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FURTHER OBSERVATIONS ON THE FEEDING HABITS OF THE OYSTERCATCHER (*HÆMATOPUS OSTRALEGUS*).

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Mytilus edulis.

In a previous paper* I gave the results of my observations on the manner in which the Oystercatcher feeds upon the Edible Mussel. There are, however, one or two matters to which it is necessary to return and some new observations to record. I stated that of Mussels buried under sand, as a rule only those are opened which present the ventral fissure, and at the time I expressed reasons for this limitation which further experience has confirmed. On another page I unwittingly created the impression that all Mussels under sand or mud are placed in a vertical position. This is, of course, not always the case. The meaning I intended to convey is that those Mussels which are placed in a vertical position under sand or mud must be opened through the posterior ends, owing to the presence of the mud which prevents the Oystercatcher from reaching any other part of the Mussel quickly enough to separate the valves. To this extent buried Mussels differ from those situated on the exposed banks where a Mussel, though it happens to rest in a vertical position, is not necessarily opened through the posterior end.

When watching the Oystercatcher engaged in turning over Limpets, I was much impressed by the nature of the preliminary

* "Notes on the Oystercatcher" ('Zoologist,' 1908, pp. 201–212).

stroke. It seemed to me analogous to the preliminary tapping of the Mussels which I have recorded as an endeavour of the Oystercatcher to see whether or not its bill would pass between the valves of a Mussel which was gaping slightly in the presence of surrounding moisture. Careful approaching and watching have, however, failed to reveal any Mussel with its valves separated to an extent likely to admit the bill, excepting, of course, at the hiatus on the ventral border. This being so, a new explanation is required of the tapping. More precise observation of the tapping shows that frequently in attacks on the dorsal border, and more rarely in attacks on the ventral border, the bill does not descend in the mesial plane of the shell, but obliquely inclined towards it, so that the bill strikes unevenly the cleft between the valves, and brings pressure to bear more on one valve than on the other. If the Mussel is relaxed and is taken unawares, that valve is depressed below the level of the other in the region of contact. That is to say, one valve is rotated off its neighbour, and an abnormal gap is formed between the edges of the valves which is sufficiently wide to admit the tip of the bill. The bill is then pushed in and moved into the mesial plane of the Mussel which can be opened up on the spot, or detached and dealt with in a more suitable place. The full beauty of this little manœuvre lies in the fact that entrance can be repeated apparently an indefinite number of times to the same Mussel, provided the bill is withdrawn in the way it entered. This is due to the persistent tendency of the Mussel to contract its valves firmly together in the abnormal, rotated position. This, then, appears to be the correct explanation of the tapping. It is an attempt on the part of the Oystercatcher to take a relaxed Mussel unawares, to rotate the one valve off the other by tapping, and thereby to gain admission to the shell. This conclusion was tested by experiments which added the following information. The valves cannot be rotated when the shells are dry and firmly closed. Rotation is impossible after the shells are warned by touching them, and also when the shells rest evenly on solid rock. While one shell is being experimented upon, the shells in the vicinity are audibly contracting their valves, and it is necessary to go a foot or two away before proceeding to tap another shell. The stroke must be delivered obliquely into the cleft between the valves, and without too much force, in order to avoid injury to either valve. Rotation can be produced readily by a stroke made on the posterior end of a shell, provided it is made above or below the equator of the shell.

The largest Mussel I have so far found opened by an Oystercatcher measured two inches in length by seven-eighths of an inch in breadth (2 in. × $\frac{7}{8}$ in.). But this was quite an exceptional size. The shell had been detached and opened through the ventral fissure, and it showed no fracture.

Shells ranging from one and three-eighths inches in length by five-eighths of an inch in breadth ($1\frac{3}{8} \times \frac{5}{8}$) to five-eighths by five-sixteenths ($\frac{5}{8} \times \frac{5}{16}$) are sometimes treated in a way that differs from that ordinarily seen. The bird takes each shell in turn without selection except as regards size. A small patch of these Mussels may have the contents of every shell removed. The shell is hammered open by the application of a rapid succession of forceful blows directed obliquely through the point of the bill to the cleft between the valves, near the posterior end of the hinge. The blows crush a portion of that valve which has the more pressure to bear, and drive the fragments into the interior of the shell. The bill is pushed home through the newly formed opening, and is then employed, if necessary, to open up the shell by any one of the ways I have already described. The method can always be recognized at a glance by noting that there is no preliminary inspection or tapping; the bill is raised clearly off the shell in the intervals of the succession of blows; there is no real downward progress until the final blow breaks the shell; there is an extraordinary hurry and display of brute force; and very often there is no laterally inclined or rotary leverage, as the blows usually make a hole in the shell big enough to allow of the whole contents being removed without separating the valves, or the leverage and scooping up of the contents are combined in one operation. The peculiar manner of hammering the shell distinguishes this method from the more usual one in which the bill is pushed home between the valves by a series of thrusts without intermediate recoil, and in which leverage is always requisite to open up the shell and allow of the contents being removed. Shells which present the ventral border are also hammered, and the blows are delivered into the hiatus in the border of the shell. That this should be so in the absence of any apparent necessity to hammer is peculiar, but it probably represents the continuity of a habit fixed for the time being. The hammering method has two advantages and a number of drawbacks. It is a rapidly and fairly assured way of getting food. The birds may be seen to rush from one shell to another, hammer each one open in turn, lever the valves apart if necessary, and wolf the contents. In three minutes a single bird opened and cleared twenty-six shells, varying from one inch to three-quarters of an inch in length. Another worked at an average rate of seven to eight shells per minute, the shells varying from seven-eighths to five-eighths of an inch in length. It maintained this speed for three-quarters of an hour, and continued to open shells, though less quickly, for another quarter of an hour. Thus it must have cleared the contents of upwards of four hundred shells in one hour. The drawbacks are considerable, but they evidently do not outweigh the advantages of rapidity and comparative certainty. The output of energy is enormous. One can scarcely doubt that the birds are making violent exertions, and, though a small amount of visual selection is exercised over the sizes of the shells as the birds hurry from one to another, yet a considerable proportion of the shells successfully resists the hammering, and the birds have, perforce, to pass on to others. As a rule, five to eight strokes with the point of the bill are sufficient to perforate the shell. In one case the bird returned three times, making four attacks altogether on a single shell. Each attack consisted of twenty to thirty powerful blows, making some eighty strokes in all, before the onslaught met with success. In another, the bird hammered five or six times without result. At once pressing the point of the bill firmly and obliquely on the summit of the shell, it walked round through quarter of a circle, and in its new position applied several thrusts downwards. Still keeping up pressure, it walked back to its old position and hammered seven or eight times, the last stroke sending the bill deeply into the shell. In other cases the hammering was preceded by firm pressure of the point of the bill on the summit of the shell for a few seconds with, at the same time, vigorous shaking of the

bill sidewise. These examples indicate the difficulties the birds sometimes meet with, and they also bring out an interesting point. In the ordinary Mussel shell presenting the dorsal border the two valves meet at an acute angle, and by their mutual interaction offer the maximum resistance to pressure from without. Partly from direct observation and partly by the inspection of the shell-remains, it became clear that the special purpose of the two manœuvres last described was to rotate the one valve partially off the other, thereby to deprive the one of the other's support, and so make it the more easily crushed. In these two cases the attempt was made to depress the one valve below the level of the other by sheer force in small and comparatively weak Mussels which were, however, presumably resisting to their utmost. A third disadvantage is brought to light by examining the Mussels after the birds have left. The shells are usually cleaned out *in situ*, and, in general, it is not common for a shell opened by hammering to be removed to a bare place as a preliminary to the removal of the contents. Most bear evidence of having been opened through the dorsal border, and show the ordinary line of fracture extending from a point on the border posterior to the hinge to the anterior end. When the elliptic portion remaining with the hinge is broken into two portions, the posterior part shows marked depression. In addition, when the two valves are approximated, a hiatus remains in one valve posterior to the hinge, and generally the part corresponding to it is found in fragments inside the shell. In some shells this hiatus alone is present, and shows that levering had not been necessary.* A few show that they were hammered open through the posterior end, and a still smaller number through the ventral cleft. In these last the bill was driven truly between the valves, but the margins show signs of rougher usage than do the margins of shells opened by thrusting, and, as in the majority of these, there is no fracture. The shells are rarely well cleaned, the attachments of the mantle to the valves being generally left untouched, and the birds refuse those portions of the flesh which have got mixed with the fragments of the shell driven into them

* *Cf. ibid.*, p. 204, where I have advanced the depression of the posterior fragment and the presence of a hiatus as material evidence of the *accidental* opening of the larger shells where no leverage was required.

by the process of hammering. There is, thus, a considerable loss of feeding material. This loss is the third disadvantage of the method.

Still smaller shells—that is, those ranging from five-eighths of an inch to half an inch in length ($\frac{5}{8}$ in. to $\frac{1}{2}$ in.)—are treated in a cavalier fashion commensurate to their feebler powers of resistance.* They may be entered by a single, even, downward thrust of the bill between the valves and then levered open, or they may be hammered open with or without subsequent leverage. These shells are much crushed. Sometimes they are seized crosswise within the tips of the mandibles, and either jerked from their anchorage, or pulled off with an apparently gentle to and fro motion of the bill, or levered up by raising the tip of the bill and depressing the head, a neighbouring shell being used as a fulcrum. These easy ways differ markedly from that accorded to the larger shells, which need powerful tugging to detach them from the rocks. Then, the shells which have been removed so easily are set down on a bare place and hammered open. If wide separation of the valves is necessary, the requisite leverage is very often combined with scooping-up of the contents; and the acme of the process is reached when a bird enters a small shell either by thrusting or hammering, jerks it off the rock, scoops up the contents in mid-air, and casts away the empty shell by a vigorous shake of the head, leaving the soft body of the Mussel within the tips of the mandibles. This proceeding takes place so quickly that it is inconceivable the bill can have been introduced into the shell otherwise than slightly open, and in one instance, at least, I believe the relative positions of the mandibles never changed from the beginning to the end of the operation, though at no time was it possible, as viewed at the range of observation, to say that the mandibles were even separated.

Modiola modiolus.

The Oystercatcher searches for immature individuals of the Horse Mussel near low water and in the pools between tide-marks. Very often the shells are scattered rather than crowded

* *Cf. ibid.*, p. 210, where a method of opening these shells is first described.

together, and, as a rule, they are well hidden amongst vegetation, or in the sandy concretions of diverse materials that clothe the rocks in many places. In consequence, the search for *Modiola* takes the form of a close and extensive inspection, with frequent, vigorous probing into the concretions in selected spots. The shells are entered and opened up precisely as if they were those of the Edible Mussel. But in the majority of cases they are dragged from their anchorage before being levered widely open and cleared of their contents. This difference is no doubt due to the difficulty which would be experienced in separating the valves amongst matted vegetation or miscellaneous concretions. After detaching the shell, the Oystercatcher selects some kind of support, such as a crevice in the rock, on which to rest the shell before levering it open. A support is the more necessary when the shell has been entered through the hiatus in the ventral border, owing to the rounded form of the dorsal surface. For a similar reason nesting is occasionally employed.

The shells vary in size from two and a quarter inches in length by one and a quarter inches in breadth ($2\frac{1}{4}$ in. $\times$ $1\frac{1}{4}$ in.) to nine-sixteenths of an inch in length by five-sixteenths of an inch in breadth ($\frac{9}{16} \times \frac{5}{16}$), the average size of a hundred shells being one and three-sixteenths inches by five-eighths of an inch ($1\frac{3}{16} \times \frac{5}{8}$). These hundred shells include eleven which were opened by the hammering method. Of the eleven, the largest measures one and a quarter inches by five-eighths of an inch ($1\frac{1}{4}$ in. $\times$ $\frac{5}{8}$ in.), and the smallest as given above, the average size being fifteen-sixteenths of an inch by seven-sixteenths of an inch ($\frac{15}{16}$ in. $\times$ $\frac{7}{16}$ in.). The smallest shell opened by the thrusting method measures five-eighths of a inch by three-eighths of an inch ($\frac{5}{8}$ in. $\times$ $\frac{3}{8}$ in.). The biggest shell of the whole series is exceptionally large. It had been entered through the hiatus in the ventral border, and was uninjured. Of the hundred shells, sixty-four were entered *viâ* the ventral border, six through the posterior end, and thirty by the dorsal border. These figures roughly reverse the percentages obtained from *Mytilus edulis*. The cause, as in the latter case, is to be found in the natural position of the shells. In *Modiola* the habit of living more or less hidden under vegetation and other cover allows, apparently, of the assumption of various attitudes, and, as a matter of fact, by far the commonest position is a more or less oblique one with the ventral border superior. Of the eleven hammered shells included in the general total, ten were opened through the dorsal border, and only one through the ventral.

Owing to the great development of soft epidermis in the growing *Modiola* as compared with the thin covering of *Mytilus*, it is possible in a large number of shells to see, from the marks made by the pressure of the bill, where the bill was introduced between the valves. The study of these impressions confirms the results obtained more or less indirectly from *Mytilus*. When the bill is pushed into the shell through the dorsal border and leverage is applied, one valve splits along a curved line extending from a point near the posterior end of the hinge to the anterior end. When the bill is introduced through the ventral hiatus, no fracture is caused, as a rule, and if one does occur it runs transversely across the shell, or more rarely it takes a quadrangular form. In one of the shells opened by the thrusting method, the bill, after being pushed into the shell through the hiatus in the ventral border, had perforated a worn part of the shell an eighth of an inch obliquely behind the posterior end of the hinge; in another case entered similarly, the bill had been pushed through the dorsal cleft just behind the hinge, causing comminution and eversion of the edges of the valves at that point. In two of the hammered shells the blows had been delivered so evenly between the two valves in each case that a semi-ellipse of each valve had been driven inwards before the bill. As it happened, one shell had been attacked at the summit of the dorsal border, and the other through the hiatus in the ventral border.

Tapes pullastra.

The shells of *Tapes pullastra* are found in the same localities as are those of the Horse Mussel. But, in comparison with the latter, the *Tapes* are much better hidden from sight under vegetation, in sandy concretions, or in colonies of *Mytilus*, while a proportion of them resides in the holes made by rock-boring molluscs. The Oystercatcher discovers the shells by a laborious process of inspecting and probing the materials in which they are imbedded, and having found a shell it has usually no difficulty in gaining admission, owing to the great protrusion and slow

retraction of the foot and the syphons. The bird forces its bill well in between the valves by a series of powerful downward thrusts which merge imperceptibly into as powerful upward jerks, for the purpose of extracting the shell from its home. The shell is then carried to a suitable crevice in the rock, on which it is deposited hinge downwards, and where it is opened up by firmly applied lateral leverage. The mollusc is torn out in successive portions, adherent fragments of shell, if any, being vigorously shaken off before each mouthful is swallowed. The greater number of the shells is detached apparently for the same reason as that applying to *Modiola*, and, owing to the form of the region of the hinge, a support to the shell is essential before leverage can be applied. The bird may spend some time in uncertain wandering in search of such a place, and once a suitable crevice is found it may be used repeatedly by nesting the shells. Usually a depression in the rock is utilized, but an irregularity in the concretionary matter adhering to the rock or a bristly tuft of vegetation will serve. I found a shell resting between a Limpet and a low ridge of rock, and another placed endwise against the same ridge.

Of one hundred and six shells, the largest measures one and an eighth inches in length by one and a half inches in breadth ($1\frac{1}{8}$ in. $\times$ $1\frac{1}{2}$ in.), and the smallest three-eighths of an inch by five-eighths of an inch ($\frac{3}{8}$ in. $\times$ $\frac{5}{8}$ in.), the average being eleven-sixteenths by fifteen-sixteenths ($\frac{11}{16}$ in. $\times$ $\frac{15}{16}$ in.); 77 per cent. are entire and 23 per cent. are fractured. The lines of fracture are very various, and bear no apparent relation to the size of the shell. Perhaps the commonest form is a transverse fracture about the equator of one valve, with comminution of the ventral portion. But vertical and oblique fractures are not infrequent, removal of either the anterior or the posterior end of one valve sometimes occurs, and a general crushing of the valve is by no means rare. Owing to the comparative hardness of the shell and the absence of epidermis there are seldom marks to indicate the mode of entry. I have found abrasions at the middle of the ventral border in a number of cases, and in one a V-shaped nick had bèen made in the truncated end of one valve. Judged by direct observation, the usual mode of entry is through the ventral border.

The treatment of shells situated in *Pholas* or *Saxicava* borings depends on the amount of room around the shells. If there is plenty of room, the shell may be extracted and dealt with as in the other cases, or it may be laid open and cleared of its contents *in situ*. If the shell is a tight fit so that it can neither be expanded nor extracted, a fragment is broken transversely off the end of one valve (the posterior end) by vigorous lateral leverage, and through the enlarged opening the contents of the shell are removed.

Pholas crispata.

On each of several occasions, when watching Oystercatchers at work on the shales, I saw one bore very deeply through the sand-covering portions of the shale, and shake the bill vigorously and repeatedly from side to side in such a way as to suggest that the bill was being resisted laterally by the solid rock. Swallowing movements followed in each case without the bill having been withdrawn into view. Though suspecting *Pholas*, I was unable to exclude the possibility of a deeply seated *Tapes*. At the same time, I was aware that many borings occupied by live *Pholades* were wide enough at the entrances to admit freely the bill of an Oystercatcher. The matter was eventually settled by the discovery of a *Pholas crispata* in a pool not far from an empty boring in the shales, and soon after the Oystercatchers had left. The two valves had been separated, and lay on their external surfaces slightly apart. One valve had been fractured transversely an eighth of an inch from the posterior end, which was awanting. Fragments of flesh were still adherent to the valves, showing that the specimen had been recently opened. The entire valve measured nine-sixteenths of an inch in length by seven-eighths of an inch in breadth. The apophyses were intact.

Purpura lapillus.

Since the preliminary note relating to this species was printed,* I have examined two hundred and ninety-four shells, all of which bore evidence of having being dealt with by the Oystercatcher. Of these, four (1 per cent.) reached the first stage of opening, and sixty-one (21 per cent) the second or completed stage, the remaining two hundred and twenty-nine

* 'Zoologist,' 1910, pp. 109–112.

(78 per cent.) being accounted failures. Of the sixty-one which reached the second stage, four (6·6 per cent.) were completely opened up in one stage, shell being extruded, in each case, equal in area to that more usually extruded in two portions. The average size of fifty-six shells which reached the second stage was fifteen-sixteenths of an inch ($\frac{15}{16}$ in.), the largest being one and one-eighth inches ($1\frac{1}{8}$ in.), and the smallest thirteen-sixteenths of an inch ($\frac{13}{16}$ in.). The four shells reaching the first stage averaged one and a sixteenth inches ($1\frac{1}{16}$ in.), the largest being one and one-eighth inches ($1\frac{1}{8}$ in.). A longer series, however, would probably lower the average. I did not systematically measure the failures, as they did not show visually any variance from the others. The largest measured was one and one-eighth inches ($1\frac{1}{8}$ in.) in length.

By direct observation I have seen all the methods in use at each stage of opening the shells—thrusting, hammering, or longitudinal rolling at the first stage; lateral leverage, thrusting, hammering, or longitudinal rolling at the second. Often the several modes are put in force successively when strong resistance is encountered. The birds appear to vary in the degree of pertinacity with which they attack the more difficult shells, some birds giving in after a single bout, others returning repeatedly and with renewed energy. In the first paper I recorded the introduction of the upper mandible alone into the aperture of the shell. This fashion occurs but rarely, and in some cases, at least, is apparently dependent on the mode of carrying the shell by the outer lip. The more usual plan is to carry the shell crosswise between the tips of the mandibles, and to insert the bill into the interior of the shell for the purpose of opening it.

An examination of the failures yielded some interesting results when the shells had been dealt with on rock. As a rule, each presented on the lower surface of the last whorl a single bulb of percussion, at a point on the external surface corresponding roughly to the edge of the operculum inside, and in the second stage, when not completed, at a point in line with the margin of the first opening and the edge of the pillar. Experimentally, similar bulbs can be produced by making five or six thrusts inside the shell, but it is difficult to adhere to a single spot. In a few of the naturally treated shells, several or many bulbs were present. In some, longitudinal or oblique scratches or grooves were visible on the lower surface of the last whorl, and usually had associated with them a diffusely abraded area on the lower surface of the second last whorl. These scratches cannot be reproduced by simple longitudinal or obliquely inclined rolling of the shells under pressure. It is necessary, in addition, to impart a small amount of bodily movement to the shells in the direction of pressure.

Patella vulgata.

According to Robert Gray,* the Oystercatcher inspects the Limpets one after another, in order to see whether or not the shells are at all raised from the rock. On meeting such a one the bird promptly pushes its bill under the Limpet, and neatly turns it over. One foot is then placed on the shell, and the body of the animal is "taken out as cleanly as if done with a knife or other sharp instrument."

When the Oystercatcher is about to overturn a Limpet it lowers its head and inclines the bill at a low angle towards the ground, the attitude and purpose of the bird being similar to those of a battering-ram in action. For a reason which I shall explain immediately, the bill is directed downwards and forwards, with its sides at right angles to the plane of the ground. In this peculiar attitude the Oystercatcher delivers a sharp push or chipping stroke to a portion of the edge of the selected Limpet. With a small Limpet the stroke, if successful, shifts the animal bodily from its seat. The advancing edge of the shell catches in some obstruction, and the shell topples over. With larger shells the stroke has usually to be followed up by firm and evidently laborious pushing, assisted, it may be, by swaying of the bill from side to side, with finally a raising of the head and the bill, or a to and fro rotation of the bill through barely a quarter of a circle. In these larger shells the bill is obviously forced under the animal, and the process of overturning is usually completed by means of some more patent form of leverage. The Limpet is then seized and carried by the flesh, the edge of the shell, or by being held in the line of its breadth

* 'Birds of the West of Scotland,' p. 270.

within the tips of the mandibles. It is deposited in a suitable crevice of the rock or on sand, and the contents are separated from the shell by chipping through the friable attachments of the mollusc to the internal surface of the shell, the process of detachment often being completed by the bird shaking its bill, and flicking the shell off the body of the mollusc as the head is raised.

The shells vary from one and three-quarter inches in length by one and a half inches in breadth ($1\frac{3}{4}$ in. × $1\frac{1}{2}$ in.), to half an inch in length by seven-sixteenths of an inch in breadth ($\frac{1}{2}$ in. × $\frac{7}{16}$ in.), the average size of one hundred and thirty-four shells being seven-eighths of an inch by eleven-sixteenths of an inch ($\frac{7}{8}$ in. × $\frac{11}{16}$ in.). Out of one hundred and sixty-one shells, 85 per cent. are whole, or at most only abraded at one part of the margin of the shell, and 15 per cent. are fractured. In the series the occurrence of abrasion and fracture has no visible relation to the size of the Limpet, and no recognisable rule of position in relation to the margin of the shell. The fracture may be a small V-shaped chip out of the edge of the shell, a larger quadrangular fragment, or, as in a few cases, it may be semi-annular. The shells are invariably well cleaned. They are carried in about equal numbers to crevices in the rock and to sand for the purpose of removing the contents. In no case was a footmark impressed on the sand so as to overlap the shell, or its mark if the shell had been flicked away. In each case a wide gap separated the shell or its impress from the corresponding footprints. This agrees with my observations. I have not as yet been able to detect an Oystercatcher in the act of steadying a shell with one of its feet. On rock, evidence of equal value cannot be adduced, but some sort of support is of invariable occurrence in order to render the shells stable during the removal of their contents. Usually it takes the form of a crack or depression in the rock. Further, nesting of the shells is common for the same purpose, two, three, or four being piled one on the top of another, in each case as a preliminary to the extraction of the mollusc. On one occasion I found a nest of five *Tapes* and three Limpets in that order from below upwards.

After going over the evidence derived from direct observations, and from an examination of the shells, I feel there are at least two matters which demand further explanation. One is the peculiar attitude of the bird in the moment of the attack, especially as regards the bill, and the other the nature of the pushing or chipping stroke. Having repeatedly verified the original observation that the bill is held with the sides vertical in the operation of overturning a Limpet, I have no doubt that it is actually so, and the problem comes to be, Why does the Oystercatcher instinctively ignore the expediency of pushing the bill flatly under the Limpet? The answer is bound up with the nature of the sharp push or chipping stroke. In the first place, a Limpet, when bone dry externally, adheres to the rock so tenaciously that no pressure likely to be within the capacity of the Oystercatcher is able to move it. In the second, a Limpet, when it is moist as in a pool, in the tidewash, or soon after the ebb has left it, is generally relaxed and slightly raised from the rock. The Limpets which fall into the second category are those sought after by the Oystercatcher, and it is an additional advantage if there be a slight irregularity, either in the shell or the surface of the rock, at one point on the margin of the shell. When, however, one of these Limpets is experimentally warned by tapping it gently, it draws itself tightly on to the rock, and passes into the first category. Thus the main essential is apparently a taking of the Limpet unawares, and a secondary advantage the existence of a slight local increase of the normal gap between a relaxed shell and the rock. Limpets, of course, are to be found in the tidewash with the shell separated from the rock more than enough to admit the depth of a bill, and others are attached to such hopelessly irregular pieces of rock that the insertion of the bill is an easy matter. On the other hand, a Limpet, whether it is relaxed or holding firmly, is absolutely safe when it is sunk in a depression of its own making in the rock. For such as these the peculiar method of the Oystercatcher is not called into play. After the tide has receded, and even before the rocks have dried, the average Limpet presents so small a crack between the shell and the rock that it would be impossible to push the bill under the shell without the aid of some special mechanism. This is supplied by the sharp push or chipping stroke. When it is made experimentally in the case of the smaller shells, the result is exactly as I have described it

from direct observation of the Oystercatcher at work. With the larger shells, while it is easy to reproduce the natural occurrence, it is not so easy to find out what actually occurs during the rapid succession of events. The blow must be delivered at a low angle; otherwise it serves merely to warn the Limpet to settle down more firmly on the rock. And the instrument must be held with its sides, or rather the plane of its depth, at right angles to the plane of the ground. I find that at the moment of the stroke, made under these conditions, the instrument representing the bill does not pass under the shell, but gives a sharp blow to the edge of the shell. The blow shifts the Limpet bodily a fraction of an inch in the direction of the pressure. The animal then holds on, and the upper part of its body undergoes distortion, pressing the advancing edge of the shell firmly on to the rock, and raising the near edge against which the instrument is pushed. In some cases this proves sufficient. If the shell is out of the water, and the stroke has been made quickly, a rushing sound is heard, as of air passing in under the foot, and the shell topples over. In others the instrument must be passed under the shell. To do this, hard pushing is required to distort the body of the Limpet, and to raise the near edge of the shell still more. Probably the obliquely truncated tip of the bill, as it occurs in at least some Oystercatchers, assists in raising the edge of the shell under pressure. After getting the tip past the edge of the shell, the instrument must then be pushed under the edge of the foot, a proceeding which is made easier by swaying the instrument from side to side. This manœuvre produces an abrasion on the edge of the shell similar to that proceeding from a similar cause in nature. As soon as the instrument passes to a varying distance under the foot the rushing sound is heard, and the shell topples over. If, however, the movement is carried out slowly the rushing sound is not heard. Leverage by raising the base of the instrument is a disadvantage at an early stage, as in the likely event of failure the Limpet gets a better grip of the rock during the return movement. It, however, hastens the overturning when the hold of the animal is weakening. Instead of this form of leverage, rotation of the instrument through barely a quarter of a circle is equally helpful at this later stage. Experimentally, the instrument passes more easily under the shell, with its sides parallel and not at right angles to the ground. But the Limpet is well able to retain its hold, owing apparently to the slight separation of the foot from the rock. No rushing sound is heard. Leverage proves impossible, and when it is tried the steel instrument bends under the strain to the point of snapping. Further, its withdrawal, after the failure to overturn the Limpet, is a matter of very real difficulty. Thus the use of the bill, with its sides vertical to the ground, is an advantage and a safeguard. It necessitates the edge of the shell being raised to a greater height than is the case when the bill is used flatly; it favours, by this greater separation, first, of the edge of the shell, and, secondly, of the edge of the foot from the rock, the entrance of air or water under the foot; and it renders the withdrawal of the bill from under the Limpet more easy in the event of failure.

Though in the above description I virtually make out that the admittance of air or water is essential to the overturning of the shells, my strict position is that in many cases a rushing sound is heard just before a shell which is out of the tide topples over, and the sound is more like that of air entering a vacuum than of air escaping from a cavity under pressure.

Tectura (Acmæa) testudinalis.

I found one shell of this *genus* and *species* amongst a quantity of Limpets which had been overturned by the Oystercatcher. It measured five-eighths of an inch in length by half an inch in breadth ($\frac{5}{8}$ in. × $\frac{1}{2}$ in.), and was fractured at the larger end. Some friable material still remained along the line where the body of the animal had been attached. The record is interesting, if only on account of the evenness of the edge of the shell, which does not favour an attack at any particular part of the circumference.