Mr. Darwin on Earth-Worms.[1]

It is rather surprising that the combined operations of worms in great numbers and for a great length of time have been hitherto so little noticed. For anyone who walks over a grass-plot, and observes the number of worm-casts, each consisting of from a quarter to half an ounce of fine black earth, or even more, must perceive that a very considerable disturbance of the under soil is constantly going on. If, moreover, he finds that worm-casts, which have been swept away or removed, are replaced in a single night, he will be aware that if, say, even an ounce of subsoil is thus daily brought up from the depth of many inches over a square yard, the quantity so raised to the surface in a year, and spread by rain, wind, and the tread of cattle, over an acre of ground, must amount to many tons. This earthy matter is dispersed among the roots and root-leaves of grasses and other low-growing plants, which in turn are always making an effort to grow through and out of them; so that in the course of years the whole surface of the ground may be said to consist entirely of a layer of worm-earth. The somewhat sticky or viscous consistency of worm-casts causes them at once to adhere to plants, and to be less easily dissolved by rain and dew. The air finds its way through worm-holes to the deeper roots, and this alone undoubtedly gives a great stimulus to growth.

Mr. Darwin (p. 165) estimates the outspread of fresh earth at eighteen tons in a year for every acre of land in which worms are tolerably numerous. This, of course, is a much larger amount than is usually spread over the fields by the farmer in the shape of manure; and worm-casts are really manure, not only as being composed of finely mixed and triturated mould, but as containing some acids derived from digested vegetable matter in the passage through the animal's intestines. For worms *eat* earth, besides consuming prodigious quantities of decaying vegetable matter. They are extremely greedy creatures, and leaves pulled into their holes are soon drawn down and devoured. It is certain that the greater part of the leaves which fall in autumn, and which seem so soon and so mysteriously to disappear, are disposed of in this way. Any observer may notice fields and lawns bristling with leaves, mostly grouped in little bunches with the stalk upwards; and that in a very short time nothing is left but the fibrous skeletons of midribs and stalks that have been drawn by worms into the mouths of their holes. Newly fallen leaves may indeed be blown away into hedge-bottoms and

[1] *The Formation of Vegetable Mould through the Action of Worms.* With Observations on their Habits. By Charles Dawn, LL.D, F.R.S. Murray, 1881. Price 9*s*.

ditches; but in a short time leaves on a meadow become so saturated by rain and dew, and retained by the growth of grass, that the wind does not stir them at all.

To make this point quite clear, I selected a spot on a meadow thickly studded with worm-casts, but quite clear of leaves, being far from any trees. Over it I scattered a few handfuls of damp and sodden fallen leaves of different kinds, treading them down so that they could not be blown away. I visited the spot daily for a week, and watched the gradual decrease till not a single leaf was left. I think worms come out at night and feed on leaves not drawn into their holes. The latter expedient is adopted to supply food in the daytime. Leaves may often be found gnawed into rags, which have evidently never been twisted into a plug for a worm-hole. I do not think slugs or snails ever feed on dead leaves.

If the worm-casts are dissolved in water, a quantity of sand or chalk, according to the subsoil in which they burrow, may often be observed, together with small pellets of half-digested fibre, and minute particles of lime, cinder, or stone. Now the rich black mould may afford some nourishment, but pure sand cannot. The inference is, that the greater part of the earth bored out of the hole is actually swallowed, and ejected on the surface. The mole, whose larger operations are very similar, simply clears out its tunnel by raking the earth in a hillock through a hole in the grass. The turf-clad ant-hills, with which fields and commons are sometimes covered, are formed in the same way, by vegetation ever rising above the level of the crumbled earth, scooped out of the nests of *Formica flava*. The worm eats its way in; fresh undersoil is constantly brought up from a depth of two or three feet, and supplied to the roots of grass; and thus the surface is ever being renewed for the nourishment of new vegetation, as the old dies and is eaten up. In loose soil, the worm effects an entrance by pushing aside the earth; for it is a strong, muscular creature in proportion to its size. But as this is impossible in compact earth, another process is adopted—that of boring like a gimlet, in which case all the earth removed passes through the body. I have dissolved black worm-casts in water, and found that in some of them nearly half the sediment was pure sand. Place a large lob-worm in a pot of loose earth, and it will push its way down so as to be out of sight in a few minutes. Small as its mouth is, and quite toothless, it can suck down an immense quantity of matter in a short time.

An enormous quantity of earth is taken into the stomachs of animals in grazing. Whether they like earth or not, they cannot help eating it; for the worm-casts stand up erect like so many little towers, and some must be taken in with almost every mouthful of grass. This earth then undergoes another modification, by being spread in the form of dung from the larger animals. That cattle actually enjoy eating earth is certain; a horse fed on hay will lick earth greedily with his tongue, as I have myself witnessed; and very

often he will stir up the water of a pond with his foot in order to make it muddy before drinking.

It is conceivable that, as there seems a use and a fitness in everything in Nature, the peculiar tower-shaped form of the worm-cast is anything but 'accidental.' It may be that a quantity of earth is essential to the digestion of the graminivorous animals, and that it is supplied to them in this way, as well as by roots pulled up in grazing. If so, both the grass that grows and the means of assimilating it are largely due to the unseen workers which swarm in every garden and every meadow. In the space of a single measured square yard of grass I have counted as many as sixty worm-casts, and collected from them earth, roughly speaking, enough to fill a half-pint pot.

Another function of worms is the germination of seeds. Nothing is more common than to see the seed of the ash or the sycamore drawn into a worm-hole and rooting there. Experiments made with worms kept in a flower-pot of moist earth show that they will drag down seeds of almost any kind, that these seeds generally grow, and that the worm feeds on the rootlets. Mr. Darwin is of opinion (p. 115) that small seeds and stones are carried down for the purpose of lining the bottom of the holes.

A curious proof that worms do nibble roots is the languishing state of a plant in a flower-pot which happens to contain a worm. The worm will grow, is never seen on the surface (for worms seldom come out except at night), and, having no dead leaves to feed on, it will gnaw the rootlets of the plant, which in turn will languish. Generally, a few pellets of black earth will be found under the aperture at the bottom—an indication of the nature of the malady. Turn your pot upside down, and you will find your enemy in the form of a lob-worm, coiling itself among the roots. I sprinkled some canary-seed round three worm-holes in my garden, and the very next morning considerably more than half had been dragged down each hole. The next morning every seed was gone, and not by birds, for I watched the seeds in the day-time. Moreover, I found seeds sticking in the holes.

About three years ago, I made many careful experiments on the food and habits of the earth-worm, the results of which were published in Nos. 162 and 163 of 'Science Gossip,' and reprinted in 'Natural History Rambles' by J. E. Taylor. They agree in nearly every respect with Mr. Darwin's observations. But they differ in one important particular. Mr. Darwin says (p. 30) that worms are very fond of fresh raw meat. Many attempts to get them to eat any kind of meat, while kept in a flower-pot, were failures, though bits of stick, string, leaves, feathers, straw, &c., were readily drawn into their holes, and seeds scattered on the surface were always removed.

The intelligence shown by worms in drawing in leaves nearly always with the stalk upwards and the pointed end downwards, is

very remarkable indeed; for it unquestionably shows a *design* which in a creature without brain, and credited only with 'cerebral ganglia,' is difficult to account for, as Mr. Darwin admits (p. 98). Again, the use and object of plugging up their holes with leaves and bits of string, or stick, or feathers which they cannot possibly devour, is not easy to discover. It may be to keep out the wet, or to keep in the warmth, or to exclude beetles, ants, centipedes, and other noxious insects; certainly it is in great part for the purposes of food, for the ends of the leaves, if carefully drawn out, will be seen to have been nibbled or sucked away, having first been lubricated, as Mr. Darwin has proved, by a digestive alkaline fluid, which discolours the part so moistened. But worms do not always stop up their holes; we find them occasionally quite open, or covered only by the worm-cast. This may happen, either because the creature is not exposed to these enemies in all places alike, or because no material is within its reach for the closing of the hole. Lay a piece of string on the ground near a worm-hole, and you are pretty sure to find it next morning forming a plug to the aperture. Very often indeed, they pile up small pebbles or bits of cinder, and if these are raked away with the hand they are sure to be replaced next night. It is not very easy to catch a worm at work, for the creature is so timid that it will withdraw itself instantly on feeling the vibration of an approaching step. I have, however, succeeded in watching the process, and have seen a worm with its tail in its hole (in which it adheres firmly by erecting the bristles on its rings), moving round in a circle and collecting, by a sudden jerk, every pebble within its reach, to pile upon the spot. Pebbles of considerable size are moved in this way, the mouth adhering to them by suction.

A clergyman once told me, that, having to cross a field about midnight with a lantern, he was amazed at the enormous number of lob-worms outside of their holes and crawling about the grass. There is no doubt that vast numbers of these stragglers are seized by the birds in early morning, the lightness of their tread giving the worm, which is totally blind, no indication of their approach.

It is a mystery how worms are sensitive to light; but it is certain that they are so. I have often witnessed their hasty withdrawal on bringing a candle suddenly, late in the evening, to the flower-pot in which they were kept. We may imagine they can distinguish day from night by the dew-damp or the sun's warmth; but the light of a candle or lamp affords no such indications.

Worms appear to lie in the day-time with the head withdrawn an inch or two within the hole. Sometimes, on taking off a worm-cast suddenly, you will see them move further down. It is thus that the sharp beak of a thrush or a blackbird is enabled to extract them.

Worms have a curious habit, which I cannot account for, of making their holes either at the sides of a gravel-walk in a garden, or on the very margin of the grass which overhangs it. It is by these means chiefly that the grass in time encroaches on the path.

Worms are easily brought to the surface by watering the ground with brine, lime-water, or an infusion of walnut leaves. They are extremely numerous in all gardens which have a deep, rich soil. If a spade or fork be stuck in deep, and moved to and fro for a minute or two, the worms will come wriggling out of their holes for the space of about a yard round it; the reason of which, in an animal naturally concealing itself, is not easy to explain.

The subject, in its economic aspect, is really extremely curious, important, and interesting. There can be no greater mistake than to regard these investigations as trifling and unworthy of a man of mind. Mr. Darwin does not hesitate to say (p. 313, and I fully agree with him), '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 organised creatures.' The influence of the worm in gradually causing the real or apparent sinking of large stones, old pavements, foundations, &c., which Mr. Darwin discusses at great length, is curious enough in an antiquarian point of view. But it touches us nearly to infer, what is possibly not far from the truth, that 'no worms—no vegetables, no milk, and no butter.' Whether this proposition be taken quite literally or not, it is impossible for a moment to doubt that the fertility of pasture-land is perpetually renovated by the worm-casts, which are either dissolved by rain or dried and blown away in crumbling fragments. Everyone knows how they disfigure a grass-plot, and how soon a scythe is made blunt by mowing through them. An interesting illustration is, the benefit which pastures derive from having a hurdle of thorns drawn over them. There is no weight of pressure, as in the case of the horse-roller; it is merely like the combing and brushing of hair; but the somewhat viscid worm-casts are thus dispersed and evenly spread; for rain has the tendency to break them down, and melt them into little patches, which the hurdle will effectually disperse. Where there is abundance of food, and the earth itself is very rich, worms do not appear to nibble the rootlets of vegetables, or to do any harm to them, as they unquestionably do to the plants in flower-pots. It is, however, very probable that, in the absence of fallen leaves, they gnaw the rootlets of the grass.

Mr. Darwin tells us that the worm-holes are lined smoothly with the excrementitious matter, a part of which may often be seen, when newly ejected, in a pasty state. The worm itself lubricates the tortuous passage by the slime exuded from his body, and by this means he can escape the quicker from his enemies, the birds and the moles. It is not easy, Mr. Darwin remarks, to understand how the worm can so turn itself in its hole as to protrude the anal part; the head, which acts as a feeler, being protruded in all other operations. The answer is, that worm-holes are, like rabbit-burrows, not simple, but complex. A worm can therefore push up its body with either end projecting, by *backing*, so to say, into a branch aperture. I found this out by keeping worms in a pot of rather tenacious earth, which

I subsequently dried, turned out of the pot, and cut asunder so as to examine the course and direction of the passages. By this simple process the whole mystery of a worm's subterranean operations was revealed.

That a large part of the deep alluvial soil in valleys is simply *worm-earth*, partly washed, but more often blown, from the higher ground, cannot be doubted. On level fields, where small pieces of bone or cinders, spread as manure, will be found lying below the surface in a very few years, this is due to complex causes. One is, no doubt, the constant blowing of dust; but more is done by the accretion of earth round the crown of plants, while the root has, as it were, anchored the object, and it thus becomes buried, as the axis of the plant makes its way upwards and the root-leaves die off. The soil of a field is rather in constant circulation than in any process of steady rise; for all that is thrown up must make a hollow, and therefore elevation and subsidence nearly neutralise each other. Mr. Darwin accordingly found the actual rise on the surface of fields to be extremely slow, not more than the fifth of an inch in a year (p. 134). It is a subject very difficult indeed to put to any certain test. There can be no doubt that the heavy tread of animals pasturing tends to close up and break in the numerous passages made by both moles and worms. Possibly a good deal of the earth thrown up in worm-casts is washed back into the holes during heavy rains. To some extent, however, this is prevented by the stopping up the holes with leaves.

That worms, which feed so largely on dead leaves that they may almost be regarded as autumnal scavengers very essential even to our health, should also find nutriment from swallowing earth, seems very singular. It may be, after all, that the earth only passes through them, and acts as a scour to get rid of the quantity of vegetable matter, roots, mosses, &c., consumed. The worm has a gizzard, and it grinds its food by the aid of little pebbles which are sometimes ejected in the worm-casts. It is certain, as I have said, that graminivorous animals do swallow quantities of earth, probably with the same result. To ascertain this, I once sat on the grass by the head of a tame Alderney cow, and watched it nibbling off the worm-casts in grazing. I have also noticed small tufts of grass lying on loose fen soil, torn up by the roots during grazing; yet very much more must have been eaten, earth and all. Even some savage tribes, it is well known, are earth-eaters or clay-eaters to a very considerable extent.[2] I, for one, am not yet fully convinced that worms obtain any nutriment from the earth that passes through them. The general absence of worms from poor and sandy soils is, perhaps, a difficulty; but may it not be explained by the general scantiness of vegetation and of dead leaves in such localities?

It is stated, however (p. 104), as an argument on the other side, that worm-casts abound most where there are fewest dead leaves, and

[2] See Mr. Brown's *Races of Mankind*, vol. i. pp. 289-90, for many examples.

the converse; so that it would seem as if the creature could live and thrive on either of these totally different kinds of nutriment. But surely, as a general rule, there are more worms and more fallen leaves in gardens than in the open fields.

Mr. Darwin well observes (p. 4), that what is commonly described as 'vegetable mould' is more properly animal mould. It is, in fact, an amalgamation of both; it is the residue of digested vegetable matter intimately blended with earth that has been well pounded, pulverised, and mixed in the stomachs of innumerable worms. It would be a curious experiment, though both a tedious and a difficult one, to watch the appearance of a given patch of grass-land full of worm-casts, and of a similar patch kept entirely free from worms by the occasional pouring on of some infusion which kills them. But it is not likely that much difference would be observable for a few years, because the ground would already be virtually a stratum of worm-casts.

Let anyone fill a small flower-pot with worm-casts, and another with virgin earth, and plant a bean or a pea in each, and then observe the difference between the growth of the two. This is an interesting and very easy experiment, which it is worth while to try on a large scale, for it would thus be conclusive in its results.

I planted two beans in this way, keeping the two pots always side by side, and under exactly the same conditions. The bean in virgin earth came up about twenty-four hours sooner than the other, and maintained the start in the race till both were four inches high. Then the worm-earth proved the richer; and the bean grown in it was six inches high when the other was but five and a half inches.

One most curious organ in the worm has been well explained by Mr. Darwin. A little below the mouth, and about the middle of the œsophagus, is a cluster of glands which have the property of excreting carbonate of lime, apparently for the purpose of neutralising the acids contained in dead leaves (p. 53). The lime is formed in small concrete masses in these glands, and particles of it are not unfrequently ejected in the worm-casts. Very minute experiments enabled Mr. Darwin to distinguish these from the small stones taken into the gizzard for the purpose of comminuting the food.

The fact that worms, like moles, are not very often seen, accounts for the general ignorance that prevails as to their really stupendous operations in the economy of Nature. Mr. Darwin (p. 159) quotes the statement of Hensen, who estimates the number on a single acre at more than fifty thousand, weighing in the aggregate over 350 pounds! Mr. Darwin thinks the estimate credible, though, of course, the number on different soils must vary greatly. The weight of the worm-casts annually thrown up on an acre is reckoned at from sixteen to eighteen tons (p. 165).

At the time of writing these remarks (the middle of November) the worms are in full operation in my garden, and I can remove daily and weigh the amount of earth thrown up from any one worm-

hole in twenty-four hours. The quantity appears to me greatly to exceed the calculation of Hensen (p. 160), 'less than eight grains per diem.' The weights given by Mr. Darwin (pp. 161–2) are of no value, because 'the whole of the castings appeared to have been ejected within no long time.' I find that a quarter of an ounce of wet earth is quite a moderate estimate for one worm in twenty-four hours. Hensen's estimate, it must be observed, was made from worms kept by himself in confinement. I found that twelve worm-casts, taken quite fresh from a grass-plot, weighed, when dried, nearly an ounce and three-quarters.

To ascertain the rate at which the worm-casts are thrown up, I adopted the following experiment. From a measured and marked space of four square yards, on a grass-plot thickly studded with these little hillocks, I removed eighty-seven one by one as I counted them, and trode the turf down perfectly level. In twenty-four hours not a single worm-cast had been thrown up; but the night had been very stormy, and three-quarters of an inch of rain had fallen. The next day, at the same hour, I found fifteen; but the preceding night had also been rather rainy. On the third morning, after a fine and calm night, I counted eighty-five. This seems to prove, first, that worms do not come to the surface at all in heavy rain; secondly, that the same number of them remains for some time in the same area of ground. These experiments should, of course, be repeated, and with more exact care than I could bestow.

To ascertain further to what extent worm-casts are swallowed by pasturing animals, I dissolved in water some fresh droppings from a horse, taken from a meadow. I obtained some sand, but less than I had expected, from the sediment. This also is an inquiry which deserves to be more carefully conducted, for it may be intimately connected with the healthy condition of stock, especially when they are stall-fed. I should like to see if a horse, fed only on hay and oats, would swallow a handful or two of earth placed in his manger. I should expect that he would do so; and I should argue that, if he likes it, nature requires it.

Quite lately, I watched a young bullock, tied to a post at a railway station, licking up the dust from the asphalte pavement, as far as a short rope would allow it to reach. It was amusing to see both its nose and its tongue black with the savoury repast.

My garden is surrounded with plantations of Scotch fir, and I can attest the accuracy of Mr. Darwin's statement that in nearly every case the fallen leaves or 'needles' are drawn in by the base, and not by the points. And yet I do not find one that has been nibbled. The fact that fallen leaves are drawn in stalk uppermost, on which Mr. Darwin enlarges in chapter ii., was pointed out by me in 'Science Gossip,' No. 163. There must, as I have said, be a purpose in the practice; and the practice must result either from instinct (hereditary habituation), or from design, and conscious use founded on experience.

F. A. Paley.