littoral Ascidians at Herm, and in masses of *Cellepora* from the deep water off St. Martin's Point, Guernsey, and, though it would seem to take possession of an old tunnel, yet appears capable of accommodating the hole to its own wants. Lastly, a few Annelids bore rocks, stones, and shells of various kinds, amongst which are *Leucodore*, *Dodecaceria*, *Sabella saxicava*, *Heterocirrus saxicola*, Grube* (a species I cannot at present distinguish from *Dodecaceria concharum*), besides some of the adjoining group, *Gephyrea*.

There is no more common Annelid along the rocky parts of the beach at St. Andrew's than *Leucodore ciliata* (Pl. XVIII. fig. 1); and, indeed, it is a very abundant British form in general. It especially haunts the soft blue shale at the West and Castle Rocks of the ancient city, apparently, like its companion *Pholas crispata*, because it finds such more easily excavated than the denser sandstone, just as we see it avoiding the hard granite and gneiss of the Channel Islands and the outer Hebrides, and tunnelling its galleries under the spreading base of *Corallina* and the numerous Nullipores, both free and surmounted by the tangles, or as M. de Quatrefages† found at Guettary, in the case of *Sabella saxicava*, which preferred to bore the calcareous rocks rather than the quartz with which they alternated. It is likewise abundant in the fissures of the shale and sandstone, forming tunnels amidst the muddy débris so abundant in these localities, where Dr. Johnston seems alone to have found it. Ørsted, again, gives "sandy tubes" as its sole habitation. Vast numbers of the common limpet-shells are also invaded by them, their tracks with the loop at the bottom being visible from the inner surface as whitish streaks; and the irritation frequently causes the mollusk to secrete layer upon layer of the nacreous lining. It abounds likewise in many other littoral and deep-water shells, such as *Buccinum*, *Fusus*, *Haliotis*, *Ostrea*, and *Anomia*, and, indeed, in favourable sites, almost upon every shell thick enough to bore into.

Its presence amidst the shale and sandstone is easily recognized by numerous small tubes, composed of agglutinated sand and mud (Pl. XIX. fig. 1), which project from the surface of the stone in dense groups, so as to form in many cases a kind of sward of tubes—a habit apparently characteristic of the

* Archiv für Naturges. 1855, p. 108, Taf. 4. f. 11.

† Ann. des Sc. Nat. sér. 3. Zool. tome viii. 1847.

race in all parts of the world; for the Abbé Dicquemare long ago noticed this on the coast of France, and in more recent times M. Schmarda* describes and figures a species (*Leucodore socialis*) having a similar habit, on the coast of Chili, Mr. Alex. Agassiz another on the shores of the United States, M. de Quatrefages at Boulogne, M. Claparède at Skye, and Dr. S. Wright in the Frith of Forth. Mr. Lankester, however, does not allude to this habit; and such tubes are certainly rare on the calcareous rocks. Very short ones are occasionally observed on the surface of *Corallina*. These tubes are composed, according to the nature of the site, of minute grains of sand and mud, or pure sand, cemented together by a tough secretion, which likewise gives a smooth coating to their interior. They project sometimes nearly half an inch from the stone or other material; and, when laid along the surface, in some cases they exceed this in length. If the animals are scattered, it will readily be observed that each is supplied with two independent and occasionally divergent tubes, which thus correspond to the double nature of their perforations in the stone. Both are formed in the same way, the Annelid reversing itself in its gallery at will and augmenting the length of the quiescent tube: thus the restless tentacles are observed to project now from the one and now from the other. The animal displays great energy in proceeding with its work, its tentacles resembling a struggling *Ascaris* that has been seized by the middle and is endeavouring to make its escape. Not only are these organs thrown about in all directions, but each undergoes a series of vermiform wriggings, no head meanwhile being visible from the aperture of the tube. After lashing the water for some time, they may be noticed moving along the surface of the stone with a serpentine motion like independent worms, and seizing any convenient particle of mud, sand, or food they may encounter. Upon effecting this, the tentacle is not contracted as in the Hydrozoa and Actinozoa, but its vermiform motions along the rocky surface remain unaltered, while the particle is observed to wend its way towards the mouth of the tube along the tentacle in a remarkable manner, to be seized by the lips of the animal. Baster† distinctly noticed this quality in the tentacles of *Leucodore*, mentioning that, however unwilling, the prey was dragged by the organs into the tube and consumed at leisure. Hence he inferred they had many of the properties pertaining to the tentacles of polypes. The fact also did not escape the notice of that most patient and keen observer of nature, Sir J. Dalyell, in "*Spio seticornis*;" for he says, "The particles that may be selected for the edifices are

* Neue wirb. Thiere, i. ii. p. 64, tab. 26. figs. 209 & 209 a.

† Basteri Opuscula Subseciva, tom. ii. lib. 3. p. 135.

seized and passed along the tentaculum, and apparently carried to the mouth*". If the particle of sand, for instance, after entering the mouth of the tube, is considered suitable, it is by-and-by pushed out with the snout, and arranged on the circumference of the tube with the glutinous secretion. Occasionally the proximity of other tubes affords an opportunity for abstracting particles therefrom, as well as causes frequent collisions with neighbouring tentacula, especially apparent when two take possession of the same prey. Now and then a small mass of mud and sand may be seen travelling outwards from the tube along the tentacle, to be dropped at some distance. Quantities of débris, again, may sometimes be observed issuing from both apertures; and in those vessels in which the animals have been vigorously at work on new sites, heaps of minute grains of sand or altered shale are grouped on the flat surface around the tubes; or if these are elevated in the vessel and project horizontally, the débris falls to the bottom or clouds the side of the glass. Where the basis material is bluish shale, this débris has a brownish colour, and the particles assume a somewhat definite ovoid shape, so that the heaps have a peculiar miliary appearance. The alteration in the colour in this case is interesting, showing that in all probability the masses have passed through the digestive tract of the Annelid. Moreover we may be fairly warranted, from the appearances, in assuming that at least some of the constituents of such heaps are the results of the boring, and not all due to the seizure of external particles from (in this case) the smooth surface of the shale. There was nothing peculiar in the instance of the sandstone, whose loose débris after boring resembled the grains of sand removed from the mass.

The benefits of a tube superadded to the gallery in the stone are apparent; for the tentacles are thus enabled to take a longer sweep through the surrounding water for the capture of minute structures while the delicate body remains protected. Moreover a field of competition is opened up to these social Annelids, in which it must at least occasionally occur that the best and most rapid builder of these tubes is placed under more favourable conditions for existence than those with shorter tubes or those confined to the dead level of the rock or shell.

When the animal happens to find a large mass of loose material near its tubes, it sometimes protrudes its head and anterior region, and aids the tentacles in dragging it towards the mouth of the tube, or occasionally the anterior part of the body is extruded in an exploratory manner; but, as a rule, they are very shy. A free animal is now and then encountered, and, if in perfect health,

* Power of the Creator &c. vol. ii. p. 159.

it is not the helpless animal described by Dr. Johnston*, but progresses very actively indeed, either on a horizontal or perpendicular surface; and if circumstances are unfavourable for its gaining the stone, or, if it so chooses, it fashions a tube round its body with ease and rapidity (provided materials are forthcoming), either on the bottom or along the side of the vessel. Nor is it satisfied with the construction of one home, but roams about from place to place and forms several. In such instances the tube is not generally turned on itself, but is more or less linear, the cup of the anal segment communicating freely with the water by the open end of the tube. They are also not unfrequently found swimming on the surface of the water, like other Annelids.

The first point that strikes the observer in regard to the perforations in the sandstone and shale is that they are grouped in pairs, sometimes with a thicker and sometimes with a thinner intervening column. In many cases this column would seem to be formed of débris; but in others, especially those in shell, sandstone, and *Corallina*, some of the original material is left; so that, by this feature, the observer is seldom left in doubt as to the identity of any particular gallery he encounters. From the exterior the tubes, as usually observed, proceed inwards either as nearly straight or more or less curved cylindrical galleries, and terminate in the case of each pair by joining in a loop at the bottom, the latter being either abruptly or gently curved, according to the thickness of the intervening column. This siphonal form of gallery is very general among the Annelida and other burrowing animals; various *Terebellæ*, *Eunice sanguinea*, *Cirratulus cirratus*, and others follow this habit in the fissures of rocks; while *Corophium longicorne*, so abundant in company with *Edwardsia* on some of our muddy or clayey shores, has its burrow of the same characteristic formation. In *Leucodore*, as a rule, the intervening column attains the largest dimensions inferiorly, a considerable wedge of sound shale being often left at the loop. The latter, moreover, in some was marked by two or three grooves, showing that at various times the animal had altered the depth of its galleries to suit its convenience, perhaps in relation to the length of its built-up or external tube, though this is not a matter of much consequence. All the tubes were lined by the delicate secretion before mentioned.

In the borings in shell, Nullipore, and *Corallina* the tube or perforation had not, in our specimens, the form of a keyhole, as mentioned by Mr. Lankester, but possessed a solid column of the original structure, or else one of consolidated débris, intervening between the tunnels. In the sea-worn specimens of

* Catalogue of Worms, Brit. Mus. p. 206.

chalk and limestone, the empty perforations, however, do exhibit a form somewhat like a keyhole in transverse section; but in the calcareous rocks and stones containing living specimens the double tube is completed by an intervening column of débris, except at the loop. In not a few of the worn pieces of chalk and limestone, only the widened inferior end or junction of the tube remains. This is a point of some interest, since *Dodecaceria concharum* abounds in the same sites, and its gallery is distinguished in transverse section by having no incurvation, or only a very slight incurvation in the middle, and is not double; yet the dried remains of this worm might most aptly be described "as a black carbonaceous film," whereas the dried remnants of *Leucodore* are of a pale or straw-yellow hue.

Amongst the minute fragments of flint which form the fine gravel of Luccomb Chine, in the Isle of Wight, are many loose rounded pieces of limestone and chalk more or less perforated by *Leucodore* and *Dodecaceria*; but the living examples of the former occur chiefly between half tide and low-water mark, the best site being at the verge of the latter, and this more especially as regards *Dodecaceria*. *Leucodore* is not only abundant in the substance of the rocks themselves, as mentioned by Mr. Lankester, but swarms under the spreading base of *Corallina*, though, on account of the inconspicuous nature of the apertures in the latter, little or no trace of the borings can be observed until the surface is split off. Besides, in this (littoral) region there are numerous flattened stones, one or two feet square, that have their surfaces quite worm-eaten by the perforations of the Annelids, whose now vacant galleries have been considerably enlarged by the action of the sand and surf. Occasionally the borings in these large stones were arranged in a linear series, the worm having attacked the commencing fissures as the most vulnerable parts of the mass. At White-Cliff Bay, again, the perforations in the chalky rocks abounded in the same region, and were of a somewhat larger size than those made by our northern examples.

Descriptions of the general structure of *Leucodore* have been published by the Abbé Dicquemare, Dr. Johnston, MM. Ersted, Grube, Claparède, and Keferstein; so that my remarks at present shall be confined to the tentacles, bristles, hooks, and anal segment.

The tentacles (Pl. XIX. figs. 1 & 2) are a pair of very mobile muscular organs, possessing in each case a ciliated furrow on the inner side, Dr. Johnston being in error in averring that the inferior side is so supplied. Dr. Strethill Wright* has given a somewhat minute account of their microscopic appearance in

* Edinb. New Phil. Journ. 1857, vol. vi. p. 90.

this species (in all probability), which he termed *Spio seticornis*. He observed that the tentacles, when seizing a fragment of oyster, attached themselves to it "not by winding themselves round it, but by simple adhesion, as if they were studded with numerous suckers and hooks, like the arms of the cuttle-fish." This prehensile apparatus "consists of numerous large papillæ thickly crowded together along the borders of the tentacles," each having an "acuminated soft cilium or spine." On forcibly pressing the tentacle, "the spine-bearing papillæ burst, and there issues from each of them a . . . pear-shaped capsule (trichocyst) . . . which, again, on rupture, discharges a multitude of acicular spicules." He likewise states that the tentacles are furnished with "a ciliated band running from the tip to the base," but does not point out the actual disposition thereof. In his drawing of the tentacle (fig. 18) the papillæ are ranged along each side of the organ from base to apex.

When the tentacle is extended, as in its ordinary motions (Pl. XIX. fig. 1), there is little or no appearance of wrinkles. A very considerable alteration, however, ensues on placing the animal, even without irritating pressure, between glasses, and certainly much more so if the tentacle itself is removed by violence. The ciliated groove along the inner border, like the rest of the organ, is minutely granular, especially towards the tip, the latter, on the slightest contraction, assuming a minutely warty aspect (fig. 2). Besides the long cilia which cover the furrow, there are various motionless hairs along the opposite or exterior border of the organ, as indicated by Prof. Keferstein, and which are also present on various other parts of the animal. The wrinkling of the tentacles in most views is very marked, the whole organ being crossed by transverse seams, between every two of which a series of very distinct temporary papillæ occur at the edge, which papillæ sometimes do possess a motionless cilium or "spine," and are more likely to do so under paralyzing pressure; but the appearance shown by Dr. Wright is the result of injury, and not a natural interpretation of their anatomy, however closely his outline may indicate what he saw. These temporary papillæ, in common with the entire surface of the furrow, certainly present a streaked appearance; but such is due to the compressed cilia; and I have never been able to see the remarkable "trichocysts" and their acicular contents as described by this ingenious naturalist, to whose observations I gave due respect by repeated examinations. Circular cells filled with minute granules often escaped through the delicate epiderm of the pressed organ, together with minute granules and swarms of discarded cilia; but there was no

trace of the "trichocysts." M. de Quatrefages*, again, in his remarks on the respiration of the Annelids, refers to a drawing of the tentacle of a *Polydora*, which may or may not be this species. He shows the ciliated region to be cellular, but does not notice crenations.

On the tentacles of several were the curious parasitic forms represented in Pl. XIX. fig. 3. They were attached by a short stalk, and, when set free, moved rapidly through the water by the aid of their cilia, which in their fixed condition were next the tentacle.

The fifth body-segment of the worm has the characteristic strong hooks (Pl. XVIII. fig. 2), which are accompanied by the peculiar bristles with spear-shaped heads (fig. 3), besides the minute dorsal fascicle of the ordinary structure. The tip of each of the first series is strongly curved; and towards the concave side thereof a spur projects, apparently with a twist backwards and ventrally; and hence, if the organs are separated and pressed between glasses, this spur in not a few cases almost escapes observation: this is especially the case in spirit preparations. In the larger southern examples the spur is less visible than in the smaller, as the hook under pressure assumes a position which hides the projection; it is very evident, however, when the hook is viewed *in situ*. The shaft of the hook in the large examples is marked at intervals by transverse striæ. Mr. Lankester's figures† may be taken as the representatives of altered bristles from specimens in which they have been subjected to some morbid influence, either due to the nature of the habitat (calcareous rock) or otherwise. Other specimens from the same rock show the ordinary structure with the single spur beneath the tip. In some of the altered specimens the spear-shaped bristles accompanying the hooks are absent. Mr. Alex. Agassiz has given a better view of their structure, though he does not refer to the spear-shaped bristles which accompany them. In the majority of the specimens from St. Andrew's three of the hooks were well developed, the first being the longest, and the fifth and sixth rudimentary but nevertheless showing the secondary fang or spur even more distinctly than the others. In larger examples from Cobo Bay, Guernsey, and the southern shores of England, these hooks are more numerous‡.

* Ann. des Sc. Nat. sér. 3. Zool. tome xiv. pl. 5. fig. 10.

† Ann. Nat. Hist. ser. 4. vol. i. 1868, pl. 11. fig. 9.

‡ At the late meeting of the British Association, Mr. Lankester, while at once admitting the erroneous condition of his own published drawing of the hooks, denied the accuracy of mine as exhibited in a large coloured drawing accurately copied from the two figures (Pl. XVIII. figs. 2 a, b) ac-

The inferior appendages of the rest of the body-segments consist of characteristic hooks—organs, I may add, that have received but scant justice from their artists, with the exception of M. Claparède* and Mr. Agassiz, though the latter appears to have slightly misapprehended their true nature, as he speaks of “a stiff bristle extending from the base of the curve”—which can only refer to the wing of the structure, about to be described. The figure† of this careful observer, though earlier, is more correct than Mr. Lankester's. When the hook is pressed flatly between glasses (Pl. XVIII. fig. 4 a), the crown shows a long tooth in front, with a shorter superior process and a distinct wing; but the latter, of course, has been altered by pressure, as, when viewed under favourable circumstances (fig. 4 b), it has a wing on each side of the crown and upper part of the shaft. Dr. Thomas Williams was in error when he assigned a dorsal position to these hooks‡. The bristles throughout conform to one type (fig. 5), having a long shaft, somewhat abruptly bent and tapered at the tip, which has a narrow process or wing on each side.

The anal segment is furnished with a peculiar cup (fig. 6), whose margin does not form a continuous ring, but is inflected and slit in the middle of the dorsal surface. A few minute and motionless cilia are placed round the margin. The papilla of the anal orifice is richly ciliated. The organ does not impress the observer as being eminently adapted for adhering to surfaces, after the manner of a sucker; nor have I been so fortunate as to see the animal using it for this purpose. Mr. A. Agassiz and MM. Claparède and De Quatrefages, however, have seen the Annelid employing it for such; and M. Meczni-koff§ is another author who mentions that a “sucking-disk” is met with in *Leucodore*. Dr. Williams, again, remarks that the anal segment is expanded with geometrical exactitude into a hollow cone, which acts on the principle of the sucker, the worm “letting down its weight on the part, in order to press

companying this paper. He said that, instead of one spur, there were several spurs beneath the curved tip. Of course I have found no reason to alter an opinion formed after an examination of specimens from the north, east, and west of Scotland, from the north-east, south, and south-west of England, and from the Channel Islands. Mr. Agassiz and Prof. Keferstein, moreover, show only one process; and though M. de Quatrefages represents at least two beneath the tip of the hook of his *Leucodore nasuta* from Bréhat, I am bound to add that many of this distinguished author's drawings are not scientifically accurate. I do not know on what authority my friend made his statement; and it is to be hoped he will clear up the mystery.

* Archiv für Anat. u. Phys. 1861, Taf. 13.

† Ann. Nat. Hist. ser. 3. vol. xix. pl. 6. fig. 38.

‡ Report Brit. Assoc. 1851, p. 208.

§ Zeitschr. für wiss. Zool. Bd. xvi.

out the water with which the bottom of the tube may be filled ;” and thus the Annelid “amid the raging billows is securely anchored to its cell.” From the siphonal nature of the tube, this description cannot apply in any degree.

Another very common borer in shells, nullipore, and calcareous rock is *Dodecaceria concharum*, Ærst., a Cirratulean which has a larger tube, shaped something like a keyhole in transverse section, and terminating in a slightly dilated, smooth, cæcal extremity. This animal likewise lives in the fissures of the rocks in the Channel Islands, forming in the mud long galleries bent in various ways, but always readily distinguishable from those of *Leucodore*. In addition to the foregoing localities, a specimen was sent me alive from St. Andrews rocks in its characteristic tube in sandstone. In this instance the perforation in the stone was lined by a considerable coating of carbonate of lime, so that it had a smooth whitish aspect—as if the animal had not relished constant contact with the rough grains of sand, and had fashioned a coating analogous to the well-known secretion of *Teredo*. Even in the spreading base of *Corallina officinalis*, the gallery inhabited by this animal is often so smooth, and its appearance on fracture so characteristic, that the observer is led to suspect the existence of some secretion which covers over the roughnesses of the tube and the rocky surface. The bristles (Pl. XX. fig. 4) in this species have a dilated and flattened tip with a finely serrated edge, and taper to a fine point. The shape of the hooks (figs. 2 & 3) is peculiar and characteristic, and enables the observer to distinguish the dried remnants at once. The animal tinges the spirit of a rich dark-green hue, just as Sark specimens of its ally *Cirratulus cirratus* do, but gives no acid reaction to test-paper. The *Nereis sextentaculata* of Delle Chiaje*, which lives in holes in the rocks of the Neapolitan shores, is, in all probability, referable to the same species: and the *Narganseta corallii* of Leidy† is likewise either the same or a very closely allied form. The latter bores dead portions of *Astrangea astræformis*.

A third British borer is *Sabella saxicava*, Quatref., which, according to Messrs. Stewart and Lankester, is found in the limestones near Plymouth; and I have found it abundantly in Oyster, *Pecten*, *Anomia*, and other dead and living shells dredged off the Channel Islands, as well as perforating the *Balani* that cover the sides of the Gouliot caves at Sark, near

* Memorie sulla Storia e Notomia degli Animali senza Vertebre del Regno di Napoli, vol. iii. p. 176, tab. 43. fig. 16.

† “Marine Invert. of Rhode Island and New Jersey,” Journ. Acad. Nat. Sc. Philad. ser. 2. vol. iii.

low-water mark, my attention having been first directed to the latter site by Dr. Bowerbank, who kindly sent me dried specimens. In these caves the tube of the Annelid is often coiled in its groove beneath the *Balani*, and then pierces the shell of the latter to appear on the upper surface. It likewise bores abundantly in *Cellepora pumicosa*, and in one instance had bored quite through the valve of a living *Pecten pusio*. It often occurs in the same oyster-shell in a combined attack with *Gastrochæna dubia*, *Leucodore*, and boring sponges, or sometimes places its tubes in groups in convenient fissures of the shell without boring, so that they can be dislodged *en masse* like short and contorted tubes of *Tubularia indivisa*. Another site is under empty limpet-shells amongst muddy débris, part of each tube being inserted into a perforation in the shell; while, again, the cracks and fissures of the rocks near low-water mark afford a very favourite habitat in the Channel Islands, and their tubes are often seen projecting through incrusting sponges and Ascidians, both simple and compound. The species has a tough horny tube, whose exposed portion is furnished with minute grains of sand; but the immersed portion is hyaline and more delicate. The boring in the shell and limestone is circular, and, though often more or less curved or coiled, it is not to be confounded with the work of *Dodecaceria* or *Leucodore*. I need not allude further at present to the structure of the species, save to observe that its branchiæ are speckled with pale green and white, and furnished with two or three brown pigment-specks exteriorly, and that its hooks (Pl. XX. figs. 5 & 6) (which are accompanied by broadly spear-tipped minute bristles, fig. 7) and bristles (fig. 8) have the structure represented. The body shows a distinct acid reaction towards the posterior end, and especially at the tip of the tail.

The fourth native borer is a little *Sipunculus*, which externally appears to be identical with *S. Johnstoni* of Forbes. It occurs in limestone on the shores of the Isle of Wight, bores into the spreading base of *Corallina* with the foregoing forms in the Channel Islands, tunnels the mud in the fissures of various rocks, and one occurred in a shell sent by Mr. Gwyn Jeffreys in his rich Zetlandic collection of 1867. The form of the perforation in the latter case is club-shaped; and a young specimen had bored its tiny gallery from the tube of its parent—a very rare occurrence amongst the true Annelids. In this instance the tubes of *Campanularia verticillata* had taken possession of several of these minute galleries after the death or exit of the original inhabitant. This boring *Sipunculus* is quite neutral to test-paper.

Annelidan borings have been noticed by many observers. In 1765 Baster* describes and figures the very species (*Leucodore ciliata*), I have no doubt, which has just been brought forward by Mr. Lankester. He observes, "Alteram *Nereidis* speciem, quam hic describo, voco *minimam tentaculis longissimis*;" and his next sentence shows that he had at least as extensive an acquaintance with its habitat as some very recent writers:—"Hæc in lapidibus, ostreis, aliisque piscibus testaceis, qui e limoso maris fundo petuntur, reperitur quam frequentissime, habitans semper in parvo ex limo aut arena constructo tubulo." This author, although he does not further allude to the habitations in the stones, mentions that he put a quantity of sand beside them in a glass vessel, and that they very soon bored into this, and constructed tubes at the entrance of their tunnels. The Abbé Dicquemare† in 1781 also refers to the same species, and he gives figures of the animal which, however inaccurate, may at least bear comparison with some of very modern date. He called it a sea-insect, and he cites it as an influential agent in destroying the calcareous rocks and stones in the neighbourhood of Havre. In a second paper by the same author‡, what appears to be a *Sabellaria* is described, which, it is stated, prolongs its tail within the rock or stone, as well as fashions a tube of coarse sand or fine gravel outside. He advanced the idea of a solvent to account for these borings, an explanation all the more likely, as his specimens of rocks bored by marine "insects" were all calcareous. Dr. P. C. Abildgaard§ gives fair descriptions and figures of two species which bore into the marble cliffs and calcareous stones below water at Santa Cruz in the West Indies. He calls the one *Terebella bicornis*, and the other *Terebella stellata*. The first is a *Cymospira* (*C. bicornis*) characterized by having a hard, horny, flattish operculum, from which project two branched antler-shaped processes. He also mentions at the end of his paper that another was sent him with three horns on its operculum, the third being closely appressed to the plate; but the animal was otherwise similar to the first. The latter is thus closely related to the *Cymospira tricornis* of Dr. Baird||, who remarks that it had apparently burrowed in Madrepore—a habit characteristic of other species of the genus, whose galleries occasionally pierce

* Basteri Opuscula Subseciva, tom. ii. lib. iii. p. 134, tab. xii. fig. ii. A, C.

† Observat. et Mém. Phys. tom. xviii. 1781.

‡ Op. cit. tom. xx. 1782.

§ Schrift. Gesellsch. ntrf. Freund. Berlin, i. 1789, pp. 138–144. I am indebted to Dr. Albert Günther for a copy of this paper, he having sent a complete translation, instead of a mere abstract in the original (German).

|| Journ. Linn. Soc. vol. viii. 1865, p. 17.

the fractured blocks in all directions. The second species of stone-borer (*T. stellata* = *Pomatostegus stellatus*, Mörch, Schmarda, &c.) described by Dr. Abildgaard has an operculum composed of three flats or plates raised one above another, and supported by a central column or axis, and likewise has been found perforating coral reefs. Mr. Osler* alludes to the abundance of worm-perforations (when treating on the same subject) in the Mollusca, thus—"The boring Annelids are innumerable in calcareous rocks, and are found to attack every marine shell almost as soon as it has acquired sufficient thickness to afford them a nidus;" and he further instances the cases of the *Nereides*, *Arenicola piscatorum*, and *Terebella conchilega*, as well as that of the *Spatangi* burying themselves in sand. His figure of *T. conchilega*, however, very much resembles *T. littoralis*. Mr. Templeton† fairly describes the perforations of a species, which is probably *L. ciliata*, in the limestone rocks of Whitehead, Belfast Lough, and figures the perforated stone and the animal in various positions. Mr. Garner‡ refers to the subject in the Zoological Transactions, thus, "Certain Annelides apparently possess the power of excavating. The rocks on our coast are pierced by a minute worm, probably of the genus *Diplothis* of Montagu; it is strongly ciliated, but its mouth does not appear adapted for making its way into such hard substances." His figure is doubtless intended to represent *Leucodore*; but only two eyes are shown, and there is no structural distinction made at the fifth segment of the body. In the same Transactions, Mr. R. Templeton§ mentions a borer in the corals of the Isle of France called *Anisomelus luteus*, which has numerous long, hollow, prehensile tentacles, that seize prey like Sapajous' tails. It forms for itself a minute tube on the surface, as well as bores into the coral. M. CErsted|| next describes the boring of *Dodecaceria concharum* in shells. M. de Quatrefages¶ details the perforations of *Sabella saxicava*, and points out the interest which such would have to the geologist; for though a *Helix* might perforate limestone like the marine lithophagous mollusca, and thus render its pristine site ambiguous, there could be no doubt about the ancient condition of stones bored by this *Sabella*. In his recent work he refers more than once to the subject**. Dr. Williams†† observed the boring habit of *Leu-*

* Phil. Trans. 1826, p. 342.

† Loudon's Mag. Nat. Hist. ix. 1836, p. 234.

‡ Zool. Trans. vol. ii. p. 95.

§ Zool. Trans. vol. ii. p. 27, tab. v. figs. 9-14.

|| Annulat. Danic. Consp. p. 44, 1843.

¶ Ann. des Soc. Nat. sér. 3, Zool. tom. viii. 1847.

** Hist. Nat. des Annelés, vol. i. pp. 129 and 133; vol. ii. pp. 295, 415, 437, 552, 583, 597.

†† Report Brit. Assoc. 1851, p. 208.

codore ciliata, but did not enter into the *modus operandi*. M. Marcel de Serres * describes the genus *Stoa*, one of the chief characteristics of which is that it perforates West-Indian shells—a fact, however, which had previously been observed by other naturalists. M. Valenciennes †, in his remarks on the perforating *Echini*, instances the case of a *Sipunculus* that bores wood. M. Lacaze-Duthiers ‡ describes, in a careful paper, *Bonellia viridis*, a Gephyrean which bores calcareous rocks on the shores of Corsica. Prof. Grube § has lately described two other forms beside that first mentioned, viz. *Sabella saxicola* and *Phascolosoma verrucosum*, which perforate the limestones of Martinsica and the island of Lussin in the Adriatic.

The chemical theory in regard to such borings, it is well known, has frequently been brought forward by zoologists in the instances of Mollusca and Sponges, and lately has even been assumed with regard to the Bryozoa ||. Moreover it has more than once been promulgated to explain the means whereby Annelids perforate shells and rocks. Besides those already alluded to, Mr. Osler, for instance, brings forward the case of the Annelids to show that a shell is not essential to the boring-process, and in support of the solvent theory; yet he could not find any such agent in the animals. Like his successor Mr. Lankester, he gets over the “argillaceous” difficulty by averring that they do not bore in this material, but, more fertile in resources, he hints that they probably inhabit cavities bored by other animals ¶. A. S. Ørsted considered that *Dodecaceria concharum* bored partly by aid of the secretion of its alimentary canal (which, says he, contains muriatic acid), and partly by aid of its hooks. Sir J. Dalyell ** likewise thought that the tube of this animal might be enlarged by some solvent. Mr. Spence Bate †† accounts for the majority of marine borings by an ingenious theory which adroitly shifts the onus of the solvent from the animal itself to its surroundings; or, in other words, he avers that the solution of the difficulty and the rock is achieved by the agency of *free carbonic acid held in solution by sea-water*. He instances “the groove sunk by the *Spiroglyphus*, which Annelide affords a good example to illustrate the theory; for it not only sinks a groove in the shell on which it has erected its own, but, should its contortions bring it into contact with any portion of its own

* Ann. des Sc. Nat. sér. 4. tom. iv. 1855, p. 230, pl. 8 c. figs. 1–8.

† Compt. Rend. Acad. Sc. Paris, tom. lxi. 1855.

‡ Ann. des Sc. Nat. sér. 4, Zool. tom. x. p. 49, pls. 1–4.

§ Ein Ausflug nach Triest und dem Quarnero, pp. 47, 48, 1861; and Die Insel Lussin u. ihre Meeresfauna, 1864.

|| Ann. Nat. Hist. ser. 3. vol. xvii. p. 472.

¶ Phil. Trans. 1826.

** Pow. Creat. vol. ii. p. 210.

†† Transact. Brit. Assoc. 1849, p. 73–75.

shell, it absorbs it equally with any other." It will be observed that in the last clause he anticipates and answers one of Mr. Lankester's recent queries*. It may also be remarked in passing, that it is probable that the genus (*Spiroglyphus*) here referred to is the same as the *Stoa* of M. Marcel de Serres, as hinted by Mr. Shuttleworth in the same vol. of the 'Ann. des Sc. Nat.'

This chemical or solvent theory has been shown by many authorities to be inadequate to explain all the facts connected with the boring of the Mollusca; for, besides the boring of wood by the *Teredo*, some of the *Pholades* perforate gneiss, mica-schist, talc, peat, resin, and sandstone, as well as calcareous rocks; and I would only refer to the careful digest and observations on the subject in the 'British Mollusca' of Messrs. Forbes and Hanley, and to the experienced and recent remarks of Mr. Gwyn Jeffreys †. M. Valenciennes is of the same opinion with regard to the *Echini*. Indeed MM. Cailiaud ‡ and Fischer §, in describing the borings of *E. lividus*, show that it excavates (notwithstanding the adverse opinion of Mr. Trevelyan ||) not only calcareous rocks, but gneiss, granite, whitestone (leptynite), schist, &c., while foreign species invade basalt: and the former author, in his first plate, represents several specimens of *Echinus lividus*, of the natural size, located in their holes in granite from Croisic, on the coast of France. Dr. Bowerbank ¶ likewise, in his careful and conscientious observations on the boring question, gives no support to such a theory; and Mr. Hancock ** could find no trace of acid in his specimens of *Cliona*. M. de Quatrefages adds his weight into the scale against the idea of a solvent in the Annelidan perforations. Lastly, although Mr. Lankester appends the following sentence to his letter in the 'Annals' for July last, "It is almost impossible to assign any but a chemical means of excavation to *Bonellia*," it may be remarked that M. Lacaze-Duthiers, in the original paper, appears to be more cautious than to attribute its work to such an agency.

Physiologically it cannot be considered that carbonic acid in

* Ann. Nat. Hist. ser. 4. vol. i. p. 237, line 9 from bottom.

† Brit. Mollusca, vol. i. Introd. p. xxvii, and vol. iii. p. 94.

‡ Catalogue des Rad., des Annél., des Cirrhip. et des Mollusques Marins &c. dans le Départ. de la Loire Inférieure: Nantes, 1865.

§ Ann. des Sci. Nat. Zool. sér. 5. tom. i. 1864, p. 321.

|| This gentleman considered that the animal (*E. lividus*) possessed neither chemical nor mechanical power of perforating rocks, but that such excavations were produced by countless generations of such creatures, which thus, after the lapse of ages, gradually had worn the stone away. (Edinb. Phil. Journ. vol. xlvi. 1849, p. 386.)

¶ British Spongiadae, vol. i. p. 221.

** Ann. Nat. Hist. ser. 2. vol. iii. p. 329.

a free state, and in such a quantity as to act on calcareous rock or shell, is a likely accompaniment to such an animal as *Leucodore* working in a tube, whatever may be the case with the salivary glands of *Dolium*, *Tritonium*, *Aplysia*, and the acid secretion of *Gastrochæna* and other Mollusca. Annelids are very sensitive to irritants and narcotics, and must be judged by the same rules in this respect as the majority of other animals. And this statement is not impugned by the fact that a few, such as *Cirratulus*, may occasionally be found burrowing in odoriferous mud, like the ubiquitous crustacean *Carcinus mænas*. It therefore appears to me to be just as prudent and useful to bring forward the chemical theory in regard to the perforations of *Limnoria* and *Chelura terebrans* in wood, of the *Pholas crispata* in the hard shale and sandstone in company with *Leucodore* at St. Andrews, in regard to the deep cavities made by *Patella vulgata* in the latter rock on the same sites, in regard to the borings of the *Echini* and the wide interlacing channels of *Hymeniacidon* in shells and stones on all our shores, as to produce it for the explanation of Annelidan perforations. Yet Mr. Lankester prefaced his observations on the boring of *Leucodore* by the statement that he was prepared to find such due to chemical action, because an acid reaction was found in *Sabella saxicava**. We are thus prepared for the following remark:—“Supposing, then, the agency in *Leucodore* to be a chemical one, has any acid been observed? It has: specimens of *Leucodore*, placed on litmus-paper, give a strong acid reaction.” I have carefully tested for acidity in numerous specimens of *Leucodore* from St. Andrews; but not a trace thereof rewarded my attempts, though an ambiguous stain is occasionally produced by old sea-water in which they and other Annelids have been confined. No acid reaction at all was visible; and to apply the epithet “strong” to such a case would certainly be after the fashion of a chemistry unknown to us. Moreover I asked a distinguished young chemist, Dr. Crum Brown, to repeat the tests. He wrote me as follows:—“I found exactly as you have stated on the labels, viz. that *Cephalothrix filiformis* has a marked acid reaction in every part of its body, and that *Leucodore ciliata* is quite neutral. The perforated and grooved stone is not calcareous, and is scarcely attacked by acids: prolonged action of tolerably strong hydrochloric acid dissolves a little iron.... It appears to be a kind of mica schist.” I was not more suc-

* I am glad to say that Mr. Lankester has since seen reason to change his opinion. While maintaining the correctness of his statement with regard to the acidity of *Leucodore*, he withdrew his chemical theory after the reading of my paper at the Meeting of the British Association.

cessful in finding acid traces in the southern examples. For a considerable time I have been familiar with an acid reaction in the cutaneous textures of many Nemerteans, such as *Borlasia olivacea*, *B. octoculata*, *B. lactea*, *Lineus longissimus*, *Stylus purpureus*, *Cephalothrix filiformis*, *Ommatoplea alba*, *O. melanocephala*, *O. gracilis*, &c.; indeed acidity seems characteristic of the group, the only exceptions as yet observed being in the deeply tinted *O. purpurea* and in *O. pulchra*, which have an alkaline reaction, rendering red litmus-paper blue. One of the most vivid red streaks is caused by the common *Cephalothrix filiformis*, referred to above. Some species of *Chone*, again, which do not bore, likewise give an acid stain to litmus-paper. The mere presence of acidity, therefore, is no proof whatever that an animal bores. None of the Nemerteans, for instance, do so, their habitats being in muddy sand under stones between tide-marks, in fissures of rocks, or in the cavities of old shells and stones from deep water. It is well to bear in mind also that *Dodecaceria concharum* and *Sipunculus*, both very common borers, show no acid reaction when tested with litmus-paper.

While thus shutting out the chemical means of boring from being the law to be applied universally to the perforations made by Annelids, I should deem it rash at present, on my part, to promulgate any new theory, or to support any of the old.

Mr. Lankester concludes his paper with some remarks on "the specific title and distinction of the lithodomous *Leucodore*." "The boring species," he says, "does not differ obviously from *Leucodore ciliata*. I have not been able to make a comparison of specimens; but it seems probable they differ only in habit." Yet he suggests the name of *L. calcarea* for the boring form. I cannot agree with the author here either; for I have never seen more than a single British species of *Leucodore*, which, however, bores in materials very varied in their composition. It is unsafe to suspect a form to vary specifically simply on the ground of its habitat; and assuredly some more weight would have been given to his view of this matter if he had founded the distinction on the abnormality of the hooks of the fifth segment of the body, or on the absence of the spear-tipped bristles which accompany them. The perusal of the remarks of M. de Quatrefages* on the different species of *Leucodore* is somewhat unsatisfactory; and it appears to me to be by no means certain that at least five of his species do not refer to one, or at most to two forms. It is further worthy of note that, so far as I am aware, no other observer (excluding the more than doubtful cases of M.

* Hist. Nat. des Annelés, vol. ii. p. 296 et seq.

Ersted and Mr. Lankester) has clearly made out another European species; for I consider Leuckart's *Leucodore muticum** a somewhat inaccurately described *L. ciliatus*, Johnston. The possession of only two eyes, and the fact that the great hooks occur on the "sixth" segment of the body, and are three-toothed, characterize the *L. nasutus* of M. de Quatrefages. The author states that the anal segment terminates in a flattened cup, which permits the Annelid to attach itself to solid bodies; and his figure shows no split in the margin. If the latter arrangement is correct, then the previous characters may hold. It is also but fair to remark that specimens occur at St. Andrews with two eyes, and even with one only, and that the anterior pair in all, being on a lower level, are less easily seen from the dorsum than the posterior. The same may be said of *L. audax* and its circular cup. Moreover, as the latter assumes somewhat altered appearances in those whose tails are regenerating, some caution is needed in basing specific differences thereon. His *L. Fabricii* rests, as a species, upon characters that require further elucidation; and the remarks on *L. ciliata* are based on Dr. Johnston's description; and hence the author is misled as to the structure of the hooks of the sixth segment (fifth of the body), which really, as already mentioned, have a secondary spur or process. *L. dubia* is also founded on insufficient data. Lastly, there can be little doubt that the *Polydora cornuta* described by M. Claparède†, and given by M. de Quatrefages as the type of a new genus, is nothing more than *L. ciliata*. The want of scientific accuracy in the figures of the genus in the 'Annelés' renders identification difficult.

EXPLANATION OF THE PLATES.

PLATE XVIII.

- Fig. 1.* *Leucodore ciliata*, Johnst.; enlarged under a lens.
Fig. 2. Great hooks of the fifth segment of the body: *a*, as usually seen in the separated and perfect organ under pressure; *b*, a more complete view, as obtained in the living animal or in a favourable spirit preparation. × 700 diameters.
Fig. 3. Spear-tipped bristles accompanying the former. × 700 diams.
Fig. 4. Hooks of the posterior region of the body: *a*, pressed between glasses; *b*, seen in front, so as to exhibit both wings. × 700 diams.
Fig. 5. Front and side view of two of the bristles of the same species. × 700 diams.
Fig. 6. Caudal segment and its cup. × 210 diams.

PLATE XIX.

- Fig. 1.* Tubes erected by *Leucodore* at the apertures of its tunnel. The

* "Zur Kenntniss der Fauna von Island," Archiv für Naturges. 1849, p. 200, Taf. iii. fig. 12.

† Recherches Anat. sur les Annélides, Turb. &c. 1861, p. 47, et *op. cit.*

attenuated tentacles are seen protruding from the mouth of one. Enlarged under a lens.

Fig. 2. Tentacle of *Leucodore*, magnified. The organ is in the somewhat contracted condition in which it usually appears when the animal is placed between glasses: *a*, ciliated groove on the inner surface; *b*, cavity of tentacle; *c*, blood-vessel.

Fig. 3. Ciliated parasite attached to a fragment of the tentacle, *a*. $\times 700$ diams.

PLATE XX.

Fig. 1. *Dodecaceria concharum*, $\text{\O}erst.$, from a tangle-root, St. Andrews. Enlarged under a lens.

Fig. 2. Hook of the same species. $\times 350$ diams.

Fig. 3. Extremities of two of the latter: *a*, of the same specimen; *b*, of a developing or somewhat imperfect specimen. $\times 700$ diams.

Fig. 4. Bristles from a dried specimen in limestone from Torquay, sent by Dr. Bowerbank. $\times 350$ diams.

Fig. 5. Posterior hook of a small *Sabella saxicava*, from a dried specimen in a *Balanus* sent by Dr. Bowerbank. $\times 700$ diams.

Fig. 6. Thoracic hook of *S. saxicava*. $\times 350$ diams.

Fig. 7. Minute spear-shaped bristles accompanying the latter. $\times 700$ diams.

Fig. 8. Bristles of the same species: *a* & *b*, two of the forms met with in the thoracic region, the latter being viewed laterally; *c*, posterior bristle from the dried specimen referred to under fig. 5. $\times 350$ diams.

XXXIV.—*On the Structure of the Shells of Brachiopoda.*

To the Editors of the Annals and Magazine of Natural History.

Oban, Sept. 21, 1868.

GENTLEMEN,

On my return from the mission of scientific research into the zoology of the deep sea, with the charge of which I have had the honour to be entrusted by the Admiralty, at the instance of the Council of the Royal Society (and the very remarkable results of which will be made public at the earliest possible period), I find the note of Prof. King contained in your last Number, on which I have only to remark that the admission he has cited of the fallacy of his original imputation upon the accuracy of my researches into the structure of the shells of Brachiopoda is limited to the single case of the recent *Rhynchonella psittacea*, which did not enter into his original charge, because he had not then examined it. That charge was founded upon his superficial examination of fossil *Rhynchonellida* and *Spiriferida*; and neither then nor since has Prof. King made the slightest retractation of it. By declining to reply to my last three questions, he leaves the matter exactly where it was before; so that it must be presumed that

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Hyalothrix, Gray, P, Z. S. 1867, p. 119.

Bark smooth. Polypes oblong when contracted, low. Tentacles 40.

Hyalothrix lusitanica Gray, l. c. 1867, p. 119. B.M.

Type *Hyalothrix lusitanica*, Bocap-e, P. Z. S. 1864, p. 205, t. 22 ; 1865, p. 662 ; Gray, Ann. & Mag.: Nat. Hist. 1866, xvii. p. 287; Loven, Ann. & Mag. N. IT. 1868, p. 90.

Var. *sjyongifera*.

H. lusitanica, Bocape, Ann. & Mag. Nat. Hist. 1868, ii. p. 36; Bowerbank, P. Z. S. 1867, p. 902.

Hob. Portugal.

P.S. Dr. Perceval Wright, who has just returned from dredging for Hyalonemata on the coast of Portugal, informs me (Sept. 14) that he believes the coral (*H. lusitanica*) grows at the bottom of the sea in deep water, with the free part of the coil sunk in the sand. He also mentioned to me that M. Bo-

cage has some specimens of the sponge that grows on the H. lusitanicum with a shallow cavity that is covered with a netted lid formed of spicules, like the lid of Ewpectella. I do not find any trace of such a lid in the three sponges on the Hyalomema Sieboldii in the British Museum ; but it seems to exist in some specimens of that sponge, as Dr. Loven says that Prof. Schultze found " the flattened surface of the smaller and younger specimen (No. 4) covered by a network of spicules similar to that which covers the free end of Eujilectea." (Ann. & Mag. N. H. 1868, ii. p. 89.)

XXXIII. — On the Boring of certain Annelids,

By W. C. McIntosh, M.D., F.L.S.*

[Plates XVII., XIX., XX.]

At the Meeting of the British Association held at Dundee, my friend Mr. E. Bay Lankester read a very interesting paper on " Lithodomous Annelids," or, rather, on the boring of *Sabella saxicava*, Quatref., and *Leucodora ciliata*, Johnst., chiefly with reference to the latter. In the discussion which followed, Mr. Gwyn Jeffreys and I strongly opposed the theory advocated by the author as to the action of a purely chemical agency in the production of the perforations. I specially mentioned that *Leucodora ciliata* bores in aluminous shale — a fact fatal to the chemical (or acid) theory — and am

* Communicated by the Author, having been read at the Meeting of

the British Association at Norwich, Aug. 24, 1868.

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now compelled to make a few remarks on the subject at this stage, on account of the publication of the above-mentioned paper in the 'Annals of Natural History' for April of this year (1868). In the latter publication the author states that " Dr. McIntosh was the only observer at Dundee who expressed a belief that these Annelids perforate rocks other than carbonate of lime. He said he had seen aluminous shale so bored ; but I think he had other excavations in mind, such as Annelids will make in the semisolid silt filling cracks in shale, or else that he has since seen reason to change his opinion ; for he has not produced any such specimen of shale, although then challenged to do so. I submit that the opinion as to aluminous shale, unsupported by any chemical test or specimen, and confessedly only casually noticed, should not be of any weight in the balance against the facts as to the exclusive erosion of limestone which are above recorded." I had for the time forgotten the subject till I saw this paper (and for the first time its challenge) in the ' Annals ;' yet, on referring to my notes on *Leucodore ciliata* made several years ago, I find that it bores not only in aluminous shale, but in a material, in a chemical sense, even more impenetrable.

Boring and burrowing are very common features in the British Annelida. The majority are fitted chiefly for perforating sand or sandy mud, such as the Lumbrici, Nereis, Cirratulus, Eteone, Glycera, Arenicola, Scalibregma, Ammotrypane, Ophelia, Trivisia, Aricia, Terebella, Sahella, Macla, and others ; and the modes in which they pursue this their daily occupation vary greatly. Glycera and Nereis especially disappear with rapidity amongst the sand by boring with their proboscides, the former passing its elongated organ through a considerable space in a single thrust. Eteone dashes through the water in ever-varying screw-coils, and carries its snout with equal facility through sand ; and the motions of Ammotrypane are even more vigorous, especially as regards penetration of the latter. The efforts, again, of Scalibregma, Ophelia, Trivisia, and Macla are less violent ; but they easily penetrate the same semisolid medium. Some, such as Nereis pelagica and Dumerilii, occasionally occupy galleries in the stems of softened Laminariae ; while Hediste (Nereis) diversicolor bores in vast numbers in the peat of Perrelle Bay, in Guernsey, and more sparingly in casual pieces of the same material on the eastern shores of North Uist. Several delight to bore in muddy clay, such as Eunice, Lumbrinereis, and Nofocinus. Many species occur in galleries between the layers of shale and sandstone, and in the cracks of granite, gneiss, and other rocks, amidst sandy mud,

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as well as elsewhere, such as several of the Bionidic Eunicid
Lysidice Tropionia, Syllis armillaris Psamathe fusca, Cas-
talia junctata Eulalia., Thelepus (Venusia) and Aphlephina.
Of these, Lysidice is often found under the calcareous spread-
ing base of *Coralina officinalis* along with *Leucodore* under
the large littoral Ascidians at Herra, and in masses of *Celle-
pora* from the deep water off St. Martin's Point, Guernsey,
and, though it would seem to take possession of an old tunnel,
yet appears capable of accommodating the hole to its own
wants. Lastly, a few Annelids bore rocks, stones, and shells
of various kinds, amongst which are *Leucodore* *Dodecaceria*
Sabella saxicava *Heterocirrus saxicola* *Grube** (a species I
cannot at present distinguish from *Dodecaceria concharum*),
besides some of the adjoining group, *Gephyrea*.

There is no more common Annelid along the rocky parts of
the beach at St. Andrew's than *Leucodore ciliata* (Pl. XVIII.
fig. 1) ; and, indeed, it is a very abundant British form in general.
It especially haunts the soft blue shale at the West and Castle
Rocks of the ancient city, apparently, like its companion *Pho-
las crisimata* because it finds such more easily excavated than
the denser sandstone, just as we see it avoiding the hard gra-
nite and gneiss of the Channel Islands and the outer Hebrides,
and tunnelling its galleries under the spreading base of Coral-

Una and the numerous Nullipores, both free and surmounted by the tangles, or as M. de Quatrefages found at Guettary, in the case of *Sabella saxtcava*, which preferred to bore the calcareous rocks rather than the quartz with which they alternated. It is likewise abundant in the fissures of the shale and sandstone, forming tunnels amidst the muddy debris so abundant in these localities, where Dr. Johnston seems alone to have found it. OErsted, again, gives "sandy tubes" as its sole habitation. Vast numbers of the common limpet-shells are also invaded by them, their tracks with the loop at the bottom being visible from the inner surface as whitish streaks; and the irritation frequently causes the mollusk to secrete layer upon layer of the nacreous lining. It abounds likewise in many other littoral and deep-water shells, such as *Buccinuni*, *Fusus*, *Haliotisy* *Ostrea*, and *Anomia*, and, indeed, in favourable sites, almost upon every shell thick enough to bore into.

Its presence amidst the shale and sandstone is easily recognized by numerous small tubes, composed of agglutinated sand and mud (PL XIX. fig. 1), which project from the surface of the stone in dense groups, so as to form in many cases a kind of sward of tubes — a habit apparently characteristic of the

* Archiv für Naturges. 1855, p. 108, Taf. 4. f. 11.

t Ann. des Sc. Nat. ser. 3. Zool. tonic viii. 1847.

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race in all parts of the world ; for the Abb^e Dicquemare long ago noticed this on the coast of France, and in more recent times M. Schmarda* describes and figures a species [Leucodore socialis) having a similar habit, on the coast of Chili, Mr. Alex. Agassiz another on the shores of the United States, M. de Quatrefages at Boulogne, M. Clapar^{de} at Skye, and Dr. S. Wright in the Frith of Forth. Mr. Lankester, however, does not allude to this habit ; and such tubes are certainly rare on the calcareous rocks. Very short ones are occasionally observed on the surface of Corallina. These tubes are composed, according to the nature of the site, of minute grains of sand and mud, or pure sand, cemented together by a tough secretion, which likewise gives a smooth coating to their interior. They project sometimes nearly half an inch from the stone or other material; and, when laid along the surface, in some cases they exceed this in length. If the animals are scattered, it will readily be observed that each is supplied with two independent and occasionally divergent tubes, which thus correspond to the double nature of their perforations in the stone. Both are formed in the same way, the Annelid reversing itself in its gallery at will and augmenting the length of the quiescent tube : thus the restless tentacles are observed to project now from the one and now from the other. The animal displays great energy in proceeding with its work, its tentacles resembling a struggling Ascaris that has been seized by the

middle and is endeavouring to make its escape. Not only are these organs thrown about in all directions, but each undergoes a series of vermiform wriggings, no head meanwhile being visible from the aperture of the tube. After lashing the water for some time, they may be noticed moving along the surface of the stone with a serpentine motion like independent worms, and seizing any convenient particle of mud, sand, or food they may encounter. Upon effecting this, the tentacle is not contracted as in the Hydrozoa and Actinozoa, but its vermiform motions along the rocky surface remain unaltered, while the particle is observed to wend its way towards the mouth of the tube along the tentacle in a remarkable manner, to be seized by the lips of the animal. Basterf distinctly noticed this quality in the tentacles of *Leucodore*[^] mentioning that, however unwilling, the prey was dragged by the organs into the tube and consumed at leisure. Hence he inferred they had many of the properties pertaining to the tentacles of polypes. The fact also did not escape the notice of that most patient and keen observer of nature. Sir J. Dalyell, in "*Spio seticornis*"^{^^} for he says, " The particles that may be selected for the edifices arc

« Neue wirb. Thiere, i. ii. p. G4, tab. 2G. figs. 209 & 209 a.

t Basteri Opuscula Subseciva, torn. ii. lib. 3. p. 135.

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seized and passed along the tentaculum, and apparently carried to the mouth". If the particle of sand, for instance, after entering the mouth of the tube, is considered suitable, it is by-and-by pushed out with the snout, and arranged on the circumference of the tube with the glutinous secretion. Occasionally the proximity of other tubes affords an opportunity for abstracting particles therefrom, as well as causes frequent collisions with neighbouring tentacula, especially apparent when two take possession of the same prey. Now and then a small mass of mud and sand may be seen travelling outwards from the tube along the tentacle, to be dropped at some distance. Quantities of debris, again, may sometimes be observed issuing from both apertures; and in those vessels in which the animals have been vigorously at work on new sites, heaps of minute grains of sand or altered shale are grouped on the flat surface around the tubes ; or if these are elevated in the vessel and project horizontally, the debris falls to the bottom or clouds the side of the glass. Where the basis material is bluish shale, this debris has a brownish colour, and the particles assume a somewhat definite ovoid shape, so that the heaps have a peculiar miliary appearance. The alteration in the colour in this case is interesting, showing that in all probability the masses have passed through the digestive tract of the Annelid. Moreover we may be fairly warranted, from the appearances, in assuming that at least some of the constituents of such heaps are the results of the boring, and not all due to the seizure of external particles from (in this case) the smooth surface of the shale. There was nothing peculiar in the instance of the sandstone,

whose loose debris after boring resembled the grains of sand removed from the mass.

The benefits of a tube superadded to the gallery in the stone are apparent ; for the tentacles are thus enabled to take a longer sweep through the surrounding water for the capture of minute structures while the delicate body remains protected. Moreover a field of competition is opened up to these social Annelids, in which it must at least occasionally occur that the best and most rapid builder of these tubes is placed under more favourable conditions for existence than those with shorter tubes or those confined to the dead level of the rock or shell.

When the animal happens to find a large mass of loose material near its tubes, it sometimes protrudes its head and anterior region, and aids the tentacles in dragging it towards the mouth of the tube, or occasionally the anterior part of the body is extruded in an exploratory manner ; but, as a rule, they are very shy. A free animal is now and then encountered, and, if in perfect health,

* Power of the Creator &c. vol. ii. p. 109.

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it is not the helpless animal described by Dr. Johnston *, but

progresses very actively indeed, either on a horizontal or perpendicular surface ; and if circumstances are unfavourable for its gaining the stone, or, if it so chooses, it fashions a tube round its body with ease and rapidity (provided materials are forthcoming), either on the bottom or along the side of the vessel. Nor is it satisfied with the construction of one home, but roams about from place to place and forms several. In such instances the tube is not generally turned on itself, but is more or less linear, the cup of the anal segment communicating freely with the water by the open end of the tube. They are also not unfrequently found swimming on the surface of the water, like other Annelids.

The first point that strikes the observer in regard to the perforations in the sandstone and shale is that they are grouped in pairs, sometimes with a thicker and sometimes with a thinner intervening column. In many cases this column would seem to be formed of debris ; but in others, especially those in shell, sandstone, and Corallina^ some of the original material is left ; so that, by this feature, the observer is seldom left in doubt as to the identity of any particular gallery he encounters. From the exterior the tubes, as usually observed, proceed inwards either as nearly straight or more or less curved cylindrical galleries, and terminate in the case of each pair by joining in a loop at the bottom, the latter being either abruptly or gently curved, according to the thickness of the intervening column. This siphonal form of gallery is very general among the Annelida and other burrowing animals ; various TerebeUm^

Eunice sanguinea^ *Cirratulus cirratus*^ and others follow this habit in the fissures of rocks; while *Goroplium longicome*, so abundant in company with *Edwardsia* on some of our* muddy or clayey shores, has its burrow of the same characteristic formation. In *Leucodore*^ as a rule, the intervening column attains the largest dimensions inferiorly, a considerable wedge of sound shale being often left at the loop. The latter, moreover, in some was marked by two or three grooves, showing that at various times the animal had altered the depth of its galleries to suit its convenience, perhaps in relation to the length of its built-up or external tube, though this is not a matter of much consequence. All the tubes were lined by the delicate secretion before mentioned.

In the borings in shell, *Nullipore*, and *Corallina* the tube or perforation had not, in our specimens, the form of a keyhole, as mentioned by Mr. Lankester, but possessed a solid column of the original structure, or else one of consolidated debris, intervening between the tunnels. In the sea-worn specimens of

* Catalogue of Worms, Brit. Mus. p. 20H.

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chalk and limestone, the empty perforations, however, do exhibit a form somewhat like a keyhole in transverse section ;

but in the calcareous rocks and stones containing living specimens the double tube is completed by an intervening column of debris, except at the loop. In not a few of the worn pieces of chalk and limestone, only the widened inferior end or junction of the tube remains. This is a point of some interest, since *Dodecaceria concharum* abounds in the same sites, and its gallery is distinguished in transverse section by having no incurvation, or only a very slight incurvation in the middle, and is not double ; yet the dried remains of this worm might most aptly be described " as a black carbonaceous film," whereas the dried remnants of *Leucodore* are of a pale or straw-yellow hue.

Amongst the minute fragments of flint which form the fine gravel of Luccomb Chine, in the Isle of Wight, are many loose rounded pieces of limestone and chalk more or less perforated by *Leucodore* and *Dodecaceria* ; but the living examples of the former occur chiefly between half tide and low-water mark, the best site being at the verge of the latter, and this more especially as regards *Dodecaceria*. *Leucodore* is not only abundant in the substance of the rocks themselves, as mentioned by Mr. Lankester, but swarms under the spreading base of *Corallina*^ though, on account of the inconspicuous nature of the apertures in the latter, little or no trace of the borings can be observed until the surface is split off". Besides, in the littoral region there are numerous flattened stones, one or two feet square, that have their surfaces quite worm-eaten by the perforations of the Annelids, whose now vacant galleries have been considerably enlarged by the action of the sand and surf. Occasionally the borings in these large stones

were arranged in a linear series, the worm having attacked the commencing fissures as the most vulnerable parts of the mass. At White-Cliff Bay, again, the perforations in the chalky rocks abounded in the same region, and were of a somewhat larger size than those made by our northern examples.

Descriptions of the general structure of Leucodore have been published by the Abbé Dicquemare, Dr. Johnston, M. Quidstedt, Grube, Claparède, and Keferstein ; so that my remarks at present shall be confined to the tentacles, bristles, hooks, and anal segment.

The tentacles (Pl. XIX. figs. 1 & 2) are a pair of very mobile muscular organs, possessing in each case a ciliated furrow on the inner side, Dr. Johnston being in error in averring that the inferior side is so supplied. Dr. Strethill Wright* has given a somewhat minute account of their microscopic appearance in

* Edinb. New Journ, 18-57, vol. vi. p. 90.

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this species (in all probability), which he termed *Sano seticornis*. He observed that the tentacles, when seizing a fragment of oyster, attached themselves to it " not by winding

themselves round it, but by simple adhesion, as if they were studded with numerous suckers and hooks, like the arms of the cuttle-fish." This prehensile apparatus " consists of numerous large papillae thickly crowded together along the borders of the tentacles," each having an " acuminate soft cilium or spine." On forcibly pressing the tentacle, " the spine-bearing papillae burst, and there issues from each of them a . . . pear-shaped capsule (trichocyst) which, again, on rupture, discharges a multitude of acicular spicules." He likewise states that the tentacles are furnished with " a ciliated band running from the tip to the base," but does not point out the actual disposition thereof. In his drawing of the tentacle (fig. 18) the papillae are ranged along each side of the organ from base to apex.

When the tentacle is extended, as in its ordinary motions (Pl. XIX. fig. 1), there is little or no appearance of wrinkles. A very considerable alteration, however, ensues on placing the animal, even without irritating pressure, between glasses, and certainly much more so if the tentacle itself is removed by violence. The ciliated groove along the inner border, like the rest of the organ, is minutely granular, especially towards the tip, the latter, on the slightest contraction, assuming a minutely warty aspect (fig. 2). Besides the long cilia which cover the furrow, there are various motionless hairs along the opposite or exterior border of the organ, as indicated by Prof. Kernerstein, and which are also present on various other parts of the animal. The wrinkling of the tentacles in most views is very marked,

the whole organ being crossed by transverse seams, between every two of which a series of very distinct temporary papillae occur at the edge, which papillae sometimes do possess a motionless cilium or " spine," and are more likely to do so under paralyzing pressure ; but the appearance shown by Dr. Wright is the result of injury, and not a natural interpretation of their anatomy, however closely his outline may indicate what he saw. These temporary papillae, in common with the entire surface of the furrow, certainly present a streaked appearance ; but such is due to the compressed cilia ; and I have never been able to see the remarkable " trichocysts " and their acicular contents as described by this ingenious naturalist, to whose observations I gave due respect by repeated examinations. Circular cells filled with minute granules often escaped through the delicate epiderm of the pressed organ, together with minute granules and swarms of discarded cilia : but there was no

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trace of the " trichocysts." M. de Quatrefages*, again, in his remarks on the respiration of the Annelids, refers to a drawing of the tentacle of a *Polyclora*^ which may or may not be this species. He shows the ciliated region to be cellular, but does not notice crenations.

On the tentacles of several were the curious parasitic forms represented in PL XIX. fig. 3. They were attached by a short stalk, and, when set free, moved rapidly through the water by the aid of their cilia, which in their fixed condition were next the tentacle.

The fifth body-segment of the worm has the characteristic strong hooks (Pl. XVIII. fig. 2), which are accompanied by the peculiar bristles with spear-shaped heads (fig. 3), besides the minute dorsal fascicle of the ordinary structure. The tip of each of the first series is strongly curved ; and towards the concave side thereof a spur projects, apparently with a twist backwards and ventrally ; and hence, if the organs are separated and pressed between glasses, this spur in not a few cases almost escapes observation : this is especially the case in spirit preparations. In the larger southern examples the spur is less visible than in the smaller, as the hook under pressure assumes a position which hides the projection ; it is very evident, however, when the hook is viewed in situ. The shaft of the hook in the large examples is marked at intervals by transverse striffi. Mr. Lankester's figures f may be taken as the representatives of altered bristles from specimens in which they have been subjected to some morbid influence, either due to the natm'e of the habitat (calcareous rock) or otherwise. Other specimens from the same rock show the ordinary structm'e with the single spur beneath the tip. In some of the altered specimens the spear-shaped bristles accompanying the hooks are absent. Mr. Alex. Agassiz has given a better view of their structm-e, though he does not refer to the spear-shaped

bristles which accompany them. In the majority of the specimens from St. Andrew's three of the hooks were well developed, the first being the longest, and the fifth and sixth rudimentary but nevertheless showing the secondary fang or spur even more distinctly than the others. In larger examples from Cobo Bay, Guernsey, and the southern shores of England, these hooks are more numerous J.

* Ann. des Sc. Nat. ser. 3. Zool. tome xiv. pi. 5. fig. 10.

t Ann. Nat. Hist. ser. 4. vol. i. 1868, pi. 11. fig. 9.

\ At the late meeting of the British Association, IVL*. Lankester, while at once admitting the erroneous condition of his own published drawing of the hooks, denied the accuracy of mine as exhibited in a large coloured drawing accurately copied from the two figures (Pl. XVIII. figs. 2 a, h) ac-

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The inferior appendages of the rest of the body-segments consist of characteristic hooks — organs, I may add, that have received but scant justice from their artists, with the exception of M. Claparède* and Mr. Agassiz, though the latter appears to have slightly misapprehended their true nature, as he speaks of " a stiff bristle extending from the base of the curve" — which

can only refer to the wing of the structure, about to be described. The figure of this careful observer, though earlier, is more correct than Mr. Lankester's. When the hook is pressed flatly between glasses (Pl. XVIII. fig. 4 a), the crown shows a long tooth in front, with a shorter superior process and a distinct wing ; but the latter, of course, has been altered by pressure, as, when viewed under favourable circumstances (fig. 4 J), it has a wing on each side of the crown and upper part of the shaft. Dr. Thomas Williams was in error when he assigned a dorsal position to these hooks. The bristles throughout conform to one type (fig. 5), having a long shaft, somewhat abruptly bent and tapered at the tip, which has a narrow process or wing on each side.

The anal segment is furnished with a peculiar cup (fig. 6), whose margin does not form a continuous ring, but is inflected and slit in the middle of the dorsal surface. A few minute and motionless cilia are placed round the margin. The papilla of the anal orifice is richly ciliated. The organ does not impress the observer as being eminently adapted for adhering to surfaces, after the manner of a sucker ; nor have I been so fortunate as to see the animal using it for this purpose. Mr. A. Agassiz and MM. Claparède and De Quatrefages, however, have seen the Annelid employing it for such ; and M. Mccznikoff is another author who mentions that a " sucking-disk " is met with in *Leucodore*. Dr. Williams, again, remarks that the anal segment is expanded with geometrical exactitude into a hollow cone, which acts on the principle of the sucker, the

worm " letting down its weight on the part, in order to press

companying this paper. He said that, instead of one spur, there were several spurs beneath the curved tip. Of course I have found no reason to alter an opinion formed after an examination of specimens from the north, east, and west of Scotland, from the north-east, south, and south-west of England, and from the Channel Islands. Mr. Agassiz and Prof. Keferstein, moreover, show only one process ; and though M. de Quatrefages represents at least two beneath the tip of the hook of his *Levcodorensis* from Brehat, I am bound to add that many of this distinguished author's drawings are not scientifically accurate. I do not know on what authority my friend made his statement ; and it is to be hoped he will clear up the mystery. * *Archiv für Anat. u. Phys.* 1(S3), Tnf. 1-i.

> *Ann. Nat. Hist. ser. 3. vol. xix. pi, G. fig. -38.*

X *Report Brit. Assoc. 1851, p. 208.*

§ *Zeitschr. für wiss. Zool. Bd. xvi.*

Ann. d; Mag. N. Hist. f. Ser. 4. TW. ii. 20

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out the water with which the bottom of the tube may be filled ; "

and thus the Annelid " amid the raging billows is securely

anchored to its cell." From the siphonal nature of the tube, this description cannot apply in any degree.

Another very common borer in shells, nuUipore, and calcareous rock is *Dodecaceria concliarum* Q^{rst.}, a Cirratulean which has a larger tube, shaped something like a keyhole in transverse section, and terminating in a slightly dilated, smooth, cseccal extremity. This animal likewise lives in the fissures of the rocks in the Channel Islands, forming in the mud long galleries bent in various ways, but always readily distinguishable from those of *Leucodore*. In addition to the foregoing localities, a specimen was sent me alive from St. Andrews rocks in its characteristic tube in sandstone. In this instance the perforation in the stone was lined by a considerable coating of carbonate of lime, so that it had a smooth whitish aspect — as if the animal had not relished constant contact with the rough grains of sand, and had fashioned a coating analogous to the well-known secretion of *Teredo*. Even in the spreading base of *Corallina officinalis*, the gallery inhabited by this animal is often so smooth, and its appearance on fracture so characteristic, that the observer is led to suspect the existence of some secretion which covers over the roughnesses of the tube and the rocky surface. The bristles (PL XX. fig. 4) in this species have a dilated and flattened tip with a finely serrated edge, and taper to a fine point. The shape of the hooks (figs. 2 & 3) is peculiar and characteristic, and enables the observer to distinguish the dried remnants at once. The animal tinges the spirit of a rich dark -green hue, just as Sark specimens of its ally *Cirratuliis cirratiis* do, but gives

no acid reaction to test-paper. The *Nereis sextentacidata* of Delle Chiaje*, which lives in holes in the rocks of the Neapolitan shores, is, in all probability, referable to the same species : and the *Narganseta coraUii* of Leidy j" is likewise either the same or a very closely allied form. The latter bores dead portions of *Astrangea astrceformis*.

A third British borer is *Sahella saxicava*, Quatref., which, according to Messrs. Stewart and Lankester, is found in the limestones near Plymouth ; and I have found it abundantly in Oyster, Pecten, Anomia, and other dead and living shells dredged off the Channel Islands, as well as perforating the Balani that cover the sides of the Gouliot caves at Sark, near

* Memorie sulla Storia e Notomia degli Animali senza Vertebre del Regno di Napoli, vol. iii. p. 176, tab. 43. fig. 16.

t " Marine Invert, of Rhode Island and New Jersey," .Tourn, Acad. Nat. Sc. Philad. ser. 2. vol. iii.

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low-water mark, my attention having been first directed to the latter site by Dr. Bowerbank, who kindly sent me dried specimens. In these caves the tube of the Annelid is often coiled

in its groove beneath the Balani, and then pierces the shell of the latter to appear on the upper surface. It likewise bores abundantly in *Gallepora pumicosa*, and in one instance had bored quite through the valve of a living *Pecten pusio*. It often occurs in the same oyster-shell in a combined attack with *Gastrochcena diibia*^ *Leucodore*^ and boring sponges, or sometimes places its tubes in groups in convenient fissures of the shell without boring, so that they can be dislodged en masse like short and contorted tubes of *Tubularia indivisa*. Another site is under empty limpet-shells amongst muddy debris, part of each tube being inserted into a perforation in the shell ; while, again, the cracks and fissures of the rocks near low-water mark afibrd a very favourite habitat in the Channel Islands, and their tubes are often seen projecting through incrusting sponges and Ascidians, both simple and compound. The species has a tough horny tube, whose exposed portion is furnished with minute grains of sand ; but the immersed portion is hyaline and more delicate. The boring in the shell and limestone is circular, and, though often more or less curved or coiled, it is not to be confounded with the work of *Dodecaceria* or *Leucodore*. I need not allude further at present to the structure of the species, save to observe that its branchiae are speckled with pale green and white, and furnished with two or three brown pigment-specks exteriorly, and that its hooks (Pl. XX. figs. 5 & 6) (which are accompanied by broadly spear-tipped minute bristles, fig. 7) and bristles (fig. 8) have the structure represented. The body shows a distinct acid reaction towards the posterior end, and especially

at the tip of the tail.

The fourth native borer is a little Sipunculus, which externally appears to be identical with *S. Johnstoni* of Forbes. It occurs in limestone on the shores of the Isle of Wight, bores into the spreading base of *Corallina* with the foregoing forms in the Channel Islands, tunnels the mud in the fissures of various rocks, and one occurred in a shell sent by Mr. Gwyn Jeffreys in his rich Zetlandic collection of 1867. The form of the perforation in the latter case is club-shaped ; and a young specimen had bored its tiny gallery from the tube of its parent — a very rare occurrence amongst the true Annelids. In this instance the tubes of *Campanularia verticillata* had taken possession of several of these minute galleries after the death or exit of the original inhabitant. This boring Sipunculus is quite neutral to test-paper.

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Annelidan borings have been noticed by many observers.

In 1765 Baster* describes and figures the very species

[*Leucodora ciliata*), I have no doubt, which has just been

brought forward by Mr. Lankester. He observes, "Alteram

Nereidis speciem, quam hie describo, voco minimam tentaculis longissimis ; " and his next sentence shows that he had at least as extensive an acquaintance with its habitat as some very recent writers : — " Heec in lapidibus, ostreis, aliisque piscibus testaceis, qui e limoso maris fundo petuntur, reperitur quam frequentissime, habitans semper in parvo ex limo aut arena constructo tubulo." This author, although he does not further allude to the habitations in the stones, mentions that he put a quantity of sand beside them in a glass vessel, and that they very soon bored into tliis, and constructed tubes at the entrance of their tunnels. The Abbe Dicquemaref in 1781 also refers to the same species, and he gives figures of the animal which, however inaccurate, may at least bear comparison with some of very modern date. He called it a sea-insect, and he cites it as an influential agent in destroying the calcareous rocks and stones in the neighbourhood of Havre. In a second paper by the same author [^] what appears to be a SaheUaria is described, which, it is stated, prolongs its tail within the rock or stone, as well as fashions a tube of coarse sand or fine gravel outside. He advanced the idea of a solvent to account for these borings, an explanation all the more likely, as his specimens of rocks bored by marine " insects " were all calcareous. Dr. P. C. Abildgaard § gives fair descriptions and figures of two species which bore into the marble cliffs and calcareous stones below water at Santa Cruz in the West Indies. He calls the one Terebella hicornis[^] and the other Terebella stellata. Tlie first is a Cymospira [C. hicornis) characterized by having a hard, horny, flattish operculum, from which project two branched antler-shaped processes. He

also mentions at the end of his paper that another was sent him with three horns on its operculum, the third being closely appressed to the plate ; but the animal was otherwise similar to the first. The latter is thus closely related to the *Cymospira tricornis* of Dr. Baird ||, who remarks that it had apparently burrowed in Madrepore — a habit characteristic of other species of the genus, whose galleries occasionally pierce

* Basteri Opuscula Subseciva, torn. ii. lib. iii. p. 134, tab. xii. fig. ii. a, c.

t Observat. et M^m. Phys. torn, xviii. 1781.

X Op. cit. torn. XX. 1782.

§ Schrift. Gesellsch. ntrf. Freund. Berlin, i. 1789, pp. 138-144. I am indebted to Dr. Albert Gtintner for a copy of this paper, he having sent a complete translation, instead of a mere abstract in the original (German).

II .Tourn. Linn. Soc. vol. viii. 1865, p. 17.

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the fractured blocks in all directions. The second species of stone-borer (*T. steUafa* = *Pomatostegus steUatus*, Morcli, Sclmiarda, &c.) described by Dr. Abildgaard has an operculum

composed of three flats or plates raised one above another, and supported by a central column or axis, and likewise has been found perforating coral reefs. Mr. Osier * alludes to the abundance of worm-perforations (when treating on the same subject) in the Mollusca, thus — " The boring Annelids are innumerable in calcareous rocks, and are found to attack every marine shell almost as soon as it has acquired sufficient thickness to afford them a nidus ;" and he further instances the cases of the *Nereides*, *Arenicola jiscatorum*, and *Terehella conchilega*, as well as that of the *Spatangi* burying themselves in sand. His figure of *T. conchilega*, however, very much resembles *T. Uttoralis*. Mr. Templeton f fairly describes the perforations of a species, which is probably *L. ciliata*, in the limestone rocks of Whitehead, Belfast Lough, and figures the perforated stone and the animal in various positions. Mr. Garner \ refers to the subject in the Zoological Transactions, thus, " Certain Annelides apparently possess the power of excavating. The rocks on our coast are pierced by a minute worm, probably of the genus *Diplois* of Montagu ; it is strongly ciliated, but its mouth does not appear adapted for making its way into such hard substances." His figure is doubtless intended to represent *Leucodore* ; but only two eyes are shown, and there is no structural distinction made at the fifth segment of the body. In the same Transactions, Mr. R. Templeton § mentions a borer in the corals of the Isle of France called *Anisomelus luteus*, which has numerous long, hollow, prehensile tentacles, that seize prey like *Sapajous'* tails. It forms for itself a minute tube on the surface, as well as bores into the

coral. M. CErsted || next describes the boring of Dodecaceria concharum in shells. M. de Quatrefages ^ details the perforations of Sabella saxicava, and points out the interest which such would have to the geologist ; for though a Helix might perforate limestone like the marine lithophagous mollusca, and thus render its pristine site ambiguous, there could be no doubt about the ancient condition of stones bored by this Sabella. In his recent work he refers more than once to the subject**. Dr. Williamsff observed the boring habit of Lea-

* Phil. Trans. 1826, p. 843.

t Loudon's Mag. Nat. Hist. ix. 183C, p. 234.

\ Zool. Trans, vol. ii. p. 95.

§ Zool. Trans, vol. ii. p. 27, tab. v. figs. 9-14.

Il Annulat. Danic. Cousp. p. 44, 184.3.

il Ann. des Soc. Nat. sor. 3, Zool. torn. viii. 1847.

** Hist. Nat. des Auneles, vol. i. pp. 129 and 133; vol. ii. pp. 295, 415,

437, 552, 583, 597. ft Report Brit. Assoc. 1851, p. 208.

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codore ciliata, but did not enter into the modus operandi. M.

Marcel de Serres * describes the genus Stoa^ one of the chief characteristics of which is that it perforates West-Indian shells

— a fact, however, which had previously been observed by other

naturalists. M. Valenciennes f, in his remarks on the perforating Echini instances the case of a Sipu7iculus that bores wood. M. Lacaze-Duthiers % describes, in a careful paper, Bonellia viridis, a Gephyrean which bores calcareous rocks on the shores of Corsica. Prof. Grube § has lately described two other forms beside that first mentioned, viz. Sabella saxicola and Phascolosoma verrucosum^ which perforate the limestones of Martinsica and the island of Lussin in the Adriatic.

The chemical theory in regard to such borings, it is well known, has frequently been brought forward by zoologists in the instances of Mollusca and Sponges, and lately has even been assumed with regard to the Bryozoa||. Moreover it has more than once been promulgated to explain the means whereby Annelids perforate shells and rocks. Besides those already alluded to, Mr. Osier, for instance, brings forward the case of the Annelids to show that a shell is not essential to the boring-process, and in support of the solvent theory ; yet he could not find any such agent in the animals. Like his successor Mr. Lankester, he gets over the " argillaceous " difficulty by averring that they do not bore in this material, but, more fertile in resources, he hints that they probably inhabit cavities bored by other animals ^. A. S. Oersted considered that Dodecaceria concharum bored partly by aid of the secretion of its alimentary canal (which, says he, contains muriatic acid), and partly by aid of its hooks. Sir J. Dalyell** likewise thought that the tube of this animal might be enlarged by some solvent. Mr. Spence Bate ft accounts for the majority of marine borings by an ingenious theory which ach-oitly

shifts the onus of the solvent from the animal itself to its surroundings ; or, in other words, he avers that the solution of the difficulty and the rock is achieved by the agency of free carbonic acid held in solution by sea-water. He instances " the groove sunk by the Spirogyrus^ which Annelide affords a good example to illustrate the theory ; for it not only sinks a groove in the shell on which it has erected its own, but, should its contortions bring it into contact with any portion of its own

* Ann. des Sc. Nat. sér. 4, torn. iv. 1855, p. 230, pi. 8 c. figs. 1-8.

t Compt. Rend. Acad. Sc. Paris, torn. lxi. 1855.

X Ann. des Sc. Nat. ser. 4, Zool. torn. x. p. 49, pis. 1-4.

§ Ein Ausflug nach Triest und dem Quarnero, pp. 47, 48, 1861 ; and

Die Insel Lussin u. ihre Meeresfauna, 1864.

II Ann. Nat. Hist. ser. 3. vol. xvii. p. 472.

11 Phil. Trans. 1826. ** Pow. Great, vol. ii. p. 210.

tt Transact. Brit. Assoc. 1849, p. 73-75.

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shell, it absorbs it equally with any other." It will be observed that in the last clause he anticipates and answers one of Mr. Lankester's recent queries*. It may also be remarked

in passing, that it is probable that the genus (*Sinroglyphus*) here referred to is the same as the *Stoa* of M. Marcel de Serres, as hinted by Mr. Shuttleworth in the same vol. of the 'Ann. des Sc. Nat.'

This chemical or solvent theory has been shown by many authorities to be inadequate to explain all the facts connected with the boring of the Mollusca ; for, besides the boring of wood by the *Teredo*^ some of the *Pholades* perforate gneiss, mica-schist, talc, peat, resin, and sandstone, as well as calcareous rocks ; and I would only refer to the careful digest and observations on the subject in the 'British Mollusca ' of Messrs. Forbes and Hanley, and to the experienced and recent remarks of Mr. Gwyn Jeffreys f. M. Valenciennes is of the same opinion with regard to the *Echini*. Indeed MIM. Cail- liaud J and Fischer §, in describing the borings of *E. lividiis*, show that it excavates (notwithstanding the adverse opinion of Mr. Trevelyan ||) not only calcareous rocks, but gneiss, granite, whetstone (*leptynite*), schist, &c., while foreign species invade basalt : and the former author, in his first plate, represents several specimens of *Echinus lividus*, of the natural size, located in their holes in granite from Croisic, on the coast of France. Dr. Bowerbank^ likewise, in his careful and conscientious observations on the boring question, gives no support to such a theory ; and Mr. Hancock ** could find no trace of acid in his specimens of *Cliona*. M. de Quatrefages adds his weight into the scale against the idea of a solvent in the Annelidan perforations. Lastly, although Mr. Lankester ap-

pende the following sentence to his letter in the ' Annals '
for July last, "It is almost impossible to assign any but a
chemical means of excavation to Bonellia" it may be re-
marked that M. Lacaze-Duthiers, in the original paper, appears
to be more cautious than to attribute its work to such an
agency.

Physiologically it cannot be considered that carbonic acid in

* Ann. Nat. Hist, ser. 4. vol, i. p. 237, lino 9 from bottom,
t Brit. Mollusca, vol. i. Introd. p. xxvii, and vol. iii. p. 94.

\ Catalogue des Rad., des Ann41., des Cirrliip. et des MoUusques Marins
&c. dans le Depart, de la Loire Inferieure : Nantes, 1865,

§ Ann, des Sci. Nat. Zool, s^r, 5. torn, i, 18G4, p. 321.

11 This gentleman considered that the animal {E. lividus) possessed
neither chemical nor mechanical power of perforating rocks, but that
such excavations were produced by countless generations of such creatures,
which thus, after the lapse of ages, gradually had worn the stone away.
(Edinb. Phil. Journ. vol. xvi. 1849, p. 386.)

11 British Spongiadse, vol. i. p. 221.

* * Ann. Nat. Hist. ter. 2. vol. iii. p. 329,

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a free state, and in such a quantity as to act on calcareous rock or shell, is a likely accompaniment to such an animal as *Leucodore* working in a tube, whatever may be the case with the salivary glands of *Dolium*^ *Tritonium*, *Aplysia*^ and the acid secretion of *Gastrochcena* and other Mollusca. Annelids are very sensitive to irritants and narcotics, and must be judged by the same rules in this respect as the majority of other animals. And this statement is not impugned by the fact that a few, such as *Cirratulus*, may occasionally be found boring in odoriferous mud, like the ubiquitous crustacean *Carcinus* *mamas*. It therefore appears to me to be just as prudent and useful to bring forward the chemical theory in regard to the perforations of *Limnoria* and *Chelura* *terebrans* in wood, of the *P/wlas* *crispata* in the hard shale and sandstone in company with *Leucodore* at St. Andrews, in regard to the deep cavities made by *Patella* *vulgata* in the latter rock on the same sites, in regard to the borings of the *Echini* and the wide interlacing channels of *Hynieniacidon* in shells and stones on all our shores, as to produce it for the explanation of Annelidan perforations. Yet Mr. Lankester prefaced his observations on the boring of *Leucodore* by the statement that he was prepared to find such due to chemical action, because an acid reaction was found in *Sabella* *saxi-cava*^*. We are thus prepared for the following remark : —

" Supposing, then, the agency in Leucodore to be a chemical one, has any acid been observed ? It has : specimens of Leucodore, placed on litmus-paper, give a strong acid reaction." I have carefully tested for acidity in numerous specimens of Leucodore from St. Andrews ; but not a trace thereof rewarded my attempts, though an ambiguous stain is occasionally produced by old sea-water in which they and other Annelids have been confined. No acid reaction at all was visible ; and to apply the epithet " strong" to such a case would certainly be after the fashion of a chemistry unknown to us. Moreover I asked a distinguished young chemist. Dr. Crum Brown, to repeat the tests. He wrote me as follows : — " I found exactly as you have stated on the labels, viz. that *Cephalothrix filiformis* has a marked acid reaction in every part of its body, and that *Leucodore ciliata* is quite neutral. The perforated and grooved stone is not calcareous, and is scarcely attacked by acids : prolonged action of tolerably strong hydrochloric acid dissolves a little iron. ... It appears to be a kind of mica schist." I was not more suc-

* I am glad to say that Mr. Lankester has since seen reason to change his opinion. While maintaining the correctness of his statement with regard to the acidity of Leucodore, he withdrew his chemical theory after the reading of my paper at the Meeting of the British Association.

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successful in finding acid traces in the southern examples. For a considerable time I have been familiar with an acid reaction in the cutaneous textures of many Nemerteans, such as *Borlasia olivacea*^ *B. octocolata*, *B. Inctea*^ *Lineus lo7igissimus*^ *Stylus purjmreus*^ *Cephalothrix Jiliformis*, *Ommato2^lea alba*^ *O. melanocejyhala*, *O. gracilis*^ &c. ; indeed acidity seems characteristic of the group, the only exceptions as yet observed being in the deeply tinted *O. purpurea* and in *O. pulchra*^ which have an alkaline reaction, rendering red litmus-paper blue. One of the most vivid red streaks is caused by the common *Gepliahilirix filiformis*, referred to above. Some species of *Gkone*, again, which do not bore, likewise give an acid stain to litmus-paper. The mere presence of acidity, therefore, is no proof whatever that an animal bores. None of the Nemerteans, for instance, do so, their habitats being in muddy sand under stones between tide-marks, in fissures of rocks, or in the cavities of old shells and stones from deep water. It is well to bear in mind also that *Dodecaceria concharum* and *Stpunculus*, both very common borers, show no acid reaction when tested with litmus-paper.

While thus shutting out the chemical means of boring from being the law to be applied universally to the perforations made by Annelids, I should deem it rash at present, on my part, to promulgate any new theory, or to support any of the old.

Mr. Lankester concludes his paper with some remarks on "the specific title and distinction of the lithodomous Leucodorey" The boring species," he says, "does not differ obviously from Leucodore ciliata. I have not been able to make a comparison of specimens ; but it seems probable they differ only in habit." Yet he suggests the name of *L. calcarea* for the boring form. I cannot agree with the author here either ; for I have never seen more than a single British species of *Leucodore*^a which, however, bores in materials very varied in their composition. It is unsafe to suspect a form to vary specifically simply on the ground of its habitat ; and assuredly some more weight would have been given to his view of this matter if he had founded the distinction on the abnormality of the hooks of the fifth segment of the body, or on the absence of the spear-tipped bristles which accompany them. The perusal of the remarks of M. de Quatrefages* on the different species of *Leucodore* is somewhat unsatisfactory ; and it appears to me to be by no means certain that at least five of his species do not refer to one, or at most to two forms. It is further worthy of note that, so far as I am aware, no other observer (excluding the more than doubtful cases of M.

* Hist. Nat. des Anneles, vol. ii. p. 20(3 d scq).

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Oersted and Mr. Lankester) has clearly made out another European species ; for I consider Leuckart's *Leucodore muticum* * a somewhat inaccurately described *L. ciliatus*, Johnston. The possession of only two eyes, and the fact that the great hooks occur on the " sixth" segment of the body, and are three-toothed, characterize the *L. nasutus* of M. de Quatrefages. The author states that the anal segment terminates in a flattened cup, which permits the Annelid to attach itself to solid bodies ; and his figure shows no split in the margin. If the latter arrangement is correct, then the previous characters may hold. It is also but fair to remark that specimens occur at St. Andrews with two eyes, and even with one only, and that the anterior pair in all, being on a lower level, are less easily seen from the dorsum than the posterior. The same may be said of *L. audax* and its circular cup. Moreover, as the latter assumes somewhat altered characters in those whose tails are regenerating, some caution is needed in basing specific differences thereon. His *L. Fabricii* rests, as a species, upon characters that require further elucidation ; and the remarks on *L. ciliata* are based on Dr. Johnston's description; and hence the author is misled as to the structure of the hooks of the sixth segment (fifth of the body), which really, as already mentioned, have a secondary spur or process. *L. dahia* is also founded on insufficient data. Lastly, there can be little doubt that the *Polydora cornuta* described by M. Claparède, and given by M. de Quatrefages as the type of a new genus, is nothing more than *L. ciliata*. The want of scientific accuracy in the figures of the genus in the ' *Annelids*'

renders identification difficult.

EXPLANATION OF THE PLATES.

Plate XVIII.

Fig. 1. *Leucodore ciliata*, Jolinst. ; enlarged under a lens.

Fig. 2. Great hooks of the fifth segment of the body : a, as usually seen

in the separated and perfect organ under pressure ; b, a more

complete view, as obtained in the living animal or in a favourable

spirit preparation. X 700 diameters.

Fig. 3. Spear-tipped bristles accompanying the former, x 700 diams.

Fig. 4. Hooks of the posterior region of the body : a, pressed between

glasses ; b, seen in front, so as to exhibit both wings, x 700

diams.

Fig. 5. Front and side view of two of the bristles of the same species.

X 700 diams.

Fig. 6. Caudal segment and its cup. x 210 diams.

Plate XIX.

Fig. 1. Tubes erected by *Leucodore* at the apertures of its tunnel. The

* " Zur Kenntniss der Fauna von Island/' Archiv fiir Naturges. 1849,

p. 200, Taf. iii. fig. 12.

t Recherches Anat. sur les Annelides, Turb. &c. 1801, p. 47, et op. cit.

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attenuated tentacles are seen protruding from the mouth of one.

Enlarged under a lens.

Fig. 2. Tentacle of *Leucodora*, magnified. The organ is in the somewhat contracted condition in which it usually appears when the animal is placed between glasses : a, ciliated groove on the inner surface ; b, cavity of tentacle ; c, blood-vessel.

Fig. 3. Ciliated parasite attached to a fragment of the tentacle, a, x 700 diams.

Plate XX.

Fig. 1. *Dodecaceria concharum*, first., from a tangle-root, St. Andrews.

Enlarged under a lens.

Fig. 2. Hook of the same species, x 350 diams.

Fig. 3. Extremities of two of the latter : a, of the same specimen ; b, of

a developing or somewhat imperfect specimen, x 700 diams.

Fig. 4. Bristles from a dried specimen in limestone from Torquay, sent

by Dr. Bowerbank. x 300 diams.

Fig. 5, Posterior hook of a small *Sabella saxicava*, from a dried specimen

in a *Balanus* sent by Dr. Bowerbank, X 700 diams.

Fig. 6. Thoracic hook of *S. saxicava*. X 350 diams.

Fig. 7. Minute spear-shaped bristles accompanying the latter. X 700

diams.

Fig. 8. Bristles of the same species : a & h, two of the forms met with in

the thoracic region, the latter being viewed laterally ; c, posterior

bristle from the dried specimen referred to under fig. 5. X 350

diams.

XXXIV. — On the Structure of the Shells of Brachiopoda.

To the Editors of the Annals and Magazine of Natural History.

. Oban, Sept. 21, 1868.

Gentlemen,

On my return from the mission of scientific research into the zoology of the deep sea, with the charge of which I have had the honour to be entrusted by the Admiralty, at the instance of the Council of the Royal Society (and the very re-

markable results of which will be made public at the earliest possible period) , I find the note of Prof. King contained in your last Number, on which I have only to remark that the admission he has cited of the fallacy of his original imputation upon the accuracy of my researches into the structure of the shells of Brachiopoda is limited to the single case of the recent *Rhynchonella jpsittacea.*, which did not enter into his original charge, because he had not then examined it. That charge was founded upon his superficial examination of fossil *Rhynchonella* and *Spiniferida* ; and neither then nor since has Prof. King made the slightest retractation of it. By declining to reply to my last three questions, he leaves the matter exactly where it was before ; so that it must be presumed that