# XXV. *On burrowing and boring marine animals.* *By* Edward Osler, *Esq.* *Communicated February* 15, 1826, *by* L. W. Dyllwin, *Esq. F. R. S.*

Read May 25, 1826.

The neighbourhood of Swansea offers remarkable facilities for observing the habits of the burrowing marine animals. Many Spatangi, innumerable Annelides, and a variety of bivalves are found on its extensive sandy shores; considerable beds of decayed wood are inhabited by Pholas candida; and the rocks at the western extremity of the bay abound with Lithophagi.

My chief object in this paper, is to explain the mechanism by which the boring and burrowing shell fish form their habitations; but as there are facts connected with the burrowing of other marine animals which are yet but imperfectly understood, I shall first advert briefly to the latter.

The Nereides found in sand bury themselves by the rapid undulating motion which they employ in swimming; and they travel through the sand with great facility by extending the anterior rings, and bringing up the posterior part of the body after them. Their progress is very much assisted by the action of their numerous bristly feet.

The Arenicola piscatorum of Lamarck (Lumbricus marinus of Linnæus), connects the naked with the sedentary Annelides. A viscid secretion exudes from the anterior half of the animal to which the sand adheres; and hence, when the worm is dug up, this part is generally found to be covered with an imperfect arenaceous tube; within which the motions of the body are performed with perfect freedom, but which cannot be removed entire. This tube is in fact left behind in the progress of the animal, and forms a complete lining for the hole, which it supports, and keeps pervious through its whole length. The worm is thus enabled to ascend readily to the surface, and the water is admitted freely to the branchiæ.

A few of the anterior rings of the Arenicola progressively diminish in size, and each admits of being completely folded within the ring immediately behind it. Hence, when they are fully retracted, the anterior extremity of the animal is truncated abruptly; while it is extended to a regular cone when they are projected to a point just short of developing the mouth. This is its boring apparatus. The rings being retracted, the flat head of the Arenicola is directed against the sand; when the projection of the cone opens a passage for the body. The opening thus made would however be insufficient, and the branchiæ might be injured while forced through a narrow passage; but that the animal, immediately on completing the penetration, distends the penetrating rings very considerably. By the advance of the body the opening made for it is occupied; and the rings being thus received into each other, the cone is ready to be again projected. In the progress of the animal, the gluten which exudes from it cements the surrounding sand, and gives that support to the sides of the hole, without which it would immediately fall in.

The habits of the Terebella conchilega are so remarkable, and at the same time are so easily observed, that it is scarcely possible to read the minutely accurate description of it given by Pallas, in his Miscellania Zoologica, without a feeling of surprise at his having overlooked them. It does not indeed appear that he had ever met with the animal in its natural situation, or that he was even aware of its propensity to burrow. His observations were made upon specimens thrown on shore by storms; and that which his figure represents is evidently a starved one.

But notwithstanding these disadvantages, his description is remarkably accurate and complete. Perhaps the surface which he has denominated "ventral," might with more propriety be considered as the "*dorsal;*" but this is too unimportant to be made a subject of dispute. The tentaculæ are much more extensile than he has stated; but this he could have known only by seeing them in action. If, when observing the motions of the animal, he had put some sand at the bottom of the vessel, an experiment, his neglect of which is the more extraordinary, since he employed it in his observations on the Pectinaria belgica, he would probably have completed his subject. His specimens must have been very weak and sickly indeed if they did not at least attempt to form a tube, and to bury themselves; for I have ascertained that a serious wound, and even the loss of the entire tail, does not prevent them from attempting, and even completing these tasks.

On these shores the Terebella conchilega is the most abundant of all the larger Annelides, with the exception of the Arenicola, and perhaps of the Sabellaria alveolata. They are most numerous about midway between high and low water mark, where the sand is mixed with a large proportion of stones. By the shifting of the sands in storms, they are often buried to a considerable depth, and at other times have several inches of their tubes exposed. In the first case they speedily work up to the surface; in the other, the exposed portion of tube is soon broken off by the waves, or crumbles when dried by the sun. Their tubes are very long, and the animal remains towards the bottom, except when seeking its food. Hence specimens are to be obtained in general only in favourable situations, as it is almost impossible to dig up the whole tube.

As soon as the Terebella conchilega is removed from its tube, it throws itself into spiral folds. This contraction, which appears to be involuntary, is effected by the muscular bands, which extend the whole length of the ventral surface. The dorsal surface therefore constantly forms the outer or convex part of all the folds. If now it is placed under water upon sand, it straightens the body, and presently all the tentaculæ are seen in full action. They are extended in every direction, often to a length exceeding an inch and half; and they are seen dragging in small fragments of shells, and the larger particles of sand. These it places behind the scales projecting from the anterior and lower part of the head, where they are immediately cemented by a gluten which exudes from the animal; bending the head from side to side, while it continues to apply the materials of its tube, the conchilega has very soon formed a complete collar, which it employs itself to lengthen regularly from every part of its circumference with a persevering activity highly interesting. To fix the different fragments compactly, it presses them into their places with the erected scales, at the same time retracting the body a little. Hence, the fragments being raised by the scales, are generally fixed by their posterior edges; and thus overlaying each other, often give the tube an imbricated appearance.

When the tube is from half an inch to an inch in length, the animal proceeds to burrow; directing its head against the sand, it penetrates by a slight extension of it, effected by the circular contraction of some of the posterior rings, which presses the viscera forward. The penetrating force is very inconsiderable, because the animal having to form its tube as it descends, can advance but slowly. It is now of course obliged to avail itself of the materials with which it may happen to come into contact. Its progress is marked by the gradual disappearance of the tail, which continues to advance into the tube till the whole has entered. Soon after the conchilega is found to have turned within the tube, and its head appears at the surface. This motion is clearly effected by the longitudinal muscles (fig. 1, *c. c. c.*), which have been stated to throw the animal into folds, and which must also raise the tail to the surface whenever the fæces are to be discharged.

In summer the whole task is completed in four or five hours; but in cold weather, when the animals are more sluggish, and the gluten appears to be secreted in smaller quantity, their progress is slower in proportion.

The extremity of the tube is generally ornamented with a number of branches, composed of single rows of sandy or shelly particles. These are formed accidentally from time to time, by the adhesion of sand to the tentaculæ when thrown out in quest of prey. The gluten exuding from the tentaculæ cements the grains to each other and to the tube. I have very often known these branches to be formed by the animals I kept in confinement.

The Spatangus buries itself in the sand by the action of its bristles: those on its under surface are short and thick, diverging from the centre towards the circumference; and at their extremities becoming expanded, flattened and curved, with the convexity downward. Around the sides they are straight, longer, but much slighter than the others, diminishing in thickness towards their extremities; and, in the state of inaction, resting flat upon the body, with their points directed backward. A few long stout spines arise in a crescent from the back, which converge till their points meet. All are attached to the crest individually by a small muscular papilla.

The flat bristles have a limited rotatory motion, and admit also of being moderately depressed: the lateral ones are extended nearly to a right angle with the body, and are directed downward, even beyond the perpendicular: the long dorsal spines admit only of being erected to the perpendicular, or reclined backward to a moderately acute angle with the body.

The operations of the animal are best observed by placing it on the sand immediately after it has been dug up, as it soon perishes out of the water The motion of the short flat bristles forms in a little time, a quicksand under it, into which it sinks by its own weight so far as to enable the lowest of the lateral bristles to act upon the sand. These are directed downward, raised, and then returned to the side, to be again depressed and elevated. Thus they co-operate with the flat bristles in loosening the sand, while they throw up that which has been reduced to a semi-fluid state; and, at the same time, act in some degree as levers to depress the Spatangus with a force greater than it could have derived from its weight alone. As the animal sinks, more of the bristles are enabled to act, and its progress becomes more rapid; while the semi-fluid sand which it throws up flows slowly back upon it and covers it, when it has sunk below the level of the surface. The long dorsal spines prevent the sand from closing completely, and preserve a small round hole, by which water is admitted to the animal, and which marks its situation.

The burrowing of Bivalves into sand may be observed at all times by persons near the coast: all that is necessary is to place a few of them on a bed of sand, covered with sea-water. The animals, which from their small size or the little depth at which they reside, are particularly liable to be exposed, will generally burrow readily; but the large species will scarcely attempt to bury themselves except in the very young state. It may be proper to observe, that those thrown on shore by storms will very rarely attempt to burrow; and that there is a considerable difference in this respect, even in the animals just taken from their natural situations; some burying themselves immediately, while the greater number will remain inactive for two or three days.

When the animal would burrow, it projects and elongates the foot, distending it until every part of it, except the point, appears semi-transparent. Directing its point downward, it insinuates it into the sand until it is nearly buried. A circular motion is now given to the shell, by which its anterior point is quickly brought nearly into contact with the foot, and immediately returned to its former situation. It thus moves on the foot, as on a fulcrum, with a see-saw motion. The foot, which had been partially retracted, is again gradually projected as far as possible into the sand, when the circular motion of the shell is repeated. When the animal is moderately active, the strokes follow each other at intervals of 20 or 30 seconds. The apparent progress is at first but small; the shell, which is raised on its edge at the middle of the stroke, falling back on its side at the end of it: but when the shell is buried so far as to be supported on its edge, it advances more rapidly, sinking visibly at every stroke, till nothing but the extremity of the syphon can be perceived above the sand.

The instinct which directs the animal thus to procure a shelter, operates at the earliest period of its existence. On examining a Mya truncata, dug up on the preceding day, and which, when grown, will not attempt to burrow, I found two young ones, entangled in the folds of cuticle at the extremity of the syphon, scarcely more than a line in length, and apparently but just excluded. Being placed on sand in a glass of sea-water, they buried themselves immediately.

The motions by which the animals burrow are effected by two pair of muscles, which arise from the shell, and are inserted into the foot. The anterior muscles, (fig. 2, *a*) arise at the upper margin of the anterior adductor, and uniting immediately below the mouth, pass down together to their insertion. The posterior (fig. 2, *b*), take their origin at the upper margin of the posterior adductor; and passing forward and downward, meet near or upon the body of the animal, and advance together along its posterior edge. The foot itself is embraced by fibres given off from all these muscles.

A tube opens just within the mouth, going off nearly at a right angle with the œsophagus: it proceeds in a curvilinear direction through the body, immediately above the foot: its course is indicated in the figure by the dotted line at *c*. It is this tube which conveys the water by which the foot is distended. In some of the largest species, as Cyprina islandica, a transverse section of the foot shows a single chain of pores along its whole length, which communicate with the principal tube, and transmit the water to the cellular portion of the foot.

It is scarcely necessary to detail the action of these several organs. The point of the foot being solid, is adapted to precede the distended portion in penetrating the sand. A viscid matter is secreted from the surface of the foot when distended, which, by agglutinating the sand around it, fixes it more firmly, and thus augments the force of the stroke. The operation of the anterior and posterior muscles of the foot cannot require explanation.

The locomotive Bivalves travel by a series of motions precisely similar to those employed in burrowing, and which are effected by a similar arrangement of muscles. The foot, instead of being pointed downward, is projected horizontally just beneath the surface of the sand; and the shell is brought forward by the successive contraction of the anterior and the posterior muscles. The Venus gallina is particularly disposed thus to travel, and indeed is generally to be found most readily by the furrow which it has ploughed up in its progress. In the summer it is met with on these shores in considerable numbers, above a furlong from low-water mark; though at other seasons it is rarely seen, excepting after storms. Anodonta cygnæa offers an example of the same kind. It is thus, also, that Cyclas cornea crawls over a smooth surface, fixing itself by a viscid gluten, which exudes from the elongated foot in such quantity, that the animal in its progress leaves a silvery track like that of a snail. I have repeatedly seen small ones crawl up the side of a glass, and even support themselves on the surface of the water by a broad filament of this gluten extended from the side of the vessel.

Although not habitually residing under the sand, the Buccinum undatum is entitled to a place among the burrowing marine animals. It is often found to have completely buried itself, apparently, for shelter; and there are very strong reasons for suspecting that it habitually burrows in pursuit of its prey.

As in the Bivalves inhabiting sand, its foot is the instrument of penetration; and like them, it has the power of distending this organ to a size, nearly, if not quite equal to that of the shell. A section of the foot shows it to be divided into two nearly equal parts; the powerful muscle, which extends from the operculum to the spire, forming the upper, or posterior half, and a cellular spongy mass constituting the remainder. The lower surface of this portion is the disc on which the animal crawls; and being considerably longer than the muscle, it is folded upon itself, when retracted within the shell; and the operculum lies flat above it when it is projected and extended. A transverse section of the foot near the part where it joins the body, shows four considerable tubes penetrating the spongy portion, and very near each other; three of which are in a line parallel to, and almost in contact with the muscle; the fourth, a little below the middle one of the three. By a series of transverse sections of the foot, parallel to the operculum, we are enabled to trace these tubes; and to ascertain that they become rapidly smaller as they advance, until they are quite lost; the longest of them not admitting of being traced quite to the operculum. All these tubes are given off at the extreme anterior point of the thorax from a considerable one, (fig. 3, *l*,) which, being situated under the muscular floor of this cavity, takes a direction to the right side, and running just within the origins of the muscles of the trunk (*k*) passes out of the thorax, nearly in contact with, and on the right side of the œsophagus. It terminates nearly midway between the heart and the rectum, (*m*) opening into a considerable cavity, which has the liver underneath, and the membrane enveloping the spire above it. When the animal contracts the distended foot, the water is seen to flow out between the mantle and the shell on the right side. The tube and cavity are easily inflated by a blow-pipe introduced into one of the tubes of the foot.

The moderately distended foot can scarcely be retracted within the margin of the shell; and when fully injected, it is elastic, and of a very large size. The cavity which it opens into the sand is therefore fully adequate to receive the shell, which is drawn down into it by the contraction of the muscle of the spire. From the attachment of this muscle, the spire is the part more directly acted upon, and which is depressed in the greatest degree. Hence the notch is always uppermost, and the Buccinum, when completely buried, is enabled to communicate with the water by its respiratory syphon.

The Pholas can be observed to bore only in the young state. They are found completely buried, when so minute as to be almost invisible; and the rapidity of their growth for the first few weeks, compels them to exert themselves perseveringly in effecting the enlargement of their habitation. Hence if a few of the young animals, which may be procured in abundance very early in the spring, are placed in a pan of water upon some of the substance which they had inhabited, they will, in a short time, begin to work, and continue to do so, at intervals, for two or three days; thus affording ample opportunity for observing the process.

The only species of Pholas now found on these shores, and consequently, the only one whose habits I have had an opportunity of observing, is P. candida. It is, therefore, to this that my observations must be considered to apply more directly.

The Pholas differs in many particulars from all other Bivalves; and its peculiarities of structure are so essentially connected with its method of boring, that a full description of them is necessary.

From the syphonal, or posterior extremity of the valves, their dorsal edges are directed inward, till they meet at the hinge, whence they again separate; and, finally, converge towards their points. There is, consequently, a triangular gape behind the hinge, which is lost by bringing the dorsal edges into contact; and an egg-shaped one before it, which becomes an oval, when the anterior points of the valves are approximated. The ventral margins have also a considerable convexity. At a fourth of the length of the valves from their anterior points, their edges are rolled in to form an umbo, which is covered with a reflected semi-pearlacious fold; and at the inner part of this is a round, prominent, cartilaginous spot, the point of union between the valves. In P. candida, a short process is given off from beneath this spot in the left valve, (fig. 4, *a*) and a thin, flat ligament from a corresponding tubercle in the right, which, passing obliquely backward, meet at the middle of their length, and are thence united to their extremities. The connection thus obtained is so weak, that it is extremely difficult to remove the fish without separating the valves: it is, indeed, only strong enough to make the hinge the constant centre of motion.

A long, thin, curved process is given off from beneath the umbo, (fig. 4, *b*). Its convexity corresponds with that of the valve, and its direction is a little obliquely backward. I believe this process to be characteristic of an animal which bores mechanically by employing its shell as a rasp. The anterior and lower portion of the shell is thicker than any other part, and its surface is armed with much stronger spines; and it is this portion which the Pholas employs in boring.

The Pholas is quite destitute of the elastic ligament which connects and expands the shell in other Bivalves. Its connections are chiefly muscular, and its motions are effected exclusively by the action of muscles. It is evident that, by this arrangement, the greatest possible freedom of motion is secured.

The Pholas is provided with four sets of muscles, in addition to those belonging to the syphon. The posterior adductor, (fig. 4, *c*,) is a flat muscle, connecting the valves nearly midway between the hinge and the extremity of the shell, and having its attachments at about $\frac{1}{8}$ of an inch within its dorsal margins. It lies so superficially, that its action is seen when the animal employs it in boring. The anterior adductor (*a*) is attached to the reflected folds which cover the umbo. It extends from a point a little before the hinge, nearly to the anterior extremity of the shell, and is covered by the accessory valve. The ventral margins are connected by muscular fibres, from the opening in the mantle through which the foot is projected, as far as the origin of the syphon. A pair of muscles, which may be termed "lateral," arise from the points of the long, hooked processes, which, becoming fan-shaped, as they pass over the body, are inserted into the sides of the foot.

The offices of these muscles are peculiar. The shell is closed, not by the adductors, but by the fibres which connect the ventral margins of the valves; and it is opened by that part of the anterior adductor which lies nearest to the hinge, and which thus performs an office analogous to that of the ligament in other Bivalves. The other portion of this muscle antagonizes the posterior adductor. By its contraction, the anterior points of the valves are brought into contact, and their dorsal margins separated as widely as possible. The action of the posterior adductor reverses this state; and, in uniting the dorsal margins, expands the anterior and armed portion of the shell. The foot of the Pholas, like that of the Gasteropodes, is a flat disc, by which the animal can attach itself firmly. When it is thus fixed, the lateral muscles, acting in an oblique direction, will raise the posterior end of the shell, and press its armed extremity forward and downward: or, if one of them should contract more strongly than the other, it will bring down the corresponding side of the shell, which will be restored to its erect position by the action of the opposite muscle.

The Pholas has two methods of boring. In the first, it fixes itself by the foot, and raises itself almost perpendicularly, thus pressing the operative part of the shell upon the substance to which it adheres: it now proceeds to execute a succession of partial rotatory motions, effected by the alternate contraction of the lateral muscles, employing one valve only, by turning on its side, and immediately regaining the erect position. I have observed that this method is almost exclusively employed by the very young animals; and it certainly is particularly adapted for penetrating in a direction nearly perpendicular; so that they may be completely buried in the shortest possible time. It may be observed, that the posterior extremities of the valves are much less produced in the very minute Pholades than they afterwards become; and thus the time required to complete a habitation is still farther diminished.

But when the Pholades have exceeded two, or, at the utmost, three lines in length, I have never observed them to work in the manner I have described: the altered figure of the shell, and the increased weight of that part of the animal behind the hinge, would prevent it from raising itself so perpendicularly as at first, independent of the narrow space which it now occupies. In the motions required to enlarge its habitation, the adductors perform a very essential part. The animal being attached by the foot, brings the anterior points of the shell into contact. The lateral muscles now contract, and raising the posterior extremity of the shell, press its operative part against the bottom of the hole; and, the moment after, the action of the posterior adductor brings the dorsal margins of the valves into contact, so that the strong rasp-like portions are suddenly separated, and scrape rapidly and forcibly over the substance on which they press. As soon as this is effected, the posterior extremity sinks, and the stroke is immediately repeated by the successive contraction of the anterior adductor, the lateral, and the posterior adductor muscles.

The particles rubbed off, and which, in a short time, completely clog the shell, are removed in a very simple manner. When the projected syphon is distended with water, the Pholas closes the orifices of the tubes, and retracts them suddenly. The water which they contained is thus ejected forcibly from the opening in the mantle; and the jet is prolonged by the gradual closure of the valves, to expel the water contained within the shell. The chamber occupied by the animal is thus completely cleansed; but, as many of the particles washed out of it will be deposited before they reach the mouth of the hole, the passage along which the Pholas projects its syphon is constantly found to be lined with a soft mud.

As a British animal, I believe the Teredo to be nearly, and probably quite extinct. In the harbours of Falmouth and Plymouth, where, some years ago, it was so abundant, it is no longer to be found. In the Royal dock-yard at Devonport, I was shown two specimens which had been taken out of a pile many years before, but they were treasured as a curiosity; and I was assured by Mr. CHURCHILL, the master shipwright, that at present they are never met with. The shipping of Swansea trade to every part of the kingdom, and we have nearly four thousand arrivals in the year, chiefly from coasting voyages; but, though very few of the vessels are coppered, we never see the Teredo.

Two causes may be assigned for this complete destruction, either of which appears sufficient to account for it. An imported shell-fish, if pelagic, may naturalize itself permanently; but where, like the Teredo, it always resides near the surface, and often in situations which are left dry during the ebb, it is necessarily affected by changes of temperature; and the animal which is naturally the inhabitant of a warm climate, will be destroyed by a severe winter. It is probable that the Teredo was formerly preserved only by occasional importations, which are now prevented by the general use of copper sheathing.

Independent of causes connected with climate, the Teredo would diminish, and become extinct for want of a nidus. Where piles had been destroyed by them, care would be taken to preserve the new ones from their ravages by a covering which the young animals cannot penetrate. Valuable timber would not be placed within their reach; and wood, neglected because useless, is generally too small to contain a large Teredo. They would therefore perish from confinement before they were full grown. The Pholas dactylus, which, but a few years since, was very numerous in Swansea bay, has been lost here from this cause. The large beds of peat-wood, into which they formally burrowed, were gradually broken up by the sea, until they became so thin that the Pholades, before they were full grown, were stopped by the gravel and perished.

Having been unable to procure the living animal, I can offer to the Society only the results of my observations on some specimens sent me from the Mediterranean.

Every peculiarity of structure upon which the boring power of the Pholas has been shown to depend, exists in an equally marked degree in the Teredo. We find the thin and obliquely placed ligament of Pholas candida, the superficial muscle connecting the valves before the hinge, the posterior adductor and the muscles passing from the lateral processes to be inserted into the foot. The muscles indeed vary in their relative size, because their size is proportioned to the force they are required to exert, which differs in the two animals. Most species of the Pholas have comparatively large shells, and burrow into substances of but a moderate degree of hardness; while the shell of the Teredo is very small, and it penetrates the hardest wood. The office of the anterior adductor being only to close the valves, its size is in proportion to the weight of the shell. It is by the contraction of the posterior adductor that the animal effects the stroke; and the force of this muscle will therefore depend upon the resistance to be overcome. Hence, in the Teredo, the anterior adductor is much smaller than in the Pholas, while the posterior adductor is far more powerful in proportion. The lateral muscles are more distinct than in Pholas candida, but they are very short. It is not probable therefore that the Teredo can bore, as the young Pholades have been described to do, by the action of these muscles alone.

The posterior adductor is attached to a large process in each valve, which, in the common Teredo is a perpendicular oval plate, resting against the dorsal margin of the valve, and formed by a prolongation and expansion of the tubercle at the hinge. About a third part of it is concealed within the shell, and the upper margin is rolled outward at its anterior end. In the Teredo palmulatus this process is nearly triangular with the apex to the hinge; and is formed by an extension of the shell itself, of which it is a mere beaklike projection. Both these processes are represented in the drawings.

If all the boring shell fish penetrated mechanically, it would be reasonable to expect that their powers should evidently be in proportion to the hardness of the bodies which they inhabit: this is found to be the case in the different species of Pholas; but the Lithophagi, which would have the greatest mechanical resistance to overcome, appear to be destitute even of the smallest mechanical force. They have nothing which in the slightest degree resembles the boring apparatus of the Pholas. On the contrary, their shell, as in the bimusculous Conchiferæ, is expanded by a powerful elastic ligament, and closed by two large round internal adductors. The valves in most of the species shut close, and the foot is not an instrument adapted for firm adhesion.

Four species of Lithophagi are found in the neighbourhood of Swansea; but as the Saxicava rugosa (Mytilus rugosus of Linnæus,) is so abundant, that it may be procured in any quantity, I shall take it as the type of the family.

The general structure of Saxicava rugosa is very similar to that of the Bivalves which burrow into sand. The number and attachments of its muscles, as well of the adductors as those connected with the foot, are exactly the same. The foot is directed nearly horizontally forward, and in its state of contraction is very small, but it admits of being distended and much elongated: I have repeatedly observed it extended in young animals to the length fully equal to that of the shell: when in this state, it is seen to contain an opaque white line or tube, which passes forward from the part where it joins the body, and terminates abruptly on the under surface near its extremity. This tube becomes black when the animal has been preserved in a saturated solution of muriate of soda. The mantle is of a greyish white colour, opaque, and remarkably thick. A byssus arises from a longitudinal slit in the posterior part of the base of the foot; and passing out with this organ through the opening in the mantle, attaches the animal to some part of its hole.

I have had an opportunity of observing the young of Saxicava rugosa, before they had begun to bury themselves. The activity which they displayed was a perfect contrast to the extreme sluggishness of the older animals. They travelled over the stone by extending and fixing the foot, and then bringing the shell forward by the action of its anterior and posterior muscles, exactly in the same manner as the locomotive Bivalves. In their progress they turned the foot in different directions almost at every step, appearing to examine the surface of the stone for a suitable spot on which to fix themselves. At length they attached the byssus, and from that time no motion could be observed in the shell. I placed one of these young animals in a valve of Mya truncata; it crawled about almost without intermission for the greater part of two days, and at length fixed itself in a crevice by the side of the ligament. During the five subsequent days it was perfectly quiescent: it perished at the expiration of that time, apparently destroyed by the putrefaction of the ligament. I have taken many hundreds of the animals from their holes, and kept them in confinement till they died, but never saw one of them attempt to change its place.

It is evident that the Saxicava does not bore like the Pholas, by a rotatory motion, for the hole is not quite round, and its smallest diameter is not equal to the depth of the Saxicava, from the hinge to the ventral margin. The animal therefore has not room to turn itself; and its attachment by a short byssus imposes an additional restraint upon it: indeed, an examination of its muscles is sufficient to show that they cannot effect a rotatory motion. The only boring motion which can be supposed to be given to the shell is that effected by the action of the muscles of the foot; that, in fact, by which a Bivalve buries itself in the sand; but this, although so well adapted for travelling over a smooth surface, or for burrowing into a substance penetrable by the foot, would be ineffectual here, because the animal being already in contact with the rock, the foot cannot be projected to form a fixed point beyond the shell. Even were it otherwise, the texture of the shell is so soft, that it could make no impression upon the stone without being itself acted on; and the effect of this would be permanent, because superficial injuries of the shell are never repaired. But nothing of this kind is met with. I have even found a Saxicava fixed between two others, which was so compressed that it was quite flat, and little more than a third of its proper thickness; yet neither of the three showed the slightest mark of friction, and the cuticle of the sides in contact was as perfect as usual.

But independent of the presumption afforded by the softness and smoothness of the shell, and by the absence of any arrangement of muscles which might employ it with effect had it been strong enough to act on hard stone, it is easy to collect facts affording ample proof that the shell cannot be the instrument of penetration. I have a specimen of calcareous stone of extraordinary hardness, containing small masses of silex, some of which project into the holes formed by Saxicava rugosa, and Venerupis irus. The lime has been smoothly cleared around the base of these projecting portions from situations with which the shell could not possibly have come into contact. In another specimen, in which the lime is mixed with a large proportion of clay, there is a small round stratum of stone entirely argillaceous, and not one-twentieth of an inch in thickness. The lime surrounding this stratum has been removed by three Saxicavæ, which have bored down upon it from different directions. The shell of one of them remains in its hole, and shows that the progress of the animal was arrested by the stratum long before its death. There is a deep groove across one valve, in which the stratum is nearly buried; and which has evidently been caused, not by friction against the stratum, but by the growth of the shell on each side of it; this is shown in fig. 6.

If additional proof is required, it is supplied by the fact that many naked animals of the softest texture form their habitations in limestone. The boring Annelides 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. They may, indeed, be considered to perform the very important office of destroying shells when they become useless; thus preventing accumulations which, in a few ages, would fill every harbour. The thick oyster shells on these coasts are always occupied by a kind of sponge. It is a fibrous yellow pulp, filling a number of irregular cells, which open freely into each other, and eventually occupy and destroy the whole shell. The cells communicate with the surface by a number of small, round, and polished holes, each of which is occupied by a tough, and apparently inirritable tube, which adheres firmly to its circumference. These holes have been observed by every conchologist, and were supposed by Montagu to be formed by Mya bidentata. The yellow substance is not peculiar to the oyster, nor is it disease; for I have met with it in dead shells, and have found it extended to the surface through a considerable thickness of coralline. The penetration of all these naked animals leads irresistibly to the conclusion, that a shell is not essential to the boring process; and it would be inconsistent with the simplicity observable in every part of nature, to suppose that she has provided such different means for accomplishing the same end.

Whatever may be the instrument of penetration, it is situated at the lower and anterior part of the animal. Where the Saxicavæ are numerous, their holes communicate very freely; and it is common to meet with one which has attached its byssus to another. In this case, it is always found that the shell of the second has been acted on in a direction, and to an extent, which corresponds with the range of the foot of the assailant. When the animals meet laterally, they become compressed and distorted in the course of their growth, but their shells are never injured.

If the Lithophagi perforate mechanically, the shell and the foot are the only instruments which they can possibly employ. It has been shown that the shell is not adapted, or even required, for this purpose; and it must be quite unnecessary to attempt to prove that a stone cannot be rubbed away by a mere vesicle, like the distended foot; especially when it is observed that the syphon, which is so much thicker and stronger, is preserved from the effects of friction by a particular strong cuticle. To ascertain that the mechanical powers of the animal are quite unequal to make an impression upon a stone, would of itself almost justify the presumption that the task is effected by a solvent.

But the theory of a solvent does not rest on mere negative proof. It appears impossible to explain, on any other grounds, the animal's exclusive choice of calcareous matter; a choice evidently depending on its inability to penetrate stones of a different nature. I have already alluded to specimens, in which silex projects into their holes, and in which a very small stratum of insoluble stone has arrested the progress of the Saxicava. An exception may perhaps be taken to the hardness of the silex, though it certainly is not harder than the stone in which it is imbedded; but I am unable to perceive how the fact connected with the other specimen is to be explained away. It may be observed too, that in this specimen the holes, instead of being smooth, and almost polished, as usual, are uniformly rough; presenting, when examined under a glass, precisely the fretted appearance which should be produced where the soluble portion of a stone has been dissolved, and the insoluble particles are left projecting from the surface; and even stronger facts may be adduced. Specimens are at all times to be obtained in which the shell has been extensively acted on by others; while the cuticle, which had necessarily been exposed to the same agent, remains uninjured, and overhanging the breach.

In Montagu's Testacea Britannica, it is stated on the authority of Pulteney, that Venerupis irus (Donax irus of Linnæus) has been found in clay; and the author affirms that he himself possessed specimens of Mya pholadia in stones not calcareous. Facts presenting so serious an exception to the general habits of the animal to bore into lime, would be fatal to the theory of a solvent, did they not admit of full explanation. The young animals, in seeking a convenient spot, almost invariably fix themselves in holes or crevices which afford them immediate shelter. Hence, they are occasionally found lodged among the roots of fuci; and they will sometimes find a shelter in stone, upon which they are unable to act. I have met once with a Mya distorta, and repeatedly with Saxicava rugosa and præcisa, lodged in soft argillaceous stone; but in every such case the hole had clearly been made by a pholas, the remains of whose shells were generally found in it more or less dissolved by the Saxicava. The specimens I observed were in masses of rock, honeycombed by the pholas; which, having probably been brought among ballast, have for many years formed part of the boundaries of the oyster banks in this neighbourhood, and which are within a very short distance of rocks abounding with Lithophagi. I have often found Mytilus edulis, and occasionally Mya truncata, in similar situations. These are the only circumstances under which I have found the Lithophagi inhabiting insoluble stones, and such an exception confirms the general rule.

I have stated, that where the Saxicavæ are abundant, their holes very often communicate; and that their shells are acted on when exposed to the foot of another. On examining a considerable number, taken indiscriminately from the same rock, I have found that the shells of more than half had been thus injured. As long as the injury is superficial, no attempt is made to repair it; but when the shell is nearly or quite penetrated, the breach becomes filled, not with new shell, but with a firm yellow substance, which is insoluble even in a strong mineral acid. It would be difficult to conceive a fact short of absolute demonstration, which could give a more decisive support to the theory of a solvent. A peculiar provision is given to the animal to preserve it from destruction by an injury, to which it is particularly exposed. The supposition of mechanical penetration would require us to believe that a newly formed substance, much softer than that which has been destroyed, can stop the progress of the mischief, and even repair it, under the continued application of the original destructive force.

I have delayed the communication of this paper for many months, from a wish to complete the subject by detecting the solvent; but every experiment I have made for this purpose has been quite unsuccessful. Litmus paper applied to every part of Saxicavæ just taken from their holes, shells stained, and sea-water tinged with the same test, in which animals of every size were kept till they died, gave no indication of the presence of an acid. The water in which a mass of rock, containing above an hundred Saxicavæ had been kept for a week, afforded a precipitate, when treated with oxalic acid, only equal to that obtained from the same quantity of common sea-water. To explain the failure of these experiments, it may be observed, that where the Lithophagi happen to be lodged in situations which afford them sufficient room and shelter, they make no attempt to enlarge their habitation. Thus, Saxicava præcisa is more frequently found among groups of Serpulæ than in a hole which it has excavated; and I have obtained full grown specimens of Hiatella arctica (Solen minutus of Linn.) attached by the byssus to a Pecten. It may therefore be presumed that the solvent is secreted only when its agency is required; and this would sufficiently explain why a free acid cannot be detected in the animal. Litmus, in the smallest quantity, acts as a poison upon them. The animals exposed to it remain with their syphons half projected, which they do not attempt to retract on being touched, and perish in a few hours. If an increased quantity of calcareous salts could be detected in water in which they had been kept, the experiment would be a decisive one; but when it is considered that the animals live in the open sea, and are to be obtained only at low tides, it is not to be expected that they will work when confined in a small vessel, and deprived of food.

Had the question been previously balanced, our inability to detect a solvent would justify strong doubts of its existence: but while all the facts connected with the natural history of the Lithophagi afford a strong and consistent support to the theory of a solvent, and are opposed as decidedly to the supposition of penetration by a mechanical force, the failure of the experiments cannot be considered to militate very strongly against the only inference to be drawn from the facts. I regret my inability to offer the last decisive proof, which would have set the question finally at rest; but I feel persuaded that, should future enquiries be successful in ascertaining facts which have escaped my observation, they will tend to substantiate the conclusion which I have been led to support.

## EXPLANATION OF THE FIGURES PLATES XIV, XV.

Fig. 1. The Terebella conchilega, as it appears when proceeding to collect materials for its tube; *a*, the mouth; *b b*, the larger scales below the head, with which it fixes the materials of its tube; *c c c*, the course of one of the muscles by which the animal throws itself into folds. In specimens, which have been deprived of food for a few days, the muscular fibres become beautifully distinct.

The figure given by PALLAS, and which is I believe the only one we possess, is not only drawn from a bad specimen, but is so very carelessly engraved, as to be inaccurate in almost every respect.

Fig. 2. A burrowing bivalve; Lutraria compressa: the left valve, syphon, mantle, and branchiæ removed.

*a*, The anterior, and *b*, the posterior muscles of the foot; *c*, the course of the tube by which the foot is distended with water; *d* and *e*, the adductors.

Fig. 3. The animal of Buccinum undatum; part of the

spire, and the branchiæ removed; the mantle turned to the right side; the upper part of the thorax cut away to expose its cavity, from which the boring trunk and salivary glands have been taken.

*a a*, The foot; *b*, the head; *c*, a kind of platform raised above the floor of the thoracic cavity, on which the point of the boring trunk rests, and which leads to the mouth; *d*, the cavity of the thorax; *e*, the mantle; *f*, the rectum; *g*, the stomach; *h*, the heart, thrown below, and to the right side of its natural situation, to allow the opening of the tube to be seen; *i*, the respiratory trunk; *k*, the origins of the muscles of the boring trunk; *l*, the course of the tube by which the foot is supplied with water; *m*, its termination.

Fig. 4. Pholas candida, one-half larger than nature. The fish has been removed, leaving only the adductors, and the shell is expanded excessively to show the hinge.

*a*, The ligament and process to which it is attached; *b*, the lateral process; *c*, the posterior, and *d*, the anterior adductor.

Fig. v. Pholas candida; the posterior part of the right valve removed to show the lateral muscle arising from the point of its process, and passing to its insertion into the side of the foot. Its extreme fibres extend beyond the foot on each side, and, uniting with the corresponding fibres of the opposite muscle, embrace the body. This muscle is so blended with the general covering of the body, that it cannot be seen, even with a glass, except at its origin; but its firmness makes it easy to raise it by dissection, and to display it, as in the figure, on a piece of dark paper.

Fig. vi. A mass of impure calcareous stone, containing a

Fig. 1.

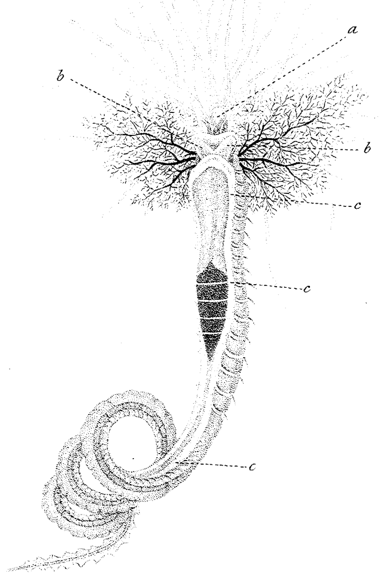



Fig. 2.

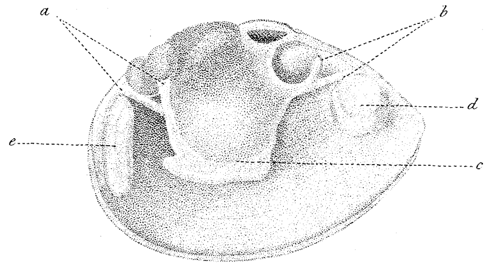



Fig. 3.

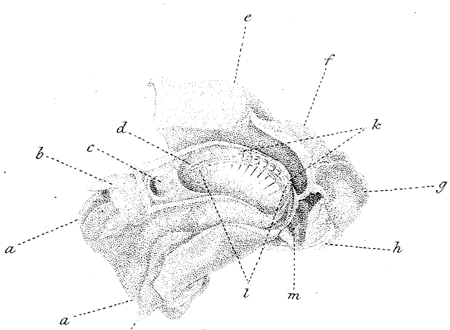
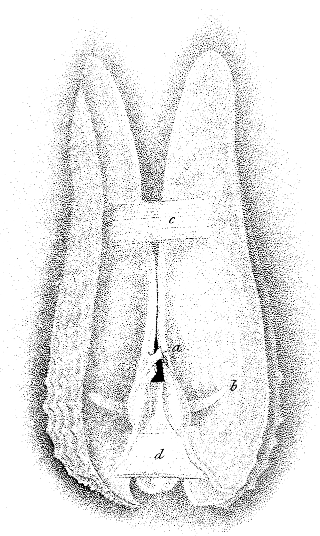



Fig. 4.




E. Osler del. J. Basire sc.

Fig. 5.

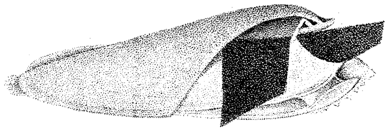


Fig. 6.

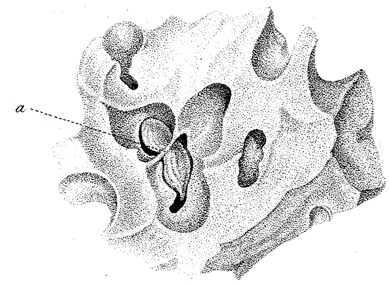



Fig. 7.

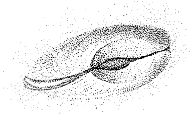


Fig. 8.

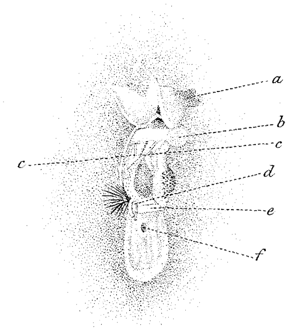



Fig. 9.

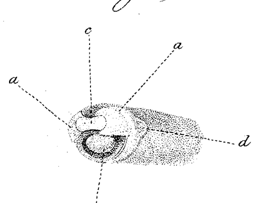
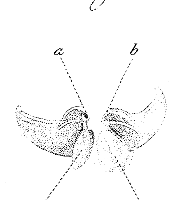



Fig. 10.



small argillaceous stratum, which a Saxicava rugosa has been unable to overcome.

*a*, The stratum confining the shell.

Fig. 7. The shell of a Saxicava rugosa which has been injured by another. The umbo has been removed, but the ligament and the cuticle, which extends from it to the anterior extremity of the shell, remain uninjured.

Fig. 8. The animal of Saxicava rugosa; the branchiæ removed, the mantle divided and thrown back; *a*, the syphon; *b*, the posterior adductor; *c c*, the posterior muscles of the foot; *d*, the foot, with its tube and byssus; *e*, the anterior adductor; *f*, the opening in the mantle for the foot. The anterior muscles of the foot are concealed by the body.

Fig. 9. Teredo palmulatus; *a a*, the boring shells; *b*, the foot; *c*, the anterior adductor; *d*, the process to which the posterior adductor is attached.

Fig. 10. Teredo communis; the boring shells separated to show the posterior adductor. *a*, The ligament; *b*, the process to which it is attached; *c*, the posterior adductor attached to one of its processes; *d*, the corresponding process in the other valve.