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MR. DARWIN'S NEW WORK.*

MR. DARWIN'S latest volume, on "The Formation of Vegetable Mould, through the Action of Worms," contains information which to the ordinary reader will be as interesting and surprising as that found in any of the works which the public have previously received from the same skilled pen. "The story told by Mr. Darwin, of the silent but constant activities of the despised creature which he brings under our notice, affords another striking illustration of the fact that the commonest and humblest objects in Nature, when attentively studied, are capable of yielding rich material for observation and reflection, and that in the great economy of the material world, the most important and valuable results are often brought about by the lowliest agencies. The reader accustomed to the pursuit of natural science, and consequently unprepared by the marvellous possibilities which are constantly being made in the humblest and simplest studies in every department of Nature, would scarcely expect to find that worms would repay any very close and attentive observation; and yet we venture to say that, after a perusal of this book, such a reader will be likely to conclude not only that a worm is by no means such a worthless, insignificant, and uninteresting creature as it has been commonly supposed to be, but also that we are only, ever now, beginning to understand the perfection of that system of arrangement, of adaptation of means to ends, which prevails in the universe, and which comprehends the lowliest as well as the highest things, and which is constantly bringing forth beneficent results from the most obscure and minute agencies.

The book before us is written with the direct simplicity and clearness which characterize Mr. Darwin's style, and which make it possible for one who knows nothing of the technical terminology of science to read his works with intelligence and zest; and every page is marked by evidences of that persistence in investigation, that scrupulous accuracy in detail, and that persistent regard for facts, which have gone far to secure for Mr. Darwin his high reputation as a man of science. Readers, indeed, who have a quick sense of humour,

in, at any rate, a keen appreciation of the ludicrous, and are not wholly absorbed in considering scientific results, will sometimes feel a smile passing over their faces as they picture to themselves some of the experiments of which Mr. Darwin gives us a graphic narration in these pages. All but the strictest devotees of science will be prepared to forgive the irrelevance of a quiet laugh at the idea of the great naturalist's attention to the unhappy worms which, for the convenience of constant observation, he kept in pans of earth in his study. To think of Mr. Darwin approaching these creatures with light tread, and probably in his stocking-put, lest he should disturb them by creating a vibration in the floor; of his showing at them and playing notes of the piano to them, to find out if they had any sense of hearing; of his testing his eye-lenses upon them suddenly to find out if they had any perception of light; of his testing their taste by supplying them with pieces of meat of various kinds, roast, boiled, and raw, and their intelligence by providing them with certain triangular pieces of paper, which they drew into their holes; all this, we confess, although the confession may prove our lack of the gravity which befits the consideration of a strictly scientific subject, has its amusing aspect to us, and touches our sense of the incongruous, besides, in its greater aspect, testifying to the indefatigable labiousness and ingenuity and to the minute carelessness of the learned author.

Mr. Darwin's study of worms has extended, it appears, over a period of about half a century. As long ago as 1832, he read a paper before a learned society on the "Formation of Mould," in which he discussed the operations of worms, and mentioned some examples of their activity, and ever since then he appears to have kept the subject before him, and to have been accumulating information upon it. The results of such prolonged attention on the part of so competent an observer, may be regarded as practically all but exhaustive, and this book cannot fail to be regarded as the standard of appeal in this department of inquiry for a long time to come. The present volume consists of seven chapters, in addition to a brief introduction. The first two chapters treat of "The Habits of Worms"; the third chapter is upon "The Amount of Fine Earth brought up by Worms to the Surface"; the fourth chapter is on "The

Part which Worms have played in the Build of Ancient Buildings"; the fifth and sixth chapters are on "The Action of Worms in the Formation of the Land"; and the concluding chapter gives a comprehensive and interesting summary of the information upon the entire subject.

In his Introduction Mr. Darwin, with characteristic modesty, defines his subject as being "the share which worms have taken in the formation of the layer of vegetable mould which covers the whole surface of the land in every moderately humid country." The mould referred to, we are informed, "is generally of a blackish colour and a few inches in thickness." A series of observations led Mr. Darwin to the conclusion that by the persistent activity of the worms, tillis this mould was constantly being turned over, triturated, and improved; that, in fact, "all the vegetable mould over the whole country has passed many times through, and will again pass many times through, the mechanical action of worms," and that consequently "the term 'animal mould' would be in some respect more appropriate than that commonly used of 'vegetable mould'." In reply to the remark which has been made that the work thus represented as having been accomplished by creatures so small and weak as worms, Mr. Darwin instructively says, "Here we have an illustration of that facility to run up the effects of a continually recurrent cause, which has often retarded the progress of science, as formerly in the case of geology, and more recently in that of the principle of evolution." The carefully collected facts in this volume sufficiently sustain and reinforce the implied rebuke.

In treating of the habits of the worms, Mr. Darwin begins by saying something of their distribution, especially in this country. They abound on chalk downs and commons where the soil is poor and the grass short and thin; but "they are almost or quite as numerous in some of the London parks, where the grass grows well and the soil appears rich." They have a great liking for paved court-yards near houses. But it would appear that they distribute themselves sometimes in the same field in a capricious manner; and the safest generalisation upon this point perhaps is, that they prefer a moderate amount of damp. During the heat of summer and the extreme cold of winter, they bury themselves in the earth as soon

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distance and cease to work. The night is their period of activity, and then they issue forth from their burrows. They generally, however, keep their tails in their burrows, and they have a power of expanding their tails and of making use of some "short, slightly reflexed bristles, with which their bodies are armed," in such a way that they cannot be dragged out of the ground without pulling them in pieces. Mr. Darwin doubts whether a worm can find its way back to a burrow which it has once left; although, he says, "they apparently leave their burrows on a voyage of discovery, and that they find new ones to inhabit." They have a way of lying near the mouths of their burrows for hours together, and, of course, readily fall victims to the blackbirds and other enemies, on the look out for them. Their persistence in what, from a worm's point of view, must be regarded as a foolish habit, is due, Mr. Darwin suggests, to their love of warmth; and it will surprise many people to learn that worms, especially the more luxurious of them, we presume, "often cover the mouths of their burrows with leaves, apparently to prevent their bodies from coming into contact with the cold damp earth."

Of the structure of worms Mr. Darwin gives an elaborate description. A worm of good-size consists of from one to two hundred almost cylindrical rings, each surrounded by bristles; its muscular system is well developed; it has a mouth and something which corresponds to the proboscis or trunk in other animals; it has some "calcareous glands," in this respect being unique in the animal kingdom, and these perform an important part in its process of digestion; and it has a gizzard. Worms have no jaws or teeth, and they breathe through the skin. Their nervous system is "fairly developed." By a series of observations and experiments Mr. Darwin was led to the conclusion that worms, although they have no eyes, are sensitive to light, and are capable of perceiving the distinction between night and day. They have no faculty of hearing, but they are "extremely sensitive to vibrations among solid objects." They have, it would seem, but a feeble sense of smell, and can only perceive certain odours. "Of all their senses, that of touch, including in this term the perception of a vibration, seems to be the most highly developed." Mr. Darwin compares them in this respect to a blind man, who forms an idea of objects by the touch, and he thinks that there is some reason to believe that worms by means of touch are "enabled to gain a general notion of the form of an object." In the sense of taste worms appear to be also fairly well endowed, and, like superior creatures, they have their decided preferences with regard to food. They are, indeed, omnivorous, and they live chiefly on half-decayed leaves, but they are very fond of cabbage leaves, and

make nice distinctions between the different sorts; they have a decided weakness for onions; they prefer fat to any other kind of meat, and they like it fresh better than putrid; moreover—and this is the chief objection for which they seem to exist—they swallow an enormous quantity of earth, out of which they extract any digestible matter which it may contain, casting it forth afterwards in a triturated and much improved condition. Mr. Darwin describes a protracted series of experiments carefully adapted and carried out with a view of ascertaining whether worms were to be credited with intelligence, and he came to the conclusion that they were. Referring our readers to the volume for the account of the experiments, which, by the way, may serve as a valuable lesson in the art of observing for scientific purposes, we may quote a brief passage in which the conclusions are summed up.

The Intelligence of Worms.

If worms are able to judge, either before diving or after having drawn an object down to the mouths of their burrows, how best to drag it in, they must acquire some notion of its general shape. This they probably acquire by touching it in many places with the anterior extremity of their bodies, which serves as a tactile organ. It may be well to remember how perfect the sense of touch becomes in a man when he is blind and deaf, as are worms. If worms have the power of acquiring some notion, however rude, of the shape of an object and of their burrows, as seems to be the case, they deserve to be called intelligent; for they do act in nearly the same manner as would a man under similar circumstances.

To men up, as chance does not determine the manner in which objects are drawn into the burrows, and as the existence of specialized instincts for such particular cases cannot be admitted, the first and most natural supposition is that worms try all methods until they at last succeed; but many appearances are opposed to such a supposition. One alternative plan is left, namely, that worms, although standing low in the scale of organization, possess some degree of intelligence. This will make every one as very improbable; but it may be doubted whether we know enough about the nervous system of the lower animals to justify our natural distrust of such a conclusion. With respect to the small size of the cerebral ganglia, we should remember what a mass of inherited knowledge, with some power of adapting means to an end, is crowded into the minute basis of a medusa.

In the construction of their holes, or burrows, worms display an amount of skill which may well excite them to be compared with creatures of a higher order, whose labours have more frequently been held up to admiration. As illustrative of a fine instinct, nearly approaching the faculty of intelligence, we extract the following from amongst many interesting pages on the same subject.

The Habitations of Worms.

The burrows run down perpendicularly, or more commonly a little obliquely. They are not sometimes to branch, but as far as I have seen this does not occur, except in recently dug ground and near the surface. They are generally, or as I believe, invariably, lined with a thin layer of fine, dark-coloured earth

colled by the worms; so that they start at first but make a little wider than their ultimate diameter. I have seen several burrows in undisturbed sand thus lined at a depth of 30, 50, and others close to the surface than lined in twenty days' ground. The walls of fresh burrows are often dotted with little globular pellets of rolled earth, still soft and viscid; and these, as it appears, are spread out on all sides by the worm as it travels up or down the burrow. The lining thus formed becomes very compact and smooth when recently dug, and closely fits the worm's body. The minute rolled bristles which project in rows on all sides from the body, that have excellent points of support, and the burrow is rendered well adapted for the rapid movement of the animal. The lining appears also to strengthen the walls, and perhaps save the worm's body from being scratched. I think so because several burrows which passed through a layer of sifted sand-silica, spread over the soil to a thickness of the inch, and were then dug, had an unusual thickness. In this case the worms, judging from the castings, had pushed the sand away on all sides, and had not consolidated any of them. In another place, burrows similarly lined, passed through a layer of coarse sand-silica, $\frac{1}{2}$ inch in thickness. We thus see that the burrows are not mere excavations, but may rather be compared with tunnels lined with cement.

The mouths of the burrow are, in addition, often lined with leaves; and this is an instinct distinct from that of plugging them up, and does not appear to have been hitherto noticed. Many leaves of the Scotch pine (Pinus sylvestris) were given to worms kept in confinement in two pots; and when after several weeks the earth was carefully broken up, the upper parts of three oblique burrows were found surrounded for lengths of 7, 4, and $\frac{1}{2}$ inches with pine-leaves, together with fragments of other leaves which had been given to the worms, as food. Green earth and bits of silk, which had been scattered on the surface of the soil, were stuck into the interstices between the pine-leaves; and these insertion were likewise plastered with the viscid castings voided by the worms. The structure thus formed resembled so well, that I succeeded in removing one with only a little earth adhering to it. It consisted of a slightly curved cylindrical mass, the interior of which could be seen through holes in the sides and at either end. The pine-leaves had all been drawn in by their bases; and the sharp points of the needles had been pressed into the lining of rolled earth. Had this not been effectually done, the sharp points would have prevented the retreat of the worms into their burrows; and these same worms would have resembled trees armed with converging points of wire, rendering the ingress of an animal easy and its egress difficult or impossible. The skill shown by these worms is noteworthy, and is the more remarkable, as the Scotch pine is not a native of this district.

We must not linger over the interesting particulars contained in the chapter on the quantity of the mould annually accumulated by the process of the passing of earth through the bodies of worms; but we may mention that calculations, founded on careful tests, are given, showing that in an acre of land, the weight of earth turned over every year was found to range, in four cases, from 736 tons to 1875 tons. We must content ourselves with one or two more quotations, and they shall be from the concluding chapter, in which, as we have remarked, the results are summarized. Take the following, which points out the services which worms render in the fertilisation of the earth.

Effects of Worm-activity on the Soil.

Worms prepare the ground in an excellent manner for the growth of fibrous-rooted plants and the seedlings of all kinds. They periodically expose the mould to the air, and with it as that an access larger than the particles which they can swallow are left in it. They bring the whole into mutually together, the purifier who prepares life and for his closest plants. In this state it is well fitted to retain moisture and to absorb all soluble substances, as well as for the process of aëriation. The bones of dead animals, the harder parts of insects, the shells of land animals, human excreta, &c., are before long all buried beneath it, and are before long all buried beneath it. It is converted into a more or less decomposed state within reach of the roots of plants. Worms likewise drag up infinite number of dead leaves and other parts of plants into their burrows, partly for the sake of plugging them up and partly to feed.

The leaves which are dragged into the burrows as food, after being torn into the finest shreds, partly digested and saturated with the mucous and silicious secretions, are completely rot in much earth. This earth leaves the dark coloured rich humus which almost everywhere covers the surface of the land with a deeply cellulosid layer or mantle. The Hessian plough two worms in a round eighteen inches in diameter, which was filled with soil, on which fallen leaves were spread; and these were soon dragged into their burrows to a depth of six. After about six weeks an almost uniform layer of soil, a centimeter (4 in.) in thickness, was converted into humus by having passed through the alimentary canal of these two worms. It is believed by some persons that ground-larvæ, which often penetrate the ground almost perpendicularly to a depth of five or six feet, similarly act in this manner; notwithstanding that the usual castings point out the ascending of the burrows, instead of check the surface directly entering them. They show the air is permeate deeply into the ground. They also greatly facilitate the downward passage of rocks of moderate size; and these will be made of the burrows with which the burrows are filled. Many worms are very diligent in having their bodies by their legs, and when buried to a considerable depth beneath accumulated castings the deposit will, at some future time they are accidentally uncovered and germinate.

The concluding passage of the volume contains a suggestive allusion to an almost inaccessible source of interest to the thoughtful observer—that, namely, of the obscure and apparently insignificant agencies in the material world by means of which beneficial and beautiful results are so often secured.

Legacy Agencies in Nature.

When we behold a wide, well-cultured surface, we should remember that its accumulation, on which so much of its beauty depends, is in a large degree the result of the incessant, slowly but surely, work of worms. It is a marvellous reflection that the whole of the superficial mould over any such surface has passed, and will again pass, every five years through the bodies of worms. The plough is one of the most ancient and most valuable of man's inventions, but long before he entered the land was in fact regularly ploughed, and still continues to be thus ploughed by earth-worms. It may be doubted whether there are many other animals which have played so important a part in the history of the world, as have these lowly organized creatures. Some other animals, however, and more lowly organized, namely, corals, have done the most conspicuous work in having constructed in-

visible reefs and islands in the great oceans; but these are almost confined to the tropical zones.

Mr. Darwin's book, like all able and thorough books relating to any branch of natural history, will serve to give interest to many a country walk, which, apart from such means of picking-up and cultivating inquiry and observation, might prove dull and dreary. The volume reminds us that those who penetrate ever so short a distance into the great realm of Nature, in the true spirit of seekers of the truth, will surely be rewarded, and will often meet with surprises; and readers of these chapters will find themselves led to the conclusion that worms are not, after all, the despicable creatures which they have been commonly supposed to be.

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"The Formation of Vegetable Mould Through the Action of Worms, with Observations on their Habits. By CHARLES DARWIN. (Vol. 54.) D. Appleton & Co. P. p.

MR. DARWIN ON WORMS."

THIS American edition, bearing the date of the coming year, but issued in November, 1881, is page for page identical with the original London edition, published early in the autumn.

In every object which Mr. Darwin treats he treats us abiding interest. And the present volume is noteworthy, if for nothing else, as an additional and very marked exemplification of the veteran author's genius in drawing significant lessons from seemingly insignificant things. He who now carelessly treats upon a worm (that is to say, upon an earth-worm) may

know—what before he probably never suspected—that he is illustrating a benefactor to the human race. For to earth-worms is mainly due the formation of that dark-colored rich humus—the so-called vegetable mould, which in every moderately humid country almost everywhere covers the surface of the land with a layer or mantle, the importance of which to agriculture is quite incalculable. Not only was this layer of finely comminuted materials mainly produced by worms, but it is undergoing constant change and renewal by their action, underlying materials being continually brought to the surface and the whole world periodically exposed to the air, stones and all particles larger than the worms can swallow completely sifted out and buried beneath, and the whole intimately mingled together in a way which a gardener preparing fine soil for his choicest plants and seeds can fully testify.

In this case it is well fitted to retain moisture and to absorb all soluble substances, as well as for the process of aëriation, says the author, upon which the productivity of the soil largely depends. He con-

The plough is one of the most ancient and most valuable of man's inventions; but long before it entered the land was in fact regularly ploughed, and still continues to be thus ploughed, by earth-worms. It may be doubted whether there are many other animals which have played so important a part in the history of the world as these lowly organized creatures.

Next to the agriculturalist, the anthologist should be thankful to these creatures which sometimes were thought to be servicable only to the angle. For,

They protect and preserve for an indefinitely long period every object, not liable to decay, which is dropped on the surface of the land, by burying it beneath their castings. Thus, both many stones and curious fossiliferous gravels and other ancient remains have been preserved, though, no doubt the worms in their state have been largely aided by such moisture and being from the adjoining land, especially when retired.

Not only may work have, as when they undermine such pavements and cause unequal subsidences.

Even old massive walls may be undermined and subside; and no building is in this respect so safe, unless the foundation be 6 or 7 feet beneath the surface as a depth at which worms cannot work. It is probable that many monuments and some old walls have fallen down from having been undermined by worms.

As to how these effluvia produced, and how it is proved that such visible creatures are capable of bringing to pass such great results, we must refer to the book itself, which is easy and interesting reading, and—thanks to large type—of no formidable extent. In short, earth-worms largely soil, lay earth in making their burrows, and also for the sake of extracting any nutritious matter it may contain; and this is evident mainly on the surface of the ground in the form of the well-known worm-castings. It was in the year 1877 that Mr. Darwin communicated to the Geological Society of London, and published in its Transactions, a paper on *The Formation of Mould*—in which it was shown that small fragments of burnt wood, sticks, &c., which had been thickly strewn over the surface of several meadows, were found after a few years lying at the depth of some inches beneath the turf, but still bearing a layer.

The supposition that this apparent sinking of superficial matter is due to the large quantity of soil earth brought up to the surface by worms in the form of castings was made by Mr. Darwin's constant and thoughtful observations, and this he at that time proceeded to verify, by ascending into the soil, which objects left on the surface of the soil were in this way buried beneath it. He was thus led to conclude that all the vegetable mould over the whole country has passed many times through, and will again pass many times through the intestinal canal of worms,

and therefore that it should rather be called "animal" than "vegetable" mould. Regarding to the subject now in later days, Mr. Darwin confirms his conclusions by another and more direct line of evidence, namely, by weighing all the worm castings thrown up on a measured space within a given time, as also by meticulous and prolonged observations of the habits and actions of these animals. There is also an interesting chapter on the part which worms have played in the burial of ancient buildings, as at the old Roman remains at Silchester and Wroxeter, and at Beaulieu Abbey, destroyed by Henry VIII; and two others on their action in the denudation of the land.

A large part of the chapter on the habits of worms is devoted to the question of their *Intelligence*, and to an account of the investigations made by Mr. Darwin and his son Francis in this regard, founded mainly upon observations of their management in closing and opening their burrows, and in dragging into them various kinds of leaves and other articles of food. Adopting the idea that in-