Literature.

THE FORMATION OF VEGETABLE MOULD, THROUGH THE ACTION OF WORMS, with Observations on their Habits. By CHARLES DARWIN, LL.D., F.R.S.

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THROUGHOUT a great part of his life, Mr Darwin has made a study of worms. So long ago as 1837, he read before the Geological Society of London a paper on the operations of the worm in the soil. Even at that time he held very much the same views as he now expounds at greater fulness and with more elaboration in this interesting volume. In 1837, he pointed out that the vegetable mould over the whole country has passed many times through, and will again pass many times through, the intestinal canals of worms. This view of the operations of one of the seemingly least important of creatures was much controverted. It has been contended that it is impossible that the worms could do the work which Mr Darwin says they accomplish. Our author has long pondered over the subject, and he still adheres to his opinions of four and forty years ago.

A considerable portion of the early part of the book is occupied with an account of the habits of worms. Mr Darwin kept worms for many months in his study in pots filled with earth, and closely observed and noted their habits. He has also had the benefit of observations made for him by other naturalists. He tells us that the number of the species of worms in this country has not been ascertained. In Scandinavia there are eight species; and in Germany the same number is noted, with some strongly-marked varieties. The castings of worms are found in very different stations throughout the country. They abound in chalk-downs, where the soil is poor and the grass short and thin. They are almost equally numerous in the rich soil and abundant grass of the London parks. They are numerous in paved courtyards close to houses. They are to be met in black peat in a boggy field; but they are very rare or quite absent in the drier, brown, fibrous peat so much valued by gardeners. On dry sandy gravelly tracts, where heath, moss, or lichen alone grow, hardly any worms can be found. Wherever there is a pathway through a tract of this nature, on which some short grass springs, there also will be found the worm castings. Mr Darwin says that a 'layer, though a thin one, of fine earth, which probably long retains some moisture, is in all cases, as I believe, necessary for the existence of the castings of worms, and the mere compression of the soil appears to be in some degree favourable to them, for they often abound in old gravel walks, and in footpaths across fields.' Worm castings are rare in the Alps; but Dr M'Intosh found some on Schiehallion at a height of 1500 feet. 'They are numerous on some hills near Turin, at from 2000 to 3000 feet above the sea, and at a great altitude on the Nilgiri Mountains in South India, and on the Himalaya.'

Earthworms are semi-aquatic. They demand a certain degree of moisture. M. Perrier found that their exposure to the dry air of a room for only a single night was fatal to them; while he kept several large worms alive for nearly four months completely submerged in water.

HABITS OF WORMS.

During the summer when the ground is dry, they penetrate to a considerable depth and cease to work, as they do during the winter when the ground is frozen. Worms are nocturnal in their habits, and at night may be seen crawling about in large numbers, but usually with their tails still inserted in their burrows. By the expansion of this part of their bodies, and with the help of the short, slightly reflexed bristles, with which their bodies are armed, they hold so fast that they can seldom be dragged out of the ground without being torn into pieces. During the day they remain in their burrows, except at the pairing season, when those which inhabit adjoining burrows expose the greater part of their bodies for an hour or two in the early morning. Sick individuals, which are generally affected by the parasitic larva of a fly, must also be excepted, as they wander about during the day and die on the surface. After heavy rain succeeding dry weather, an astonishing number of dead worms may sometimes be seen lying on the ground. Mr Galton informs me that on one such occasion (March 1881), the dead worms averaged more than two and a half paces in length on a walk in Hyde Park, four paces in width. He counted no less than 45 dead worms in one place in a length of sixteen paces. From the facts above given, it is not probable that these worms could have been drowned, and if they had been drowned they would have perished in their burrows. I believe that they were already sick, and that their deaths were merely hastened by the ground being flooded.

Worms have no eyes, but they are not insensible to light. They can distinguish day from night, as their habits are different during these two periods. It is believed that the light passes through the skin and in some way excites the cerebral ganglia, which are situated at the anterior extremity of the body. Worms are sensitive to a low temperature. They do not come out of their burrows during frost; and, in fact, on the approach of winter descend deeply into the earth to escape the frost. In the same way, in the height of summer, when the soil under the surface is destitute of moisture, the worms descend further and cease for the time to work. Worms are utterly destitute of the sense of hearing. Mr Darwin says:—

> They took not the least notice of the shrill notes from a metal whistle, which was repeatedly sounded near them; nor did they of the deepest and loudest tones of a bassoon. They were indifferent to shouts, if care was taken that the breath did not strike them. When placed on a table close to the keys of a piano, which was played as loudly as possible, they remained perfectly quiet.

In worms the sense of smell is apparently confined to the perception of certain odours, and is feeble. They showed perfect indifference to the odour of tobacco and to perfumes. They are, however, able to discover, apparently by scent, certain kinds of food of which they are fond:—

> The result was different when cabbage-leaves and pieces of onion were employed, both of which are devoured with much relish by worms. Small square pieces of fresh and half-decayed cabbage-leaves and of onion bulbs were on nine occasions buried in my pots, between about ½ of an inch of common garden soil; and they were always discovered by the worms. One bit of cabbage was discovered and removed in the course of two nights; seven were removed by the next morning—that is, after a single night; two others after two nights; and the seventh bit after three nights. Two pieces of onion were discovered and removed after three nights.

Mr Darwin discovered that worms prefer the green to red cabbage. They are also fond of the leaves of the celery, while the leaves of carrot were preferred to any other kind of vegetable food. The worm is, however, no epicure. Its appetite is omnivorous. It eats raw flesh of all kinds, and prefers raw fat to almost anything else. It is a cannibal, and eats the bodies of dead worms. Its chief food is necessarily decayed leaves, of which it eats all kinds, save a few which have an unpleasant taste or are too tough. The worm pulls the leaves into its burrow, seizing them by the tips. It lines its burrow with leaves, and often covers the mouth of the burrow with them, so as to protect itself from cold and from assault by its enemies. The store of leaves it takes into its hole the worm covers with a kind of secretion, which apparently assists in preparing them for digestion:—

> From the secretion with which the leaves are moistened being alkaline, and from its acting both on the starch-granules and on the protoplasmic contents of the cells, we may infer that it resembles in nature not saliva, but pancreatic secretion; and we know from Frédéricq that a secretion of this kind is found in the intestines of worms. As the leaves which are dragged into the burrows are often dry and shrivelled, it is indispensable for their disintegration by the unarmed mouths of worms that they should first be moistened and softened; and fresh leaves, however soft and tender they may be, are similarly treated, probably from habit. The result is that they are partially digested before they are taken into the alimentary canal. I am not aware of any other case of extra-stomachal digestion having been recorded. The boa-constrictor bathes its prey with saliva, but this is solely for lubricating it. Perhaps the nearest analogy may be found in such plants as Drosera and Dionæa; for here animal matter is digested and converted into peptone not within a stomach, but on the surfaces of the leaves.

Worms excavate their burrows in two ways. They push the earth away on all sides, and they also swallow it. In the former case, the anterior extremity, stretched out and attenuated, is pushed into a crevice or hole, and the pharynx swells, and pushes away the earth on all sides. Mr Darwin recites the following experiments:—

> A worm was placed in loose mould, and it buried itself in between two and three minutes. On another occasion, four worms disappeared in 15 minutes between the sides of the pot and the earth, which had been moderately pressed down. On a third occasion, three large worms and a small one were placed on loose mould well mixed with fine sand and firmly pressed down, and they all disappeared, except the tail of one, in 35 minutes. On a fourth occasion, six large worms were placed on argillaceous mud mixed with sand firmly pressed down, and they disappeared, except the extreme tips of the tails of two of them, in 67 minutes. In none of these cases did the worms swallow, as far as could be seen, any earth. They generally entered the ground close to the sides of the pot.
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> A pot was next filled with very fine ferruginous sand, which was pressed down, well watered, and then rendered extremely compact. A large worm left on the surface did not succeed in penetrating it for some hours, and did not bury itself completely until 40 hours 40 minutes had elapsed. This was effected by the sand being swallowed, as was evident by the large quantity ejected from the vent, long before the whole body had disappeared. Castings of a similar nature continued to be ejected from the burrow during the whole of the following day.

It may be held as certain that, whenever a worm burrows to a depth of some feet in undisturbed compact ground, it must form its passage by swallowing the earth. Though they usually live near the surface, worms burrow to a considerable extent during long continued dry weather and severe cold. Worms have been found in Germany at a depth of three to six feet from the surface. In some earth near an old Roman villa that had probably not been disturbed for centuries, a worm was met at a depth of 66 inches in the month of August. We have referred to the fact that the worm usually lines its burrow with leaves. The ingenuity of the little blind creature in coating the sides of its habitation is very wonderful. Mr Darwin supplies the following particulars on this point:—

> Many leaves of the Scotch fir or 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 3½ inches with pine-leaves, together with fragments of other leaves which had been given the worms as food. Glass beads and bits of tile, which had been strewed on the surface of the soil, were stuck into the interstices between the pine-leaves; and these interstices were likewise plastered with the viscid castings voided by worms. The structures thus formed cohered so well, that I succeeded in removing one with only a little earth adhering to it. It consisted of a slightly curved cylindrical case, 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 voided earth. Had this not been effectually done, the sharp points would have prevented the retreat of the worms into their burrows; and these structures would have resembled traps 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.

Worms usually eject their castings on the ground, coming to the surface for the purpose. They sometimes empty their bodies in any cavity they can find. Some of the castings are of considerable size. Mr Darwin gives engravings showing 'towers' of castings found near Nice and at Calcutta, both being from 2½ to 3 inches in height. 'A small cylindrical passage runs up the centre of each tower, through which the worm ascends to eject the earth which it has swallowed, and thus to add to its height.' In the Nilgiris in South India, castings have been found on a plateau of the height of 7000 feet. The worms that eject these are only seen during the wet season. These creatures are said to be as thick as a man's little finger, and to be 12 to 15 inches in length. Their castings weigh from 3 oz. to 4½ oz.!

We should point out that worms swallow earth, not only to make a passage for themselves, but also for food. Mr Darwin points out that 'ordinary mould can hardly fail to contain many ova, larvæ, and small living or dead creatures, spores of cryptogamic plants, and micrococci, such as those which give rise to saltpetre. These various organisms, together with some cellulose from any leaves and roots not utterly decayed, may well account for such large quantities of mould being swallowed by worms.'

Worms are found in great abundance in the fine soil in gardens. As many as 64 open burrows have been found in a space of 14½ square feet. Mr Darwin says that, when digging in a grain field near Maer Hall, in Staffordshire, he found a cake of dry earth as large as his two open hands, which was penetrated by seven burrows as large as goose-quills. Hensen, who has given much study to the subject, calculates that there are 53,767 worms in an acre of land. His estimate is, however, based on the numbers he found in a garden; and Mr Darwin is content to take half of Hensen's numbers as representing the worms to be found in an acre of agricultural land.

Mr Darwin entered into elaborate experiments and calculations to estimate the quantity of mould that is produced by the castings of worms. These resulted in the conclusion that the 26,886 worms in an acre of land each eject on an average 20 ounces in the year. There would therefore be cast up on an acre 15 tons yearly. Mr Darwin believes that of the quantity ten tons may be earth, which is simply earth passed through the bodies of the worms. The conclusion at which he arrives is not a little surprising:

> The result for a country of the size of Great Britain, within a period not very long in a geological sense, such as a million years, cannot be insignificant; for the ten tons of earth has to be multiplied first by the above number of years, and then by the number of acres fully stocked with worms; and in England, together with Scotland, the land which is cultivated and is well fitted for these animals, has been estimated at above 32 million acres. The product is 320 million million tons.

The worm, it will be seen, plays no unimportant part in the economy of nature. It is, indeed, a great improver of land. Perhaps, it is the most potent factor in the amelioration of the soil. Mr Darwin thus describes and illustrates the process:—

THE WORM A GREAT AGRICULTURAL IMPROVER.

> Worms prepare the ground in an excellent manner for the growth of fibrous-rooted plants and for seedlings of all kinds. They periodically expose the mould to the air, and sift it so that all stones larger than the particles which they can swallow are left in it. They mingle the whole intimately together, like a gardener who prepares fine soil for his choicest plants. In this state, it is well fitted to retain moisture and to absorb all soluble substances, as well as to favour the nitrification. The bones of dead animals, the harder parts of insects, the shells of land-molluscs, leaves, twigs, &c., are before long all buried beneath the accumulated castings of worms, and are thus brought, in a more or less decayed state, within reach of the roots of plants. Worms likewise drag an infinite number of dead leaves and other parts of plants into their burrows, partly for the sake of plugging them up and partly as food.
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> The leaves which are dragged into the burrows as food, after being torn into the finest shreds, partially digested, and saturated with the intestinal and urinary secretions, are commingled with much earth. This earth forms the dark coloured rich humus which almost everywhere covers the surface of the land with a fairly well-defined layer or mantle. Von Hensen placed two worms in a vessel 18 inches in diameter, which was filled with sand, on which fallen leaves were strewed; and these were soon dragged into their burrows to a depth of 3 inches. After about six weeks, an almost uniform layer of sand, a centimeter (⅖ inch) in thickness, was converted into humus by having passed through the alimentary canals of these two worms.

As Mr Darwin observes, though the plough is one of the most ancient and most valuable of man's inventions, yet 'long before man existed, the land was, in fact, regularly ploughed and still continues to be thus ploughed by earth-worms.' The worm, then, is the First Ploughman. This little labourer asks no return for his labours. He does not stipulate for compensation for his improvements. He pursues the even tenor of his way in darkness, and without hearing or uttering a sound. But he does his work, fertilising the soil in which he lives and labours, and even in his death enriching the ground, of which his race have been the oldest occupiers.

Mr Darwin has made many invaluable contributions to literature and science. He has not, however, written anything more interesting than this monograph on the life, labours, and wonderful results of the efforts of one of the feeblest of Earth's creatures.

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